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Department of International Development Engineering, Graduate School of Science and Engineering, Tokyo Institute of Technology http://www.ide.titech.ac.jp/TR

Preface

Master theses of Department of International Development Engineering, Tokyo Institute of Technology were presented successfully on August 4, 2014 and February 12, 2015, respectively. This technical report consists of the abstracts of those theses.

TECHNICAL REPORT OF INTERNATIONAL DEVELOPMENT ENGINEERING TRIDE-2016-01

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Arching effect in undercut slope with planes of discontinuity

Student Number: 12M51379 Name: Thanachote TECHAWONGSAKORN Supervisor: Thirapong Pipatpongsa

不連続面を有する斜面法尻におけるアーチ作用 テチャウォンサコン タナチョート

Physical models of undercut slope with various patterns of discontinuous planes in different dip angles and dip directions were undertaken to characterize arching effect for mining applications. Consequences of symmetrical and unsymmetrical patterns of faults resulted in differences of failure width and geometries of collapsed slope. Slopes with discontinuities failed at narrower undercut widths with different failure mechanisms from those without discontinuities, confirming that faults potentially weaken slope. The lowermost sliced portion of slope displaced towards the pit during excavation due to widening separation of fault planes and eventually led to beam-like failure rather than arch-shaped detachment. This study indicated that arching effect is reduced in undercut slopes having discontinuous planes; hence, geological structures should be considered in design criteria.

1 Introduction

The Mae Moh open-pit coal mine and Mae Moh lignite-fired thermal power plant located in Lampang province, northern Thailand is one of the main source of energy for the generation of electricity throughout the northern provinces of Thailand. Both mine and power plant have been operated under Electricity Generating Authority of Thailand (EGAT) since 1952.

The thermal power plant, which is the largest lignite-fired power plant in Southeast Asia, provides the total capacity of 2,400 Megawatts which represents about 15% of the total electrical energy demand in Thailand. The fuel used in electric generation is supplied by an open-pit mine that can serve the stable and lowest fuel cost per unit for electricity production in Thailand until 2028. The Mae Moh mine is also the largest open-pit mine in Southeast Asia. The pit has a maximum width about 4 km and a maximum length about 9.5 km. The mine currently produces annual production about 15 million tons, representing about 80% of the whole production in Thailand. Clay seam in the shearing zone (see Fig.1) was observed in the site [1]. This clay seam potentially causes a failure because of its low shear strength, especially when excavating the slope without prior removing upside unstable rock masses.



Figure 1: Cross-section of unstable slope of the Mae Moh mine (Courtesy of EGAT)

As a consequence of the excavation difficulty, the physical model of undercut slope has been studied in order to understand the failure mechanisms and determine the maximum excavated width. The details of undercut slope experiment will be clarified. Previous research has convinced the mechanical idealization by validating with the results of physical models with sufficient reliability for practical designs [2]. However, the effects of faults existing at the actual site have not included in the previous study. Therefore, slope models were improved by inserting in this study.

This research pays attention to the influence of discontinuous planes on the failure mechanisms of undercut slopes i.e. how discontinuous planes affect arch action of slope and maximum failure width. Series of experiments were conducted by varying the alignment and dip angle of faults in the slope as well as changing the excavated position.

2 Theoretical background

According to the plastic limit of beam, stress distribution on rectangular cross section with a width *b* and a height *h* is shown in Fig. 2. The equilibrium of between tension and compression yielding on tension side and compression side is expressed by Eq.(1) where σ_c is unconfined compressive strength, $\sigma_t = a\sigma_c$ is uniaxial tensile strength, $a = (1 - sin\phi)/(1 + sin\phi)$ and ϕ is a friction angle of material.

$$b(h-y)\sigma_c = by\sigma_t \tag{1}$$

The neutral axis y is obtained from Eq.(1):

$$y = \frac{n}{1+a} \tag{2}$$

Then plastic moment M_p can be determined via Eq.(3) where *T* is a summation of tensile force acting on the tension side:

$$M_p = T \frac{h}{2} = \frac{1}{2} b h^2 \frac{a}{1+a} \sigma_c$$
(3)



Figure 2: Rectangular cross section analysis



Figure 3: Fixed-end beam with uniformly distributed load

According the collapse mechanism of fixed-end beam under uniformly distributed load as shown in Fig. 3, the collapse load w can be derived by the balance between external and internal plastic works after formation of three plastic hinges due to negative bending moment at both ends and positive bending moment at the middle of the beam:

$$M_p 2\theta + 2M_p \theta = 2 \int wx \theta dx \tag{4}$$

$$4M_p\theta = \frac{w\theta l^2}{4} \tag{5}$$

$$w = \frac{16M_p^1}{l^2} \tag{6}$$

Let $l = B_f$, hence:

$$B_f = 4 \sqrt{\frac{M_p}{w}} \tag{7}$$

Next, uniformly distributed load w is calculated by subtracted the driving load due to cascading down self-weight mass along the inclined plane by the interface friction between the soil mass and the bedding plane (see Fig. 4).

$$w = \gamma t s \left(sin\alpha - tan \phi_i cos\alpha - \frac{c_i}{\gamma t} \right) \tag{8}$$



Figure 4: Idealization of discontinuous portion failure mechanism

Hence, the failure width B_f under the beam-failure assumption is predicted by using Eqs.(3), (7), and (8).

3 Experimental methods

Figure 5 shows the overview of undercut-slope physical model. The model consists of 2 parts; i.e. basal part and slope part. Both are made of moist silica sand no.6. The dimension of basal part is 1.30 m wide, 0.40 m long, and 0.06 m thick. It is laid on an acrylic plate and laterally supported by the sand paper. The dimension of slope part is 1.30 m wide, 0.80 m long, and 0.06 m thick. It is laid on Teflon plate with an inclined angle 40° and laterally supported by the sand paper. In the slope part, pressure gauges are installed to observe the changes of magnitude and to depict the trajectories of the major principal stress.

After constructing the model, faults are inserted into the slope part by using cutting blade in order to make discontinuous planes. There are 3 series of experiments i.e. slope without fault, slope with 3 parallel faults at 15 cm, 25 cm, 35 cm from the toe of slope (see Fig. 5, left), and slope with 3 slanted faults (see Fig. 5, right). In each series of experiment with faults, there are 3 types of faults i.e. faults normal to the slope plane, faults in vertical direction, and faults in horizontal direction (see Fig. 6). Digital camera installed parallel to the slope plane is used to capture a series of photos for GeoPIV analysis [3]. Moreover, high speed camera is installed to observe the slow motion of failure mechanisms.

After the preparation of physical model, the basal part is excavated symmetrically from the center line and gradually expanded in a symmetrical manner until the failure is observed. However, some experiments were excavated either from the left or right lateral support for observing the effects of excavated location and lateral constraints.



Figure 5: Undercut slope physical model



Figure 6: Different dip direction of faults

Table 1 shows the basic material parameters of silica sand no.6 which is used in the experiment. Water content is checked and controlled at 10% before

conducting the experiments. Bulk density is controlled at 13.68 kN/m³ during constructing the model. Interface friction angle and interface adhesion shown in the table are obtained from a series of slip test of free-standing block of sand on the Teflon plate [4].

Parameters	Value
Water content	10%
Bulk density	13.68 kN/m^3
Interface friction angle	21°
Interface adhesion	0.15 kPa
Unconfined compressive strength	1.59 kPa

Table 1: Material parameters of silica sand no.6

4 Experimental results

Firstly, the effect of different dip angle of faults is considered. The test with horizontal faults, which is the smallest dip angle, resulted in the largest failure width. On the other hand, the test with vertical faults, which is the largest dip angle, resulted in the smallest failure width.

Secondly, the effect of initial excavated location is considered. The tests which initial excavated location started from either right or left lateral support resulted in a larger failure width than that which initial excavated location started from the center line.

Fable	2:	Summary	of failure	width
		A/		

Tests	Initial excavated location	Average failure width (cm)
No fault	Center	45.6
No fault	Right	50
3 normal parallel faults	Center	39.2
3 normal parallel faults	Right	55
3 vertical parallel faults	Center	35
3 horizontal parallel faults	Center	65
3 normal slanted faults	Center	45
3 normal slanted faults	Right	92.5
3 normal slanted faults	Left	50
3 vertical slanted faults	Center	35
3 horizontal slanted faults	Center	55



Figure 7: Failure mechanism of the test with 3 normal parallel faults



(a) Selected mesh of patches



(b) Displacement vectors



(c) Deviatoric strain contours

Figure 8: PIV analysis of test with 3 normal parallel faults

Thirdly, as can be seen in Fig. 7, the separated opening appeared at the lowest fault, and then the tension crack developed at the right and left of the beam. After that, tension crack occurs at the bottom of the beam. Next, considering PIV analysis as shown in Figs. 8(a)-(c). In Figs. 8(c), dark area in contour of deviatoric strain represents an opening separation along the discontinuous plane. This mechanism are different from those observed in the test without fault Comparing the experimental result and [5]. idealization, the average failure width of the test with 3 normal parallel faults which initial excavated location started from center line is 39.2 cm. And the failure width calculated from beam-failure assumption is 37.6 cm. Therefore, the theoretical prediction is in reasonably acceptable agreement with experimental results.

Lastly, considering the result from pressure gauges, Fig. 10 shows the graph plotted between the excavated width and the soil pressure measurement of test 3 with normal parallel faults which initial excavated location started from center line. The red circle marks the switch of stress trajectory from active condition to passive condition at the location of pressure P2 and P4. In the same manner, the black circle marks the switch of stress trajectory at the location of pressure P5 and P6. Two vertical red lines indicate the first and the second failure. As can be seen in the graphs, before failure is observed, the arch action tends to change from active condition which minor principal stress is continuous to passive condition which major principal stress is continuous (see P4 which is plotted in yellow line and P6 which is plotted in green line) [6].



Figure 9: Installed location of pressure gauges





5 Conclusions

The 1^{st} series of undercut slope without fault was conducted in order to compare the results with the 2^{nd} and 3^{rd} series, namely, undercut slope with 3 parallel and 3 slanted faults, respectively. Some experiments are chosen to repeatedly conduct to confirm the reproducibility of physical models. According to the results from experiments, it can be concluded that,

1) Dip angle of fault affects to the stability of slope i.e. slope with less dip angle of fault is more stable than the more one.

2) Excavated location and lateral supports also affect to the stability of slope i.e. failure width of

slope which excavated location is near lateral support is wider than those which excavated location is at the center line.

3) Pressure gauge is one of alternative apparatus which can be used to monitor the failure. In other words, the switch of trajectory of major principal stress indicates the failure-prone condition.

4) For PIV analysis, the results can be used to predict the shape of failure. In practice, despite prism poles are used to monitor the displacement of slope at the site instead of PIV technique, this study suggests the suitable locations on the slope for monitoring or warning purposes.

6 References

- [1] Pipatpongsa, T., M.H. Khosravi, and J. Takemura. Physical modeling of arch action in undercut slopes with actual engineering practice to Mae Moh open-pit mine of Thailand. in The 18th International Conference on Soil Mechanics and Geotechnical Engineering (ICSMGE18). 2013. Paris, France.
- [2] Khosravi, M.H., Arching effect in geomaterials with applications to retaining walls and undercut slopes, in Department of International Development Engineering. 2012, Tokyo Institute of Technology.
- [3] White, D.J. and W.A. Take, GeoPIV: Particle Image Velocimetry (PIV) software for use in geotechnical testing. 2002.
- [4] Techawongsakorn, T., et al., Slip mechanisms and interface shear strength between moist silica sand and acrylic plate, in The 47th Japan National Conference on Geotechnical Engineering. 2013, The Japanese Geotechnical Society: Toyama International Conference Center. p. 895-896.
- [5] Khosravi, M.H., et al., Arch action over an excavated pit in a stable scarp investigated by physical model tests. Soils and Foundations, 2011. 51(4): p. 723-735.
- [6] Pipatpongsa, T., et al., Slope failures along oblique plane due to sequential removals of propping portion in physical model tests, in The 15th National Convention on Civil Engineering, Engineering Institute of Thailand. 2010: Ubon Ratchathani University. p. p.135 CD-ROM.

FACTORS AFFECTING INFORMATION COMMUNICATION TECHNOLOGY (ICT) INTEGRATION OF PRIMARY SCHOOL TEACHERS IN MONGOLIA

Student Number: 12M51480Name: Tsogtsaikhan OYUNSupervisors: Shinobu YAMAGUCHI and Jun-Ichi TAKADA

There is no consolidated view on how to measure teachers' effectiveness of ICT use in school settings should be measured. Modifying the performance standards created by the International Society for Technology in Education, this study developed the instrument in Mongolian context together with Mongolian education experts. Using this instrument, 359 primary school teachers were sampled. Data was analyzed by exploratory factor analysis to find the distinct construct, and multiple regression analysis to find the factor affecting teachers' use of ICT in teaching and communication. The results found both teacher-level and school-level factors contributing to the integration of ICT in the teaching process. These results highlight the importance of individual teachers and schools roles in ICT integration.

1 Introduction

Until 1990, the Mongolian education system was widely acknowledged for providing universal access for its population that was both dispersed and mobile as nomadic pastoralists. At the end of 1980s, the adult literacy rate marked 99% [1].

During the 1990s, Mongolia went through the decentralization process and shifted to the marketoriented economy. During this period, every sector was facing difficulties. In education sector, the budget was decreased and the literacy rate was dropped due to the increased number of school dropouts and inadequate school infrastructure [2].

Since then, Mongolian education reform took place with several new legal acts, such as New Education Law (1993, 2002) and New Educational Standard (2005). Primary and secondary education experienced a major transition from 10-year school system to 12-year school system. The current 12-year education system consists of primary education of six years and children starting at the age of six, which expands the length of primary schooling and increases role of the teachers [3].

Besides the education reform, the Mongolian Government has been providing better ICT infrastructure to offer more opportunities for national development. Master Plan on Education (2006) defines ICT as the most appropriate tool for improving access and quality of education. In this context, ICT is identified as an important tool to promote teaching and classroom management [4].

Currently in Mongolia, the primary and secondary school teachers are expected to know how to integrate ICT in school context. However, there is a limited number of studies conducted to understand how the teachers are integrating ICT into their teaching and other school activities. The series of education reform, particularly emphasizing the importance of the development of teaching skills, include ICT use in education. The development of proper instrument is necessary to determine the current status of teaching in integrating ICT in their teaching. However, there is no standardized instrument to measure the level of such skills in Mongolian education context. Given this background, the research objectives are twofold: 1) to develop an instrument to measure teachers' use of ICT in Mongolian context; and 2) to investigate factors affecting teachers' use of ICT of primary school teachers in teaching and other activities in Mongolia.

2 Literature Review

Measuring teachers' use of ICT were often focused on teachers' frequency of using ICT [5][6][7]. ICT integration in this study is also referring to teachers' ICT use in school settings. More specifically, it measures how frequent teachers using ICT in their teaching and other school activities.

2.1 Instruments to measure teachers' ICT integration

Several standards and instruments have been used to measure teachers' ICT integration. For example, the National Educational Technology Standards for Teachers (NETS-T) developed by the International Society for Technology in Education (ISTE) is widely adopted in the North America as indicators for teachers' proficiency in ICT [8]. It consists of six standard areas and 23 performance indicators in forming a structure and boundary in evaluating teachers' proficiency in ICT use in schools.

Both developed and developing countries have adopted the NETS-T in their national technology plans, certification, licensure, curriculum plans or assessment plans including Norway, Costa Rica, Malaysia, Japan, Korea, Australia, the Philippines, China and Turkey. Using the performance standards, Hsu's study developed equivalent ICT integration scales and validated with large number of samples [9]. However, there is no standardized measurement being applied in developing countries.

2.2 Factors affecting teachers ICT integration

Following the framework used by Tondeur [10], school level factors are categorized into contextual and cultural variables, and teacher level factors are categorized into structural and cultural variables.

Contextual school characteristics consist of the characteristics such as school infrastructure and school size while cultural school characteristics include leadership and school support. Structural teacher characteristics are fixed information such as teachers' gender and years of teaching. Cultural teacher characteristics include teachers' positive perception related to use of technology, computer attitudes and training attendances.

3 Methodology

The data collection took place between January 2013 and June 2014 including three field visits in Mongolia. Both quantitative and qualitative data collection and analysis were employed.

3.1 Research process

To achieve two research objectives mentioned earlier, three research questions are identified.

1) What is the ICT integration measurement applicable in the Mongolian context?

2) Which school characteristics are associated with primary school teachers' ICT integration in Mongolia?3) Which teacher characteristics are associated with primary school teachers' ICT integration in Mongolia?

In order to develop an instrument to measure teachers' ICT integration, three steps are followed: 1) selection of ICT integration framework, 2) identification of potential ICT integration framework for Mongolia, and 3) localization of ICT integration framework in Mongolian context.

As for the first step, this study modified NETS-T to be applied in Mongolian context with the following reason: 1) its popularly used in both developed and developing countries; 2) multiple cases using NETS-T in Asia; and 3) validation with large samples of teachers in Taiwan.

For the second step, Hsu's study was carefully analyzed to identify categories applicable to measure ICT skills of primary school teachers in Mongolia. As a result, the study identified three categories that Mongolian primary schools teachers are currently using ICT. These three categories are the areas of 1) lesson preparation, 2) communication, and 3) selfdevelopment activities.

As the third step, the original question items from Hsu's study were analyzed and pilot tested with 22 Mongolian education experts. The draft instrument was revised and survey questionnaire was produced (table 1).

The newly developed instrument was used for data collection to answer research question 2 and 3.

3.2 Data collection

The survey questionnaire consists of three sections: 1) teacher background information (18 items); 2) school background information (17 items); and 3) use of ICT (12 items). A total of 571 questionnaires were distributed to three different regions reflecting regional diversity in Mongolia from August to September, 2013. A total of 413 questionnaires were returned, yielding

72% response rate. Finally, 359 questionnaires were considered valid for data analysis.



Figure 1: Data collection sites in Mongolia Source: Created by author

In order to supplement qualitative analysis, the focus group discussion and interview with a total of 13 teachers and education experts were conducted in Tokyo and Ulaanbaatar in 2014.

Table 1: The instrument (Section 3 of the survey)

	-					
		Question Items				
	1.	Use the Internet to search for information as				
:uc		supplementary teaching and learning material				
atic	2.	Use the computer to create teaching material,				
oar		class demonstrations and exam questions				
rel	3.	Use Power point and other presentation software				
n p		to create presentation to present teaching				
sso		material in class				
Le	4.	Use the Scratch and other software to record, edit				
		sound or music in my teaching material				
	1.	Use e-mail or chat to communicate with students				
on		and parents for collaboration and to give advice				
ati	2. Use e-mail or chat to communicate with o					
nic		teachers				
nu	3.	Use e-mail or chat to communicate with ECD				
imi		methodologist				
Č	4.	Use e-mail or chat to communicate with				
		professors and experts				
t	1.	Spent time to learn and practice ICT skills				
nen	2.	Use online courses for professional development				
lf- prr	3.	Use VCDs and DVDs for self-development				
Se elo	4.	Working by team to learn ICT skills				
levi						
0						

Note: 4-point-Likert scales (1=never use to 4=very often) Source: developed by author based on Hsu's study

3.3 Data analysis

3.3.1 Quantitative analysis

The quantitative analysis includes three components. First, descriptive analysis was conducted to illustrate the demographics of teachers and school characteristics of the data set. Second, exploratory factor analysis was conducted to verify whether the new instrument is measuring the intended constructs. Third, multiple regression analysis was utilized to find the factors affecting the ICT integration scales of primary school teachers.

3.3.2 Qualitative analysis

The qualitative analysis using face-to-face focus group discussions and individual interviews with education experts and primary school teachers were used to verify and explain the results of quantitative analysis.

4 Findings

4.1 Descriptive statistics

As for the basic demographics, 93% of the respondents were female teachers. 40.1% falls into the age between 31 and 40. 40.4% of the teachers have 1 to 10 years of teaching experience. 68.5% have bachelor's degrees and 9.2% obtain master's degrees. Regarding the computer ownership, while 78% of the teachers have their own computer, only 23% have an access to internet at home.

As for school characteristics, 56% of the schools are located in soum centers, while 21% are located in aimag centers and 23% in Ulaanbaatar city. 57% of the schools are connected to the internet, but only 10.6% have an access to internet at classroom level. Most teachers do not own computer at school (72.1%) and 38.5% have an access to internet at teacher development center at school.

4.2 Exploratory factor analysis

The exploratory factor analysis was conducted to verify the newly developed scales. The Kaiser-Meyer-Olkin measure (KMO-test) was used to determine whether question items are categorized into distinct constructs. The result, KMO=.870, is considered adequate, indicating its value greater than 0.5. Further, the factor extraction method was conducted to determine how many constructs are to be identified. The result shows that only two constructs are retained, which satisfied Eigen value greater than 1. Finally, factor rotation method was used to interpret newly identified scales. As a result, original three scales (lesson preparation, communication, and self-development) were re-categorized into two new scales.

The focus group discussion was organized to discuss the new constructs. They were named as 1) IT usage scale, and 2) Communication scale. These two new scales were utilized for the further analysis

4.3 Multiple regression analysis

The multiple regressions analysis was used to identify the factors affecting teachers' use of ICT for teaching and communication. Fourteen independent variables were chosen based on literature review and interview with Mongolian teachers.

The result of the multiple linear regressions on the primary school teachers' IT usage and communication scales are follows:

Equation (1) depicts that the use of ICT for teaching (*ITUS*) is predicted by five determinants, namely, school support, positive perception, school location, training and frequency of using computer per week. First, the stronger the level of teachers' agreement that school is supporting the use of ICT (*SSp*), teachers' frequency of IT usage in teaching increases by 0.342 scale score. Second, if the teachers have higher perception (P) on IT usage in teaching, their frequency IT usage in teaching increases by 0.233 scale score. Further, if a school is located in aimag center or in Ulaanbaatar (DL1), teachers' frequency of

IT usage in teaching increases by 0.170 scale score. Other influencing factors include teachers' attendance for training (*T*) and frequency of using computer per week (*F*). This model explains 31.7% of the variance of IT usage scale of primary school teachers in Mongolia.

ITUS=0.626+0.17(DL1)+0.342(SSp)+0.233(P) +0.132(F)+0.139(T)(1)

Equation (2) shows that primary school teachers' use of ICT for communication (CS) is predicted by six determinants, namely, school location, access to internet at school, access to internet at home, school support, years of teaching and teachers' title. First, if a school is located in Ulaanbaatar (DL2), the frequency of using ICT for communication increases by 0.366 scale score. Second, if a school has internet connection (*IS*). teachers' frequency of using ICT for communication increases by 0.338 scale score. Third, if the teacher has the internet connection at home (IH), frequency of using ICT for communication increases by 0.276 scale score. Other factors influencing on teachers' use of ICT for communication include school support (SSp), years of teaching (YOT) and teachers' title (DTI). It was found that both years of teaching and teachers' title are negatively associating with teachers' use of ICT for communication. The second model explains 41.1% of the variance of communication scale of primary school teachers in Mongolia.

CS = 0.713 + 0.366(DL2) + 0.338(IS) + 0.249(SSp)-0.21(YOT) - 0.159(DT1) + 0.276(IH)(2)

All the findings from the multiple regression analysis were discussed with interview with Mongolian teachers.

5 Discussion

The study confirmed that nine factors are associated with teachers' ICT integration in Mongolia. As for the school level factors, *school location, access to the internet at school* and *school support* were found to have significant association. Among these influencing factors, the analysis found the *school support* is the strongest determinant for both teachers' use of ICT for teaching and communication. This means if the school promotes integrating ICT into their school activities, teachers are likely to adopt new modes of ICT. The qualitative analysis also confirmed that teachers believe school support is the most important factor for their ICT integration, which supports the current literature [11].

In Mongolia, soum center schools are considered rural while aimag center and Ulaanbaatar city schools are considered urban. The study confirmed that urban school teachers have more frequent use of ICT for their teaching and communication activities, which is argued by current discussion [12].

As for the teacher level factors, teachers' *positive perception, training attendance, frequency of using computer per week, access to the internet at home,*

teachers' years of teaching and *teachers' title* were found to have significant association with teachers' ICT integration in Mongolia.

The study also confirmed *positive perception* of teachers increases the use of ICT for teaching, which supports current literature [13].

The findings of this study supports the literature [14] indicating the importance of the *teacher training*. It found that the more frequent teacher attends ICT related training, the more frequent they use ICT in teaching. In Mongolia, training is the only way that teachers can learn about how to utilize ICT into their teaching and school works once they graduate from college.

Study also confirmed that *access to internet both at school and home* have a significant association with teachers' frequency of using ICT for communication, which is argued by multiple literature [7][10]. In Mongolia, not every teacher is able to utilize Internet at school or home for finding information and communicating. Qualitative data illustrated that, the limited access to internet via computer has been greatly improved with a smart phone usage in Mongolia, and thus, the role of smart phone can be the further area of investigation.

The study confirmed previous studies that teachers with greater seniority and more years of experience seemed to be slower in learning communication tools or making multimedia lesson materials [7][15]. In Mongolia, the younger teachers are able to learn how to use ICT into their teaching when they are studying at colleges and universities. But the teachers, who have more teaching experiences and higher titles, could not learn these skills during their college education in the past.

Other factors such as teachers' gender, school size, and computer ownership were not making difference for teachers' ICT integration in Mongolia, and thus, further investigation is required.

6 Conclusion

The study contributed in developing the instrument to measure how teachers use the ICT to enhance their ICT integration in teaching in Mongolian context. It also investigated the teacher level and school level factors affecting frequency of teachers using ICT for teaching and communication activities.

The instrument developed in this study utilized Hsu's ICT integration scales and localized, identifying two scales, namely IT usage (measuring frequency of using ICT for teaching) and communication (measuring frequency of using ICT for communication).

The study found that six teacher level factors and three school level factors are affecting teachers' ICT integration scales. For Mongolian primary school teachers, positive perception on ICT use in teaching and school support are found to be important factors increasing the frequency of ICT use in school settings. With the rapid infrastructure development, influence of Internet connections both at schools and homes are found to be significant factors influencing teachers' use of ICT.

These findings have important policy implications for local government and school administrators to develop more effective ICT implementation and teacher training at school level in Mongolia.

References

- Gita Steiner Khamsi & Ines Stolpe (2004). Decentralization and recentralization reform in Mongolia: tracing the swing of the pendulum. *Comparative Education*, 40:1, 29-53
- [2] Sukhbaatar, J., Yamaguchi, S., Takada, J.,R. Bat-Erdene, L., Orgilmaa. (2012). Sustainable use of ICT for teacher training in primary schools in Mongolia-Phase 2, Final report submitted to Japanese Ministry of Education, Culture, Sport, Science and Technology, Japan.
- [3] Onodera, J., Yamaguchi, S., (2011). ICT use in primary schools: Comparative analysis of five rural provinces in Mongolia. Conference Proceedings, 55th Annual Conference on Comparative and International Education Society, Montreal, Canada.
- [4] Ministry of Education and Science (MECS), (2012). Master plan to develop education of Mongolian in 2006-2015. From: <u>http://www.mecs.gov.mn/data/lavlah/master_paln/educatio</u> n/EDU MP mon.pdf
- [5] Mueller, J., Wood, E., Willoughby, T., Ross, C., & Specht, J. (2008). Identifying discriminating variables between teachers who fully integrate computers and teachers with limited integration. *Computers & Education*, 51(4), 1523– 1537.
- [6] Becker, H. J. (2001). How are teachers using computers in instruction? American Educational Research Association, Seattle, WA.
- [7] Hsu Shihkuan and Kuan Ping-Yin. (2013). The impact of multilevel factors on technology integration: the case of Taiwanese grade 1–9 teachers and schools. *Education Tech Research Dev* 61:25–50, DOI 10.1007/s11423-012-9269-y
- [8] ISTE. (2000). National education technology standards and performance indicators for teachers (NETS). From: <u>http://www.iste.org/docs/pdfs/nets_for_teachers_2000.pdf?</u> <u>sfvrsn=2</u>
- [9] Hsu.S. (2010). Developing a scale for teacher integration of information and communication technology in grades 1–9. *Journal of Computer Assisted Learning* 26(3):175–189. doi:10.1111/j.1365-2729.2010.00348.x
- [10] Tondeur, J., Valcke, M., & van Braak, J. (2008). A multidimensional approach to determinants of computer use in primary education: Teacher and school characteristics. *Journal of Computer Assisted Learning*, 24(6), 494–506.
- [11] Dawson, C., & Rakes, G. C. (2003). The influence of principals' technology training on integration of technology into schools. *Journal of Research on Technology in Education*, 36(1), 29–49.
- [12] Toprakci, E. (2006). Obstacles at integration of schools into information and communication technologies by taking into consideration the opinions of the teachers and principals of primary and secondary schools in Turkey. *Journal of Instructional Science and Technology* (e-JIST), 9(1), 1-16.
- [13] Van Braak, J., Tondeur, J., & Valcke, M. (2004). Explaining different types of computer use among primary school teachers. *European Journal of Psychology of Education*, 19(4), 407–422.
- [14] Davis, N., Preston, C., & Sahin, I. (2009). Training teachers to use new technologies impacts multiple ecologies: Evidence from a National Initiative. British Journal of Educational Technology, 40(5), 861–878.
- [15] Inan, F. A., & Lowther, D. L. (2010). Factors affecting technology integration in K-12 classrooms: A path model. Educational Technology Research and Development, 58(2), 137–154.

THE STUDY OF ECONOMIC DEVELOPMENT EFFECT ON FLOOD DAMAGE

Student Number: 12M5356 Name: Tarinee Thongcharoen Supervisor: Naoya ABE

Floods, among all types of natural disasters, are the most common types and the leading cause of economic damages and fatalities. In reality, physical, economic, social and political factors determine vulnerability of population and their capacity to cope with and recover from natural hazards. The reduction in the risk of floods can be undertaken by reducing these vulnerabilities. The first step to reduce vulnerability is to identify them. This study proposed an Economic and Social Vulnerability Index involving three approaches, which consist of several combinations of economic and social development indicators, to investigate the relationship between economic and social development and flood damages. The proposed index can be used to determine vulnerability status of a particular country and for international benchmarking on vulnerability. The study aims to describe the impact of economic and social development of countries on flood damages in terms of fatalities and economic loss and identify the most vulnerable group of countries based on the proposed index.

1. Introduction

Nowadays, there are increasing concerns toward disasters and their destructive effects. This may be due to the frequent occurrences and overwhelmingly devastating impacts of disasters that many countries suffered in the last decade (EM-DAT, 2013). Flood is one of the most prevalent and problematic natural disasters. The number of floods that occurred during 2004-2012 was observed to be increasing sharply throughout every region around the world. Regarding geographic regions, Asia suffers the highest loss from floods among all regions.

Flood damages across countries with different income levels, according to the World Bank's definition, account for different proportions of the total damages from floods (Figure 1). For high-income countries, while damages in terms of fatality are very low, 25% of the total damages in terms of direct economic loss is still accounted for. The uppermiddle income countries suffered the most in terms of both number of people affected and direct economic loss from flooding. The sum of the damages suffered by these countries accounted for over 50% of the total direct economic loss. These differences in the amount of damages suggest that not only geographical differences but also levels of economic development have an effect on the amount of damages from floods.

Vulnerability is the degree to which a population, individual or organization is unable to anticipate, cope with, resist and recover from the impacts of disasters (WHO, 2002). The vulnerability perspective regarding risks of floods assumes that damages from floods will be experienced when a disaster strikes an underprivileged population. A good combination of preparation, prevention and structural measures before, during and after floods are necessary for damage mitigation and prevention. However, the necessary degrees of measures vary for different countries as the degrees of vulnerability among countries are at different degrees. It is essential for governments, policy makers and individuals to be aware of their respective risk levels and acknowledge their own vulnerability and capability to be able to adapt and adopt appropriate measures against floods. Moreover, international cooperation and exchanges of knowledge and technologies among countries with similar situations and capabilities can lead to more efficient development of flood awareness and prevention policy.



Low Lower-middle Upper-middle High

Figure 1: The percentage of total damages from flood during 2004-2012 according to country's income level (Source: EM-DAT version 12.07, 2013)

2. Objectives of the study

The study has two objectives, as stated below:

- a) To examine which economic and social indicators best explain which countries are most likely to suffer higher economic losses from flood and identify the correlation that exist between said indicators and economic loss from flood.
- b) To develop a standardized data index that factor in key economic and social vulnerabilities from floods and identify the groups of countries, which experience similar impacts in terms of economic loss from flood.

3. Research Methodology

3.1 Fatality and percentage of economic loss from flood to GDP as a proxy for flood damages

In this study, two dimensions of damages due to flooding were considered: fatality and percentage of economic loss from flood to GDP. The selection criteria of the two dimensions are discussed in the succeeding paragraphs.

Once flood strikes a community, the most destructive consequence of the disaster result in loss of life, or in other words, loss in human resources because the loss of life cannot be recovered. Other consequences would result in economic loss, which can be recovered depending on the capacity of the community. However, the same amount of direct economic loss from flood can have different extent of consequences because of size of economies. For example, flooding in Guyana in 2006 affected the country badly and had chain consequences to several sectors in the country. According to EM-DAT (2013), the economic loss by flood accounted for 11.85% of GDP in that year and it took the country to recover for several months to get back to the same economic level as before the event. As another example, Austria experienced approximately similar amount of economic loss from flood in 2009 with that in Guyana in 2006. Even though the level of loss was high, it only accounted for 0.05% of Austria's' GDP and have lower effect to the overall economy of the country.

Both fatality and percentage of economic loss to GDP are summed up for every event within a year. By doing this, the effect of occurrence was indirectly considered with the assumption that the effect of floods will eventually result in fatality or economic loss. If there were high occurrences of floods and each flood resulted in small amount of damages, the final value of the damages would be high. However, if a country experienced flood several times but those floods yielded no damages, the occurrence of floods will be neglected since they result no damage in term of economic loss and fatality.

3.2 Economic and Social Development Vulnerability Index

Vulnerability is understood as the degree to which a country or a community is likely to experience harm due to exposure to a hazard. In actuality, vulnerability depends on several factors.

Under the assumption that wealthy people will have more capability to cope with emergency event like flood and other disaster due to higher income, good quality of life and better education (Baritto. F. 2008, Banuri. S. 2005, Schumacher. I. & Strobl. E. 2011), three aspects of economic and social vulnerabilities was considered: economic resilience, distribution of wealth, human health and well-being. A set of indicators proposed as indirect measures of economic and social vulnerabilities are compared against the relative magnitude of economic losses to GDP and fatality. The key indicators include the following: Gross saving per capita, Human Development Index (HDI), Income distribution index (Gini). In order to investigate the effect of education levels on flood damages, three approaches to compute the index were proposed. With the assumption that educated populations are more capable of disseminating information and preparing the risk prevention measures against disaster, approach 1, 2 and approach 3 were created to see the effect of higher education level on figures of damages. Approach 2 and 3 composed of the same 3 proxy indicators for each aspect like those in approach 1 with extra indicators on secondary and tertiary education level accordingly. The indicators for each approach are shown in Table 1.

Table 1	List (of Key	Indicators	for	com	puting	index
)					

Approach	Indicators				
1	Gini	HDI	Gross saving		
2	Gini	HDI	Gross saving	Secondary	
3	Gini	HDI	Gross saving	Secondary T	ertiary

3.3 Methodology Framework.

The objectives and methodologies used in this study are summarized in Figure 2. First, methodology for computing economic and social vulnerability index values adopted from the inequality-adjusted HDI methodology proposed by the United Nations Development Program (UNDP) in 2010. Second, the data analysis employed principle correspondence analysis (PCA) to assign a weighted linear combination to the original indicators (shown in Table 1) in order to make a comparison with the results from economic and social vulnerability index

Third, to choose the best approach for creating an index, which has the most power to explain the effect of economic loss and fatality. Pearson's correlation was used to show the relationship between the amount of damages and Index values and figures of damages and component scores in this case the percentage of economic loss. Finally, cluster analysis (CA) was used in order to identify the group of countries with similar levels of vulnerability and extent of damages. The most vulnerable group identified by using cluster analysis was found to be associated with 2 conditions. First, the group of countries had the lowest average level of index value or component score. Second, the group with the lowest score also had the highest average percentage of economic loss to GDP.

Figure 2: Methodology framework and result from each procedure



4. Data

Two data sets were used in this study. The first included information on flood characteristics. The data was obtained from the OFDA/CRED International Data Base. The original data includes 1,518 observations during 2004-2012 periods. In order to analyze the data on a per country and yearly basis, the data was rearranged. Data on economic losses from events that occurred in the same year within the same country are combined together and set as a new observation. The final number of observations considered, then, was reduced to 736 events. Each country's economic and social development data were collected from several sources.

In order to compute the index, all data must be available. Nonetheless, some countries were not included in the database for various reasons, mainly for their unavailability of certain crucial data. For some countries, data for economic and social indicators are available in some years but missing in other years. When considered available data of gross saving from 2004-2012, values of the same country changed rapidly even between consecutive years. This lead to the difficulties in predicting or assuming the trend of the indicator and would be inappropriate to treat the missing year data with the data from the available year. This also applied to other indicators as well. To avoid this bias, the year which is richest in terms of data availability were used for further analysis. Hence, the analysis only considered flood events in year 2004.

5. Conclusions and Recommendations

The damages from floods and economic and social indicators for countries, which floods struck in 2004, have been examined.

a) The results showed that, among the three proposed approaches, the composition of five economic and social development indicators (i.e., Human Development Index, income distribution index, gross saving per capita, secondary education and tertiary education level enrolments) was considered to be the best approach to identify countries with high flood vulnerability in terms of economic loss with the highest correlation coefficient when compared to other approaches (Table 2). The negative coefficients represent that as index values or component scores increase, the figures of damages decrease. The results suggest that higher levels of education (i.e., which reflects awareness level of disaster preparedness) correlate to lower damages from flood.

b) The result shows that current vulnerability to flood in term of economic and social development in Bangladesh, Bhutan, India, Indonesia, Iraq and Tajikistan is profound. Regarding fatality, Nepal, China. Bangladesh and India seem to have a unique characteristic in the extent of damage and difference level of economic and social development.

 Table 2: The comparison of Pearson correlation coefficients

 for Index and Component with figures of damages

	Approach	Ecogdp*	Fatality**
	1	0.0137	-0.1843
PCA	2	-0.0502	-0.1754
	3	-0.0739	-0.1997
	1	-0.1181	-0.1707
Index	2	-0.1429	-0.2273
	3	-0.1442	-0.2048

*Ecogdp is the percentage of economic loss from flood to Gross Domestic Product (GDP). **Fatality is the number of people killed by flood

6. Limitations and Future Research

While the study consist of important aspects of economic and social vulnerability, it has also raised a number of potential directions for further research. First, limitation in data accessibility for countries with poor recording system can lead to miscalculation of the analysis. Data on least developed countries is very poor and these countries have been excluded from the study. An effort should be done to improve available information on a predefined list of indicators.

Second, the results of the analysis in the study relied on the quality of the data-set. In order to obtain the most precise result, the data had better be as much accurate as possible. While the occurrence of disaster can be recorded when the event happens, the measurement of economic and social damages due to the disaster event tend to be difficult and time-consuming, and often resulting in the annual-basis data with uncertainty. As a result, the group of vulnerable countries according to economic and social vulnerability index, in this study, is only a snapshot of time (2004) and may not fully represent previous trends or on-going evolutions of certain dimensions. Nonetheless, due to rapid changing on the trend of flood occurrence and severity, it is more appropriate to rely on the most recent available data to reflect the present condition for future study.

Third, the percentage of economic loss to flood was used as a proxy for country's flood sensitivity and to explain the extent of which economic loss from flood affected that country economic. However, there are many aspects of economic activities that are not included in the measurement of GDP. The result may not be accurate for some countries. For example, the Philippine have large remittance from aboard resulting the large number in GNI. Timor-Leste's GNI also higher than GDP because of international aid. Finally, the index is intended to spatially identify economic and social vulnerable populations and focus on the different effect from level of education. However, direct linkages between disasters and the economy and social development are complicated and not clear. To investigate further relationship between economic loss from floods, geographic characteristics environment conditions and other country characteristics, which can be effect by flood, should be consider.

References:

EM-DAT the International Disaster Database (2013). Data version 12.07, www.emdat.be

World Bank (2014). Country and Lending Groups, http://data.worldbank.org/ Baritto, F. (2008). Disasters, Vulnerability and resilience: A methodological framework from an economic perspective. ICTSD – UN-ISDR., Switzerland. Banuri, S. (2005). The Macroeconomic Impact of Natural Disasters. Term Paper

ECO 5322-01. Department of Economics. Richardson, Texas. December.

Jonkman, S. N., & Kelman, I. (2005). An analysis of the causes and circumstances of flood disaster deaths. *Disasters*, 29(1), 75–97

Rygel, L., O'sullivan, D., & Yarnal, B. (2006). A Method for Constructing a Social Vulnerability Index: An Application to Hurricane Storm Surges in a Developed Country. *Mitigation and Adaptation Strategies for Global Change*, *11*(3), 741–764.

Schumacher, I., & Strobl, E. (2011). Economic development and losses due to natural disasters: The role of hazard exposure. *Ecological Economics*, *72*, 97–105.

Plate, E. J. (2002). Flood risk and flood management. Journal of Hydrology, 267(1-2), 2–11.

STUDY OF PROPAGATION MECHANISMS IN INDOOR MULTIPATH CHANNELS AT 11 GHz

Student Number: 12M51362 Name: BELBASE Khagendra Supervisor: TAKADA Jun-ichi

11 GHzにおける屋内マルチパスチャネルの伝搬メカニズム

Abstract

This thesis investigates the dominant propagation mechanisms in indoor line-of-sight (LOS) environments with the help of channel measurement and ray tracing simulation. Double-directional channel sounding was performed using 24×24 multiple-input multiple-output (MIMO) channel sounder at 11 GHz with 400 MHz bandwidth to get the MIMO channel transfer function. Path parameters from ray tracing simulation and antenna array response were used to reconstruct the ray tracing based channel transfer function. Beamforming was applied to the channel transfer function to get angle resolved power spectrum. Then the angular and delay power spectra were used to identify the dominant propagation mechanisms in considered environments. Along with LOS component, walls and window reflected paths were found to be the dominant propagation mechanisms observed in both measurement and simulation. But ray tracing failed to predict the scattering power from the long and thin metal objects such as window frame and metal pillar edge which are the significant objects observed in measurement.

1 Introduction

With the ever growing demand of higher data rates in mobile systems, use of new transmission techniques and wider frequency bandwidth is necessary. However, the frequency bands in the lower microwave range (below 6 GHz) are already congested or have limited bandwidth available for further use. Therefore exploring the upper frequency bands where the wider bandwidth is available is inevitable choice for the future high bit rate communication systems [1]. Along with the use of higher frequencies, use of multiple antennas at both transmitter and receiver popularly known as MIMO system can increase the data rate significantly. Since the performance of MIMO systems highly depends on the directional and delay characteristics of the channel, study of the channel should not be limited to the study of path loss characteristics and more detailed analysis on directions of arrival (DOA), direction of departure (DOD), and time delay of arrival of the multipath components is needed. These characteristics are dictated by the dominant propagation mechanisms in considered environments.

In wireless communication systems, propagation channel is not the controllable phenomenon. But if the appropriate channel models are known, the transceivers including antennas can be designed to exploit the channel to achieve maximum data rate. Therefore this work is focused on the study of wideband MIMO propagation channel at 11 GHz in indoor environments. This frequency is of particular interest because of the availability of wider bandwidth, and the higher path loss which is suitable for reducing the cell size in future small cell mobile systems.

In order to study the dominant propagation mechanisms, the measurement and ray tracing simulation are performed in this study. Ray-tracing algorithms are popular approaches for propagation prediction and modeling since they can investigate most of the radio propagation mechanisms of wireless channels. But the ray-tracing algorithms do not include the non-specular scattering effects, which are common in micro-cell and indoor environments. Channel sounding measurements are the foundation for

Parameter	Value
Carrier Frequency	11 GHz
Signal Bandwidth	400 MHz
Delay resolution	2.5 ns



Table 1: Specification of channel sounder

Figure 1: Channel Sounder

channel modeling as they can represent the realistic environments. Although the they provide the most accurate characteristics of the channel, the task of channel sounding is very complex, costly and time consuming. So, the use of propagation simulation tools is a very efficient way to predict the channel for characterization.

The previous studies in outdoor microcell have shown that the metallic objects with dimensions as small as tens of radio wavelengths can be the source of significant scattering [2, 3]. Also the double directional MIMO channel sounding data is used to identify the propagation mechanisms in indoor environments at 5.3 GHz [4]. Since the type and size of objects in indoor environments are different from outdoors, dominant mechanisms are expected to be different. At 11 GHz, scatterers as small as few tens of centimeters can have the significant effect in received multipath components. Therefore, the objective of this study is to analyze and compare directional wideband channel characteristics of measurement and simulation to find the significant discrepancies of mechanisms.

2 Methodology

2.1 Channel Sounding

Channel sounding refers to the task of measuring the properties of propagation channel. 24×24 MIMO channel sounder is used in this study [5], as shown in Fig. 1. This sounder has a very high delay resolution of 2.5 ns, so has the capability to distinguish multipath components with high accuracy. By using the uniform circular array (UCA) antennas for beamforming, it can achieve the angular reso-



Figure 2: Example of ray tracing output for Room B

lution of 30 degrees. The specification of channel sounder are given in Table. 1.

2.1.1 Description of the environment

The environment considered in this study is indoor line-ofsight (LOS) scenario. Two hall and room environments are investigated for the dominant propagation mechanisms. One is a big hall (Hall A) of size 30 m \times 10 m \times 7 m having concrete walls and large glass windows. The floor is made of concrete and the ceiling is considered to be a open space. Another is the room (Room B) of size 18 m \times 10 m \times 3 m with concrete walls having metallic boards at the end, metallic floor, and concrete ceiling. The windows are covered with metallic blinders so can be considered to be metallic. The room was made empty by moving all the furniture in one side of the room. The detailed location, shape and orientation of these rooms are described in [1].

2.2 Ray Tracing Simulation

Ray Tracing simulation is one of the widely used techniques for the prediction of site-specific propagation channel. It uses geometrical optics (GO) to trace the paths taken by the electromagnetic waves when they travel from transmitter to the receiver in the given environment. In this study, commercial ray tracing software RapLab [6], which implements the image method of ray tracing to find the ray paths from transmitter to the receiver is used as a simulator. The building model, reconstructed from point cloud data of 3D measurement, was simplified further by removing the small objects which are difficult to handle by GO based ray tracing simulators. In Hall A, some pieces of furniture were present while doing the measurement, but were discarded in the simulation. In Room B, projectors and LCD display screens which were fixed on ceiling were discarded. The walls are modeled as concrete, windows as glass plates, and metallic boards and pillars are modeled as steel. The used values of relative permittivity (ϵ_r) and the conductivity (σ) for concrete and glass are shown in Table 2. The conductivity of steel is set to 1.03×10^7 Siemens/meter. The simulator takes into account of the reflection and diffraction of the ray-paths based on the conductivity and dielectric property of the walls and other

Table 2: Material parameters used in simulation

Material	Rel. Permittivity (ϵ_r)	Conductivity (σ) S/m
Concrete	6.76	2.3×10^{-3}
Glass	5.0	1.0×10^{-12}



surrounding scatterers. Since the material properties has a very big influence in the computed results, some trial simulations were done to select the material types to best fit the measurement results. One sample ray tracing result for Room B is shown in Fig. 2.

3 Path Loss and Polarization Characteristics

To study path loss from the measurement, transmitter was moved along a route and channel transfer function is measured at a fixed receiver. Antenna arrays having dual polarized i.e. vertically polarized (VP) and horizontally polarized (HP) antenna elements with omni-directional azimuth radiation pattern with a gain of 4 dBi are used. Then the path loss is calculated using the spatial averaging as mentioned in [1]. This averaging was performed over the distance of 0.5 m (20 λ) to mitigate the effect of small scale fading. Ray tracing simulation was also done with moving transmitter and fixed receiver with the same locations as in measurement. Small scale fading in ray tracing was mitigated using the random phase approach as described in [7]. This approach realized the spatial averaging considering that for a nearby locations, the magnitude of received power is almost same but the phase is different based on total path length traveled by a wave.

The measured and simulated path losses were then fitted into the power-law model, which is a linear plot in log-log scale where abscissa is distance and ordinate is path loss. This linear model is represented by

$$L[dB] = a \cdot 10 \log_{10}(d[m]) + b + X, \tag{1}$$

where *a* and *b* denote the path loss exponent and the intercept at 1 m distance, respectively. And, $X \sim N(0, \sigma^2)$ indicates a log-normally distributed random variable with zero mean and variance σ^2 . Here σ represents the standard deviation. Fig. 3 and Fig. 4 show the path loss characteristics obtained from measurement and simulation respectively for the co-polarization and cross-polarization cases for Hall A. Ray tracing simulation is found to have better accuracy in predicting the path loss characteristics for co-polarization case. Since the measurement antenna have cross polarization discrimination (XPD) value of about 16 dB, it cannot measure the cross-polarization power if cross-polarization XPR is found to be 30 dB, this means the limitation of measurement antennas make it impossible to

discuss about the cross-polarization path loss. But the values of co-polarization power ratio (CPR) are showing the good match with mean value near 0 dB in measurement and simulation for both environments. This means the path loss behavior of the channel is similar for vertically polarized and horizontally polarized waves.

4 Identifcation of Dominant Propagation Mechanisms

To study the dominant propagation mechanisms and site specific behavior, two-dimensional double-directional measurement was conducted using uniform circular antenna array (UCA) to obtain the 24×24 MIMO channel transfer function. Ray tracing based channel transfer function is reconstructed using the antenna calibration data and path parameters obtained from the simulation. This reconstruction is necessary as the direct comparison of measurement and simulation results is not effective because of the different resolution limits of these two approaches. The results from ray tracing has infinitesimal resolution in angular and delay domain but the measured result's resolution is limited bay system bandwidth and beamwidth of the antenna used in channel measurement.

4.1 Channel Transfer Function Reconstruction

The ray tracing based channel transfer function can be written as [8]

$$\mathbf{H}(f) = \sum_{l=1}^{L} \mathbf{a}_{\mathrm{R},l} \left(\varphi_{\mathrm{R},l}, \theta_{\mathrm{R},l}, f\right) \mathbf{\Gamma}_{l}$$
$$\mathbf{a}_{\mathrm{T},l}^{T} \left(\varphi_{\mathrm{T},l}, \theta_{\mathrm{T},l}, f\right) e^{-\mathrm{j}2\pi f \tau_{l}} , \quad (2)$$

where L is total number of ray-paths obtained from the ray-tracing simulation, $\mathbf{a}_{\mathrm{R}}(\varphi_{\mathrm{R},l}, \theta_{\mathrm{R},l}, f)$ is the array response of receiving antenna array, which is the function of azimuth $(\varphi_{\mathrm{R},l})$, co-elevation $(\theta_{\mathrm{R},l})$ and frequency f of the l-th, and $\mathbf{a}_{\mathrm{T}}(\varphi_{\mathrm{T},l}, \theta_{\mathrm{T},l}, f)$ is the array response of transmit antenna array. The delay time τ_l corresponds to path length of l-th path. $\mathbf{H}(f) \in \mathbb{C}^{M_{\mathrm{R}} \times M_{\mathrm{T}}}$, and $M_{\mathrm{T}}, M_{\mathrm{R}}$ are number of antenna elements at transmitter and receiver side in the measurement. The dual-polarized complex path weight for l-th path is given in matrix form as

$$\Gamma_{l} = \begin{bmatrix} \gamma_{\mathrm{VV},l} & \gamma_{\mathrm{VH},l} \\ \gamma_{\mathrm{HV},l} & \gamma_{\mathrm{HH},l} \end{bmatrix} \in \mathbb{C}^{2 \times 2}$$
(3)

where, $\gamma_{\rm VV}$ and $\gamma_{\rm HH}$ are the co-polarized path weights i.e. when the transmitting and receiving antenna polarizations are same. Similarly, $\gamma_{\rm VH}$ and $\gamma_{\rm HV}$ are the cross-polarized path weights when the cross polarized antennas are used.

4.2 Beamforming

Beamforming or matched filtering of the reconstructed channel transfer function using ray tracing and the measured channel transfer function is done to obtain the double-directional power spectrum [9]. The angular power spectrum from beamforming is calculated as follows:

$$P_{\rm BF}\left(\varphi_{\rm Rx},\varphi_{\rm Tx},f\right) = \frac{\mathbf{a}_{f}^{H}\left(\varphi_{\rm Rx},f\right)\mathbf{H}_{f}\mathbf{a}_{f}^{*}\left(\varphi_{\rm Tx},f\right)}{\|\mathbf{a}_{f}\left(\varphi_{\rm Rx},f\right)\|^{2}\|\mathbf{a}_{f}\left(\varphi_{\rm Tx},f\right)\|^{2}}$$
(4)



Figure 5: Measured angular delay profile for Hall A

where $\mathbf{a}_f(\varphi_{\mathrm{Tx}}, f)$ and $\mathbf{a}_f(\varphi_{\mathrm{Rx}}, f)$ are transmitter and receiver array response in the azimuth plane, and \mathbf{H}_f is the channel transfer function constructed in (2), or the measured channel transfer function. The beamforming is applied in every 6° in the entire azimuth plane (from 0° to 360°) for co-elevation angle of 90° since the dominant paths are coming from the azimuth plane because of the equal antenna heights at transmitter and receiver. Further analysis of the channel and the identification of the dominant propagation mechanisms is done using this beamformed power spectrum.

4.3 Angular Delay Power Spectrum

To study multipaths in double azimuth and delay domain, angle resolved channel impulse response is obtained by taking inverse discrete Fourier transform (IDFT) to the beamformed power spectrum.

$$P_{\text{ADS}}\left(\varphi_{\text{Rx}},\varphi_{\text{Tx}},\tau\right) = \text{IDFT}\left\{P_{\text{BF}}\left(\varphi_{\text{Rx}},\varphi_{\text{Tx}},f\right)\right\}$$
(5)

This is a double directional complex impulse response. To calculate the transmitter side angular delay spectrum, the squared amplitude of the impulse response is summed up along the receiver azimuth for each delay unit. Mathematically,

$$P_{\text{TAS}}\left(\varphi_{\text{Tx}},\tau\right) = \frac{\Delta_{\varphi_{\text{Rx}}}}{B_{\text{Rx}}} \sum_{\varphi_{\text{Rx}}} |P_{\text{ADS}}\left(\varphi_{\text{Rx}},\varphi_{\text{Tx}},\tau\right)|^2 \quad (6)$$

where $\Delta_{\varphi_{Rx}}$ and B_{Rx} denote the resolution of antenna pattern data and half-power beam width respectively of the beamformer at the receiver. Similarly we can calculate the angular delay spectrum at the receiver. The angular delay power spectra when overlapped with building model, scatterers could be identified by tracing the rays from the location of transmitter and receiver as shown in Fig. 5. From this figure, dominant paths in measurement were found to be the LOS component and single bounce reflection from concrete wall, glass window, metallic pillar, and glass screen. Glass screen path could not be detected by simulation because of small mismatch in the orientation of glass screen in the simulation model. Since it is difficult to find all the discrepancies from angular power spectra, delay domain characteristics at the same point is analyzed further with the help of delay power spectrum.



Figure 6: Power Delay Spectrum from measurement and simulation, Hall A

4.4 Delay Power Spectrum

The delay power spectrum represents the average power of the received signal along the delay. It is obtained by summing up the squared amplitude of double directional channel impulse response with respect to transmit and received azimuth. It is defined as

$$P_{\rm DS}\left(\tau\right) = \frac{\Delta_{\varphi_{\rm Tx}} \Delta_{\varphi_{\rm Rx}}}{B_{\rm Tx} B_{\rm Rx}} \sum_{\varphi_{\rm Rx}} \sum_{\varphi_{\rm Tx}} |P_{\rm ADS}\left(\varphi_{\rm Rx}, \varphi_{\rm Tx}, \tau\right)|^2$$
(7)

Fig. 6 shows the delay power spectrum for the same Tx Rx locations and it is representing the same multipath as those depicted in Fig. 5. From this power spectrum, two paths which arrive at the delay of 70 and 72 ns are found to have major discrepancy with about 5 dB higher power observed in measurement. The first path is coming from the metallic pillar and the second is coming from the window. These identified scatterers are shown in Fig. 7 and Fig. 8. For the path coming from metal pillar, reflection from flat face was dominant and diffraction from the vertical edge has negligible power in the ray tracing. But from measurement, scattering from the edge appears to be dominant and ray tracing fails to predict this power. For the path arriving from window reflection, scattering from metal frame is attributed to the additional power seen in measurement. Window is modeled as a glass in the beginning and model with metal frames is added to check if ray tracing results could be improved. But it is found that ray tracing could not include this scattering even the frames are modeled. Another finding is that the horizontal polarized signal was not showing the scattering from that location, which shows the polarization dependency of the scattering objects. Similar analysis was done for Room B and dominant propagation mechanisms were found to be the LOS component, 4 single bounce reflections from windows and metallic boards and two more double bounce reflections from wall end metallic boards. Major scattering objects causing discrepancies were identified as the vertical section of window frame for vertical polarization and top horizontal frame for the horizontally polarized signals.

5 Conclusion and Future Work

In this work, it has been identified that window frames and metal pillars in indoor environments have significant con-





Figure 7: Steel pillar

Figure 8: Metal frames in window

tribution in received multipath component in the measurement, but not in the ray tracing simulation. Also the polarization dependency of the scatterer's orientation is examined. Using the measurement results, it is confirmed that vertically oriented metallic objects scatter the power when vertically polarized signal is incident and horizontal metal frames scatter the power for the horizontally polarized wave. Ray tracing could not include these effects which limits the accuracy of the ray tracing simulation. Use of physical optics approach to take into account of the metal scattering along with the geometrical optics assumption of ray tracing is expected to improve the accuracy of the simulation results.

References

- [1] M. Kim, Y. Konishi, Y. Chang, and J. Takada, "Large Scale Parameters and Double-Directional Characterization of Indoor Wideband Radio Multipath Channels at 11 GHz," *IEEE Trans. Antennas Propagat.*, vol. 62, no. 1, pp. 430–441, January 2014.
- [2] M. Ghoraishi, J. Takada, and T. Imai, "Identification of Scattering Objects in Microcell Urban Mobile Propagation Channel," *IEEE Trans. Antennas Propag.*, vol. 54, no. 11, pp. 3473–3480, Nov. 2006.
- [3] N. Lertsirisopon, G. S. Ching, M. Ghoraishi, J. Takada, I. Ida, and Y. Oishi, "Investigation of non-specular scattering by comparing directional channel characteristics from microcell measurement and simulation," *IET Microw. Antennas Propag.*, vol. 2, no. 8, pp. 913– 921, 2008.
- [4] J. Poutanen, K. Haneda, J. Salmi, V.-M. Kolmonen, F. Tufvesson, and P. Vainikainen, "Analysis of Radio Wave Scattering Processes for Indoor MIMO Channel Models," in Proc. IEEE Int. Symp. Personal, Indoor and Mobile Radio Communications, Tokyo, pp. 102– 106, 2009.
- [5] Y. Konishi, M. Kim, Y. Chang, and J. Takada, "Versatile Radio Channel Sounder for Double Directional and Multi-link MIMO Channel Measurements at 11 GHz," *to be published on IEICE Trans. Electron.*, vol. E97-C, no. 10, Oct. 2014.
- [6] RapLab. [Online]. Available: http://network.kke.co.jp/products/raplab/.
- [7] S. Takahashi and Y. Yamada, "Propagation-loss prediction using ray tracing with a random-phase technique," *IEICE Trans. Fundamentals.*, vol. E81-A, no. 7, pp. 1445–1451, July 1998.
- [8] H. Zhu, J. Takada, K. M. Araki, and T. Kobayashi, "A Ray-Tracing-Based Characterization and Verification of the Spatio-Temporal Channel Model for Future Wideband Wireless Systems," *IEICE Trans. Commun.*, vol. E84-B, no. 3, pp. 143–153, March 2001.
- [9] S. Zhang, "Prediction of Indoor MIMO Channels for Specific Systems using Ray Tracing Simulation," Bachelor's thesis, Tokyo Institute of Technology, March, 2013.

CITIZEN-CENTRIC PERSPECTIVE ON THE ADOPTION OF E-GOVERNMENT IN THE PHILIPPINES

Student Number: 12M51474

Name: Aldwin Uy URBINA

Supervisor: Naoya ABE

ABSTRACT

Information and communications technologies (ICTs) and the Internet are widely used as strategic means to improve the efficiency and effectiveness of governments and the accessibility of government information and services to citizens. However, due to disparities in socio-demography, access to ICTs, Internet use as well as in the patterns of Internet use, and awareness of available e-government services in the Philippines, the adoption of e-government by citizens is faced with major challenges (e.g., inequitable access to information and government services, widening of the gap between advantaged and disadvantaged groups). This study employed primary data collected through a national-scale survey conducted as a result of collaboration with a private social research institution. Results of the study confirm that a large portion of the population in the Philippines has not yet used or accessed government web portals or "online government channels". Furthermore, the study initially examined potential predictors of e-government adoption and eventually uncovered which of the potential predictors have significant influence on the use of e-government services by employing logistic regression analysis. This study intends to serve as a reference to policymakers and other relevant stakeholders in the Philippines in appropriately addressing the gaps in the adoption of e-government by citizens.

1 INTRODUCTION

ICTs and the Internet have transformed traditional means of communication and interaction among citizens. They have also been widely used in the private/business sector and the success of its utilization is extensively evidenced at a worldwide scale. This has caused governments and public sector organisations around the globe to become aware of their potential and consequently utilize them; thereby triggering investments into electronic services (Choudrie et al., 2004).

In general, the employment of ICTs and the Internet in the administration of government functions and in the delivery of public services is described as electronic government or e-government. E-government helps governments achieve greater efficiency in performing their administrative operations and improve public service delivery by providing efficient, convenient and less costly means in accessing government information and services. However, critics claim that the development of electronic public services has been primarily guided by supply side factors and that technological possibilities rather than user needs have determined the design of online public services (Verdegem and Verleye 2009).

Studies on the adoption of e-government in literature can be categorized into two groups, namely, the supplyside and the demand-side (Reddick 2005). The first group of studies is concerned on the adoption of e-government from the supply-side perspective, which deliberates factors [e.g., information technology (IT) infrastructure, financial resources for IT development, number of egovernment initiatives implemented] that are essential to the government as the supplier of public services (Reddick, 2005). On the other hand, the second group of studies mainly focuses on the demand-side perspective of e-government adoption, which explores factors that are important to the clients of the government or consumers of public services (Reddick 2005). This study is associated with the latter group, which is the demand-side of e-government adoption, particularly the use of online government portals in accessing government information and services by citizens.

1.1 Objectives of the Study

There is a threat of digital exclusion ¹ with the implementation of e-government, which can exacerbate already-wide gaps between advantaged and disadvantaged groups. Yet, interests of policymakers in e-government have been directed toward the supply-side of electronic public service delivery and consequently, there are much fewer, if not lack of, data and investigations on the demand side (or from the perspective of citizens). Hence, this study aims to respond to the proposition for more demand-side oriented assessments of e-government. Specifically, the objectives of the study are (a) to determine the current state of e-government adoption by citizens in the Philippines; (b) to examine the factors affecting the usage of online government portals or websites; to identify the significant predictors of usage and the barriers underlying the low usage of such channels; and (c) to increase the awareness and understanding of policymakers in government on the current state of e-government adoption by citizens in the Philippines and to present opportunities on how to resolve prevailing issues identified in this study.

1.2 Significance of the Study

According to the United Nations (2012), there is no comprehensive data available to assess citizen usages at the global level (UNDESA, 2012). Furthermore, there has not been any study or data on the adoption of e-government by citizens in the Philippines to date. Thus, this study intends to fill-in information gaps in the state of e-government adoption in the Philippines and responds to the advocacy for data initiatives and information sharing regarding e-government adoption for international benchmarking.

2 METHODOLOGY

This study employed primary data obtained from a national-scale survey conducted by the Social Weather

¹ Digital exclusion generally refers to the marginalization of individuals who do not have access to and cannot effectively use ICTs and the Internet.

Stations or SWS² in March 2014 in the Philippines. The multi-stage probability approach³ was used for selecting 1,200 national representative samples. The survey data was obtained through face-face interviews of voting age adults (i.e., 18 years and above).

Table 1 Summary of Key Survey Questionnaire Topics

Key Topics	Details
Socio- demographic Information	Age, Gender, Educational Attainment, , Employment Status, Socioeconomic Class, Geographical Location, Type of Settlement (i.e., Urban or Rural)
Ownership of Computer and Internet Usage	Household Ownership of Computer, Use or Non-use of the Internet, Frequency of Internet Use, Types and Number of Internet Activities Undertaken
Adoption of E-Government	Awareness of Government Websites, Use or Non-use of Government Websites, Government Information or Service Accessed through Government Websites, Satisfaction with Government Information or Service Accessed through Government Websites, Problems Encountered in Using Government Websites, Reasons for Not Using Government Websites
Perception of E-Government	Willingness to Provide Personal Information on Government Websites, Usefulness of Government Websites

The survey data were analyzed using logistic regression analysis to investigate the extent of the association concerning the propensity to use e-government services with respect to a set of explanatory variables. The following equations (1) and (2) describe the calculation for the probability of usage or non-usage of online government portals:

$$P(y = J|x) = P(y = J|x_1, x_2, ..., x_k)$$
(1)

$$P(y = J|x) = \frac{e^{\beta x}}{1 + e^{\beta x}} = \Lambda(\beta x)$$
(2)

where y is dependent variable; J is the discrete choice of a respondent (e.g., 1=Yes; 0=No); x is the independent matrix; β is the column vector for the obtained coefficients by the regression, which represents the change in the natural logarithm of P(y=J|x) for each unit change in x; and Λ = cumulative probability density function (cdf), where the probability density function (pdf) is a logistic function.

To obtain the corresponding logit function, the above equation (2) is transformed into equations (3), (4) and (5):

$$logit[P(y = J|x)] = ln\left[\frac{P(y=J|x)}{1-P(y=J|x)}\right]$$
(3)

$$logit[P(y = J|x)] = ln \left[\frac{\frac{e^{\beta x}}{1 + e^{\beta x}}}{1 - \frac{e^{\beta x}}{1 + e^{\beta x}}}\right]$$
(4)

$$logit[P(y = J|x)] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k$$
 (5)

The odds ratio (OR), which represents the constant effect of a predictor x on the likelihood that one outcome will occur, can be obtained from

$$OR = e^{\beta} \tag{6}$$

The odds ratio is a measure of effect size and therefore provides information on the strength of

relationship between two variables. When the value of OR is equal to 1, the predictor variable does not affect the outcome; when OR > 1, a unit increase in the predictor variable will increase the odds of the outcome by the value of OR; when OR < 1, a unit increase in the predictor variable will decrease the odds of the outcome by the value of OR.

3 RESULTS AND DISCUSSION

A fully effective (i.e., all answers or responses to the set of questions in the survey questionnaire were considered effective) 100% response rate was achieved since household surveys were conducted through face-to-face interviews by SWS.

3.1 Disparities in Access to ICTs and the Internet

The examination of the national survey data shows that household ownership of computer and Internet use are generally low. Computer ownership in the household and Internet use tend to be higher in younger adults, individuals with higher educational attainment, individuals who belong to higher socioeconomic classes (or have higher incomes), and live in urban areas. They are also slightly higher in individuals who are males, employed and living in the National Capital Region (NCR) and Balance Luzon geographical areas.

Among Internet users, there are more individuals who are using the Internet less often than every other week. Also, individuals who are males, belonging to higher socioeconomic classes, living in urban areas and in the capital (NCR) generally use the Internet relatively more frequently. Moreover, Internet users visit social networking sites more than undertaking any other Internet activities (e.g., getting information on current events; buy things; getting information on health or physical fitness; getting information on health topic that's hard to talk about; working on blog; using Twitter; playing online games; and sharing artwork, photos, stories or videos). However, most individuals undertake only few Internet activities (1-3 activities). Relatedly, the indicator 'breadth of Internet activities undertaken' reflects the skills and experience of individuals in using a number/variety of available Internet applications.



Figure 1 Frequency of Internet Use

3.2 Attitudes Toward E-Government

With regard to the respondents' attitudes toward egovernment, 61% of the 1,200 respondents are at least somewhat willing to provide their personal information on government websites. The respondents' willingness to provide personal information on government websites suggests that they generally find e-government trustworthy. On the other hand, 78% of the 1,200 respondents perceived government websites as useful in

² SWS is a private non-stock, nonprofit social research institution, which is responsible for the conduct of the quarterly Social Weather Surveys, which aim to provide an independent source of pertinent, accurate, timely and credible data on Philippine economic and social conditions.

³ Sampling method that is done sequentially across different hierarchal levels, e.g., from country-level to provincial to municipal to village to household to selection of household members.

supplementing traditional government services delivery channels (e.g., personal visit, postal service, telephone). Results of the respondents' reactions toward their willingness to provide their personal information on government websites and their perception on the usefulness of government websites reflect their general positive attitudes toward e-government.



Figures 2 & 3 'Willingness to Provide Personal Information on Government Websites' and 'Perceived Usefulness of Government Websites'

3.3 E-Government Awareness, Adoption and Satisfaction

The awareness and usage of government websites (419 and 104, respectively, out of 1,200 total respondents) are generally low. Consistent with the analysis on access to ICTs and the Internet, awareness and usage of government websites tend to be higher in younger adults, males, individuals with higher educational attainment, employed, individuals belonging to higher socioeconomic classes, living in urban areas and in the capital (NCR). On the other hand, 83% of users of government websites are at least somewhat satisfied with the information or service they recently accessed using government websites. Results also show that the most commonly accessed government information or services through government websites are related with social security benefits, employment or job application and health services. While there are more e-government users that did not experience any problems with government websites, those who experienced problems mentioned technical failure in the website (e.g., website is inaccessible or unavailable, website contains broken links) and delayed response to inquiry or delivery of service as the two most common problems. Furthermore, for the non-users of government websites, the major reasons given by respondents for not using government websites are: (i); lack of necessary skills and experience in using the Internet (ii) lack of awareness of available e-government services; (iii) preference for traditional service delivery channels; and (iv) lack of convenient access to the Internet.



Figure 4 Most Commonly Accessed E-Government Services

4 EXPLORATORY DATA ANALYSIS

The conceptual framework (Figure 5), derived from literature review and results obtained from the survey, generally presents the distinct research elements organized to exhibit the purported relationships that exist between predictor and outcome variables of this research. Awareness is a prerequisite to the adoption of e-government. Accordingly, satisfaction with e-government is only manifested after adoption. These concepts have been regarded in the design of the generated logistic regression models, particularly in the sample sizes considered for each model (i.e., related to the number of observations).



Figure 5 Conceptual Framework of the Study

4.1 Research Variables

Table 2 describes the dependent (outcome) and independent (predictor) variables used for the data analysis.

Table 2 Independent and Dependent Variables

Independent Variables	Dependent Variables
 Age Gender Educational Attainment Socioeconomic Status Status of Employment Geographic Location Type of Settlement Internet Use Frequency of Internet Use Breadth of Internet Use Household Ownership of Computer Trust in E-Government Perceived Usefulness of E-Government 	 Awareness of E- Government Adoption of E- Government Satisfaction with E- Government

4.2 Logistic Regression Analysis

For the data analysis, logistic regression was employed to identify the significant predictors of and their impacts on the awareness and usage of and satisfaction with online government portals or websites. A number of 13 potential predictors were considered for the three logistic regression models (i.e., awareness, adoption and satisfaction models).

Based on the results of the logistic regression models, both the awareness and adoption models are statistically significant (given the resulting p-value <0.05 significance level associated with the likelihood ratio chi-squared test with 13 degrees of freedom). On the other hand, the satisfaction model was found to be not statistically significant (p-value = 0.07, or not <0.05) thus the results of this model may not be interpreted. Results show that there are statistically significant overall relationships between the combination of independent and the dependent variables for the awareness and adoption models. The variance inflation factor (VIF) for the independent variables are within tolerable levels (ranges from 1.10-5.11), thus multicollinearity was not a concern.

Prodictor Variables	E-Government Outcome Variables			
r redictor variables	Awareness	Adoption	Satisfaction	
Age	1.00	0.96	1.06	
Gender	0.91	1.10	1.14	
Educational Attainment	1.12**	1.34**	0.80	
Socioeconomic Status	1.02	1.06	0.97	
Status of Employment	2.12**	0.98	1.88	
Geographic Location	1.27	1.81	0.65	
Type of Settlement	1.13	0.63	1.43	
Internet Use	1.24	0.98	0.66	
Frequency of Internet Use	1.44	1.45	0.44	
Breadth of Internet Use	1.30**	1.43**	1.01	
Household Ownership of Computer	0.97	4.36**	6.79	
Trust in E-Government	1.16	0.83	4.71	
Perceived Usefulness of E-Government	1.82**	3.73**	4.82	
No. of Observations	1,200	419	104	
Maximum-likelihood Estimation	-645.78	-138.89	-40.32	
Chi-squared, (13)	261.07	191.80	21.18	
Prob>Chi-Squared	0.00	0.00	0.07	
Pseudo R-squared	0.17	0.41	0.21	
Mean VIF	1.97	1.90	1.38	
** p-value is < .01 significance level				

Table 3 Logistic Regression Results (Odds Ratios)

From the results of the analysis, it was inferred that the predictor variable 'status of employment' has the highest impact on e-government awareness (OR=2.12). The variable 'perceived usefulness of e-government' (OR=1.82) closely follows as the predictor with the second highest impact while variables 'breadth of Internet use' and 'educational attainment' ranks as the third and fourth of having impacts (OR=1.30 and OR=1.12, respectively) on e-government awareness. On the other hand, predictor variable 'household ownership of computer' has the highest impact on e-government adoption (OR=4.36). The variable 'perceived usefulness of e-government' (OR=3.73) closely follows as the predictor with the second highest impact while variables 'breadth of Internet use' and 'educational attainment' ranks as the third and fourth of having impacts (OR=1.43 and OR=1.34, respectively) on e-government adoption. It can be deduced that individuals who own and access computers at their home, who perceive e-government as useful, who are skilled in using the Internet and have generally higher educational attainment are most likely to use e-government services.

5 CONCLUSIONS AND RECOMMENDATIONS

The study has revealed the current state of adoption of ICTs, the Internet and e-government by adult citizens in the Philippines. It has also identified the significant predictors and barriers of the usage of e-government services in the country. Thus, the following conclusions are drawn with respect to the objectives of the study:

a) Large portion of the population in the Philippines has not yet used or accessed e-government services.

- b) The combination of socio-demography, access to ICTs and the Internet, and attitudes toward e-government affect the adoption of e-government among citizens. The significant barriers to e-government adoption by citizens in the Philippines are the lack of awareness of available e-government services, lack of access to ICTs, lack of skills and experience in using the Internet and low education level.
- c) To overcome the barriers, it is recommended for policymakers to create policies that are conducive to the acceptance of ICTs and the Internet. The lack of access to ICTs and the lack of skills and experience in using the Internet are normally inherent to disadvantaged groups in the society since they are less likely to be exposed and interested to the use of technologies. These disadvantaged groups are usually associated with individuals with low levels of income, low education level, who are unemployed, and who lives in rural areas. Moreover, skills and experience in using the Internet are mostly acquired by individuals who have seen some value in the use of the technology. Thus, specific educational campaigns on ICT and Internet use, and on creating incentives therewith (e.g., showcasing of local cultures, products and services for rural areas), intended for each of the distinguished disadvantaged groups may be undertaken to address each group's specific needs. Furthermore, effective information and education campaigns on available online government services are equally crucial to further increase awareness and ultimately, the adoption of e-government by citizens.

6 LIMITATIONS AND FUTURE RESEARCH

The unsuccessful attempt in obtaining significant results in the logistic regression model for e-government satisfaction may be largely due to the relatively small sample size (i.e., N=104) considered in this model. Furthermore, there are several possible predictors that were not investigated (e.g., perceived ease of use and perceived risks of using online channels and channel preferences of citizens, which were inferred in literature to have effects on the usage of the Internet and egovernment services). Future research could embark on investigating these aspects to create more robust frameworks/models. Nevertheless, the large amount of data obtained from diverse study areas used in this research strengthens the generalizability of the findings.

References

- Belanger, France, and Lemuria Carter. "Trust and risk in e-government adoption." *The Journal of Strategic Information Systems* 17, no. 2 (2008): 165-176.
- Choudrie, Jyoti, et al. "Evaluating Global e-Government Sites: A View using Web Diagnostic Tools." *Electronic Journal of E-Government* 2, no. 2 (2004): 105-114.
- Horst, Mark, et al. "Perceived usefulness, personal experiences, risk perception and trust as determinants of adoption of e-government services in The Netherlands." *Computers in Human Behavior* 23, no. 4 (2007): 1838-1852.
- Reddick, Christopher. "Citizen interaction with egovernment: From the streets to servers?" Government Information Quarterly 22, no. 1 (2005): 38-57.
- Reddick, Christopher, and Michael Turner. "Channel choice and public service delivery in Canada: Comparing e-government to traditional service delivery." *Government Information Quarterly* 29 (2012): 1-11.
- UNDESA, United Nations Department of Economic and Social Affairs. *United Nations E-Government Survey 2012*. New York, United States of America: United Nations, 2012. Verdegem, Pieter, and Gino Verleye. "User-centered E-Government in practice: A
- Verdegem, Pieter, and Gino Verleye. "User-centered E-Government in practice: A comprehensive model for measuring user satisfaction." *Government Information Quarterly* 26, no. 3 (2009): 487-497.
- Wangpipatwong, Sivaporn, et al. "Understanding Citizen's Continuance Intention to Use E-Government Website: A Composite View of Technology Acceptance Model and Computer Self-efficacy." *The Electronic Journal of E-Government* 6, no. 1 (2008): 55-64.

Image Coding by Orientation Adaptive Transform with Prediction

Student No: 12M51445 Name: Gaudencio G. Bansil, Jr. Supervisor: Yukihiko Yamashita

A prediction method is proposed for image coding using the orientation adaptive vector embedded Karhunen Loève Transform (OA-VEKLT). The encoding is done by determining transform coefficients of the prediction target block. The coefficients are predicted by comparing the lower horizontal and right vertical regions of the neighboring blocks depending on the orientation. The difference between the quantized coefficients of the original image and the quantized predicted coefficients is coded by the Huffman-runlength code. Experimental results are shown to evaluate the proposed method.

1 Introduction

In this digital era, advancement in image and video technologies immensely changes the communication speed, data storage capacity, multimedia security (data encryption and decryption), better image and video quality, and international standards. Systems of image and video compressions are advancement that generates many applications that help the digital world.

The purpose of image compression is to create a system that will represent a specified image by reducing redundant and irrelevant data for diminishing storage, rapid transmission, and acceptable quality for its usage. The international standard JPEG [1, 6] is a digital image compression that utilized the *discrete* cosine transform (DCT) [2, 3]. It uses only one transform during compression making it a *non*adaptive transform coder [4]. The problem of non-adaptive transform coder is the pronounce loss of image visual artifacts on strong edges and lines. In solving this problem, adaptive transforms are created, which select an appropriate transform basis on the characteristics of the selected region. One of the transforms that some of the researches use is the Karhunen-Loève Transform (KLT). The KLT is the transform that concentrates most of energy into the first few coefficients among all unitary transforms.

Tanaka and Yamashita [5] proposed a procedure that uses a novel orthogonal transform called the *vector embedded KLT (VEKLT)*, which is derived from the correlation matrix in which an arbitrary orthonormal system is embedded. These authors also designed the Orientation adaptive vector-embedded KLT (OA-VEKLT) which can represent edges and lines, and attempt to exploit directionality in image compression.

OA-VEKLT, a variation of KLT, is developed to transform the image edges and lines to manage the directionality in image compression [5].

In this paper, I propose a procedure of *predictive coding for the OA-VEKLT (POA-VEKLT)*. This paper presents the comparison between the reconstructed images obtained by using JPEG, OA-VEKLT, and POA-VEKLT coders. The organization of this paper is as follows. In Section 2, I review JPEG and OA-VEKLT. In section 3, I present and formulate the procedure of predictive coding by OA-VEKLT. In section 4, I present the experimental results and comparison of JPEG, OA-VEKLT, and POA-VEKLT. Finally, I conclude the structure in Section 5.

2 JPEG and OA-VEKLT

2.1 JPEG

In the input, 8×8 blocks of the source image are grouped. They are shifted from unsigned integers with range $[0, 2^{P} - 1]$ to signed integers $[-2^{P-1}, 2^{P-1}-1]$, and input to the *Forward DCT (FDCT)*. At the output from the decoder, the *Inverse DCT (IDCT)* outputs 8×8 blocks to form the reconstructed image.

After processing the source image using the FDCT, the data are *quantized*. The goal of this process is to remove information which is

visually insignificant. Since quantization is a group mapping, it is the main source of lossiness in DCT-based encoders. Quantization is defined as rounding to the nearest integer of the division of each DCT coefficient by its related quantizer. In the decoder, dequantization is the process wherein the normalization is removed by multiplying the related quantizer.

After the quantization process, the DC coefficient [position (0,0), the top left corner] is separated from the other coefficients (63 AC coefficients). The last processing stage of the DCT-based encoder is the *entropy coding*. This stage encodes the quantized DCT coefficients tightly based on the quantized data statistical properties.

2.2 OA-VEKLT

KLT is a series to express a given random function. The orthogonal basis functions are obtained as the eigenvectors of the corresponding auto-covariance matrix. Suppose we create *N*-dimensional vectors from a given image by taking blocks of *N* pixels. Let $\mathbf{f} = [f(0), \ldots, f(N-1)]^T$ be a vector of the original data samples \mathcal{R}^N . The correlation matrix \mathbf{R} with respect to \mathbf{f} is given by

$$\mathbf{R} = E_f[\mathbf{f}\mathbf{f}^T], \qquad (1)$$

where we assume $\operatorname{rank}(\mathbf{R}) = N$.

The matrix **R** is real and symmetric, hence there exists eigenvalues [7] $\lambda_0 \geq \lambda_1 \geq \ldots \geq \lambda_{N-1} > 0$ and corresponding eigenvectors $\mathbf{u}_0, \ldots, \mathbf{u}_{N-1}$ such that $\{\mathbf{u}_i\}_{i=0}^{N-1}$ is an orthonormal basis of \mathcal{R}^N . The KLT matrix **U** is given by a matrix of order N whose columns are the basis vectors \mathbf{u}_i , namely,

$$\mathbf{U} = [\mathbf{u}_0 \, \mathbf{u}_1 \dots \mathbf{u}_{N-1}]^T. \tag{2}$$

The transformed vector $\mathbf{g} = [g(0), \dots g(N-1)]^T$ is obtained as $\mathbf{g} = \mathbf{U}\mathbf{f}$.

Generally, the KLT is considered as an impractical transform because it depends on input signals. Therefore, it is usual to use an appropriate correlation matrix such as the first-order Markov model, that is, $(\mathbf{R})_{ij} = \rho^{|i-j|}$, where ρ is the correlation coefficient between adjacent pixels. The matrix \mathbf{R} leads to the

fixed suboptimal KLT. For typical natural images, neighbouring pixels are strongly correlated (0.9 < ρ < 1). It has been shown that the KLT U leads to the DCT as $\rho \rightarrow 1$ [2, 3].

OA-VEKLT is an adaptive transform which manages the orientation of a local region by using the VEKLT. Suppose we create an orthonormal system $\{\mathbf{w}_i\}_{i=0}^{L-1}$ in \mathcal{R}^N , where $L \leq N$. We call a subspace spanned by $\{\mathbf{w}_i\}_{i=0}^{L-1}$ a characteristic subspace and write it by W. We introduce a matrix \mathbf{W} such as

$$\mathbf{W} = \sum_{i=1}^{L-1} \mathbf{w}_i \mathbf{w}_i^T.$$
(3)

In creating the OA-VEKLT, an orthonormal system for a characteristic subspace Wmust be designed. The following method is a characteristic subspace designed by Tanaka and Yamashita [5] for the OA-VEKLT.

Consider the subset $\{\mathbf{d}_l\}_{l=0}^{L-1}$ of the DCT basis [2] such that

$$d_{l}(p+qI) = \frac{\sqrt{2}}{I}C_{l}\cos\left[\frac{(2p+1)l\pi}{2I}\right],$$

$$p,q = 0, \dots, I-1$$

$$l = 0, \dots, L-1, L \leq I,$$

$$C_{l} = \begin{cases} \frac{1}{\sqrt{2}} & l = 0, \\ 1 & \text{otherwise}, \end{cases}$$
(4)

where I is the size of a block and onedimensional notation such that $d_l(p+qI) = d_l(p,q)$. d_l is extended from the discrete function to the continuous one, and rotated the coordinate (p,q) by the orientation θ . Then, the rotated version $\{\mathbf{d}_l^{\theta}\}_{l=0}^{L-1}$ is obtained such that

$$d_l^{\theta}(p+qI) = d_l(p'(\theta), q'(\theta)), \qquad (5)$$

where

$$\begin{bmatrix} p\prime(\theta) \\ q\prime(\theta) \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} p-I/2 \\ q-I/2 \end{bmatrix} + \begin{bmatrix} I/2 \\ I/2 \end{bmatrix},$$
$$p, q = 0, \dots, I-1.$$
(6)

Obviously, the dc vector \mathbf{d}_0 is immutable, that is, $\mathbf{d}_0^{\theta} = \mathbf{d}_0$. Since the set of vectors $\{\mathbf{d}_l^{\theta}\}_{l=0}^{L-1}$ may not be an orthonormal system, they have to be orthonormalized in order to construct an orthogonal transform. For this purpose, the Gram-Schmidt process is performed. The orthonormalized vectors are chosen as an orthonormal basis of the characteristic subspace W, and obtain the characteristic projector \mathbf{W}^{θ} as we have seen in eq.(3).

OA-VEKLT is constructed by defining the correlation matrix \mathbf{R} , which is the $N \times N$ symmetric matrix of a first-order Gauss-Markov model given by

$$(\mathbf{R})_{p+qI,p'I+q'I} = \rho^{\sqrt{(p-p')^2 + (q-q')^2}}, \quad (7)$$
$$p, p', q, q' = 0, \dots, I-1,$$

where ρ is the correlation coefficient. Using an $N \times N$ matrix **Q** such that **Q** = **R** - **RW** - **WR** + **WRW**, we obtain matrix **Q**^{θ} with respect to θ .

The DCT basis functions and the OA-VEKLT basis functions corresponding to a direction are shown in Figure 1.



Figure 1: DCT basis functions and OA-VEKLT basis functions, respectively

3 Image coding with prediction by OA-VEKLT (POA-VEKLT)

Figure 2 illustrates the encoding system for POA-VEKLT. The 512×512 pgm format image is process by DCT, and OA-VEKLTs of 8 directions . The transformed data are quantized and hold to be reprocessed. The quantized data will then be dequantized and buffered. Coefficient will now be predicted and quantized afterwards. The difference between preprocessed quantized data and the quantized predicted data (will be explained in detail later) is calculated before sending it to the coefficient coder to be delivered as bit stream data to the decoder.



Figure 2: The encoding system for POA-VEKLT

In the decoder of POA-VEKLT as shown in Figure 3. The bit stream output of the encoder is processed by the coefficient decoder. It is then dequantized, inverse transformed and buffered. The coefficient is predicted and then quantized. The sum of the quantized predicted coefficient and the decoded quantized coefficient is taken until the image is reproduced.



Figure 3: The decoding system for POA-VEKLT

Now, I will explain the proposed prediction method. Given an image block **f** and surrounding pixels **g** as shown in Figure 4. The direction of the block is determine by OA-VEKLT. I make a basis function \mathbf{v}_i on pixels surrounding the prediction target block by extrapolating \mathbf{w}_i If **f** has no direction, DCT is selected and run length coding is in succession. If **f** has a direction, the true transform coefficient is given by $\alpha_i = \langle \mathbf{f}, \mathbf{w}_i \rangle$, and α_i is estimated by minimizing

$$\left\| \mathbf{g} - \sum_{i=0}^{n} \hat{\alpha}_{i} \mathbf{v}_{i} \right\|^{2} \to min$$

$$wrt \quad n = 3 \text{ or } 7.$$
(8)



Figure 4: Prediction coding of a block using the surrounding pixels

Let $\hat{\alpha}_i$ be the solution of eq. (8). If the direction is horizontal or vertical, 8 coefficients are predicted and it is minimized with respect to $\hat{\alpha}_0 \sim \hat{\alpha}_7$. Otherwise, 4 coefficients are predicted and it is minimized with respect to $\hat{\alpha}_0 \sim \hat{\alpha}_3$. The difference of the quantized data, $q(\alpha_i) - q(\hat{\alpha}_i)$, is Huffman coded, where $q(\alpha)$ is a quantizing function.

4 Experimental Results

In this experiment, the coding and decoding of 512×512 portable gray map (pgm) format were performed by the predictive coding proposal technique. An example of a test image Barbara is shown in Fig 5, wherein the compression methods JPEG, OA-VEKLT and POA-VEKLT are numerically assessed by determining the peak signal-to-noise ratio (PSNR) and bits per pixel (bpp) of the compression methods.



Figure 5: Barbara 512 x 512 test image

PSNR is given by, $PSNR = 10 \log(\frac{255^2}{MSE})$ where MSE is mean square error, $MSE = \frac{1}{N} \sum_{i=1}^{N} |x_i - y_i|^2$; N is the total number of pixels, x_i is the pixel value of the original image and y_i is the pixel value of the noisy approximation image. Bits per pixel is determine by $bpp = \frac{F}{N}$, where F is the size of the image in bits.



Figure 6: PSNR and bpp plot of Barbara.pgm for JPEG, OA-VEKLT and POA-VEKLT coding In coding of Barbara, the PSNR of POA-VEKLT and OA-VEKLT have almost the same output and they have a little advantage compare to JPEG as shown in Figure 6.



Figure 7: PSNR and bpp plot of dollar.pgm for JPEG, OA-VEKLT and POA-VEKLT coding

In coding of the test image dollar.pgm, POA-VEKLT clearly outperforms the OA-VEKLT and JPEG as shown in the coding output PSNR vs bpp in Figure 7.

5 Conclusion

In this paper, I proposed to apply predictive coding to OA-VEKLT.

Based on the results, it can be concluded that OA-VEKLT has a potential to become better by using predictive coding. The results of dollar.pgm and Barbara.pgm compressed by POA-VEKLT outperforms OA-VEKLT and JPEG in PSNR and bit-rate comparison.

The findings suggest that the predictive coding approach has a possibility to improve the OA-VEKLT.

References

- K.R. Rao and J.J.Hwang, "Techniques and Standards for Image, Video and Audio Coding", Prentice Hall, New Jersey, 1996.
- [2] N. Ahmed, T. Natarajan, and K. R. Rao, "Discrete Cosine Transform", IEEE Trans. Computers, vol. COM-25, pp. 90-93, Jan. 1974.
- [3] K. R. Rao and P. Yip, "Discrete Cosine Transform: Algorithms, Advantages, Applications", New York, NY: Academic Press, Inc, 1990.
- [4] G.K. Wallace, "The JPEG Still Picture Compression Standard", Communications of the ACM 34, April 1991, pp. 31-44.
- [5] T. Tanaka and Y. Yamashita, "Vector-Embedded Karhunen-Loève Transform and its Application in Orientation Adaptive Coding of Images", IEICE Transmission Fundamentals, vol. E83-A, No. 6, June 2000, pp.1257-1266.
- [6] S. David, "Data Compression", Verlag, New York, Springer, 1998.
- [7] S.J. Leon, "Linear Algebra with Applications", Englewood Cliffs, NJ, Prentice Hall, 1994.

PERFORMANCE EVALUATION OF PUBLIC BUS NETWORK IN SHIRAZ CITY, IRAN

Student Number: 12M51675 Name: Maryam FEREIDOONY Supervisor: Shinya HANAOKA

Public transport is one of the social facilities, which are provided with the aim of improving social welfare. However providing efficient and effective public transport for the ever-increasing demand with the limited resource available is a challenge in the developing world. In this study Shiraz public bus transport service efficiency and effectiveness by using output-oriented BCC model (VRS) of Data Envelopment Analysis (DEA) and GIS was evaluated. Among 61 selected bus lines, 9 lines identified as inefficient and ineffective lines. Spatial investigation of inefficient and ineffectiveness lines was done by making digital map using GIS techniques, with focusing on land use, bus lines density, bus station density and population distribution around each line. Further implications of this study are to assist decision making of local government regarding improvement of bus public transport network.

1. Introduction

Public transit is an integral and important component of urban transportation network. Its advantages of convenience, speediness and effectiveness are easier to be given full play comparing to other traveling modes. Currently, such problems as congestion and slow speed of bus vehicles and deficit of bus transit enterprises emerge in many cities. This trend has stimulated much research interest on the performance evaluation of Public transport network (Taylou, Garrett, & Iseki,

2001; Murray, 2001; Tsamboulas, 2004)

However, much existing research concentrates on evaluating the performance of overall operation efficiency of the whole public transport network using Data Envelopment Analysis (DEA). Little attention has been given to the operation efficiency and service effectiveness of single bus lines.

Performance measures are navigation tools that can help public transport authorities and city governments determine where they want to go and how to get there.it helps to identify potential problems and optimal solutions (Dhingra, 2011).

Performance evaluation essentially should include two aspects, namely, the operation efficiency from the transit enterprises perspective and service effectiveness from the passenger's perspective.

As for efficiency: The service authority normally aims to minimize the operational cost without impeding the daily travel demand of the passenger.

As for effectiveness: passenger should feel that buses are available to meet their daily travel demand with lower cost.

Currently, public transit agencies are trying to operate more efficiently and effectiveness and they also begun to focus more on service planning, attempting to analyze regional and local demographics in relation to transit services (Sutton, 2005). Iran has one of the highest urban population growth rates in the world and today more than 69 percent of Iran's population is living in urban areas. In this time, public transportation in Iran cities relies mainly on the bus network and except capital Tehran the subway system is not opened yet in most cities so evaluation the efficiency and effectiveness of public bus lines is necessary. Shiraz city is selected for this study. In recent years the city has expanded enormously and paying more attention to public transportation is one of important concern of local government. Now city has two different structures, old and modern. The old structure consists of different gates and districts at different times. There are several shortages in infrastructural services and efficient public transportation in both new and historical zone.

Three objectives of this study are as follow:

- 1-Comprehend the characteristics of bus transportation passengers by conducting survey.
- 2-Evaluate the performance (Efficiency and Effectiveness) of Shiraz city bus lines by DEA.
- 3- Spatial investigation on inefficient and ineffectiveness bus lines with focusing on land use, bus lines density, bus stations density and population distribution by GIS.

The main objective of this study is to evaluate Shiraz city public bus transport operation efficiency and service effectiveness and make recommendations on possible improvements on the network and operations.



Figure 1.1 Framework

2. Methodology

2.1 Field Survey

Surveys are one of the most effective ways of collecting data from current or prospective users (Sauro, 2013). Extensive surveys were carried out in two different peak periods (7-9 AM and 5-9 PM) daily over a two-weeks duration from 7 th to 21st of June 2014.

This survey was conduct to understand the characteristics of bus public transportation passengers in Shiraz city. The questionnaire for passenger was prepared to conduct at bus stops so it was made as short as possible to obtain the required information in the waiting time. It mainly included questions on socio-economic characteristics of the customer, travel characteristics, satisfaction level and expectation of the bus stops with the help of field assistants. Most of the survey was conducted at the 4 main bus terminals of Shiraz city namely Namazy, Valiasr, Ghasrdasht and Dastgheib terminals.

2.2 Data Envelopment Analysis

Data Envelopment Analysis (DEA) has been widely used to measure the efficiencies and effectiveness of public transit network (Zhu, 2003). DEA is a nonparametric approach and linear programming technique to measure relative performance of a set of units called Decision Making Units (DMUs).

In this study DMU is the term used to refer to bus lines. DEA models can be classified based on their orientation into two types: input and output-oriented models. We adopted the output-oriented BCC model (Banker et al., 1984), as the overall objective of a bus line is maximizing output (annual revenue and annual passenger).

A reason to choose the BCC model is that it employs a Variable Return to Scale (VRS) assumption, which means that efficiency and effectiveness may increase or decrease with a change in size in input or output (LaoLiu, 2009).

Mathematically, the output-oriented BCC model can be written as:

$$Max_{u,v} \ \theta_k = \frac{\sum_{m=1}^{M} u_m y_{mk}}{\sum_{n=1}^{N} v_n x_{nk}}$$
(1)

subject to
$$\frac{\sum_{m=1}^{M} u_m y_{mj}}{\sum_{n=1}^{N} v_n x_{nj}} \le 1 \quad \forall_j \quad (2)$$

$$\sum_{n=1}^{N} v_n x_{nk} = 1$$
 (3)

$$u_m$$
, v_n , y_{mj} , $x_{nj} > 0$ (4)

n: Index of input, n=1....,N m: Index of output, m=1,....,M x_{nj} : The nth input for jth DMU y_{mj} : The mth output for jth DMU u_m , v_n : Non negative weight for nth input and mth output. θ_k : Effeciency/Effectivness ratio of DMU_k.

The targeted DMU is designated as DMU_k if efficiency and effectiveness score (θ) equal to 1 means an efficient and effective line. if efficiency and effectiveness score (θ) between 0.6 and 1 means a fairly efficient and fairly effective line and if efficiency and effectiveness score (θ) of less than 0.6 means and inefficient and ineffective line.

2.3 Selections of Input and Output Variables

The key affecting factors of operation efficiency are the resources provided by bus transit enterprises while key affecting factors of service effectiveness are passengers' service requirements (Guo, 2010). From the operator's perspective, the objective is to use as few resources as possible and make as much profit as possible. From the passengers' perspective, bus lines should meet the demand by providing cheap and direct service to them. Table 2.1 displays the input-output specifications for evaluation operational efficiency and service effectiveness.

Table 2.1 Input and output variables for the DEA model

Performance	DMU	Input variables	Output variables
Operation Efficiency	Each Bus Lines	 Line length (km) Number of vehicles Frequency (per hour) Number of bus stop (round trip) 	Annual revenue (million Rials)
Service Effectiveness	Each Bus Lines	 Average traveling time (min) Vehicle-kilometers (per day) Average distance of bus stops (m) 	Annual total number of passengers

In this study efficiency and effectiveness of 61 public bus lines was evaluated. Required GIS data was obtained from spatial planning department of municipality and additional data was obtained from traffic organization and bus company in Shiraz City. Value of line length, Number of bus stop, Average bus stop distance obtained from GIS and Number of vehicle, Frequency, Average travel time, Vehicle-Kilometers, Annual revenue, Annual number of passengers obtained from traffic organization and bus company in Shiraz city.

After applying DEA model for 61bus lines efficiency and effectiveness level of each line is calculated. GIS technique was used to visualize the distribution of bus stops and lines, examine transit service coverage and land use around ineffective and inefficient lines.

3. Case study

Shiraz is the fifth biggest city in Iran and is the capital of Fars Province. It is located in the southwest of the country on the 'Rudkhaneye Khoshk' seasonal river; 200Km from south seashore of Iran. It is built over a green plain of the Zagros Mountains, 1500 meters above sea level with a moderate climate and regular seasons. Shiraz population was 1.3 million in 2011.

According to an official survey of local government the shares of the different modes of travel in this city are as follows: private cars and taxis 66 percent, buses 19 percent and the other modes 15 percent which is an unsustainable trend in a longer term. Therefore, the public bus is the main mode of public transportation (Sharifi, 2011). This city consists of 4 bus zone.



Figure 3.1 Shiraz city bus lines

After finishing survey we evaluated efficiency and effectiveness of 61 public bus lines of Shiraz city using DEA. Required GIS data was obtained from the spatial planning department of municipality and additional data was obtained from traffic organization and bus company in Shiraz City.

4. Results

4.1 Survey Result

The public bus users are mainly young people and main reason for using bus is cheep fare as shown in Figure 4.1.1, Figure 4.1.2 and Figure 4.1.3.



Figure 4.1.1 Age



Figure 4.1.3 Reason for choosing bus

Passengers satisfaction's level of offered service by public bus company are low in case of crowdedness, comfort, station status and waiting time as shown in Figure 4.1.4.





Passenger's expectations are focused on ventilation inside bus, station condition improvement, punctuality and securities as shown in Figure 4.1.5.



Figure 4.1.5 Passenger expectation

4.2 DEA Model Result

The result in Table 4.2.1 indicate that out of the 61 lines, 14 bus lines are technically efficient, 16 bus lines are fairly efficient, and 31 bus lines are considered inefficient.

DMU	Output-Oriented VRS Efficiency	Comment	DMU	Output-Oriented VRS Efficiency	Comment
1	0.84590	Fairly efficient	71	0.44480	Inefficient
2	0.45771	Inefficient	72	0.05971	Inefficient
3	0.84093	Fairly efficient	73	0.61759	Fairly efficient
5	0.24512	Inefficient	74	0.39097	Inefficient
10	0.44899	Inefficient	75	0.65584	Fairly efficient
14	0.34244	Inefficient	76	0.69171	Fairly efficient
16	0.23662	Inefficient	77	0.47772	Inefficient
20	0.55623	Inefficient	78	0.22128	Inefficient
22	0.30748	Inefficient	79	1.00000	Efficient
24	0.41692	Inefficient	80	0.60053	Fairly efficient
26	0.36190	Inefficient	90	0.27767	Inefficient
27	1.00000	Efficient	91	0.26972	Inefficient
31	1.00000	Efficient	92	0.54286	Inefficient
33	0.88429	Fairly efficient	93	0.21306	Inefficient
35	0.07682	Inefficient	94	0.66253	Fairly efficient
36	0.13862	Inefficient	95	1.00000	Efficient
39	0.56821	Inefficient	96	1.00000	Efficient
45	0.30747	Inefficient	97	0.70779	Fairly efficient
46	0.32351	Inefficient	98	0.60955	Fairly efficient
47	0.35210	Inefficient	99	0.36265	Inefficient
48	0.18605	Inefficient	109	0.39789	Inefficient
51	1.00000	Efficient	135	0.42785	Inefficient
56	1.00000	Efficient	138	0.50062	Inefficient
57	1.00000	Efficient	148	1.00000	Efficient
59	0.41292	Inefficient	150	1.00000	Efficient
60	0.64071	Fairly efficient	151	1.00000	Efficient
62	0.11883	Inefficient	152	1.00000	Efficient
63	0.69298	Fairly efficient	154	0.66254	Fairly efficient
68	0.70164	Fairly efficient	155	0.74154	Fairly efficient
69	1.00000	Efficient	Sadra	0.80721	Fairly efficient
70	1.00000	Efficient	l.		

Table 4.2.1 Operation efficiency result

The result of the DEA model is displayed in Table 4.4.2. 8 bus lines are technically effective, 15 bus lines are fairly effective and 38 bus lines are considered ineffective.

DMU	Output-Oriented VRS Effectiveness	Comment	DMU	Output-Oriented VRS Effectiveness	Comment
1	1.00000	Effective	71	1.00000	Effective
2	1.00000	Effective	72	0.50000	Ineffective
3	0.66667	Fairly effective	73	0.83333	Fairly effective
5	0.66667	Fairly effective	74	1.00000	Effective
10	0.87500	Fairly effective	75	0.83333	Fairly effective
14	0.88893	Fairly effective	76	0.62500	Fairly effective
16	0.58333	Ineffective	77	0.84978	Fairly effective
20	0.73208	Fairly effective	78	0.50000	Ineffective
22	0.48333	Ineffective	79	0.88470	Fairly effective
24	0.81324	Fairly effective	80	0.87500	Fairly effective
26	0.87500	Fairly effective	90	0.71526	Fairly effective
27	0.81818	Fairly effective	91	0.70833	Fairly effective
31	1.00000	Effective	92	0.75000	Fairly effective
33	0.75000	Fairly effective	93	0.51667	Ineffective
35	0.54167	Ineffective	94	0.83333	Fairly effective
36	0.37500	Ineffective	95	0.33333	Ineffective
39	0.75000	Fairly effective	96	0.75000	Fairly effective
45	0.75000	Fairly effective	97	1.00000	Effective
46	0.54167	Ineffective	98	0.75000	Fairly effective
47	0.60000	Fairly effective	99	0.62500	Fairly effective
48	0.50000	Ineffective	109	0.62500	Fairly effective
51	1.00000	Effective	135	0.62500	Fairly effective
56	0.75000	Fairly effective	138	0.70833	Fairly effectiv
57	0.62500	Fairly effective	148	0.62500	Fairly effective
59	0.63333	Fairly effective	150	0.62500	Fairly effective
60	0.62500	Fairly effective	151	0.79167	Fairly effective
62	0.41667	Ineffective	152	0.87500	Fairly effectiv
63	0.25000	Ineffective	154	0.87500	Fairly effectiv
68	0.79167	Fairly effective	155	0.57500	Ineffective
69	0.45833	Ineffective	Sadra	0.50000	Ineffective
70	1.00000	Tiffereting			

Table 4.2.2 Service effectiveness result

Based on the scales of the efficiency and effectiveness scores, the lines 31,51,70 are efficient and effective lines which means they have high performance in Shiraz city and on the other hand the lines 16,22,35,36,46,48,62,72,78 are inefficient and ineffective lines which means they are the worse

performers lines in Shiraz city and should be carefully re-planned or even eliminated. In the next step digital maps was made with focusing on land use, bus lines density, bus stations density and population distribution around the inefficient and ineffective lines to make recommendation to possible improvement on the bus network and operations. Here we explain about the possible reason for inefficiency and ineffectiveness of line No.46 in Zone4.



Figure 4.2.1 Population density & Land use around Line 46



Figure 4.2.2 Density of bus line & bus station around line 46

This bus line starts from Darvaze Kazerun terminal (high density area) in central part of Shiraz to Fargangian neighborhood in west of Shiraz city. As we can see in Figure 4.2.1 population density around this line only at the beginning of the line is high. However Fargangiyan neighborhood is one the new urban development area in Shiraz city although this line is only line which gives service to this area, there are very low travel demand for this line. The original alignment of the city bus lines was determined to provide nearly high spatial coverage of the city, but not necessarily based on the expectations of the bus passenger demands from/to the various zones.

5. Conclusion

In this study we have combined DEA and GIS to examine the operational efficiency and service effectiveness of a public transit. Results indicate that among 61 lines in whole city only 3 lines had high performance and 9 lines from all 4 public bus zone and mainly from zone number 3 had the worse level of performance.

References

¹Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models of estimating technical and scale inefficiencies in data envelopment analysis.
²Chu, X., G. J. Fielding, & B. W. Lamar. (1996). Measuring transit performance using data

Cutt, A., O. J. Fletuing, & B. W. Lamar. (1996). Measuring transit performance using data envelopment analysis.
³Karlaftis, M. G. (2004). A DEA approach for evaluating the efficiency and effectiveness.

Yong, L. & L. Lin (2009). Performance evaluation of bus lines with data envelopment analysis and geographic information systems.

PORTFOLIO MANAGEMENT FOR TRANSPORTATION **INFRASTRUCTURE DEVELOPMENT PROJECTS IN THAILAND**

Student Number: 12M51451

Name: Pitchaya CHUNGSAWANANT Supervisor: Shinya HANAOKA, Keisuke MATSUKAWA

Transport project selection is one of the most important planning activities encountered by a government. Thai government is now facing with this problem because a lot of transport projects are proposed, but resources are limited; therefore, selection of an appropriate group of projects to be implemented is needed. This paper proposes a comprehensive combination of methods to evaluate, rank and select transport project portfolio. The main advantages of this combination are simple weight calculation, multi-criteria evaluation with few information from experts and optimal selection condition. This combination is expected to support Thai government to make effective decision in transport projects investment.

1. Introduction

Nowadays, in Thailand, poor quality of transport infrastructure, high freight transport cost and high energy consumption from transport sector can clearly be seen as obstacles for development of the country; therefore, Thai cabinet decided, in January 2013, to propose 70 projects, then 53 projects still remained after pre-screening process by Ministry of Transport, to improve transport infrastructures as shown in Table 1 so as to build up capacity for competitiveness in transportation system of the whole country with three main objectives. 1.) Modal shift: Promote the modal shift from the higher to lower transport cost (16 projects) 2.) Connectivity: Develop transport infrastructure and multimodal facilities to support connectivity to the sub-region and AEC (28 projects) and 3.) Mobility: Develop and upgrade transport facilities & infrastructures to increase mobility (9 projects).

Table 1:	Proposed	Thai	transport	projects
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Mode of transportation	No. of projects
Rail transport	37
Road transport	10
Water transport	5
Border facilities	18
Total	70
After pre-screening	53

However, at this moment, Thai government is now facing with problems because these 53 projects are proposed to be invested, but budgets are limited. In this case, Project Portfolio Management (PPM), which is a management activity to select project portfolio from available project proposals in order to achieve organization's goal and objectives without exceeding available resources or violating other constraints, is one suitable tool that Thai government can apply in order to find optimal project portfolio for investment.

The objective of this research is to propose a comprehensive combination of methods which can be practically applied in order to obtain optimal project portfolio for transport infrastructure development projects in Thailand.

Research framework as shown in Figure 1 begins with defining a set of possible investment projects and defining criteria for transport project evaluation. After that, project data can be prepared. All data are used as input into the combination consisting of (i) weight determination process by Proportion method, (ii) multi criteria decision making (MCDM) process by PROMETHEE II method and (iii) constraints consideration process by PROMETHEE V method in order to evaluate, rank and select optimal project portfolio.



Figure 1: Research framework

2. Methodology

The main methodology of this research focuses on comprehensive combination of Proportion method. PROMETHEE II method and PROMETHEE V method for transport project selection. Each method is explained as follow.

2.1 Proportion method

Proportion Method is a method developed by Aldian et al (2005) to determine objective and criteria weights in the research framework. Stepwise procedure of Proportion method can be explained as follow.

First is questionnaire design. The concept of questionnaire is "please rank the importance of the criteria and determine the relative importance between a given criterion and a lower rank criterion". Second, experts fill out the questionnaire, then rank of criteria and relative importance of each criterion in proportion scale as shown in Table 2 will be obtained. Finally, weight of each criterion is calculated by equation (1).

$$w_{i} = \frac{\sum_{j=1}^{n} a_{ij}}{(n x \left(\frac{n-1}{2}\right))}$$
(1)

Where w_i is weight of criterion i, n is No. of criteria, j is criterion j, a_{ii} is proportion of criterion i to j.

Table 2: Proportion of criterion i and j and definition

Criterion i (%)	Criterion j (%)	Definition $(i \ge j)$
50	50	Equally important
60	40	Moderately more important
70	30	Strongly more important
80	20	Very strongly more important
90	10	Extremely more important

Proportion method is applied in (i) weight determination process to obtain weight of each objective and each criterion. This weight will further be used as input for multi-criteria transport project evaluation in (ii) MCDM process.

2.2 PROMETHEE II method

Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE Method) developed by Brans (1982) is proposed. PROMETHEE II method is one of PROMETHEE family of outranking methods for a set of projects to be ranked and selected among criteria. This PROMETHEE II method is selected to be used to evaluate and rank Thai transport projects based on multiple conflicting criteria in (ii) MCDM process. Its stepwise procedure can be described as follow.

First, pairwise comparisons are made by finding the difference between evaluations of each pair of all projects on each criterion by equation (2). Next, find preference of alternative from equation (3).

$$d_{j}(a,b) = g_{j}(a) - g_{j}(b)$$
(2)

$$P_{i}(a,b) = F_{i}[d_{i}(a,b)]$$
(3)

Where $d_i(a,b)$ is the difference between evaluations of project a and b on each criterion j, $P_i(a,b)$ is preference of alternative a to b and F is preference function. Preference function is a tool to translate the difference between the evaluations of two projects into preference degree ranging from zero to one. In practice, usual preference function is appropriate for qualitative criteria with a small number of evaluation levels and linear preference function is the best choice for quantitative criteria.

Then, global preference index, positive and negative outranking flow can be calculated by equation (4), (5) and (6)respectively.

$$\pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j$$
(4)

$$\phi^+(a) = (\sum_{x \in A} \pi(a, x))/(n-1)$$
(5)

$$\phi^{-}(a) = (\sum_{x \in A} \pi(x, a))/(n - 1)$$
(6)

Where $\pi(a, b)$ is global preference index, w_i is weight of criterion j, $\phi^+(a)$ and $\phi^-(a)$ are positive and negative outranking flow of project a.

Finally, net outranking flow can be calculated by equation (7). This net outranking flow is the final indicator from PROMETHEE II method to rank the projects in order of priority. The higher value of net outranking flow means the higher in rank of the project.

$$\phi(a) = \phi^+(a) - \phi^-(a) \tag{7}$$

Where $\phi(a)$ denotes net outranking flow of project a.

2.3 PROMETHEE V method

PROMETHEE V method developed by Brans and Mareschal (1992) takes net outranking flow of PROMETHEE II to consider optimal selection condition and project constraints with concept of 0-1 linear programming by equation (8).

Max
$$Z = \sum_{a \in A} \phi(a) X_a$$
 (8)
Where X_a is equal to 1 if project is selected and 0 otherwise.

3. Data preparation

3.1 A set of possible investment projects

From firstly proposed 70 projects, Ministry of transport has done pre-screening to be 53 projects and make assumption to assign each project to support only one objective. Then, due to the availability of project information, 39 projects consisting of 13 projects which support objective 1 (Modal shift), 18 projects which support objective 2 (Connectivity) and 8 projects which support objective 3 (Mobility) have been selected with information shown in Table 3, 4 and 5 as follow.

Table 3: Possible investment Modal shift Projects			
Modal shift Projects (13 projects selected)			
Type of projects	No. of projects		
Double track train	11		
Sea port	2		
Table 4: Possible investment Connectivity Projects			
Connectivity Projects (18 projects selected)			
Type of projects No. of projects			
Double track train	2		
High speed train	4		
Motorway 3			
Border and Customs station	9		
Table 5: Possible investment Mobility Projects			

Table 5: Possible investment Mobility Projects			
Mobility Projects (8 projects selected)			
Type of projects	No. of projects		
MRT	8		

3.2 Criteria set up and Project data

Nine criteria covering economic, environmental, social, technical and political aspects have particularly been set up for projects in each group. Criteria No.1-8 which are budget, project time, EIRR, energy cost saving, technical risk, administrative risk, community risk and financial risk are used to evaluate projects in all three groups. For ninth criterion, logistics cost saving, quality of connectivity and travel time saving is particularly assigned to assess modal shift projects, connectivity projects and mobility projects respectively.

Most of project data in almost all criteria can be found directly from official organization except energy cost saving, logistics cost saving, quality of connectivity and travel time saving. Project data in these four criteria have to be estimated based on the assumption for unavailable data.

4. Results and Discussions

4.1 Weight of each objective and each criterion

All objectives and criteria are input of (i) weight determination process by Proportion method. Questionnaire is designed in Microsoft Excel file, and sent to eight experts (Three senior governmental officers and five university professors) by e-mail on May 1st, 2014. All responses from all experts came back during May 10th - May 28th, 2014 by e-mail, so their subjective judgments which are rank and relative importance of each objective and each criterion in proportion scale can be collected for calculation. Results of weight of each objective and each criterion are shown in Table 6, 7, 8 and 9 respectively.
Table 6:	Weight of e	each objective	of Thai trans	port projects
				P

Table 6: weight of	each objec	live of 1 har transpor	t projects	
Objective		Weight		
Objective 1: Modal shift		0.3375		
Objective 2: Connectivity		0.3708	0.3708	
Objective 3: M	obility	0.2917		
Table 7: Weight of	each criter	ion for Modal shift I	Projects	
Criteria	Weight	Criteria	Weight	
Budget	0.1347	Administrative risk	0.1017	
Project time	0.1038	Community risk	0.0938	
EIRR	0.1278	Financial risk	0.1049	
Energy cost saving	0.1132	Logistics cost saving	0.1288	
Technical risk	0.0913			
Table 8: Weight of each criterion for		ion for Connectivity	Projects	
Criteria	Weight	Criteria	Weight	
Budget	0.1333	Administrative risk	0.0920	
Project time	0.1063	Community risk	0.0979	
EIRR	0.1278	Financial risk	0.1226	
Energy cost saving	0.0927	Quality of connectivity	0.1274	
Technical risk	0.1000			

Table 9: Weight of each criterion for Mobility Projects

Criteria	Weight	Criteria	Weight
Budget	0.1247	Administrative risk	0.0948
Project time	0.1035	Community risk	0.0885
EIRR	0.1299	Financial risk	0.1205
Energy cost saving	0.1160	Travel time saving	0.1378
Technical risk	0.0844		

Meaning of weight of each objective or each criterion is the importance of that objective or that criterion when compared with others in the group. Weight of each criterion will further be used as one input into (ii) PROMETHEE II method of MCDM process for multi-criteria project evaluation in the next step of the combination.

4.2 List of projects in order of priority

Project data, criteria, criteria weights and preference function value are input. All input data are put into VISUAL PROMETHEE software, and rank in order of priority by net outranking flow is obtained as shown in Table 10, 11 and 12 respectively.

Table 10: Kank of Modal Shift Proje	Table	Modal shift Pr
-------------------------------------	-------	----------------

Rank	Description	Ø
1	Pakbara Port	0.2724
2	Song Khla 2 Port	0.2045
3	Double track: PakNamPho - Denchai	0.0700
4	Double track: SuratThanee–PadangBesar	0.0576
5	Double track: LopBuri – PakNamPho	0.0571
6	Double track: NakhonPathom – HuaHin	-0.0016
7	Double track: MabKraBao - Jira	-0.0253
8	Double track: Jira – KhonKaen	-0.0712
9	Double track: PrajuabKirikan - Chumporn	-0.0755
10	Double track: HuaHin- PrajuabKirikan	-0.1121
11	Double track: Chumporn – SuratThanee	-0.1175
12	Double track: Jira - Ubonratchathanee	-0.1201
13	Double track: KhonKaen – NongKhai	-0.1383
Table 1	1: Rank of Connectivity Projects	

Rank	Description	Ø
1	Padang Besar customs station	0.4192
2	Mukdahan customs station	0.2940

3	Chiang Kong customs station	0.2690
4	Sadao customs station	0.2198
5	Nong Khai customs station	0.2065
6	Chiang Kong distribution center	0.2031
7	Motorway: Chonburi - Mabtapud	0.1747
8	Aranyaprathet customs station	0.1735
9	Mae Sod customs station	0.0883
10	Mae Sai customs station	0.0876
11	Motorway: BangYai - Kanjanaburi	0.0237
12	Motorway: BangPaIn - Nakhonratchasima	-0.0158
13	Double track: Denchai – Chiang Kong	-0.0535
14	Double track: BanPhai – NakhonPhanom	-0.1437
15	High speed train: Bangkok - Rayong	-0.4419
16	High speed train: Bangkok – PadangBesar	-0.4496
17	High speed train: Bangkok - Nongkhai	-0.5114
18	High speed train: Bangkok - Chiangmai	-0.5434
Table 1	2: Rank of Mobility Projects	
Rank	Description	Ø
1	MRT Light Red Line	0.2414
2	MRT Dark Red Line	0.2172
3	MRT Dark Green Line	0.0815
4	MRT Blue Line	0.0583
5	MRT Purple Line	0.0288
6	Airport Rail Link	-0.1044
7	MRT Yellow Line	-0.1411
8	MRT Orange Line	-0.3817

These projects are ranked by net outranking flow (\emptyset) which is the final result from PROMETHEE II method. The higher in value of this \emptyset means the higher in ranking of the project.

4.3 Optimal portfolio of Thai transport projects

In final process of the combination, (iii) constraints consideration process is implemented. At first, three project implementation constraints are set up with concept of 1) budget limit: Investment for each project group \leq (objective weight)x(allocated budget), 2) supporting all objectives: At least one project from each group must be selected into portfolio and 3) including compulsory projects: All compulsory projects must be included in the portfolio. Compulsory projects are defined by Thai government, and their details are shown in Table 13

Table 13: List of compulsory projects

Modal shift Projects	Project with rank 5, 6, 7, 8 and 9
Connectivity Projects	Project with rank 6, 7 and 13
Mobility Projects	Project with rank 3, 4 and 5

Four scenarios of different sets of constraints are made as follow. The first scenario considers all three constraints. Second, third and fourth scenario considers only two constraints and ignores one constraint. Apply PROMETHEE V with Ø and constraints into Visual PROMETHEE software. Optimal portfolio is obtained.

4.3.1 Scenario 1: Considering all three constraints

All three constraints which are budget limit, supporting all objectives and including compulsory projects are taken into account in this scenario. Optimal portfolio for Thai transport projects investment is obtained in Table 14.

Table 14: Optimal project portfolio for scenario 1

9	Modal shift Projects

Project with rank 1, 2, 3, 4, 5, 6, 7, 8 and 9
12 Connectivity Projects
Project with rank 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 13
5 Mobility Projects
Project with rank 1, 2, 3, 4 and 5
Total: 26 projects

4.3.2 Scenario 2: Considering only constraint 1 and 2

Constraint 1 and 2 which are budget limit and supporting all objectives are taken into account in this scenario. Optimal portfolio is obtained in Table 15.

Table 15: Optimal project portfolio for scenario 2

5 Modal shift Projects
Project with rank 1, 2, 3, 4 and 5
11 Connectivity Projects
Project with rank 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11
5 Mobility Projects
Project with rank 1, 2, 3, 4 and 5
Total: 21 projects

4.3.3 Scenario 3: Considering only constraints 1 and 3

Constraints 1 and 3 which are budget limit and including compulsory projects are taken into account in this scenario. Optimal portfolio is obtained in Table 16.

Table 16: Optimal project portfolio for scenario 3

9 Modal shift Projects
Project with rank 1, 2, 3, 4, 5, 6, 7, 8 and 9
12 Connectivity Projects
Project with rank 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 13
5 Mobility Projects
Project with rank 1, 2, 3, 4 and 5
Total: 26 projects

4.3.4 Scenario 4: Considering only constraints 2 and 3

Constraints 2 and 3 which are supporting all objectives and including compulsory projects are taken into account in this scenario. Optimal portfolio is obtained in Table 17.

Table 17: Optimal project portfolio for scenario 4

9 Modal shift Projects					
Project with rank 1, 2, 3, 4, 5, 6, 7, 8 and 9					
12 Connectivity Projects					
Project with rank 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 13					
5 Mobility Projects					
Project with rank 1, 2, 3, 4 and 5					
Total: 26 projects					

From Table 14, 15, 16 and 17, it can be seen that basically project with positive value of net outranking flow is selected into portfolio according to optimal selection condition of PROMETHEE V method. In addition, it can be noticed from scenario 2 that when compulsory project constraint is not considered, projects with negative value of \emptyset disappeared; it means compulsory project constraint can have influence on portfolio selection. Moreover, after considered at scenario 4, although budget constraint is not considered, optimal project portfolio is still the same. It means net outranking flow from multi-criteria (including budget criterion) evaluation by PROMETHEE Π method has already considered appropriateness of budget.

4.4 Conventional and Proposed combination

In this research, a combination of (i), (ii) and (iii) is proposed. For conventional procedure, methodology (i) and (ii) can also be done by Analytical Hierarchy Process known as AHP Comparison of conventional method. and proposed combination of (i) and (ii) are shown in Table 18.

	Table 18:	Comparison	of conventional	and pro	posed (i)+(ii)
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	Conventional	Proposed
	(AHP+AHP)	(Proportion+PROMETHEE II)
Weight calculation	Complicated	Simple
Information	Numerous	Few
needed from experts	(i) = 108	(i) = 108
(No. of questions)	(ii) = 259	(ii) = 0

From Table 18, regarding weight calculation of conventional procedure, it is complicated because of solving eigenvalue problem with n x n matrix while the proposed combination can calculate weight with arithmetic calculation. For information in pairwise comparison needed from experts by questionnaire, it is clearly be seen that in (ii) of the proposed combination, no information from experts to make pairwise comparison between each pair of projects is needed. For this case, task of experts to make 259 pairwise comparisons of projects can be reduced.

5. Conclusions

This study is based on project portfolio management to propose a combination of (i) weight determination process by Proportion method, (ii) multi criteria decision making process by PROMETHEE II method and (iii) constraints consideration process by PROMETHEE V method to define criteria weight, evaluate and rank projects with various criteria and optimally select transport project portfolio for Thailand. From analysis of four scenarios of project implementation constraints, it can be understood that selecting project with positive net outranking flow can effectively consider and fully cover budget constraint issue, and it can be realized that compulsory project has strong influence on portfolio selection. In addition, three connected processes in the combination are carefully set up in appropriate order to include necessary procedures for comprehensive evaluation and selection. Due to advantages of this combination in simple weight calculation, multi-criteria evaluation with few information from experts and optimal selection condition, this combination is expected to support Thai government to make effective decision in transport project investment.

References

<sup>References
[1] Abu-Taleb, Maher F., and Mareschal, B., Water resources planning in the Middle East: application of the PROMETHEE V multicriteria method, European Journal of Operational Research 81, 500 – 511, 1995.
[2] Aldian, A., and Taylor, Michael A.P., A Consistent Method to Determine Flexible Criteria Weights for Multicriteria Transport Project Evaluation in Developing Countries, Journal of the Eastern Asia Society for Transportation Studies Vol. 6, 3948 – 3963, 2005.
[3] Archer, NP, and Ghasemzadeh, F. An integrated framework for project portfolio selection, International Journal of Project Management Vol. 17, No. 4, 207 – 216, 1999.
[4] Behzadian, M., Kazemzadeh, R.B., Albadvi, A., and Aghdasi, M., PROMETHEE: A comprehensive literature review on methodologies and applications, European Journal of Operational Research 200, 198 – 215, 2010.
[5] Brans, J.P., Vincke, Ph., and Mareschal, B., How to select and how to rank projects: The PROMETHEE method, European Journal of Operational Research 200, 298 – 215, 2010.
[6] Macharis, C., Springael, J., De Brucker, K., and Verbeke, A., PROMETHEE and AHP: The design of operational synergies in multicriteria analysis. Strengthening PROMETHEE with ideas of AHP, European Journal of Operational Research 153, 307 – 317, 2004.
[7] Shang, Jennifer S., Tjader, Y., and Ding, Y., A Unified Framework for Multicriteria Evaluation of Transportation Projects, IEEE Transactions on Engineering Management Vol. 51, No. 3, 300 – 313, 2004.</sup>

PERFORMANCE ANALYSIS OF OPEN LOOP MIMO SYSTEM UNDER RICIAN FADING CHANNEL

Student Number: 12M51497 Name: MAITSETSEG Nomin Supervisor: TAKADA Jun-ichi

ライスフェージングチャネルにおける開ループ型 MIMO システムの性能評価

In this work, the evaluation of the performance degradation due to the presence of line-of-sight (LOS) component for an open loop multiple input multiple output (MIMO) system under Rician fading channel is presented. The bit error rate (BER) performance of 2×2 MIMO systems in terms of the Rician K factor for space time block coding (STBC) and spatial multiplexing schemes utilizing with minimum mean square error (MMSE) receiver are analyzed. Dual-polarized diversity and multiplexing schemes are also evaluated to compare their performance in LOS MIMO environments. Monte Carlo simulation technique is used to simulate the channels and show the validity of the performance analysis. The tradeoff between multiplexing gain in dual-polarized multiplexing scheme and system robustness in STBC scheme is given in LOS scenario.

1 Introduction

In mobile communication systems, use of multiple antennas at both the transmitter and receiver side has been gaining popularity in order to meet the increasing demand of high data rate and efficient spectrum usage. Multiple input multiple output (MIMO) systems, arguably one of the most advantageous technologies in wireless communications, allows wireless systems in multipath environments to achieve greater system reliability through diversity techniques, or achieve greater system capacity through spatial multiplexing [1,2].

The main mechanism that allows MIMO systems to achieve such improvements to the performance of wireless systems is the rich scattering environment of the channel. This rich scattering environment produces multiple independent paths, which can be exploited to increase system performance. Despite the fact that MIMO system requires statistically uncorrelated, independent channels to achieve the performance improvements using multiplexing and diversity techniques, this is not always the case in the real world scenario.

The propagation environment and channel characteristics provide significant challenges for wireless communications systems. A typical MIMO system with M_t transmit and M_r receive antennas diagram is shown in Figure 1. If the line-of-sight (LOS) component is presented in such environments, channels are more correlated, which considerably degrades the performance of MIMO systems. Due to this high correlation between channels, the channel matrix becomes rank deficient, which reduces the degrees of freedom of the channel. In a pure LOS environment, the channel rank is equal to one ($R_{\rm H} = 1$).

Another factor affecting the performance of MIMO systems is the information about the channel that is known to the transmitter. MIMO systems can be classified as closed loop or open loop systems, depending on whether transmitter has feedback from receiver or not. In the closed loop system, transmission scheme can be adaptive to the channel state, but it should be fixed in the open loop system. Closed loop system outperforms open loop system,



Figure 1: A typical MIMO system

but closed loop system is not applicable for some scenarios such as one-way transmission or point to multipoint transmission.

There have been several works on Rician fading MIMO channel and its performance. Most of them considered the closed loop MIMO system under Rician fading channel, and achieved performance improvement using antenna spacing and beamforming techniques [3]. It was also shown in [4], that the impact of LOS, and Rician K factor is different for spatial multiplexing gain and diversity gain. While the increase in K factor reduces the multiplexing gain, diversity gain is less affected by Rician K factor. In [5], it was suggested that by employing co-located orthogonally polarized antennas, decorrelation between antennas was achieved. There is also a limited number of studies that have addressed the polarization to achieve performance improvement in MIMO system such as [6, 7]. Dual-polarized MIMO system has received attention recently due to its space and cost advantages, and potential to recover the multiplexing gain in LOS MIMO scenarios.

The main objective of this study is to evaluate and compare the performance of co-polarized and dual-polarized open loop MIMO transmission schemes under Rician fading channel to identify system performance dependence on Rician K factor.

2 Channel Modeling

Rician distribution is used to describe fading condition when there is a significant LOS component arriving at the receiver in addition to the multipath components modeled by Rayleigh fading. Rician fading channel model includes Rayleigh fading channel model as a special case.

Rician channel is modeled as the sum of a fixed component and a multipath fading component and is described by Eq. (1).

$$\boldsymbol{H} = \sqrt{\frac{K}{1+K}} \boldsymbol{H}_{\text{LOS}} + \sqrt{\frac{1}{1+K}} \boldsymbol{H}_{\text{NLOS}}, \qquad (1)$$

where H is the channel matrix, H_{LOS} and H_{NLOS} are the channel response matrices for LOS component and multipath fading component, respectively. K is the Rician Kfactor of the channel, defined as the ratio of the power in the LOS component of the channel to the power in the multipath fading component. The total transmitted power is normalized to unity, due to open loop MIMO system. Therefore the normalization of the multipath fading component of the channel matrix is given as:

$$E[h_{\rm nlos:m_r,m_t}^2] = 1.$$
 (2)

We have $H_{\rm NLOS}(m_{\rm t} = 1, 2, m_{\rm r} = 1, 2)$, and $h_{\rm nlos}$ denotes the channel gain between $m_{\rm t}$ th transmit antenna and $m_{\rm r}$ th receive antenna. $H_{\rm NLOS}$ is assumed to be modeled as independent and identically distributed (i.i.d.) complex Gaussian with a zero mean and variance σ^2 .

In the case where K is sufficiently small, the channel correlation is reduced. When K is equal zero (K = 0), there is no LOS part and degree of freedom is equal to two with two transmit and two receive antennas. In this case, it is possible to achieve full multiplexing gain.

The LOS components are modeled using deterministic physical channel models assuming uniform linear array (ULA) configuration aligned along $\phi = 0(x)$ direction [8]. The channel matrix H_{LOS} for LOS path which has fixed entries with unit power ($|h_{\text{los:m}_r,m_t}|^2 = 1$) is expressed as:

$$\boldsymbol{H}_{\rm LOS} = \boldsymbol{a}_{\rm r}(\phi_{\rm r})\boldsymbol{a}_{\rm t}^{\rm H}(\phi_{\rm t}), \qquad (3)$$

where a_t and a_r are the array response vectors. ϕ_t and ϕ_r are Angle of Departure (AOD) and Angle of Arrival (AOA) respectively. In this work, AOD and AOA are assumed as 90° as shown in Figure 2. With larger K, the channel can be assumed as pure LOS and NLOS part is ignored.

Performance of the dual-polarized MIMO multiplexing and diversity schemes' is analyzed in terms of Rician Kfactor in this work as well. Dual-polarized 2×2 MIMO configuration is given in Figure 3. In [6], simplified Rician channel model for dual-polarized MIMO system is given as:

$$\boldsymbol{H} = \sqrt{\frac{K}{1+K}} \boldsymbol{X}_{c} \boldsymbol{H}_{LOS} + \sqrt{\frac{1}{1+K}} \boldsymbol{X}_{c} \boldsymbol{H}_{PNLOS}, \quad (4)$$

where X_c is the antenna depolarization matrix expressed as:

$$\boldsymbol{X}_{c} = \begin{bmatrix} 1 & \sqrt{\chi_{c}} \\ \sqrt{\chi_{c}} & 1 \end{bmatrix}.$$
 (5)



Figure 2: Uniform linear array configuration



Figure 3: Dual-polarized MIMO configuration

 χ_c is the inverse of the antenna cross polarization discrimination (XPD) which is the ratio of the co-polarized and cross polarized component. XPD characterizes the antenna sensitivity to the polarization. Multipath fading component H_{NLOS} is given as:

$$H_{\rm PNLOS} = X \odot H_{\rm NLOS},$$
 (6)

where X is dependent on the polarization scheme. For well separated and uncorrelated antennas, X is given by:

$$\boldsymbol{X} = \begin{bmatrix} 1 & \sqrt{\chi \mu} \\ \sqrt{\chi} & \sqrt{\mu} \end{bmatrix},\tag{7}$$

where μ and χ are the co-polarization power ratio (CPR) and cross polarization power ratio (XPR), respectively. In this work to show the coupling between antennas, μ is assumed as equal to one. It is noted that the $H_{\rm LOS}$ is only affected by the antenna depolarization [6], with the resulting LOS component equal to $H_{\rm LOS} = a_{\rm r}(\theta_{\rm r})a_{\rm t}^{\rm H}(\theta_{\rm t})$.

Eq. (4) becomes identical to Eq. (1) when $X_c = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$ and $X = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$, so Eq. (4) can be also used for copolarized antenna case.

3 MIMO Transmission schemes

3.1 Transmit Diversity Scheme

Diversity technique is based on the principle of exploiting the multiple independent paths of the signals arriving at the receiver. From these multiple copies of the same transmitted signal, the probability that the received signal from all paths experience a deep fade is reduced, which leads to an improvement of the slope of the BER curve [2]. Simply, it is for combating system performance degradation due to fading channels. In this research, 2×2 space time block coding (STBC) scheme, known as Alamouti scheme is employed [9]. This is due to the low computational complexity of the scheme, as well as channel state information feedback is not needed to the transmitter, which satisfies the open loop MIMO condition. Since open loop MIMO system is assumed, the energy is divided evenly between the transmitters. Signal to noise ratio (SNR) at the receiver of STBC scheme is expressed as:

$$\gamma = \sum_{m_{\rm r}=1}^{M_{\rm r}} (|h_{m_{\rm r}1}|^2 + |h_{m_{\rm r}2}|^2) \frac{E_{\rm b}/N_0}{2},\tag{8}$$

where γ is the received SNR at the receiver and $E_{\rm b}/N_0$ is the SNR per bit. By using this SNR, analytical BER is estimated as follows:

$$P_{\rm b} = \frac{1}{2} {\rm erfc}(\gamma). \tag{9}$$

3.2 Spatial Multiplexing Scheme

Transmitting independent signals from each transmit antenna at the same time using the same frequency is the core idea of spatial multiplexing [1]. In spatially multiplexed MIMO system, signal detection at the receiver is a complex operation. Due to its low computational complexity and advantages over the simpler zero forcing (ZF) linear receiver, the minimum mean square error (MMSE) linear receiver is considered in this work [2]. MMSE receiver minimizes the BER and can mitigate the multistream interference with less noise enhancement within the linear receivers. Similar to the STBC scheme, total power of the system is normalized to unity and equal amounts of power is assigned to each stream. Signal to interference and noise ratio (SINR) at the $m_{\rm t}$ th stream of 2×2 spatial multiplexing MIMO system is estimated as:

$$\gamma = \frac{1}{\left(\frac{E_{\rm b}}{N_0} \boldsymbol{H}^{\rm H} \boldsymbol{H} + \boldsymbol{I}_{M_{\rm t}}\right)_{m_{\rm r},m_{\rm t}}^{-1}} - 1,$$
 (10)

where γ is the SINR for the $m_{\rm t}$ th stream, $I_{M_{\rm t}}$ is the $M_{\rm t} \times M_{\rm t}$ identity matrix, and $m_{\rm t} = m_{\rm r}$. Analytical BER is then calculated by using this estimated SINR.

$$P_{\mathrm{b},m_{\mathrm{t}}} = \frac{1}{2} \mathrm{erfc}(\gamma). \tag{11}$$

4 Performance Evaluation

Due to the LOS environment, performance degradation may occur. In order to overcome this issue, a dualpolarized MIMO system was suggested in [6]. The performance evaluation and comparison is performed on the copolarized and dual-polarized MIMO system in order to determine the performance trend in LOS scenario for MIMO transmission schemes. Monte Carlo simulation technique is used to simulate the channels in order to validate those analytical results and BER is estimated analytically. The BER performance evaluation process is illustrated in Figure 4. BER of each transmission schemes is estimated as a function of Rician K factor when $E_{\rm b}/N_0$ is equal to 10 dB.



Figure 4: Semi-analytical BER performance evaluation process



Figure 5: BER of 2×2 MIMO STBC schemes

4.1 Performance Evaluation and Comparison between Co-polarized and Dual-polarized STBC Schemes

In Figure 5, the BER performance of co-polarized STBC and dual-polarized STBC is given. It is noted that an increase in Rician K factor has less impact on performance of STBC scheme as shown in Figure 5, since the fading is reduced. When Rician factor K is large, the BER performance of co-polarized STBC scheme converges to AWGN case. There is power loss in dual-polarized STBC scheme compared to co-polarized STBC scheme. This decrease in performance is because of the reduction in received power due to the XPD.

4.2 Performance Evaluation and Comparison between Co-polarized and Dual-polarized Spatial Multiplexing Schemes

In Figure 6, the BER performance of co-polarized and dual-polarized spatial multiplexing schemes is given. In contrast to STBC scheme, BER performance is degraded in spatial multiplexing scheme with increasing Rician K factor as shown in Figure 6. When Rician K factor is large, we can not separate the stream in the co-polarized spatial multiplexing scheme due to the rank deficiency of the channel.

However, by using dual-polarized multiplexing transmis-



Figure 6: BER of 2×2 MIMO spatial multiplexing schemes

sion, the multiplexing gain is recovered and the BER performance is improved. Similar to the co-polarized STBC scheme, the BER performance converges to AWGN channel with higher value of Rician K factor. In lower scenario of Rician K factor, the performance of dual-polarized spatial multiplexing scheme is less than the co-polarized spatial multiplexing scheme. It can be concluded that with strong XPD, performance improvement is achieved in LOS MIMO scenario by using dual-polarized antenna configuration.

4.3 Performance Evaluation and Comparison between STBC and Spatial Multiplexing Schemes

In large Rician K factor scenario, two streams can be separated in dual-polarized spatial multiplexing scheme. However, when we compare the performance of co-polarized STBC and dual-polarized spatial multiplexing scheme, there is a tradeoff between system robustness and multiplexing gain as shown in Figure 7. Even though the multiplexing gain is recovered in dual-polarized MIMO system, the system is more robust in co-polarized STBC scheme.



Figure 7: BER of 2×2 MIMO transmission schemes

5 Discussion and Conclusion

In this thesis, performance evaluation of 2×2 open loop MIMO system under Rician fading channel was performed in terms of BER for the following transmission schemes:

- 2×2 STBC scheme (co-polarized)
- 2×2 Spatial Multiplexing scheme (co-polarized)
- 2×2 Dual-polarized STBC scheme
- 2×2 Dual-polarized Spatial Multiplexing scheme

STBC scheme performance improves with the presence of a LOS component and channel robustness is increased. In contrast, the poor spatial multiplexing effect is observed despite having a high SNR per bit where the MIMO channel is dominated by the LOS component.

The multiplexing gain is restored with an increase in Rician K factor in the dual-polarized MIMO spatial multiplexing scheme, thus, the performance gain was directly related with XPD factor. However in low Rician K factor scenario, the performance is less than the co-polarized spatial multiplexing case. In STBC scheme, co-polarized MIMO configuration should be preferred over dual-polarized MIMO since power loss due to polarization occurs in dual-polarized channel. In the case of multiplexing scheme, dual-polarized MIMO system performance is improved in LOS scenario because of its advantage of complete separation of the stream. The tradeoff between dual-polarized spatial multiplexing and STBC scheme should be considered in terms of system robustness.

References

- G. J. Foschini and M. J. Gans, "On Limits of Wireless Communications in a Fading Environment When Using Multiple Antennas," *Wireless Personal Communications*, vol. 6, pp. 311–335, 1998.
- [2] A.Paulraj, R.Nabar, and D.Gore, Introduction to Space Time Wireless Communications. Cambridge University Press, 2003.
- [3] K.Kobayashi, T.Ohtsuki, and T.Kaneko, "Precoding for MIMO Sytems in Line-Of-Sight Environment," *IEEE GLOBECOM 2007*, 2007.
- [4] R.Nabar, H.Bolcskei, and A.J.Paulraj, "Outage Properties of Space Time Block Codes in Correlated Rayleigh or Rician Fading Environment," *IEEE ICASSP*, vol. 1, pp. 2381–2384, 2002.
- [5] R.Nabar, H.Bolcskei, V.Erceg, D.Gesbert, and A.J.Paulraj, "Performance of Multiantenna Signaling Techniques in the Presence of Polarization Diversity," *IEEE Transaction on Signal Processing*, vol. 50, no. 2, pp. 2553–2562, 2002.
- [6] C.Oestges, "Propagation Channel, Capacity and Error Probability with Dual-Polarized Wireless Transmissions," *Indian Journal of Radio and Space Physics*, vol. 36, pp. 411–417, 2007.
- [7] J.Han, J.Baek, and J.Seo, "MIMO OFDM Transceivers with Dual-Polarized Division Multiplexing and Diversity for Mutimedia Broadcasting Services," *IEEE Transaction on Broadcasting*, vol. 59, no. 1, pp. 174–182, 2013.
- [8] F.Bohagen, P.Orten, and G.E.Oien, "On Spherical vs. Plane Wave Modeling of Line of Sight MIMO Channels," *IEEE Transaction on Communications*, vol. 57, no. 3, pp. 841–849, 2006.
- [9] S.Alamouti, "A Simple Transmit Diversity Technique for Wireless Communications," *IEEE J.Sel. Areas Commun.*, vol. 16, no. 8, pp. 1451–1458, 1998.

Wavelet Based Image Coding via Linear Prediction and Clustering

Student Number: 13M18221 Name: Shiyu Zhou Super visor: Yukihiko YAMASHITA

線形予測とクラスタリングを用いた ウェーブレット画像符号化に関する研究

周 施雨

JPEG に代表されるブロック単位の静止画像圧縮方式には,復号した画像にブロック歪が現われる問題が生 じる。JPEG2000 は離散ウェーブレット変換(DWT)を利用することによってこの問題を解決した。本研 究はウェーブレット変換による画像符号化の高度化を目的とし,「クラスタリングによりクラス分けした線 形予測によって、ウェーブレット変換係数を予測する画像符号化」を提案し,計算機実験によって,提案手 法の有効性を確かめる。

1. INTRODUCTION

Image coding methods have been invented to reduce irrelevance and redundancy of digital image data in order to store or transmit the data in an efficient form for web usage and so on. The block transform based image coding such as JPEG is successfully used for these purposes. However, JPEG suffers from a problem called the block distortion caused by its blockwise transformation. The wavelet based image coding such as JPEG2000 has solved the problem by using the discrete wavelet transform (DWT) [1,2,3].

Prediction is another key technology to enhance the performance of image coding. By sending only the difference between the original and its predicted values, the data size can be reduced. However, in the case of applying prediction to the 2-dimensional discrete wavelet transform (2D-DWT) that is used in JPEG2000, a distance of several pixels between the target pixel we want to predict and decoded pixels we can use, makes precise prediction to be difficult.

To solve this problem, in this paper, we propose to introduce prediction into the 1-dimensional transform part of 2D-DWT. We developed a linear prediction method with clustering, which does not generate any side information, to predict the detailed (high frequency) coefficients by using the approximated (lowfrequency) coefficients and the restored components. We also conducted experiments to show the advantage



(a) Vertical (b) Horizontal

Fig. 1. Coefficients of DWT decomposition



(a) First stage (b) Multi-stage

Fig. 2. Coefficients of 2D-DWT decomposition

of the proposed framework.

2. WAVELET BASED IMAGE CODING WITH PREDICTION

2.1. 2D-DWT

Daubechies proposed DWT for multiresolution signal analysis [1]. Its analysis process is as follows. An input signal is split by a low and a high frequency pass filters. Both outputs are downsampled by 1/2 and the approximated (low-frequency) and the detailed (highfrequency) coefficients are obtained respectively. Iteratively, the approximated coefficients are filtered and downsampled as input signals. Its synthesis process is almost the opposite of the analysis process.

Since an image is a 2D signal, 2D-DWT is used for image coding. To explain 2D-DWT, we define the following notations. Let *M* be the number of stages of 2D-DWT. At *m*-th stage of 2D-DWT, C_{XYm} (X, Y = L, H, I) denotes the set of transformed coefficients, where X and Y specify the type of coefficients of horizontal and vertical transforms, respectively. L and H indicate approximated and detailed coefficients, and I indicates "not transformed" ones. For example, C_{HL2} denotes horizontal detail and vertical approximate coefficients as the results of second stage 2D-DWT.

We assume that horizontal DWT is performed after vertical transform, provided that the order of transforms is commutative. First, an input image is split into the sets of vertical approximated and detailed coefficients C_{IL1} and C_{IH1} . Fig. 1 (a) illustrates the arrangement of the coefficients. C_{IL1} and C_{IH1} are respectively split into the sets of horizontal approximated coefficients, C_{LL1} and C_{LH1} , and the sets of detailed coefficients C_{HL1} and C_{HH1} . We have 4 types of coefficients totally for a stage of 2D-DWT. Fig. 2 (a) illustrates the arrangement of the coefficients. We iteratively decompose $C_{LL(m-1)}$ into C_{LLm} , C_{LHm} , C_{HL1} , and C_{HHm} m = 1, 2, ..., M (Fig. 2 (b)).

When we combine prediction with the DWT decomposition, it has to be based on the values of decodable pixels. In order to obtain a coefficient by DWT, we need several pixel values around the corresponding position of the coefficient. Furthermore, in order to obtain a pixel value by inverse DWT (IDWT) for decoding, we need several coefficients around the pixel. Thus, the prediction of 2D-DWT coefficients has been considered to be difficult because we have to predict the values of pixels that are apart from the decodable pixels by not less than several pixels.

2.2. Coding scheme with prediction

Here, we describe the proposed coding scheme using the DWT decomposition with prediction in detail.

Consider we decompose $C_{\text{LI}m}$ into $C_{\text{LL}m}$ and $C_{\text{LH}m}$ and predict $C_{\text{LH}m}$. The decomposition is done row by row from top to buttom in C_{LIm} . C_{LLm} and the rows in C_{LIm} above the target one can be decoded. If we can predict the target row in C_{LIm} , the predicted values of C_{LHm} in the row can be obtained by DWT. Since the target row is adjacent to the above rows, the target pixels we want to predict and the reference pixels we can use are adjacent. This short distance makes the prediction more precise. Then, the data size is reduced by sending not the quantized values of C_{LHm} but the quantized difference between their true and estimated values.

The reason why we predict not $C_{\text{LH}m}$ but $C_{\text{LI}m}$ is that $C_{\text{LI}m}$ is similar to a normal image so that prediction is easy. The prediction scheme can also be applied to decomposing $C_{\text{IL}m}$ into $C_{\text{LL}m}$ and $C_{\text{HL}m}$.



Fig. 3. Block diagram of encoding process of a stage

Let P_{XYm} and R_{XYm} be the sets of the predicted and the decoded coefficients of C_{XYm} , respectively. We denote the difference between C_{XYm} and P_{XYm} by D_{XYm} . The fundimental process of encoding is shown in Fig.3. And the algorithm is shown in Algorithm 1.

2.3. Encoding of coefficients

We use the SPIHT encoder with quantization to encode coefficients [4]. For the prediction, we have to fix the quality of a decoded image, quantization has to be introduced. An arithmetic coder is applied to the outputs of SPIHT.

3. PREDICTION

Here, we explain the proposed prediction algorithm when C_{ILm} on the *k*-th row is going to be predicted. We intend to use R_{ILm} in the region above the *k*-th row and R_{LLm} . Let us consider that the pixel value of C_{ILm} at (x,k) is the target to be predict. We use linear prediction with clustering for the purpose. We extract a block Algorithm 1 2D-DWT with prediction

Require: An input image C_{LL0} and the total DWT stage M.

for $m \leftarrow 1$ to M do

Obtain $C_{\text{LL}m}$, $C_{\text{LH}m}$, $C_{\text{HL}m}$, and $C_{\text{HH}m}$ from $C_{\text{LL}(m-1)}$ by 2D-DWT.

end for

Output the quantized C_{LLM} , dequantize it, and store the result into R_{LLM} .

for $m \leftarrow M$ to 1 do

for $k \leftarrow 0$ to $N_{Y,m} - 1$ do

Make $P_{\text{IL}m}$ on the *k*-th row by using $R_{\text{LL}m}$ and $R_{\text{IL}m}$ on the 0, 1, ..., (k-1)-th lines.

Make $P_{\text{HL}m}$ on the *k*-th row by DWT of $P_{\text{IL}m}$.

Make $D_{\text{HL}m}$ on the *k*-th row subtracting $P_{\text{HL}m}$ from $C_{\text{HL}m}$.

Quantize $D_{\text{HL}m}$ on the *k*-th row and dequantize the result.

Add the dequantized values and $P_{\text{HL}m}$ on the *k*-th, and store the results into $R_{\text{HL}m}$ on the *k*-th row.

Obtain R_{ILm} on the *k*-th row by IDWT.

end for

Similarly, obtain D_{LHm} and R_{LHm} .

Output the quantized values of D_{LHm} , D_{HLm} , and C_{HHm} .

Calculate $R_{LL(m-1)}$ by 2D-IDWT.

end for

data of width n_X and height n_Y from L_{ILm} and R_{ILm} . The horizontal center on the bottom row of the block is aligned to (x,k). The bottom and the other rows are extracted from L_{ILm} and R_{ILm} as shown in Fig. 4. The data is vectorized to an $(n_X n_Y)$ -dimensional vector u. We subtract the average of \bar{u} from u and define \tilde{u} .

$$\tilde{u} = u - \frac{1}{n_{\rm X} n_{\rm Y}} \bar{u} \tag{1}$$

and divide it by the standard deviation of u. The results is denoted by \hat{u} . If the standard deviation is smaller than a threshold, the data is eliminated from data. Next, we make C clusters by the k-means method [5] using the normalized vectors, and obtain the centroid vectors g_c (c = 1, 2, ..., C) and linear prediction coefficient vectors a_c . We find c that maximizes $|\langle \tilde{u}, g_c \rangle|$. It is denoted by c_{max} . The predicted value $P_{\text{IL}m}$ at (x,k)



Fig. 4. Data for prediction $(n_X = 5, n_Y = 3)$

is given by

$$\langle a_{c_{\max}}, \tilde{u} \rangle + \frac{1}{n_{\mathrm{X}} n_{\mathrm{Y}}} \bar{u}$$
 (2)

Because of downsampling of DWT, the properties of $L_{\text{IL}m}$ of pixels are very different between at even x and at odd x. Therefore we separately make two sets of g_c and a_c (c = 1, 2, ..., C) for even x and for odd x.

Here, the linear prediction coefficient vectors a_c can be obtained as follows.

$$a_c = (U_c U_c^T)^{-1} U_c v_c.$$
(3)

where J_c and $\{\hat{u}_{c,j}, \hat{v}_{c,j}\}_{j=1}^{J_c}$ be the number and the set of normalized learning data in cluster *c*. *U* is an $(n_X n_Y, J_c)$ -matrix, and $U = (\hat{u}_{c,1}, \hat{u}_{c,2}, \dots, \hat{u}_{c,J_c})$. *V* is a J_c -dimensional vector, which describes the set of predicted value. $v = (\hat{v}_{c,1}, \hat{v}_{c,2}, \dots, \hat{v}_{c,J_c})^T$.

4. EXPERIMENTAL RESULTS

In this experiment, we compare codings with and without clustered linear prediction. We encode and decode the luminance part of the standard images "Lena", "Barbara", and "Intersection" shown in Fig. 5 (a), (b), and (c). "N2" in standard color image data (SCID) database shown in Fig. 5 (d) is used as a learning data to obtain a_c and g_c . We let the number of cluster C = 128, the block width $n_X = 5$, and its height $n_Y = 3$.

Fig. 6 shows their rate distortion curves, decribe bit rate vs. PSNR (peak signal noise ratio). We can see coding with the proposed prediction scheme outperforms that without prediction for three images. Especially, improvements in 'Intersection' is larger than those of 'Lena' and 'Barbara'. This is because the properties of 'Intersection' and 'N2' are similar and they have many straight edges.



(a) Lena (b) Barbara

Fig. 5. Standard images and 1D-DWT decomposition



Fig. 6. Rate distortion curve

As for the visual quality, both methods provided almost the same results since the quantized differences are sent to the decoder.

Although our prediction method is primitive and its computational complexity is high, we can show possibilities of the proposed coding scheme using linear prediciton with clustering. It should be emphasized again that the proposed scheme does not need any side information. By a more precise and efficient prediction algorithm, we will improve the coding efficiency. Furthermore, by applying a more sophisticated coding method of coefficients, the proposed scheme can be more efficient. For example, it can be made by modifying EBCOT (Embedded Block Coding with Optimized Truncation).

5. CONCLUSIONS

In this paper, we proposed an wavelet image coding scheme using linear prediction and clustering. The proposed scheme does not need any side information. We conducted an experiment of still image coding to show advantages of the proposed scheme. For future works, we have to research on a more precise and efficient prediction method. Super-resolution techniques can be applied to improve prediction. Applying this scheme to moving image coding is a very interesting theme.

6. REFERENCES

- [1] I. Daubechies, "Ten Lectures on Wavelets," Society for Industrial and Applied Mathematics, Philadelphia, 1992
- [2] M. Vetterli, J. Kovaevi, "Wavelets and Subband Coding," PrenticeHall, Englewood Cliffs, 1995.
- [3] Geoffrey M. Davis, Aria Nosratinia, "Waveletbased Image Coding: An Overview," IEEE Trans. on Circuits and Systems for Video Technology, vol. no. 6, pp.243-250, June, 2002.
- [4] Pearlman, William A. "A new fast and efficient image codec based on set partitioning in hierarchical trees," IEEE Transactions on Circuits and Systems for Video Technology 6 (3): 243250. doi:10.1109/76.499834. ISSN 1051-8215, June 1996.
- [5] J.A. Hartigan (1975), "Clustering algorithms," John Wiley ;Sons, Inc.

11 GHz Indoor MIMO Channel Parameter Estimation Using Gradient Method

Student Number: 13M18244 Name: Shizhi ZHANG Supervisor: Jun-ichi TAKADA

勾配法を用いた11 GHz帯における屋内 MIMO チャネルパラメータ推定

チョウ カツシ

本論文では、平面を仮定したマルチパスチャネルモデルをベースとそた最尤推定法を用いて高周波帯無線チャネルの パラメータ推定を提案した.最尤推定を最適化する際共役勾配法とグローバルサーチ法の両方を用いたハイブリッド 手法で実行した.本来サーチベース法の精度を勾配法で改善すると同時に、勾配法の初期値問題をサーチベース法で 定められるメリットが考えられる.

1 Introduction

Nowadays, the growing demand for higher data rates and higher transmission efficiency requires us to optimize the existing transmission system. For this purpose the propagation channel characteristic is dominant in the system design. In the same time, the concepts of the future wireless communication are high frequency, wide band, MIMO, which can increase the channel capacity. After the stage of system design, we have to make a standard for this service. So that we have launched the massive channel sounding measurement campaign to analysis the propagation environment and help the standardize the system. The channel propagation measurement has been done in the indoor environment and outdoor environment, and the output of the measurement is the channel transfer function. However, the transmission environment always complicates the wireless channel, such as the shadowing and fading issues. For this reason, the channel model is necessary to model the channel characteristic. Generally, the multi-path model is widely utilized in channel analysis based on the approximation of plane wave in far field. This model consists of the parameters of paths (ex. direction angles, gain, delay, etc). There are some measurement campaign proceed the research into high frequency propagation channel (11 GHz in this paper). For the objective of model the high frequency channel and extract the parameters from the channel, the investigation of path parameter set becomes more important. There are several approaches for the investigation, among those the most popular one is the maximum likelihood estimation [6]. For the optimization of the likelihood function during the estimation in high parameter domain case, one method called SAGE [5] reduces the computational complexity compared to the standard traditional algorithm by optimizing the parameter domain respectively.

However, the convergence speed of SAGE is still slow and in the measurement campaign of [1] [2], the antenna radiation pattern measured has a poor resolution which will lead large errors during global searching. In order to overcome these problems and improve the accuracy of the estimation as well, this paper focuses on the conjugate gradient method which can realize a higher accuracy and fast convergence.

2 Signal Model and MLE Estimator

The electromagnetic wave can be approximated as plane wave in far field, then well known formulation of the wideband MIMO channel signal model [6] is

$$\mathbf{H}_{\mathrm{MIMO}}(f) = \sum_{l=1}^{L} \mathbf{a}_{\mathrm{Rx}}(\boldsymbol{\varphi}_{\mathrm{Rx},l}, \boldsymbol{\vartheta}_{\mathrm{Rx},l}, f) \boldsymbol{\Gamma}_{l} \mathbf{a}_{\mathrm{Tx}}^{\mathrm{T}}(\boldsymbol{\varphi}_{\mathrm{Tx},l}, \boldsymbol{\vartheta}_{\mathrm{Tx}}, f)$$
$$\cdot \exp(-j2\pi f \tau_{l}) \qquad (1)$$

, where Γ is the complex polarimetric amplitude matrix of the $l^{\rm th}$ of L paths, $\mathbf{a}_{\rm Tx}$, $\mathbf{a}_{\rm Rx}$ are the antenna pattern vectors, $\varphi_{\rm Tx}$, $\vartheta_{\rm Tx}$, $\varphi_{\rm Rx}$, $\vartheta_{\rm Rx}$ denote the azimuth and co-elevation direction of departure (DoD) and direction of arrival (DoA), f means the frequency and τ is the propagation delay, $(\cdot)^{\rm H}$ denotes the conjugate transpose.

When the transfer signal is impulse signal, (1) becomes the channel impulse response, so

$$\mathbf{x} = \mathbf{s}(\boldsymbol{\theta}) + \mathbf{n},\tag{2}$$

where \mathbf{x} is the received signal, $\mathbf{s}(\boldsymbol{\theta}) = \text{vec}\{\mathbf{H}_{\text{MIMO}}\}$ is the impulse response, $\boldsymbol{\theta}$ denotes the parameter set (e.g. DoD, DoA, delay) and \mathbf{n} is the noise vector. Here we rely on the assumption that the noise is i.i.d. zero mean Gaussian process, so that we have the probability density function

$$p(\mathbf{x}, \boldsymbol{\theta}) = \frac{1}{(\pi\sigma^2)^N} \exp\left(-\frac{\sum_{i=1}^N ||\mathbf{x}_i - \mathbf{s}(\boldsymbol{\theta})_i||^2}{\sigma^2}\right), \quad (3)$$

where N is the size of the **x**. (3) can be also called likelihood function [7] according to the estimation theory. During the estimation, the likelihood function need to be maximized. In other word, (4) needs to be minimized by the optimized parameter set $\boldsymbol{\theta}$.

$$\mathcal{L} = \hat{\boldsymbol{\theta}} = \arg\min_{\boldsymbol{\theta}} (\mathbf{x} - \mathbf{s}(\boldsymbol{\theta}))^{\mathrm{H}} (\mathbf{x} - \mathbf{s}(\boldsymbol{\theta})).$$
(4)

3 Comparison among Estimation Algorithms

In order to implement the optimization in (4), generally, there are two considerable approaches, which are search based approach and gradient based approach.

Table 1: Optimization Scheme Comparison

Optimization scheme	Accuracy	Speed
Global based	Large error	Slow
Gradient based	Good	Fast
Newton method	Very Good	Fast

Starting from the global search, which search all sample points in all parameter domains, there are many search based methods, such as bi-section search, SAGE (Space Alternative Generalization Estimation Maximization), etc. The merits of these search based approaches are the simple algorithm, simple flow, on the other hand the demerits are the intersection errors and the computational complexity.

Compared to these search based methods, gradient based approach is an analytical search method, which can reach a local peak by less iterations. Because the dominant idea of gradient based methods is consider the parameter space as a terrain in 3D space, the trial point will fall down towards the local peak like the influence of the gravity. However the calculation of the gradient is sometimes another critical problem because the complicated function formula. Some popular method like Newton-Raphson method, Quasi-Newton method, gradient method, conjugate gradient method, Lagrange method for conditional optimization problems, etc. Newton methods have the problem to calculate the Hessian matrix [4] which will also be a problem in some certain problems. The brief comparison among these optimization scheme is shown as Tab. 1. We can see that the gradient based method and Newton method have good accuracy, while they suffer from the initialization problem the most of the cases.

In this research the hybrid of the rough global search and conjugate gradient method is proposed. This proposal solved not only the large error and the slow calculation speed of the the global search but the initialization problem in the conjugate gradient method by each other.

4 Conjugate Gradient Method

The global search will omit the algorithm of global search but focus on the conjugate gradient method. From (4), the function \mathcal{L} is that we want to optimize, $\boldsymbol{\theta}$ is the parameter set to search. We take the Taylor expansion at $\boldsymbol{\theta} = \boldsymbol{\alpha}$ up to the first order like

$$\mathcal{L}(\boldsymbol{\theta}) = \mathcal{L}(\boldsymbol{\alpha}) + \frac{\partial \mathcal{L}}{\partial \theta_1} \bigg|_{\boldsymbol{\theta} = \boldsymbol{\alpha}} (\theta_1 - \alpha_1) \\ + \dots + \frac{\partial \mathcal{L}}{\partial \theta_n} \bigg|_{\boldsymbol{\theta} = \boldsymbol{\alpha}} (\theta_n - \alpha_n) + \text{higherorder.}$$
(5)

We rewrite the second term in the right hand side as

$$\mathcal{L}(\boldsymbol{\theta}) = \mathcal{L}(\boldsymbol{\alpha}) + \langle \boldsymbol{\nabla} \mathcal{L} |_{\boldsymbol{\theta} = \boldsymbol{\alpha}}, (\boldsymbol{\theta} - \boldsymbol{\alpha}) \rangle, \qquad (6)$$

where $\langle \mathbf{a}, \mathbf{b} \rangle$ is the inner product of vector \mathbf{a} and vector $\mathbf{b}, \nabla A$ denotes the gradient of a scalar field A. In 2D

Table	2:	System	Setup

Parameter	Value
Central frequency	11 GHz
Bandwidth	400 MHz
No. of subcarriers	2,048
Antenna	24×24 dual polarized micro-strip

parameter space case, the gradient express the perpendicular direction to the contour line of the function. In normal gradient method (maximum gradient method), we search the minimum point in the direction of $\nabla \mathcal{L}$ iteratively. Due to $\nabla \mathcal{L}(\boldsymbol{\theta}^{k+1}) \perp \nabla \mathcal{L}(\boldsymbol{\theta}^{k+1})$, the algorithm [8] requires infinite iterations to reach the local peak theoretically. For the accelerate the algorithm, we revise the search direction by the independence of the vector subspace [8] together with the Fletcher-Reeves' equation and the estimation flow is shown as followed.

Conjugate Gradient Method Algorithm (Non-Linear) [8]

- 1. Set an initial value θ^1 , the initial search direction $s^1 = -\nabla \mathcal{L}(\theta^1)$ and initialize the iteration number k = 1
- 2. Set the break condition: If $\nabla \mathcal{L}(\theta^k)$ is small then stop the iteration
- 3. Search through the s^k direction and find the value α^k that minimize the function
- 4. Renew the point as $\theta^{k+1} = \theta^k + \alpha^k s^k$

5. Calculate
$$\lambda^k = \frac{||\nabla \mathcal{L}(\boldsymbol{\theta}^{k+1})||^2}{||\nabla \mathcal{L}(\boldsymbol{\theta}^k)||^2}$$

- 6. Calculate the new search direction using λ^k as $s^{k+1} = -\nabla \mathcal{L} \theta^{k+1} + \lambda^k s^k$
- 7. Incrementation k = k + 1
- 8. Go to 2

5 Estimation Flow Chart and Implementation

5.1 Estimation Setup and Flow Chart

Recalling the measurement campaign [2], Table 2 describes the setup of the measurement and the estimation algorithm. Based on such setup, wireless channel knowledge has been estimated and the comparison between the estimation result and the measurement is going to be discussed.

The estimation flow chart is shown as Fig. 1

For the purpose of validation of the algorithm, a test simulation will be set up. We will construct a test channel and estimation the path parameters using the proposed approach. In this moment, the simulation setup will be introduced.

We generate the test channel with 6 paths. We use these path information to reconstruct the test channel



Figure 1: Flow chart of the estimation algorithm

whose double direction beamforming is shown as Fig. 2. This channel is an ideal channel that doesn't have the influence of the noise. Additionally, we have set all coelevation angle as 90 degree for the omission of itself.

5.2 Implementation

The Simulation has been done under the test channel constructed above, and here will show the demonstrate of the estimation. Regarded to the flow chart (Fig. 1), the demonstration will also be decided into 3 parts.

- **Delay domain search** We get the channel impulse response by taking the inverse Fourier transform to the channel matrix and do the peak searching as shown in Fig. 3. After finishing the delay domain peak search, we continue the estimation procedure by estimating the path one by one.
- Angular maxima Search the angular maxima at the delay detected in the delay domain search. For the initialization of the conjugate gradient method, we submit the delay into global search, to find the nearest grid point beside the real peak. The result is shown in Fig. 4. After the global search, we submit the output into the conjugate gradient method to refine the peak position. Generally, 2 to 3 iterations took during the conjugate gradient method because of the low dimension.

When the angular maxima is detected, we submit the directional angle to a matched filter like

$$\boldsymbol{\Gamma} = \frac{\mathbf{E}_{\mathrm{R}}(\phi_{\mathrm{R}})\mathbf{H}\mathbf{E}_{\mathrm{T}}^{\mathrm{T}}(\phi_{\mathrm{T}})}{||\mathbf{E}_{\mathrm{R}}(\phi_{\mathrm{R}})||^{2}||\mathbf{E}_{\mathrm{T}}(\phi_{\mathrm{T}})||^{2}},\tag{7}$$



Figure 2: Test Channel with 6 Paths Preset



Figure 3: Delay Domain Search Result

where $\mathbf{E}_{\mathrm{T}}(\phi_{\mathrm{T}}), \mathbf{E}_{\mathrm{R}}(\phi_{\mathrm{R}})$ is the array response in the transmit side and receive side respectively and **H** is the current channel.

$$\boldsymbol{\Gamma} = \mathbf{E}_{\mathrm{R}}^{\dagger}(\phi_{\mathrm{R}})\mathbf{H}_{\mathrm{single}}(\mathbf{E}_{\mathrm{T}}^{\dagger}(\phi_{\mathrm{T}}))^{\mathrm{T}}, \qquad (8)$$

is another calculation approach using the pseudoinverse $(\cdot)^{\dagger}$ is also considerable but not efficient.

Subtraction of path Since we have finish detecting all the parameters, we subtract the path from the channel and repeat the iteration again. From the channel model, we can just take the difference between the current channel and the one path channel, but in case of the residual power is small, we should not take such path into account, so we first judge the break condition, calculate the residual power if the residual power is above a acceptable level, we implement the subtraction.

6 Evaluation and Summary

6.1 Evaluation of the algorithm

In order to evaluate the accuracy of the channel estimation algorithm, the best way is to show the residual



Figure 4: Angular Profile Estimated Result



Figure 5: Residual Power [Percentage]

power as

$$RES = \frac{||\mathbf{H}_{meas} - \mathbf{H}_{MIMO}||}{||\mathbf{H}_{meas}||}$$
(9)

Figure. 5 shows the decrease of the residual power by the detection number of paths. The residual converges to zero after the final path detection, and it also proved that the algorithm has a good accuracy. However, the test channel has so many ideal points, when the objective channel becomes a real measurement data, some estimation coefficients may need to be considered to revise.

As a result, the estimation algorithm can detect all the path parameters correctly (with a residual power of 1 %). However, there is no noise influence in the test channel, in reality, the noise and the real measured channel data is highly expect to be taken into account.

6.2 Summary

In this abstract, the communication background has been introduced. From the background, it led us to model the high frequency propagation channel for the investigation of the channel characteristic. The wideband channel model has been introduced at the preparation stage of the estimation.

The estimation approach is based on the maximum likelihood estimation was utilized in this research. For the optimization of the likelihood function the hybrid of rough global search and the conjugate gradient method was proposed and implemented. The accuracy of this method has been evaluated by the residual power after each iteration.

However due to the test channel is in ideal condition, the feasibility in analyzing the real measurement data will be the future topic of this research.

References

- Minseok Kim, Jun-ichi Takada, Yohei Konishi, "Novel Scalable MIMO Channel Sounding Technique and Measurement Accuracy Evaluation With Transceiver Impairments," *IEEE Trans. on Instrum. and Meas.*, Vol. 61, No. 12, Dec. 2012.
- [2] Yuyuan Chang, Yohei Konishi, Minseok Kin (Tokyo Inst. of Tech.), Jiyun Shen, Yasuhiro Oda (NTT DOCOMO), Jun-ichi Takada (Tokyo Inst. of Tech.), "Analysis of Field Measurement with Wideband MIMO Sounder at 11 GHz Frequency," *IEICE Trans. Antennas Propagat.*, vol. 112, no. 384, AP2012-153, pp. 167-172, Jan. 2013.
- [3] C.-F. Yang, B,-C. Wu, and C.-J. Ko, "A raytracing method for modeling indoor wave propagation and penetration," *IEICE Trans. Antennas Propagat.*, Vol. 6, pp. 907-919, June 1998.
- [4] Jonas Medbo, Fredrid Harrysson, "Efficiency and Accuracy Enhanced Super Resolved Channel Estimation," 6th EuCAP, Prague, Czech, 2012.
- [5] B. H. Fleury, M. Tschudin, R. Heddergott, D. Dahlhaus, K. Ingeman Pedersen, "Channel Parameter Estimation in Mobile Radio Environment Using the SAGE Algorithm," *IEEE Journal on Selected Areas in Commu.*, Vol. 17, No. 3, pp. 434-450, March 1999.
- [6] Andreas Richiter, "Estimation of Radio Channel Parameters: Models and Algorithms," *Doctoral Thesis* Ilmenau University of Technology, 2005.
- [7] Steven M. Kay, "Fundamentals of Statistical Signal Processing: Estimation Theory," *Prentice Hall PTR*, 1993.
- [8] Yukihiko Yamasita, "Lecture handout for Mathematics and Statistics for International Development Engineering," Dept. of International Development Engineering, Tokyo Institute of Engineering, 2013.
- [9] Yang Miao, Jun-ichi Takada, "Pattern Reconstruction for Deviated AUT in Spherical Measurement by Using Spherical Waves," *IEICE Trans.* on Commu., E97.B(1), pp. 105-113, 2014.
- [10] M. Steinbauer, A. Molisch, and E. Bonek, "The double-directional radio channel," *IEEE Antennas Propagat. Mag.*, vol. 43, no. 4, pp. 51-63, Aug. 2001.

HUMAN BODY SHADOWING EFFECTS ON INDOOR MILLIMETER-WAVE PROPAGATION CHANNEL CHARACTERISTICS

Student Number: 13M18267 Name: Hung Pham Kinh Supervisor: Jun-ichi TAKADA

ミリ波屋内伝搬チャネル特性への人体遮蔽の影響

ファム キン フン

移動通信の爆発的普及に伴い、ギガビット級の通信速度の無線アクセスシステムの需要が高まってくる。この 問題を解決するために、広帯域を使用できるミリ波に注目が集まっている。ミリ波は、自由空間伝搬損失も遮蔽 時の回折損失も大きいため、屋内などの短距離の環境で利用される。屋内環境における伝搬パスの動的な遮蔽は 主に歩行者の移動によって生じると考えられる。ミリ波屋内伝搬チャネルにおいて、送受信アンテナが静止して いる場合の伝搬パスの歩行者遮蔽に関するモデル化が報告されている。本研究ではユーザ端末が移動する場合へ の拡張する方法について検討した。

1 Introduction

Recently, with the explosive spread of mobile communication, the demand for wireless access systems that have speed of gigabit level have been increasing. In order to meet this demand, increasing signal bandwidth is a useful method. However, the low frequency bands have been already occupied by many communication systems. From these situations, millimeter- wave that has high frequency to allow to transmit large bandwidth and therefore capable of high data rate communication, are being developed. The next generation communication systems are also expected to use both low frequency band and high frequency band simultaneously [1], where high frequency band is a important key to increase the data transmission rate.

Due to large propagation loss, millimeter-wave (mmWave) bands are expected to be used mostly in the indoor environment where the shadowing effects on propagation path by human bodies is very significant. Related to the effects of human bodies on indoor mmWave propagation channel, there are some researches which evaluated the effects when the user terminal is static [2] [3], however the model for dynamic user terminal, has not been reported.

From these situations, this research aims to evaluate the effects of human bodies on indoor mmWave propagation channel when user terminal is dynamic through simulation. The main tasks of this study are to extend the existing model for the static user terminal to the dynamic user terminal. In this study, in order to evaluate the effect of human bodies on the whole channel, we divide the whole channel into many paths, evaluate effects on each path, and then sum them up to find the effects on the whole channel.

2 Ray Tracing Method

In indoor communications, because there always exists many scatterers in propagation environment, not only the path transmitted directly from base station to user terminal,but also multipaths due to reflection and scattering from obstacles. The propagation path here is defined as the smallest entity in order to describe the radio channel. In order to find the path traveled from base station to the user terminal, ray-tracing method is a commonly used method.





The basic theory of this method is divide whole channel into many paths and then estimate the path based on information from base station, user terminal and propagation environment. In this study, the image principle based ray-tracing method in which a ray is assumed to reflect at reflecting surface with a reflection angle equal to the incidence angle. Fig.1 represents the simple illustration of image approach.

2.1 Path Gain Calculation

The path gain here is calculated as the path gain of only propagation channel without gain of antenna. The path gain of each path is calculated as summation of free space path gain, reflection gain and shadowing gain. The equation for path gain of each path and for all paths are as follows.

$$PG_{1,i} = \left(\frac{\lambda}{4\pi l_i}\right)^2 \prod_k R_{i,k} \tag{1}$$

$$PG_{2,i} = 10^{(-15 \times N)/10} \tag{2}$$

$$PG_i = PG_{1,i} + PG_{2,i} \tag{3}$$

$$PG_{total} = \sum_{i} PG_i \tag{4}$$

Here, $PG_{1,i}$ is summation of free space gain and reflection gain, $PG_{2,i}$ is path shadowing gain and PG_i is path gain of each path. *i* is index of propagation path, and $R_{i,k}$ is the k-th reflection coefficient of the i-th path, λ is wavelength, and l_i is the path length of the i-th path. Shadowing gain of each human body is -15 dB which is based on measurement data of [6]. *N* is the number of human bodies shadow a propagation path and *N* can be calculated as follows [3]

$$p_N(N) = \frac{1}{N!} (mwl)^N \times \exp(-mwl)$$
 (5)

 $p_N(N)$ is probability N human bodies shadow path l. The reflection coefficient is calculated by using Fresnel equation as follows [4]

$$R_{\parallel} = \frac{n_{12}\cos\theta_i - \sqrt{n_{12}^2 - \sin\theta_i^2}}{n_{12}\cos\theta_i + \sqrt{n_{12}^2 - \sin\theta_i^2}} \qquad (6)$$

$$R_{\perp} = \frac{\cos \theta_{i} - \sqrt{n_{12}^{2} - \sin \theta_{i}^{2}}}{\cos \theta_{i} + \sqrt{n_{12}^{2} - \sin \theta_{i}^{2}}},$$
 (7)

Where R_{\parallel} is the parallel component, R_{\perp} is perpendicular component and $n_{12} = \sqrt{\frac{\epsilon}{\epsilon_0}}$ is refractive index between two materials. In this study, simulation is performed in the cubic room where the wall is assumed to be made by concrete. The refractive index used for simulation is from measurement data of [5].

2.2 Human model

[3] showed that a human body can be modeled as a cylinder. In this study, human body is model as a vertically oriented cylinder in a rectangular coordinate system. The radius r and the height h describe the dimension of cylinder. In this study, r and h are assumed as the average size of Asian, and take values of 0.2 m and 1.7 m respectively.

The motion of human body is assumed to be random where at any timing, human bodies can move in all directions with the same probability, and after finishing simulation the density probability of human in room is identical for all positions.

3 Path Shadowing State Transition Probability (PSSTP) Model

3.1 Basic Theory

Generally, to know whether propagation path is shadowed by human bodies or not, we have to know whether the path is intersected by human bodies or not. However, such works are not simple because they take much time to compute. On the other hand, [3] proposed approaches to obtain the shadowing condition of propagation path by using two states Markov model when we know PSSTP in the case user terminal is static. Fig.2 represents the PSSTP in two states Markov model.

The shadowing events of each path are burst because once path is shadowed by a human body, it takes time to change to un-shadowed condition. It is similar for the opposite side. In this figure, P_{gb} represents the PSSTP from un-shadowed state (good state) to shadowed state (bad state) and P_{bg} represents the sate transition probability from shadowed state to un-shadowed state. From this figure, we can see that at any timing, when we know the shadowing condition (shadowed or un-shadowed) of current timing and the PSSTP, we can estimate the shadowing condition of path in the next timing.

Even for the case when user terminal is dynamic the path shadowing events are burst, so the two state Markov model can be adopted. The most important thing of this approach is how to calculate the PSSTP of each paths. The following section will explain the procedures of it.



Figure 2: Two states Markov model

For Path <i>i</i> Shadow		Shad	owing I /	Duratio	n D _{i1}			
Timing	1	2	3	4	5/	6		n
Shadowing Condition	0	0	0	1	1	0		1
Path Length l_{ik} [m]	l_{i1}	l _{i2}	l _{i3}	l _{i4}	l_{i5}	l _{i6}		lin
Shadowing Probability P_{ik}	P_{i1}	P_{i2}	P_{i3}	P_{i4}	P_{i5}	P_{i6}		P_{in}

Figure 3: Data processing

3.2 Path Shadowing Probability

When human bodies exist in propagation environment, the path shadowing can be calculated as.

$$P(l) = 1 - \exp(-mwl) \tag{8}$$

Where m is the population density [person/m²], w is the width of human body model [m], l is the length of horizontal portion of propagation path [m] which is lower than the human height. From this equation, we can see that when the propagation paths, human density and width of human body model are known the shadowing probability of them can be obtained. As explained, the path shadowing probability P can be obtained from path information, human body size and population density, so that if we know the relationship between PSSTP and the shadowing probability we can obtain the shadowing condition without calculating intersection between path and human bodies. Similar with [3], in this study, the Monte Carlo simulation is taken to estimate the PSSTP of each path. The simulation procedures are as follows. Firstly, move user terminal and human bodies, use ray-tracing method to calculate the propagation path, their path length, then using equation (8) to calculate path shadowing probability. Calculate the intersection between propagation paths and human bodies. These intersection represents whether paths are shadowed or not. Finally, from the shadowing probability information, calculate the average P_{bg} , P_{gb} . Fig.3 represents data processing to obtain P_{bg} , P_{gb} from simulation data.

The obtained data from simulation includes path length, shadowing probability and shadowing condition of each path at each timing. The length of duration when shadowing condition is 0 (un-shadowed state) is shadowing interval, length of duration when shadowing condition is larger than 0 (1,2,..., shadowed state) is shadowing duration. After calculating all shadowing interval and shadowing duration, by using following equations, we can obtain average of P, P_{bg} and P_{gb} . By plotting the results, we can obtain their relationship.

Table 1: Simulation parameter setting

Parameter	Value
Population density	0.07-0.24
Human body height	1.7 m
Human body radius	0.2 m
Room size (x, y, z)	(6, 9, 2.7) m
Base station position (x, y)	Center of room
Antenna height	1 m
Maximum reflection number	5
Refractive index	2.55- <i>j</i> 0.084
Signal frequency	60 GHz
Movement speed	1 m/s
Distance of each step	0.1 m
Simulation steps	25000



$$P_{bg,i} = \frac{1}{\operatorname{mean}(\sum_{j} I_{ij})} \tag{9}$$

$$P_{gb,i} = \frac{1}{\operatorname{mean}(\sum_j D_{ij})} \tag{10}$$

$$P_i = \operatorname{mean}(\sum_k P_{ik}) \tag{11}$$

3.3 Simulation Setting

The parameter for simulation can be seen as in table 1

3.4 Simulation Results

From the simulation, the relationship between path shadowing probability and PSSTP is plotted as shown in Fig.4. In this figure, results for the simulation where the user terminal is dynamic is compared to the existing model where the user terminal is static.

In this figure, horizontal axis denotes the average of path shadowing probability, vertical axis denotes the average of PSSTP. From this figure, the behavior of the PSSTP can be completely explained just by using path shadowing probability. When path shadowing probability is small, shadowing condition tends to move from un-shadowed state to shadowed state. On the opposite side, the similar behavior can also be observed. Also, the results for dynamic case can be well fitted by using the existing model. Use ray-tracing method to find propagation paths, paths length
Set initial shadowing condition of each path
Calculate path gain of each path and whole channel

- Set position of base station, initial position of user terminal

- Calculate shadowing probability P(l) of each path by using equation (8)

- Calculate P_{bg} , P_{gb} based on P(l) of each path using obtained relationship of them
- Base on value of P_{bg}, P_{gb} calculate the shadowing condition in next timing
- Move user terminal to new position
- Repeat procedures as explained until the expected time

Figure 5: Path gain calculation procedure



Figure 6: Path gain calculated directly

It means the PSSTP is not significantly influenced by user terminal movement, but depends on only path shadowing probability.

4 Path Gain Comparison

In order to verify the PSSTP model, the path gain obtained from that model is compared to the path gain of whole channel obtained by calculating directly through ray-tracing simulation.

4.1 Path Gain Calculation

From the obtained relationship between path shadowing probability and PSSTP, the path gain of channel can be calculated through simulation as in Fig5.

The procedures to calculate path gain directly by using intersection information obtained through ray-tracing method is same with the procedures explained above, however the shadowing condition is calculated directly based on information of intersection between human bodies and propagation paths.

4.2 Results Comparison

As seen from Fig.6 and Fig.7, at lower population density (m = 0.07, 0.13) of the room, the proposed PSSTP model can predict the path gain well. However, at higher population density (m = 0.18, 0.24) the proposed model could not predict well. The reason can be considered here is, in this study all propagation paths are assumed to be independent so the path shadowing probability of them are not dependent each other. However, in fact once a path is



Figure 7: Path gain calculated by using PSSTP model



Figure 8: Error free duration

shadowed, the paths close to it also have high probability to be shadowed. In other words, between propagation paths there is correlation related to path shadowing probability. This issues must be considered in the future work.

5 Error Duration Behavior

When a channel is affected by an obstacle, the path gain of channel will be decreased, and when path gain becomes smaller than a value called threshold, transmission between base station and user terminal cannot performed. In communication system, it is important to know the behavior of such characteristic. In this study, the error duration when path gain is smaller than threshold, and error free duration when path gain is higher than threshold are used to evaluate effects of human bodies on propagation channel. From CDF plot of path gain in Fig.6, we can see, the minimum level of path gain when it is not shadowed by any human body is about -80 dB, and when channel is affected by human bodies, path gain changes mostly from -80 dB to -90 dB. Therefore, we assume that when path gain of channel in smaller than -85 dB, the transmission between base station and user terminal is can not performed, and when path gain of channel is higher than -85 dB, transmission can be still performed. Because the accuracy of the path gain calculated by using PSSTP model is still not good, we use the path gain calculated directly from ray-tracing simulation to evaluate the error duration behavior of channel. Figure 8 and 9 show the results for error duration and error free duration.



Figure 9: Error duration

In the error free duration results, the maximum length is several hundred seconds. In the error duration results, the maximum duration for all case is only several seconds, and in both 4 cases mostly 90% of them is shorter than 1s. It means that the error free duration is much larger that error duration therefore mmWave communication can be used in indoor situations.

6 Conclusion

In this thesis, the PSSTP model was extended to the dynamic user terminal case from the existing model. The simulation results show that the PSSTP is not significantly influenced by user terminal movement, it depends on only the path shadowing probability. On other hand, the results of path gain show that the proposed model can predict the path gain well at lower population density, but the accuracy still must be considered, particularly at higher population density. Finally, the results of error duration behavior show that although mmWave is easily shadowed by human bodies, it still can be used in indoor situations. The study still has some limitations, such as the propagation environment and human movement model are simple, the effects of user who handles user terminal are not considered. These issues will be considered in future.

References

- [1] MiWEBA, "http://www.miweba.eu/"
- [2] K. Sato, T. Manabe, "Estimation of propagationpath visibility for indoor wireless LAN system under shadowing condition by human bodies", IEEE VTC 98, Ottawa, Canada, vol. 3, pp. 2109-2113, May 1998.
- [3] I. Kashiwagi, T. Taga, T. Imai, "A Path Shadowing Model focused on the Effects of Human Activities in Indoor Environments," IEEE VTC 2007 fall, pp. 889-893, Oct. 2007.
- [4] A. Goldsmith, Wireless Communication, Cambridge University Press, pp. 42, 2005
- [5] K. Sato, H. Kozima, H. Masuzawa, T. Manabe, T. Ihara, Y. Kasashima, K. Yamaki, "Measurements of reflection characteristics and refractive indices of interior construction materials in millimeter-wave hands," in Proc. 45th IEEE Veh. Technol. Conf., Chicago, IL, Jul. 26-28, 1995
- [6] 加藤明人、真鍋武嗣、"60 GHz 帯無線伝送路にお ける人体による遮蔽の影響、" 1997 進学総合大 会、B-1-33、p. 33、(1997)

Depth Image Generation by Image Segmentation

Student Number: 13M18043 Name: Soichi Uchiyama Super visor: Yukihiko YAMASHITA

Abstract

現在移動ロボットは、多数の高価なセンサーを用いて自動走行を実現している、そのため価格が高く利 用できる場面が限られている.そこで本研究では、KINECTという安価なゲーム用の2次元画像と距離画 像を取得できるセンサーを利用し、実時間で3次元空間を認識する方法を提案する、平面の歪み・物体形 状の変形・距離画像の欠損など KINECT が抱える問題の中で、より良い3次元空間の復元のために、まず 画像領域分割を用いて2次元画像を分割する.そして,2次元画像と距離画像と対応させて距離画像を分 割する. 最後に, 平面と判別された領域に対して最適な平面を推定して3次元空間の復元を行う. 本研究 では計算機実験により、提案手法の有用性を確かめる.

1 Introduction

In recent years, mobile robots realize automatic traveling with combined information obtained from GPS, a laser range finder, and a stereoscopic video camera. However, installing those sensors makes their price higher. are as shown in Table. 1. Therefore, reconstruction of three-dimensional space by matching features extracted from the two-dimensional images has been attempted. However, it doesn't work well. Then, by the two-dimensional image matching it is considered to be difficult to construct a system that supports the automatic traveling. The point cloud data generation for the three-dimensional space reconstruction from a distance image has also been attempted. But, with the increase the number of points, the required computational load for matching increases. And it will go away from the real time processing.

Therefore, I focused on an inexpensive sensor called KINECT which can obtain a two-dimensional image and a distance image for gaming machine. After it was released in November 2010, the researches using KINECT camera system as shown in Fig.1.

have developed open-source drivers and various applications. When software development kit is published from Microsoft in June 2011, KINECT is not limited to the game field but has been attempted to utilize in various fields such as medical and human flow measurement.

In this study, I propose a method to recognize the three-dimensional space for a mobile robot by using KINECT. I show the validity of the proposed method by experiment results.

Generation method of distance im-2

age

KINECT consists of a color image sensor, a distance image sensor, four-microphone array. Its specifications

Table.	1:	The	specifications	of	KINECT
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Depth acquisition system	projector-camera system
Depth resolution	640x480px
RGB resolution	1600x1200px
Frame rate	60fps(max)
The imaging range	0.8~3.5m
The spatial resolution	x, y direction 3mm
at the point of 2m	z direction 1cm

Acquisition of the distance image is done by the projector-



Fig. 1: Acquisition of the distance image

Projecting a known light pattern to objects in threedimensional space, KINECT can acquire the distance image by observing the projected pattern which shifts according to the distance. The pseudo-random pattern is used in order to recognize the position of each point. Each point of the virtual image of the projection side and the observed image of the light-receiving side are associated with each other as shown in Fig.2 by virtue of epipolar line as shown in Fig.3.

In the light pattern, by changing the size and shape of the spots for each area, KINECT obtains distance information which is accurate with respect to the near distance, and rough with respect to far distance.



Fig. 2: Triangulation



Fig. 3: Epipolar geometry

All 3D points within the field of view of a camera is included in the epipolar plane intersecting the respective image epipolar line. If a point in an image is given, the point corresponding in the other image should be on the corresponding epipolar line. This is referred to as epipolar constraint. By the epipolar constraint, 2-dimensional search for a matching point becomes one-dimensional search, and it is possible to discard mismatched points.

Pseudo-random pattern that KINECT irradiates is generated as Fig.4. The generated pseudo-random pattern

is an image illustrated by Fig.5.



Fig. 4: Generation of pseudo-random pattern



Fig. 5: Generated pseudo-random pattern

From the distance image measured by KINECT, we can see the following problems.

In Fig.6, the wall and the floor are should be plane, but they are wavy. And some shapes such as the hand are distorted. This phenomenon is also found in threedimensional reconstruction based on the point cloud.

Also, in Fig.7, the region in the red circle where the pattern is not projected because of the shadow of an object and the region in the blue circle where the pattern can not be obserbed exist.



Fig. 6: Distort image by KINECT

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Fig. 7: Regions of shadow and occlusion

3 The proposed method

To solve problems described in Chapter 2, I propose a new method for the distance image generation by using the two-dimensional image. First, I detect edges from the two-dimensional image. Then, I divide the the two-dimensional image into several regions by using the edge information. Finally, I estimate a plane to fit the point group of the target region.

For edge detection, I use the Canny edge detector. The feature of this algorithm is to make contours from candidates of edges. Contour is formed by applying a hysteresis threshold to the pixel. This means that there are two thresholds, upper and lower limits. If the pixel has a gradient greater than the upper threshold, the pixel is joined to contour. If the gradient of the pixel is smaller than the lower threshold, the pixel is discarded. In the case that the gradient of the pixel is between the thresholds, only if the pixel is connected to a pixel that has a gradient greater than the upper threshold, the pixel is joined to contour.

For image segmentation, I perform labeling on the image using the extracted edges. Then, in order to simplify and visualize, I cut out the largest region as the target region in the divided image by labeling.

For plane estimation, I use the RANSAC algorithm. RANSAC is an abbreviation of RANDdom Sample Consensus. First, RANSAC generates many planes for sets of randomly extracted sample points. This algorithm selects the plane that fits all sample points the most. This algorithm is robust when there is an outlier on the measured value.

4 Three-dimensional space recognition experiment

In order to verify the proposed method, I carried out computer experiments. Then, I show the results of the computer experiments.



Fig. 8: Image of an environment



Fig. 9: Result of Canny edge detector



Fig. 10: Target region



Fig. 11: Result of plane estimation



Fig. 12: Distance image by KINECT

Fig.8 shows an environment including a regions that can not be observed because of shadow and occlusion. Fig.9 shows the result of the Canny edge detector. Fig.10 shows the target region which has the largest area based on the labeling information. Fig.11 shows the estimated plane image derived from the RANSAC algorithm to the target region. Fig.12 shows the original distance image.

In the proposed method, I used the Canny edge detector. Then, I labeled the two-dimensional image by raster scan, and divided into several regions. After that I estimated the plane by using the RANSAC algorithm to adapt to the depth image corresponding to the target region of the two-dimensional image. Compere with Fig.11 and Fig.12, the proposed method restored the depth information of the region that can not be observed because of shadow and occlusion. I can confirm the effectiveness of the proposed method by the computer experiment.

Since canny edge detector is a powerful edge detector, it detects only strong edges with the recommended parameters, and weak edges are lost. Therefore, it is necessary to use parameters to extract more edges. But if many edges are detected, trade-off between processing time and performance will arise for image segmentation.

Also, a raster scan is not efficient for real-time performance. Therefore, rather than searching by a raster scan, probabilistic Hough transform will divide image more accurately, and real-time performance is expected to be improved.

My proposed method has restored the distance information in the regions of shadow and occlusion. However, those regions may not be truly a plane. By preparing the image channel for reliability, it would be possible for the mobile robot to handle properly the restored distance information.

5 Conclusion

In this study, I propose a new method to recognize the three-dimensional space for a mobile robot by using KINECT. I showed the proposed method restored the depth information of the region that can not be observed because of shadow and occlusion by experiments. In order to improve the plane extraction method in my proposed method, we have to investigate the following researches: to optimize the parameters of the Canny edge detector, to detect lines more efficiently by probabilistic Hough transform, and to make the measurement method of reliability for estimation.

Reference

- [1] Microsoft, "Kinect", http://www.xbox.com/ja-JP/kinect.
- [2] Gary Bradski and Adrian Kaebler, "Detailed explanation OpenCV Image processing and recognition that uses a computer vision library", Ltd. O'Reilly Japan, 2009.
- [3] IMURA Masataka, "imura : products : Labeling class", http://oshiro.bpe.es.osakau.ac.jp/people/staff/imura/products/labeling.
- [4] Murakami Shinnichi, "Image processing engineering", Tokyo Denki University Press, 1996.
- [5] Tanijiri Houju, "KINECT sensor image processing programming", Ltd. cut system, 2011.
- [6] opencv.jp, "OpenCV 2.2 C Reference", http://opencv.jp/opencv-2svn/c.

Hybrid image compression by using vector quantization (VQ) and vector-embedded Karhunen-Loève transform (VEKLT)

Studuent Number: 13M18250, Name: Kiung Park, Supervisor: Yukihiko Yamashita

ベクトル量子化 (VQ) とベクトル埋め込みKLT (VEKLT) によるハイブリッド画像圧縮

朴 基雄

本論文では、ベクトル量子化と二つの直交変換、離散コサイン変換(DCT)、ベクトル埋め込みKLTを組み合わ せ、新しいブロック変換に基づく画像圧縮法を提案する.まず、入力画像を8×8のブロックに分割し、原ブロッ クとベクトル量子化されたブロックの差分をVEKLTで変換する.同時に原ブロックをDCTで変換する.その後、 各ブロックに対して算術符号長の比較により、DCTまたはVEKLTの結果を選択し、その選択結果を基に二値イン デックス画像を作る.そして、二値インデックス画像を四分木分割し、多様なサイズのDCTを実行する.計算機 実験を行い、提案方法がピーク信号対雑音比(PSNR)と視覚評価、両面でJPEGより高い性能を持つことを示す.

I. INTRODUCTION

JPEG is an international standard for still image compression. Even if it has weak points such as blocking distortion and image quality degradation in high details, it has been used widely because its algorithm is simple and fast, and the compression ratio is enough. Quantization used in JPEG is scalar quantization. Shannon's rate-distortion theory indicates that a better performance can be achieved by coding vectors instead of scalars [1], [2]. Thus, if we introduce VQ into JPEG, we can expect a better compression performance.

Although the block prediction method is a mainstream for reducing spatial redundancy in recent years, VQ was studied popularly in the past [3]. Especially, the general concept of this paper is motivated by the method [4]. It proposes a hybrid image coding scheme combining VQ and DCT with variable block segmentation by quadtree. The residual image is segmented with a quadtree into square blocks whose size depends on their classes (low details, high details, random textures) of the region according to a rough qualitative appraisal of its local perceptual importance and coding difficulty. In this paper, low details belong to DCT category and high details belong to VEKLT [5] category for reducing their coding difficulty.

In recent years, the hybrid image coding scheme combining VQ and transformation is proposed [2], [6], [7], [8]. In the method [2], VQ and the existing image coding scheme such as JPEG or JPEG2000 can be combined and the VQ indexes do not have to be coded because they are obtained from the upsampled image of a decoded downsampled and distorted image. In the method [7], VQ is performed on a sparse representation which is obtained by compressed sensing theory in the wavelet domain. In the method [6], [8], VQ is performed on a truncated vector from DCT coefficients. The indexes and the codebook which is generated from an input by using k-means clustering algorithm are transmitted.

In this paper, a new block-transform-based image compression scheme is proposed by combining VQ and two transformations, DCT and VEKLT. To compress high details efficiently, the difference between an original block and its vector-quantized block is transformed by VEKLT which is a kind of KLT to introduce a local statistics. In the method [5], the rotated DCT basis is embedded into an orthogonal transformation matrix which is calculated from a correlation matrix such as the first-order Markov model. In this paper, the vector for DC component and the selected representative vector by VQ are embedded into the orthogonal transformation matrix which is calculated from the corresponding trained covariance matrix. The representative vectors for VQ are made by two steps. First, the candidates for the representative vectors are sampled from each training image (BSDS500 [9]) by the Gaussian mixture model (GMM) to use the probability distribution [10]. Then, the final 4096 representative vectors are extracted by k-means clustering from the groups of sampled candidates. To adopt variable block size DCT for compressing low details efficiently, quadtree decomposition is performed on the binary index image that indicates the category of each block (DCT and VEKLT). The binary index image is made from the VQ coefficients which are calculated by the inner product between a normalized input vector and a corresponding representative vector. Thus, there is no side-information for quadtree because its information is dependent on the VO coefficients. Finally, the VQ indexes are coded by Huffman coding because the number of symbols is very large, and the scalar-quantized coefficients (DCT, VEKLT, VQ) are coded by the arithmetic coding based on the basic algorithm [11].

The rest of this paper is organized as follows. In Section 2, the proposed scheme is explained by a block diagram. In Sections $3\sim5$, some key techniques of the proposed scheme are presented. In Section 6, the experimental results demonstrate the advantages of the proposed scheme. Finally, Section 7 concludes this paper.

II. PROPOSED METHOD

The proposed encoder is illustrated in Fig. 1. It can be explained by 4 steps.



A. Vector quantization

After an input image is split into 8×8 blocks, each 8×8 block is vertically scanned, normalized and vectorquantized by using squared Euclidean distance. Vector quantizer outputs a VQ index and a VQ coefficient which is calculated by the inner product between the input vector and the selected representative vector. VEKLT is performed by using the prepared transformation matrix corresponding to the VQ index. The transformed coefficients by VEKLT are scalar-quantized and arithmetic-coded, and parallelly DCT is performed on the original blocks, and the scalar-quantized AC coefficients are also arithmetic-coded. After comparing the code-length of AC coefficients from DCT and the sum of code-lengths of VEKLT coefficients, VQ coefficient, and VQ index, the shorter one is selected. If DCT is selected, its VQ index is deleted and its VQ coefficient is changed to zero. Then, the binary index image which indicates whether VEKLT or DCT is selected is constructed from the revised VQ coefficients.

B. Transformation

Quadtree decomposition is performed on the binary index image whose size is one-eighth of the input because it is split into 8×8 blocks. The quadtree data structure for the binary index image decomposes a $2^2 \times 2^2$ image block into a 3-level hierarchy, where all blocks at level *n* have size $2^n \times 2^n$, $0 \le n \le 2$ [12]. It means that the maximum block size for DCT is 32×32 . Then, a transformation among VEKLT (8×8) and DCT (8×8, 16×16 , 32×32) is performed according to the quadtree decomposed binary index image.

C. Entropy coding

There is no scalar quantization table which is used in JPEG. All coefficients are scalar-quantized equally. An entropy coder which is optimized in the proposed method

has not been developed yet, the basic arithmetic coding algorithm is used [11]. The sign and the absolute value of a coefficient sequence are arithmetic-coded because the histogram distribution of symbols is usually symmetric. The frequency of symbols is exponential-Golomb-coded for the decoder side. The difference of DC coefficients between current and previous blocks is coded to eliminate the spatial correlation of neighbor. The AC coefficients are coded after zigzag-scan with the symbol of end-of-block (EOB). The VEKLT coefficients and EOB are coded without any scanning order because they are already arranged by the descending eigenvalue order. The VQ coefficients are coded without calculating the difference because their spatial correlation is small. The VQ indexes are Huffman-coded by using the frequency of symbols estimated from the training images [9] because the number of symbols is relatively large in comparison with the length of sequence.

D. Composition of output

Finally, the encoder outputs the array of unsigned 16 bits which consists of the header and the codes of revised VQ indexes, VQ coefficients, VEKLT coefficients, DC coefficients, and AC coefficients from DCT.

III. IMPLEMENTATION OF VEKLT

Let f_i be the vertically scanned *i*-th block of image, an input can be written as

$$\boldsymbol{f}_i = \langle \boldsymbol{f}_i, \boldsymbol{\Phi}_{DC} \rangle \boldsymbol{\Phi}_{DC} + \langle \boldsymbol{f}_i, \boldsymbol{\Phi}_{i,AC} \rangle \boldsymbol{\Phi}_{i,AC}.$$

By normalizing f_i by L_2 norm, $\Phi_{i,AC}$ is obtained. Then, the representative vector $\hat{\Phi}_{k,VQ}$ nearest to $\Phi_{i,AC}$, where k is the VQ index of f_i is selected by vector quantizer. In case of 8×8 block size, the dimension of f_i is 64. Because Φ_{DC} and $\hat{\Phi}_{k,VQ}$ are perpendicular, f_i can be expanded as

$$oldsymbol{f}_i = \langle oldsymbol{f}_i, oldsymbol{\Phi}_{DC} + \langle oldsymbol{f}_i, oldsymbol{\hat{\Phi}}_{k,VQ}
angle oldsymbol{\hat{\Phi}}_{k,VQ} + \sum_{j=0}^{51} \langle oldsymbol{f}_i, oldsymbol{\Phi}_{kj}
angle oldsymbol{\Phi}_{kj}.$$

where Φ_{kj} $(j = 0, 1, \dots, 61)$ are perpendicular to both Φ_{DC} and $\hat{\Phi}_{k,VQ}$.

The remaining basis vectors Φ_{kj} $(j = 0, 1, \dots, 61)$ are obtained by VEKLT. Let \mathbf{R}_k be the covariance matrix corresponding to the VQ index k and $\mathbf{W}_k = \Phi_{DC} \Phi_{DC}^{\mathrm{T}} + \hat{\Phi}_{k,VQ} \hat{\Phi}_{k,VQ}^{\mathrm{T}}$, the symmetric matrix \mathbf{Q}_k is defined by

$$\mathbf{Q}_{\mathrm{k}} = \mathbf{R}_{\mathrm{k}} - \mathbf{R}_{\mathrm{k}}\mathbf{W}_{\mathrm{k}} - \mathbf{W}_{\mathrm{k}}\mathbf{R}_{\mathrm{k}} + \mathbf{W}_{\mathrm{k}}\mathbf{R}_{\mathrm{k}}\mathbf{W}_{\mathrm{k}}.$$

 Φ_{kj} (j = 0, ..., 61) are given by the eigenvectors of \mathbf{Q}_k corresponding to nonzero eigenvalues. The transformation matrix \mathbf{T}_k is given by

$$\mathbf{T}_{k} = [\mathbf{\Phi}_{k0}, \dots, \mathbf{\Phi}_{k61}]^{\mathrm{T}}.$$

By operating \mathbf{T}_k on \boldsymbol{f}_i , the 62 VEKLT coefficients are obtained.



Figure 2. Test images. From left to right : 'Airplane', 'Lena', 'Mandrill', 'Peppers', 'kodim03', 'kodim05', 'kodim19', 'kodim23', 'Fruits', 'Outdoor'

IV. BINARY INDEX IMAGE

The concept of the binary index image is very simple. That is just a binary expression of the scalar-quantized VQ coefficients which is reshaped into two dimensional array, whose size is one-eighth of the original image by assigning non-zero and zero values into false and true respectively. Because the value of VQ coefficient is revised by zero if DCT is selected, true means that the block is low detail and it is more efficiently decorrelated by DCT than VQ and VEKLT. On the other hand, false means that the block is high detail and it is more efficiently decorrelated by VQ and VEKLT than DCT. Quadtree decomposition is performed on the binary index image to adopt variable block size DCT for compressing low detail efficiently. At the decoder side, sideinformation for quadtree is not needed because the binary index image is dependent on the VQ coefficients. Fig. 3 shows an example of the binary index image.



Figure 3. (a) : Binary index image of 'Lena', (b) : Quadtree decomposed (a), and (c) : Binary index image modified from (b) by assigning false into true on (a)

V. CONSTRUCTION OF REPRESENTATIVE VECTORS AND CORRESPONDING VEKLT TRANSFORMATION MATRIXES

A. Representative vectors

First, the 500 training images from BSDS500 [9] are prepared. Then, the normalized input vectors are obtained from each training image. GMM is applied to them by using EM algorithm with initial values obtained by k-means. Because the mean vector has the highest probability in each cluster, it appears often in images. Thus, the 1000 mean vectors are primarily sampled from each training image. After collecting them, the 500000 candidates are obtained for the representative vectors. Finally, the 4096 vectors are extracted from the candidates by using k-means and they are normalized again. The final 4096 vectors are stored in the representative database for VQ.

B. VEKLT transformation matrixes

Because VEKLT is a kind of KLT, a covariance matrix is needed to make a transformation matrix. After inputting the

prepared training images (BSDS500) into the encoder, the covariance matrix \mathbf{R}_k is obtained from the residual signals calculated by $\mathbf{f}_i - \langle \mathbf{f}_i, \Phi_{DC} \rangle \Phi_{DC} - \langle \mathbf{f}_i, \hat{\Phi}_{k,VQ} \rangle \hat{\Phi}_{k,VQ}$, where \mathbf{f}_i have the same VQ index k. Finally, the 4096 VEKLT transformation matrixes are calculated by *Section* 3 because the number of representative vectors is 4096.

VI. EXPERIMENTAL RESULTS

All experiments are performed on a PC with Intel Core i7-3970X 3.50GHz processor. In the proposed method, both the encoder and decoder are written by MATLAB and MATLAB coder which is an application for compiling mfile to C-code is used for reducing computation time at for or if sentences. The ten test images in Fig. 2 are used to demonstrate the performance of the proposed method. The objective and perceptual qualities are evaluated by PSNR and reconstructed images respectively. We compare the performances of the proposed method and JPEG (IJG library with arithmetic option) [13]. Table. I shows the PSNR comparison. Fig. 4 (a) shows the rate-distortion relations. They show that the proposed method outperforms JPEG with a gain in PSNR of around 0.5~3.0 dB except 'Mandrill' because the fur of 'Mandrill' is difficult to be decorrelated. Especially, the proposed method performs better in PSNR if the bpp increases because the ratio of blocks which are processed by VQ and VEKLT increases (Fig. 4). Fig. 5 shows that the visual quality of the proposed method is better than that of JPEG at high details. The feature of center wood grain is well maintained in the proposed method. Fig. 6 shows that the elapsed time of the proposed method is slower than that of JPEG. However, it is faster than the conventional VQ [8].

Table I PSNR (dB) PERFORMANCE COMPARISON

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Test image	bpp	Proposed	JPEG	Test image	bpp	Proposed	JPEG
	0.25	31.87	31.13		0.25	33.10	31.95
Airplane (512×512)	0.5	35.99	34.89	Lena (512×512)	0.5	36.20	35.09
	1.0	40.08	38.86	1	1.0	39.09	38.13
Mandrill (512×512)	0.25	22.57	22.46		0.25	32.49	31.54
	0.5	24.80	24.50	Peppers (512×512)	0.5	34.70	34.13
	1.0	28.25	27.05	1	1.0	37.04	36.38
kodim03 (768×512)	0.25	34.71	33.45	kodim05 (768×512)	0.25	24.12	23.78
	0.5	38.70	36.41		0.5	27.43	26.11
	1.0	43.48	40.45	1	1.0	31.85	29.63
kodim19 (512×768)	0.25	29.57	28.66	kodim23 (768×512)	0.25	37.05	35.18
	0.5	32.37	31.54		0.5	40.45	38.69
	1.0	36.66	34.97	1	1.0	43.50	42.13
	0.25	33.47	32.64	Outdoor (2048×2560)	0.25	25.12	24.57
Fruits (2560×2048)	0.5	36.67	35.20		0.5	28.86	27.19
	1.0	40.38	38.63	1	1.0	33.87	31.25

VII. CONCLUSION

This paper proposes a new block-transform-based image compression scheme by combining VQ and two transformations, DCT and VEKLT. Experimental results demonstrate



(b) Left : Result of 'kodim03', Right : Result of 'kodim05'

 $\begin{array}{ll} \mbox{Figure 4.} & (a) \mbox{ Rate-distortion relations (X-axis : bpp, Y-axis : PSNR (dB)),} \\ (b) \mbox{ VEKLT ratio in all $8{\times}8$ blocks (X-axis : bpp, Y-axis : VEKLT ratio) } \end{array}$

the advantages of the proposed techniques. Its PSNR outperforms JPEG and its visual quality is better than that of JPEG at high details. However, there are still many aspects to be investigated in the future, such as reducing computation time, introducing block prediction, replacing DCT with more efficient transformation such as lapped biorthogonal transform (LBT), efficient scanning method in 16×16 , 32×32 blocks and entropy coding, the approximation method of a true covariance matrix, the optimum number of the representative vectors, their mining method and so on.

REFERENCES

- C. E. Shannon "A Mathematical Theroy of Communication," *Bell System Tech. Journal*, vol. 27, pp. 379-423, 623-656, 1948.
- [2] Feng Wu and Xiaoyan Sun "Image Compression by Visual Pattern Vector Quantization (VPVQ)," in *Proceedings of the Data Compression Conference*, pp. 123-131, Mar. 2008.
- [3] Nasser M. Nasrabadi and Robert A. King "Image Coding Using Vector Quantization: A Review," *IEEE Transactions on Communications*, vol. 36, no. 8, pp. 957-971, Aug. 1988.
- [4] Jacques Vaisey and Allen Gersho "Image Compression with Variable Block Size Segmentation," *IEEE Transactions on Signal Processing*, vol. 40, no. 8, pp. 2040-2060, Aug. 1992.
- [5] Toshihisa Tanaka and Yukihiko Yamashita "Image Coding Using Vectorembedded Karhunen-Loève Transform," in *Proceedings of IEEE International Conference on Image Processing*, vol. 1, pp. 482-486, Oct. 1999.
- [6] Arup Kumar Pal, G. P. Biswas and S. Mukhopadhyay "A Hybrid DCT-VQ Based Approach for Efficient Compression of Color Images," in *Proceedings* of International Conference on Computer and Communication Technology, pp. 177-181, Sep. 2010.
- [7] Mohit Kalra and D. Ghosh "Image Compression Using Wavelet Based Compressed Sensing and Vector Quantization," in *Proceedings of IEEE Conference* on Signal Processing, pp. 640-645, Oct. 2012.
- [8] Dheeren Ku Mahapatra and Uma Ranjan Jena "Partitional K-means Clustering based Hybrid DCT-Vector Quantization for Image Compression," in *Proceedings* of *IEEE Conference on Information and Communication Technologies*, pp. 1175-1179, Apr. 2013.
- [9] Pablo Arbelaez, Michael Maire, Charless Fowlkes and Jitendra Malik "Contour Detection and Hierarchical Image Segmentation," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 33, no. 5, pp. 898-916, May. 2011.
- [10] Per Hedelin and Jan Skoglund "Vector Quantization Based on Gaussian Mixture Models," *IEEE Transactions on Speech and Audio Processing*, vol. 8, no. 4, pp. 385-401, Jul. 2000.

- [11] Eric Bodden, Malte Clasen and Joachim Kneis "Arithmetic Coding revealed," Sable Technical Report, no. 2007-5. May. 2007.
- [12] Gary J. Sullivan and Richard L. Baker "Efficient Quadtree Coding of Images and Video," *IEEE Transactions on Image Processing*, vol. 3, no. 3, pp. 327-331, May, 1994.
- [13] Independent JPEG Group "JPEG library (version 9a)," Available online from http://www.ijg.org, Jan. 2014.









(c)

Figure 5. (a) : Cropped original 'kodim03', (b) : Cropped 'kodim03' reconstructed by the proposed method (bpp : 0.25), and (c) : Cropped 'kodim03' reconstructed by JPEG (bpp : 0.25)



Figure 6. Comparison of elapsed time (X-axis : bpp, Y-axis : elapsed time (s))

Electromagnetic Wave Scattering Simulation Using Physical Optics on Point Cloud Data

Student Number: 13M18050 Name: Hiroki OHARA Supervisor: Jun-ichi TAKADA

点群による物理光学法を用いた電磁波散乱シミュレーション

学籍番号: 13M18050 氏名: 小原 宏貴 指導教官: 高田 潤一

電磁波散乱問題において,散乱物が波長より十分大きい場合,マクスウェル方程式を直接解く厳密解法に比べ,散乱 物形状に対する適応性,及び計算時間の点で有利である物理光学法 (PO) が強力なシミュレーション手法として利用 されている.また,高精度な電磁界シミュレーションを行うためには,対象となる散乱物の形状を正確にモデリング する必要がある.近年,物体の3次元形状をモデル化するために,レーザスキャナを用いて大量の点群を取得し,形 状を正確に表現する手法が注目されている.本論文では,この技術をPOへ応用する方法について検討を行った.

1 Introduction

In order to increase the performance of future wireless systems, it is necessary to model the propagation channel more accurately. In the actual wireless communication environments, it is necessary to analyze not only the direct wave from the transmitter to the receiver but also the scattered wave from a scatterer. Since the back scattering affects wireless communication usually, the analysis of back scattering is one of the important studies for electromagnetic wave scattering problems.

As the method to analyze the electromagnetic wave scattering, there exist some simulation methods such as Method of Moment (MoM), Finite-Difference Time-Domain method (FDTD), Ray Tracing method (RT), and Physical Optics (PO). PO is one of the high frequency approximation methods, which gives a good accuracy for obstacles which are large enough compared to the wavelength around back scattering region.

On the other hand, it is necessary to create the geometrical model of scatterers accurately when performing electromagnetic wave scattering simulations. Usually 3D CAD is used to create models. However, it is difficult for 3D CAD to deal with models of complex objects. Recently, complex model construction using point clouds has been gaining attention due to its accuracy and speed for arbitrary shape [1]. Firstly, point clouds are measured using a laser scanner, and then a mesh generation method is used to transform the point cloud into a 3D model of the object.

In addition, the most important factor in electromagnetic wave scattering simulation is the relation between accuracy and computation time. Since there is a trade-off between the simulation accuracy and the computation time due to the number of meshes of the model, the suitable simulation parameters should be discussed.

In this study, electromagnetic wave scattering simulation using PO on point cloud data is proposed assuming a sphere which can be solved analytically for verification. In order to reduce computational load of the simulation, Quadric Edge Collapse Decimation (QECD) which is a mesh reduction method is applied, and the trade-off between simulation accuracy and computation time was examined using Radar Cross Section (RCS) and Root Mean Square Error (RMSE) based on the mesh area which is normalized to the wavelength. Finally, from this trade-off analysis, the appropriate mesh size for simulations is determined, and the simulation accuracy based on the appropriate mesh size is compared to the exact solution which can be analytically solved.

2 Physical optics

PO assumes that the surface electric current is equal to twice of the incident magnetic field on the illuminated part of the scatterer when the surface is a Perfect Electric Conductor (PEC). On the other hand, the surface electric current on the shadow part is assumed to be zero. In general, PO can accurately calculate the scattered field on the illuminated part, however, the error occurs on the shadow part. The surface electric current is defined as follows [2]

$$\boldsymbol{J}_{\rm s} = \begin{cases} 2\boldsymbol{\hat{n}} \times \boldsymbol{H}_{\rm i} & \text{Illuminated part} \\ 0 & \text{Shadow part} \end{cases}, \qquad (1)$$

where H_i is the incident magnetic field and \hat{n} is the normal vector from the surface. In order to calculate the scattered field for the mesh model, the following equation is used [2]

$$\boldsymbol{E}_{\mathrm{s}}(r,\theta,\phi) = \frac{-jkZ_0}{4\pi r} e^{-jkr} \iint_A \boldsymbol{J}_{\mathrm{s}} e^{jk\cdot\boldsymbol{g}} ds_{\mathrm{p}},\qquad(2)$$

where r is the distance from the origin to the observation point Q, k is the wave number, Z_0 is the characteristic impedance of free space, θ and ϕ are the elevation and azimuth angle of the observation point, A is the illuminated part of the surface, $ds_{\rm P}$ is the differential area of the surface, and g is the inner product of the integral point and the observation point as shown in Fig. 1. In order to evaluate the scattered field, RCS is used as follows

$$\sigma = \lim_{R \to \infty} 4\pi R^2 \frac{|E_{\rm s}|^2}{|E_{\rm i}|^2},\tag{3}$$

where $E_{\rm s}$ is the scattered electric field, $E_{\rm i}$ is the incident electric field, R is the distance between observation point and scatterer.

3 Modeling

3.1 Point cloud data

Before performing electromagnetic wave scattering simulations using the point cloud of actual environments,



Fig. 1: Coordinate system



Fig. 2: Point cloud data

it is necessary to verify the validity of the simulation using a simple model. The point cloud data in this study is shown in Fig. 2. This data was created by using Matlab, assuming that the data is obtained by a laser scanner. For example, this model has 14281 points on the surface.

3.2 Mesh

Figure 3 shows the mesh model from Fig. 2. In order to create the mesh from point cloud, Marching cubes algorithm is used to form the surface for 3D object [3]. Firstly, the volume enclosing the whole object is divided into many small cubes called voxels. Then, all the voxel vertices which exist inside the object are set a value of 1, and all vertices are set to 0. There exist 15 possible mesh patterns depending on the combination of vertices. These mesh patterns are applied to the vertices determined in the previous step to create a final 3D mesh surface. By using this technique, it is possible to create a surface from point cloud data. As a result, the surface of this model is composed of 65308 meshes.

4 Mesh reduction

4.1 Quadric edge collapse decimation

The model which is created by marching cubes has the large number of meshes on the surface because the model refers to a large amount of points. In addition, when the voxel becomes small, the number of meshes increases compared to this model. If this model is applied to PO simulation directly, the simulation accuracy becomes high. However, the computation time becomes very long due to the large number of meshes. Therefore, there exists a trade-off between the simula-



tion accuracy and the computation time. In order to improve this problem, QECD which is one of the mesh reduction methods is introduced here. Figure 4 shows the image of this algorithm [4].

4.2 Normalized mesh area

In this study, mesh reduction rate is assigned to 40%and QECD is repeated 10 times. Then, the size of each mesh on the surface becomes large. In order to evaluate the change, normalized mesh area A' which is normalized to wavelength is introduced here. The definition is indicated by the following equation [5]

$$A' = \frac{\sum_{l=1}^{m} \Delta s_l}{m\lambda^2},\tag{4}$$

where m is the number of meshes, λ is wavelength and Δs_l is each differential mesh area of the surface. The result is shown in Fig. 5. Every time QECD is applied, normalized mesh area becomes large.

5 Simulation result

5.1 Trade off between accuracy and computation time

In order to examine the appropriate model, the trade off between simulation accuracy and computation time is discussed. Low RMSE and short computation time is desirable for simulations. RMSE is calculated by using the following equation based on the simulation parameters shown in Table 1, and the incident wave is coming from +z to -z

$$\bar{\sigma}(\theta) = \sqrt{\frac{1}{N} \sum_{\theta=0}^{N} (\sigma_{\rm PO}(\theta) - \sigma_{\rm Exact}(\theta))^2},$$
 (5)

where σ_{PO} is RCS of PO simulation, σ_{Exact} is RCS of exact solution, N is the total number of observation points. When the electric field is perpendicular to



Fig. 5: Change of normalized mesh area

Table 1: Simulation parameter						
Item	Value					
Frequency f [GHz]	3.0					
Wavelength λ [m]	0.1					
Radius $a = 5\lambda$ [m]	0.5					
Incident angle θ_i [°]	0					
Incident angle ϕ_i [°]	0					
Observation angle θ [°]	$0 \le \theta \le 360$					
Step angle $\Delta \theta$ [°]	1					
Relative permittivity $\varepsilon_{\rm r}$	5.6 - j0.1					
Relative permittivity $\mu_{\rm r}$	1.0					
Surface impedance $Z_{\rm s}$ [Ω]	50					
Incident plane	z - x					
TE component	z - y					
TM component	z - x					

the incident plane, this is called TE component, and when the magnetic field is perpendicular to the incident plane, this is called TM component. In TM component and TE component, RMSE converges around 4.5 and 2.7 as shown in Fig. 6, respectively. From these results, it is found that the normalized mesh area size of 0.0371 results in the best trade-off between accuracy and computation time. In the following simulations, this appropriate mesh size is utilized and the model is shown in Fig. 7.

5.2 Simulation accuracy for appropriate model

The simulation results for appropriate model are shown in Fig. 8 to 10. The results are plotted to dBsm unit to evaluate the detail of the accuracy between PO simulation and exact solution by using the following equation.

$$RCS[dBsm] = 10 \log_{10} \sigma(\theta) \tag{6}$$

The simulations are implemented when the surface is PEC and non-PEC which has dielectric constant or surface impedance. Firstly, when the surface is PEC, PO simulation and exact solution are in good agreement around back scattering regions which are $0^{\circ} \leq \theta \leq 90^{\circ}$ and $270^{\circ} \leq \theta \leq 360^{\circ}$.

Secondly, the relative permittivity and permeability shown in Table 1 are utilized for non-PEC surface, assuming concrete [6]. By using these parameters, the reflection coefficient is calculated and applied to surface electric current. Although the attenuation of PO simulation is increased in TM component, both results in TE component are in good agreement around the back scattering region shown in Fig. 9.



Fig. 6: Relation between RMSE and computation time



Finally, the surface impedance shown in Table 1 is utilized for non-PEC surface. The reflection coefficient is also calculated by using the surface impedance, and applied to surface electric current as well. Although RCS of PO simulation in TM component is lower than that of exact solution, both results in TE component are almost identical each other around back scattering region shown in Fig. 10.

However, there exist errors in non PEC model. Error in the back scattering region is probably due to the fact that the effect of the reflection coefficient on the surface magnetic current was not considered in the simulations. In addition, in the simulations for the non-PEC case, wave penetration is not considered, and this probably explains the larger error in the forward scattering region which is $90^{\circ} \leq \theta \leq 270^{\circ}$.

6 Conclusions

A modelling method for complex objects using point cloud data was introduced. The point cloud data was





transformed into a 3D mesh by using marching cubes mesh generation algorithm and QECD was applied to reduce number of meshes. Then, the trade-off between accuracy and computation time was examined, and the appropriate mesh size was determined. Finally, comparison between PO simulation and the exact solution was conducted on PEC and non-PEC spheres. Results shows good agreement for the PEC sphere case,



Fig. 10: Surface : Impedance

but there were errors for the non-PEC sphere case. Next, the proposed simulation method will be applied on point cloud data of actual environments obtained using a laser scanner.

References

- [1] 星仰,山田貴浩, "レーザスキャナによるレンジ画像 処理,"東京電機大学出版局, 2013.
- [2] F. Chatzigeorgiadis and D. Jenn, "A MATLAB Physical-Optics RCS Prediction Code," IEEE Antennas & Propagation Magazine, Vol. 46, No. 4, pp. 137-139, 2004.
- [3] W. Lorensen and H. Cline, "Marching Cubes:A High Resolution 3D Surface Construction Algorithm," Computer Graphics, Vol. 21, No. 4, pp. 163-169, 1987.
- [4] M. Garland and P. S. Heckbert, "Surface simplification using quadric error metrics," in Proceedings of the 24th Annual Conference on Computer Graphics and Interactive Techniques, ser. SIGGRAPH '97. New York, NY, USA:ACM Press/Addison-Wesley Publishing Co., pp. 209-216, 1997.
- [5] N. Lertsirisopon, M. Ghoraishi, G. S. Ching, J. Takada and T. Imai, "Modeling of Selected Street Scatterer Objects Using Physical Optics Approximation," 電気学会計測研究会資料, 2005.
- [6] 田野井淳一,川瀬 隆治,"鉄筋コンクリート壁の電磁波シールド特性に関する研究-特定周波数の電磁波シールド方法の検討-,"東急建設技術研究所報, No. 37, 2011.

Financial Analysis of Residential Energy Storage Systems with Emphasis on Electricity Consumption Patterns

Student Number: 12M18040 Name: Teppei KATATANI Supervisor: Naoya ABE

家庭の電力消費パターンに着目した蓄電池の収益性分析

片谷 鉄平

再生可能エネルギーの普及が進む中、系統安定化対策の必要性が増してきており、蓄電池は再生可能エネルギーの出力安定化や電力需要の平準化を実現させる技術として注目を集めている。本研究では、導入が始まっている家庭用蓄電池の収益性に設置者の電力消費パターンが影響を与えると考え、世帯の多様性を考慮した複数の電力消費パターンを生成し、蓄電池の収益性を分析・評価した。

1. Introduction

Renewable energy sources (RESs), such as photovoltaic (PV), wind power, geothermal, hydro power and biomass, have been developed in order to shift from a heavy dependency on fossil fuels and to reduce carbon emission. In Japan, the introduction of a feed-in tariff (FiT) legislation, which has provided attractive price menus to renewable energy producers and the households with PV system in certain fixed period of time, stimulated further diffusion of RESs since 2012. Although RESs are carbon free power sources during their energy production processes, their power supply is intermittent, especially PV and wind power because their power output is dependent on the climate, solar radiation and wind speed. Higher penetration of these unstable generations causes problems on the power grid. In Japan, five out of ten regional utility companies have announced that they intend to cease purchasing electricity from RES generations in 2014, because of their insufficient balancing capability [1].

Energy storage system (ESS) is one of the options to maintain grid stability as a countermeasure against the volatility of RES. In the demand side, or consumer side, installation of ESS has started to spread after the Great East Japan Earthquake, and it has been expected to be adopted widely as renewables diffuse. However, the profitability of residential ESS, a critical driver of adoption, is unclear, even though the necessity of ESS has been rapidly increasing.

2. Literature Reviews

Existing research found that the economics of residential energy systems, e.g. PV, combined heat and power system, are influenced by the electricity consumption patterns in household [2, 3]. Although several research estimates the financial benefit to adopt residential ESS, they applied a few numbers or standardized pattern of electricity consumption [4, 5]. Hence, to evaluate the financial benefit of ESS, this research investigated the profitability of ESS, specifically lithium-ion batteries, with emphasis on the diversity of electricity consumption pattern mainly determined by life schedules of households, under current and future conditions.

3. Consumers' Perception toward ESS

This research conducted a web-based questionnaire survey to examine consumers' perception toward the residential ESS and reveal actual usage of ESS. We send the questionnaire to the person who owns residential PV and/or ESS. The survey was conducted from 22 to 25 of December 2014 and collected 1,119 responses, which include the owners of PV (863 responses), ESS (83 responses), and both of them (173 responses).



Figure 1. The aims of adopting residential ESS (multiple responses allowed)

The questionnaire asked the owners of ESS (256 persons) about their reasons to adopt and usage of ESS, and asked the PV users (863 persons) about their perception to adopt ESS.

Almost 76% of the PV users who do not own ESS, answered that they have recognized the availability of residential ESS. However, about 43% of the PV users answered that they have no intention to adopt the residential ESS, and only 24% of users intend to install the ESS at present. Figure 1 describes the answers to the question which asked the person who owns or intends to install ESS about the reasons or the purposes to install ESS. In addition, the ESS owners answered that they are using or own ESS for an emergency use (38%), to save on electricity bill (38%), and to consume the electricity from PV by themselves (24%). This results confirm that the financial aspect is the main concern for the adoption, specifically for those who have an interest to install ESS, though it is found that current adopters are using ESS not only for maximizing its financial benefit.

We applied the logistic regression model to investigate the factors that influence on the adoption and the intention to adopt ESS. The result tells that the income level positively affects to the adoption of ESS, and recognition of ESS affects to the intention to adopt ESS positively, which implies that consumers have positive perception toward residential ESS. The model did not confirm the influence of satisfaction with PV system on the intention to install ESS due to the low significance level.

The questionnaire also revealed that more than 60% of the PV users intend to increase PV surplus, and the revenue, by saving and/or shifting electricity consumption. However, almost 30% of respondents did not answer their monthly amount of electricity consumption.

The results of the questionnaire survey are referred in following simulations for the electricity consumption and the financial benefit of residential PV and ESS.

4. Simulation of Electricity Consumption

The present study simulated electricity consumption patterns under the assumption that the profit of ESS is also affected by those patterns. To incorporate the diversity of household types and their electricity consumption patterns, we simulated daily activity patterns of residents in households with time use survey data [6]. Figure 2 shows the flow of simulation model. Japanese Statistics Bureau has been conducting the time-use survey every five years since 1976. It measured the daily patterns and time allocation of life activities, and opens the data to the public [7]. In the result of latest survey, carried out in 2011, participation rate of 20 activities in 15-min scale average spend time and standard error ratio of each activity in weekday and Sunday were used in the simulation model. Table 1 describes seven hypothetical household types considered in our study. On behalf of occupant's life stages, the data of aged 35 - 44, aged 70 - 75, and aged 10 - 14 was obtained for young couples, elderly couples and children, respectively.

First, the schedule of being awake and the period of time at home for each occupant are estimated, and the activities at home are determined afterwards. Second, the possession of electrical appliances, e.g. TV, a washing machine, is estimated by the ownership ratio for each type of household. The attributes of appliances, power consumption and standby power, for example, are presumed homogeneous across the households. Third, calculate the electricity consumption associated with the activities by the probability of operation, quoted from the previous research [6]. Fourth, the power consumptions of heating, cooling, and lighting are calculated. The usage of heating and cooling is supposed to arise from the state of occupants and the air temperature.

The model simulated 10,000 households for each of the seven household type. Figure 3 indicates their distributions of annual electricity consumption as the result of the simulation.



Figure 2. The flow of estimating electricity consumption in each household

Table 1. Hypothetical seven household types		
Household	# of person	Household type
А	2	Young couple (double income)
В	2	Young couple
С	2	Elderly couple
D	3	Household A + a child
Е	3	Household B + a child
F	4	Household A + two children
G	4	Household B + two children

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5. Financial Analysis of Residential PV and ESS

5.1. The Role of Residential ESS

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ESS owners can potentially reduce their electricity bill if they choose some appropriate menus of electricity rate offered by utility companies (load-shifting). They also can consume less electricity from the power grid by increasing electricity consumption from residential PV systems (i.e., self-consumption), besides using ESS for an emergency. To maximize financial benefit, the operation pattern of ESS changes by the relationship among electricity retail prices, a price household pays to use electricity, and tariffs, a price of PV generation which is purchased by utility companies. We construct three different scenarios of tariff to investigate the profitability of residential PV system and ESS, which are; 37 yen/kWh, 24 yen/kWh, and 10 yen/kWh.

Scenario 1. (37 yen/kWh)

37 yen/kWh is the current tariff ensured by FiT for 10 years in Japan. Since this value is higher than the retail price in daytime and night, the owner maximize the benefit by selling PV surplus. Therefore, ESS is used to charge cheaper night electricity and discharge it during daytime.

Scenario 2. (24 yen/kWh)

If a FiT tariff is higher than the retail electricity price during the night but lower than that during the daytime, we assumed that the owner tried to charge PV surplus to ESS. However, the priority is still charging ESS at night, because that earns more profit.

Scenario 3. (10 yen/kWh)

In this case, a FiT tariff is even lower than the retail price at night, it is assumed that the owner intend to utilize PV generation by using ESS. Thus, the amount of PV surplus sold to the utility companies became smaller. Germany has been facing nearly the same situation that households introduce ESS to consume more electricity from PV instead purchasing from the grid.

Figure 4 describes an example of daily electricity consumption, PV generation, and charging/discharging patterns respectively with a case of electricity price menu, which offers cheaper retail electricity during the night (21:00 - 9:00) in the case of Scenario 1.



Figure 3. Distribution of estimated electricity consumption in each household type (A - G)



Figure 4. Daily patterns of electricity consumption, PV generation, and charging/discharging of ESS in a household (Scenario 1)

5.2. Simulation of Charging and Discharging Pattern

To estimate the charging and discharging patterns of ESS in households, we developed a simulation model. The input parameters for the model are hourly residential PV generation, hourly electricity consumption, which is estimated above, and characteristics of PV and ESS.

Hourly PV generation is estimated by an equation below,

$$E_n = H \times K \times P \div S \tag{eq.1}$$

where, E_p is the hourly electricity production from PV system (kWh), *H* is the hourly solar radiation on the PV panel (kWh/m²), *K* is the factor of loss, including heat loss and conversion efficiency of power module, *P* is the capacity of PV system (kW), and *S* is the standard intensity of solar radiation which is defined as 1 kW/m² by JIS C8918. The data of hourly solar radiation is collected from METPV-11 [8], the database of NEDO. Reflecting national average PV capacity, 4 kW system is assumed to be mounted in household. The parameters of residential PV system is summarized in Table 2.

Besides estimated electricity consumption patterns of household by this study, the actual data which had been measured in 40 households from 2002 to 2005 by the Architectural Institute of Japan, is used to estimate the profitability of ESS and PV.

As a residential ESS, this study focused a lithium-ion battery, which is currently used widely not only for the household but also for electric vehicles, because of its high energy density. The main parameters of ESS are summarized in Table 2. "Capacity" represents how much electricity it can charge in total, and "Power output" does how much electricity it can charge in a moment. Hence, ESS can charge only 1 kWh in an hour if the power output is 1 kW. Lifetime of ESS is generally expressed by the number of charging and discharging cycles. Suppose one cycle per a day, 6,000 cycles indicates 15 years as a lifetime of ESS.

With this model, by simulating hourly charging and discharging patterns to estimate the profitability of residential ESS (Figure 5), the difference of ESS operation pattern between households are purely caused by the difference of electricity consumption pattern.

Table 2. Parameters of PV and ESS

PV	
Capacity	4 kW
Lifetime	20 years
The factor of losses	75%
Inclination	30°
Orientation	0° (South)
ESS (Lithium-ion battery)	
Capacity	5 kWh
Power output	1 kW
Lifetime cycles	6,000 cycles
State of charge	10% - 90%
Efficiency	90%



Figure 5. The flow of simulating charging and discharging pattern of ESS (Scenario 1)

5.3. Estimating the Profit of ESS and PV

The owner of both PV and ESS receives the financial benefit that consist of revenue, the profit of selling PV surplus, and saving, the difference of electricity bill before and after installing PV and ESS. The annual net benefit is calculated as follows,

$$NB_t = Revenue_t + Saving_t$$
 (eq.2)

 $Revenue_t = Tariff_t \times E_{s,t}$ (eq.3)

$$Saving_t = EB_{w/o,t} - EB_{w/,t}$$
 (eq.4)

where, NB_t is the net benefit in the year t (yen), E_p is the hourly surplus electricity production of PV system (kWh), $EB_{w/o}$ is the annual electricity bill without PV and ESS, and $EB_{w/}$ is the electricity bill with PV and ESS.

Figures 6 to 9 show the result of the estimation of the annual profit that the owner could receive. Under the current tariff situation, 37 yen/kWh, variability of annual profit of PV across the household type is low. However, the variability becomes quite high if the tariff became lower, 10 yen/kWh. In addition, Figures 6 and 7 imply that the electricity consumption patterns influence on the financial benefit of PV. When the tariff is 10 yen/kWh, the expected profit is estimated higher for the household of elderly couples than for the household of young couple (double income) with a child, even their estimated annual consumption patterns are quite similar. Moreover, the estimated annual net profit of elderly couple is higher than that of young couple (double income) with two children, even the annual electricity consumption is lower. This results are mainly affected by the electricity use during the daytime in weekday, due to the difference of average time spending at home (e.g. almost 12 hours for a male who is working and 19 hours for an elderly male in average).

Figures 8 and 9 show the annual profit of ESS. In the case, 37 yen/kWh as the tariff, the variance of annual profit for the households whose electricity consumption are relatively low is high. Furthermore, it is found that the distribution of the financial benefit of ESS become wider, if a FiT tariff become lower.

5.4. Results of Financial Analysis

Internal Rate of Return (IRR), which represents the profitability of investments, is also estimated for each result of the simulation. The equation estimating IRR is,

$$IRR = r: -C_0 + \sum_{t=1}^{T} \frac{NB_t}{(1+r)^{t-1}} = 0 \qquad (eq.5)$$

where, C_0 is the initial cost, equals a system cost of PV and ESS, T is the certain period of time, equals a lifetime of PV and ESS in this study.

The system cost of PV is assumed 375,000 yen/kWh, 1.5 million yen for 4 kWh system, and the cost of ESS is assumed 200,000 yen/kWh, 1 million yen for 5 kWh system.

Estimated IRR for adopting the ESS is never beyond zero with the assumed capital cost, which indicates installing ESS has no merit from the financial aspect at present. However, considering to install ESS and PV together, estimated IRR suggested the owner could receive the payback, even it is lower than the IRR for the case to install only PV system. The result of annual profit and IRR for the 40 households in real has the same trend as the result for simulated households. Moreover, the estimated IRR has similar distribution of the annual profit. Hence, the IRR of ESS has a high variance.

This simulation analysis found that the average self-consumption rate is 33.8% without ESS in 70,000 households, and this number increases to 53.7% with ESS and lower tariff, which reduce the effect of unstable power output on the grid.



Figures 6 (upper) and 7 (lower). The annual net profit to adopt PV with the tariff 37 yen/kWh (upper), and 10 yen/kWh (lower)



Figures 8 (upper) Figure 9 (lower). The annual net profit to adopt ESS with the tariff 37 yen/kWh (upper), and 10 yen/kWh (lower)

6. Conclusion

This study analyzed the financial benefit of residential PV and ESS with the hypothesis that the benefit could vary by the combination of household electricity consumption patterns and levels of FiT tariff. We found that the electricity consumption pattern certainly influenced on the profit rather than the amount of the consumption. Although the profitability of ESS is currently estimated as quite low due to the intensive capital cost, this result, supplemented by the result of webbases survey results, suggests that consumers should measure their own electricity consumption pattern would be crucial in advance to confirm whether or not the adoption would be beneficial.

The study also confirms the possible advantages of residential ESS to reduce the amount of electricity from PV, which concerns to cause a negative effect on the power grid, if an enough incentive to consume PV electricity.

REFERENCES

- 経済産業省. (2014). 総合資源エネルギー調査会 省エネルギー・新エネルギー分科会 新エネルギー小委員会(第4回).
- [2] 藤本卓也、山口容平、岡村朋、下田吉之. (2011). 余剰電力固定価格買 取・全量買取のもとでの太陽光発電の経済性比較と普及影響評価. エ ネルギー・資源学会論文誌, 32(3).
- [3] 橋本克巳,高橋徹,齋川路之. (2004). エネルギーチェーン評価手法の 適用 -コージェネとヒートポンプの比較検討・.電力中央研究所研究 報告書, W03007.
- [4] 大嶺英太郎,小林広武,浅利真宏,上野剛. (2013). PV 設置需要家にお ける蓄電池の経済性評価-蓄電池設置により経済メリットが生じる 条件の検討-.電力中央研究所研究報告書, R12018.
- [5] J. Hoppmann, J. Vollanda, T. S. Schmidta, V. H. Hoffmann. (2014). The economic viability of battery storage for residential solar photovoltaic systems – A review and a simulation model. Renewable and Sustainable Energy Reviews, 39, 1101–1118.
- [6] 西尾健一郎,浅野浩志. (2006).世帯の多様性を考慮した家庭部門エネ ルギー需要生成ツールの開発.電力中央研究所研究報告書,Y05008.
- [7] Japanese Statistics Bureau (総務省統計局). (2011). 平成 23 年度 社会生 活基本調查.
- [8] NEDO. 年間時別日射量データベース METPV-11

Solvent Extraction of Rare Earth Metals by a Continuous Stirred Vessel

Student Number: 13M18184 Name: Takehiko YAZAKI Supervisor: Ryuichi EGASHIRA

連続式攪拌槽を用いた希土類金属の溶媒抽出

矢崎 健彦

まずPC-88Aを抽出剤として塩酸水溶液-ケロシン間におけるネオジム、ジスプロシウム、鉄の液液平衡を実測し、これ らの抽出平衡定数を求めた。ついで同様の物質系において原料水相を連続相,溶媒油相を分散相として標準型の攪拌槽 による金属の連続抽出を行った。攪拌速度の増加や水相流量の減少に伴い液液接触界面積は増加し、抽出速度も増加し た。また各金属の物質移動係数を求め、分配比が大きい条件では水相(連続相)側の物質移動抵抗が支配的であることを 確認した。

1.Introduction

Rare earth metals are industrially useful and applied to advanced technologies in many fields. Since these metals are found in resource as a mixture, they should be separated into each other. Solvent extraction is presently one of the commercialized techniques for the separation, and a number of fundamental studies of solvent extraction for rare earth metal separation have been conducted, in which the reaction equilibrium of respective rare earth metals with various kinds of extractants were mainly discussed. For the practical use of this method on industrial scale, the multi-stage stirred vessel is commonly utilized as a contacting equipment. So the information of extraction rate is necessary for effective operation, however, only few studies of the extraction rate of rare earth metals using continuous stirred vessel have been reported.

In this work, the extraction rates of metal ions by stirring vessel were studied, in which neodymium (Nd), dysprosium (Dy) and iron (Fe) were selected as model metals of light rare earth, heavy rare earth and impurity metals occurring in separation process of rare earth metals respectively. Firstly the extraction equilibrium of metals was confirmed in a batch-wise run. In the second, the continuous extractions of metals with stirred vessel were carried out under various experimental conditions, and the effects of these conditions on liquid-liquid dispersion, extraction rate and yield were studied. Finally, the mass transfer coefficients of the metal ions were estimated based on these experimental results, and the contribution of the local mass transfer resistances to the overall resistance was studied.

2.Experimental

2.1.Extraction equilibrium

The material systems and experimental conditions are shown in Tables 1 and 2. Chloride hexahydrate of Nd, Dy and Fe were used as a metal ion sources. 2-Ethylhexyl phosphonic acid mono-2-ethylhexyl ester (PC-88A) was used as an extractant, without further purification. This extractant was diluted by kerosene to be an organic phase. Hydrochloric acid was used to adjust pH in the aqueous feed solution.

In batch-wise extraction, the specified amounts of feed and solvent phases in a flask of 5.0×10^{-5} m³ were shaken in a constant temperature bath at 298 K for 12 hours to be equilibrated and these liquid phases were separated by separating funnel. The metal concentrations and *p*H in the aqueous phases were

determined by ICP-AES (SPS7800, SII Nano Technology) and *p*H meter (Horiba, F-52), respectively. **2.2.Continuous extraction**

The experimental conditions of the continuous extraction with stirred vessel are listed in Table 3. The material systems were the same as used in the extraction equilibrium measurements as Table 1.

An experimental apparatus of the continuous extraction operation is schematically shown in Fig.1. A standard type stirred vessel of 0.08 m inner diameter and height with baffles was used as a contactor. A six flat blade paddle impeller of 0.05 m diameter was equipped at the center of the vessel. The volume as a reactor inside the vessel is $V = 3.85 \times 10^{-6}$ m³. The stirred vessel was immersed in the constant temperature bath to keep the temperature of the liquids in the vessel constant. After the aqueous feed phase was provided to fill up the vessel, the supply of the organic solvent phase and the stirring were started to begin the continuous run with oil in water (O/W) type dispersion. While the feed and solvent phases separately entered through the inlets at the bottom of the vessel, the raffinate and extract phases after the extraction was obtained together through the top outlet. The flow rates of the feed and solvent phases were monitored by rotameters, and adjusted to proper values by valves. The flow rates at exit were estimated by measuring the volumes of the phases over the defined period. The obtained raffinate solutions were analyzed in the same way as used in the measurements of extraction equilibrium to determine the metal concentrations and pH.

The liquid-liquid dispersion in the stirred vessel, which should affect mass transfer, was also studied in terms of the drop size and the holdup of the dispersed phase. The drop diameters of the organic dispersed phase were measured as follows: a portion of O/W type liquid-liquid dispersion in the vessel was sampled during the run into an appropriate aqueous hydrophilic surfactant solution prepared in a pipette to avoid the coalescence of the organic phase drops; this surfactant solution containing the drops was microphotographed; and the numbers of the drops of the respective diameter ranges were counted from among the $200 \sim 300$ drops on the photograph to estimate the mean diameter and the distribution. At the end of the experimental run, the valves at the inlets of the vessel were closed simultaneously and the volumes of the liquid phases retained in the vessel were measured. From these

volumes, the holdup of the dispersed phase, the volume ratio of dispersed phase relative to total liquid in the vessel, was determined.



extraction

Table 1 Material system		
Solute in aqueous phase		NdCl ₃ 6H ₂ O DyCl ₃ 6H ₂ O FeCl ₃ 6H ₂ O
Extractant		PC-88A
Aqueous phase	Aqueous sol	ution of HCl
Organic phase	Kerosene solutio	n of PC-88A
Table 2 Experimental c	conditions of batch-w	vise extraction
Concentration of metal in initial aqueous phase, $C_{M,a}$. Concentration of PC-88A in	_{q,0} [kmol/m ³]	5.0×10 ⁻³
initial organic phase, $C_{\rm RH2, org, 0}$ [kmol/m ³]		0.25
pH of initial aqueous phase	e, <i>p</i> H ₀	0.1~3.0 (Nd)
		$-0.3 \sim 3.0$ (Dy)
		−0.3~0.6 (Fe)
Temperature, T [K]		298
Volume of aqueous phase,	V_{aq} [m ³]	2.0×10 ⁻⁶
Volume of organic phase,	$V_{\rm org}$ [m ³]	2.0×10 ⁻⁶
Table 3 Experimental c	onditions of continu	ious extraction

Table 5 Experimental conditions of continuous extraction		
Concentration of metal in aqueous feed, $C_{M,aq,in}$ [kmol/m ³] Concentration of PC-88A in	5.0×10 ⁻³	
organic solvent, C _{RH2,org,in} [kmol/n	m^3] 0.25	
pH of aqueous feed, pH_{in}	1.2~2.5 (Nd)	
	0.6~1.8 (Dy)	
	0.3 (Fe)	
Temperature, T [K]	298	
Volume flow rate of		
aqueous feed, $Q_{aq,in}[m^3/h]$	6.3×10 ⁻³ ~13.0×10 ⁻³	
Volume flow rate of		
organic solvent, $Q_{\text{org,in}}[\text{m}^3/\text{h}]$	3.0×10-6	
Stirring velocity, <i>n</i> [1/h]	1.8×10 ⁴ ~5.7×10 ⁴	

3.Results and Discussion

3.1. Extraction equilibrium

The extraction reaction of trivalent lanthanides and iron ion with PC-88A is generally expressed as

$$M^{3+} + 3\overline{(RH)_2} \rightleftharpoons \overline{MR_3(RH)_3} + 3H^+$$
(1)

where M^{3+} and $(RH)_2$ represent the metal ion and PC-88A dimer, respectively, and symbols with overbar express species in organic phase. The reaction equilibrium constant, $K_{ex,M}$, is thus, described as,

$$K_{\text{ex,M}} = \frac{c_{\text{M,org,eq}} c_{\text{H+,aq,eq}}^3}{c_{\text{M,aq,eq}} c_{\text{RH2,org,eq}}^2} = m_{\text{M}} \frac{c_{\text{H+,aq,eq}}^3}{c_{\text{RH2,org,eq}}^3}$$
(2)
The distribution ratio. m_{M} was defined as.

$$m_{\rm M} = \frac{c_{\rm M, org, eq}}{c_{\rm M, aq, eq}}$$
(3)

The arrangement of this equation leads to,

 $\log m_{\rm M} - 3\log C_{\rm RH2, org, eq} = 3pH_{\rm eq} + \log K_{\rm ex, M}$ (4) The metal and extractant concentrations in the organic phases were estimated by the material balance relationships with the metal concentration in the aqueous phase. Figure 2 shows the plots of the left side in Eq. (4) against pH_{eq} . The values of the left side in Eq. (4) increased in the order of Nd, Dy and Fe. The plots for each metal ion increased linearly with pH_{eq} with slope 3. In these measurement ranges, the extraction reaction followed Eq. (1). Then $K_{ex,M}$ of each metal ion was estimated by the intercept of the lines, drawn in Fig. 2 as solid lines, and these values are listed in Table 2. That of Fe was the largest, that is, Fe should be extracted most, followed by Dy and Nd.



Fig. 2 Relation among pH of aqueous raffinate, distribution ratio and concentration of extractant of organic extractant.

Table 5 Experimental extraction equilibrium cons	stants, K _{ex.M}
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Metal	Extraction equilibrium constant, $K_{ex,M}$
Neodymium (Nd)	1.8×10 ⁻²
Dysprosium (Dy)	1.9
Iron (Fe)	5.0×10^{2}

3.2. Continuous extraction 3.2.1. Liquid-liquid dispersion

In all experiments of continuous extraction, the system attained the steady state within 5 minutes and the liquidliquid extraction could be stably operated. The volume flow rates of inlet and outlet solutions were same in all cases, and the volume flow rates of aqueous and organic phases could be represented as $Q_{aq} = Q_{aq,in} = Q_{aq,out}a$ and $Q_{org} = Q_{org,in} = Q_{org,out}$, respectively.

The holdup of the dispersed phase to the total volume, \emptyset , sauter mean diameter of the dispersed drops, d_{32} , and the specific interfacial area, a, were estimated as,

$$\begin{array}{l} a_{32} = \sum_{l} l u^{2} / l u \\ a = 6 \emptyset / d_{32} \end{array} \tag{6}$$

where V_d , V and d represent the volume of dispersed phase, total volume, and diameter of dispersed drops. Figure 3 shows the effects of stirring velocity, n, and Q_{aq} on \emptyset . The \emptyset increased as n increased and Q_{aq} decreased. In the lower range of n, the mixing was insufficient to cause low \emptyset . As *n* increased, the flow pattern in the vessel approached to the perfect mixing condition and \emptyset attained the ratio of the organic flow rate relative to the total flow rate: $0.25 (=Q_{\text{org}}/(Q_{\text{aq}} + Q_{\text{org}}))$. Figure 4 shows the effects of n and Q_{aq} on sauter mean diameter of dispersed phase, d_{32} at fixed Q_{aq} . The d_{32} decreased as *n* or Q_{aq} increased. These tendencies were reported in the previous studies of liquid-liquid dispersion [1]. Figure 5 shows the effects of n and Q_{aq} on a. The a increased as n increased, and was less influenced by Q_{aq} , since d_{32} decreased as *n* and Q_{aq} increased, but \emptyset decreased as Q_{aq} increased. The metal species or pH in the aqueous solution had little effect on \emptyset , d_{32} and a.


Fig. 3 (a) The effect of stirring velocity on holdup. Conditions: $Q_{aq}=9.0\times10^{-3} \text{ m}^3/\text{h}$, $p_{H_{in}}=2.0 \text{ (Nd)}$, $p_{H_{in}}=1.0 \text{ (Dy)}$, $p_{H_{in}}=0.3 \text{ (Fe)}$. (b) The effect of volume flow rate of aqueous phase on holdup. Conditions: $n=2.4\times10^4 \text{ 1/h} \text{ (Nd,Dy)}$, $n=3.6\times10^4 \text{ 1/h} \text{ (Fe)}$, $p_{H_{in}}=1.2\sim2.0 \text{ (Nd)}$, $p_{H_{in}}=0.6\sim1.8 \text{ (Dy)}$, $p_{H_{in}}=0.3 \text{ (Fe)}$



Fig. 4 (a) The effect of stirring velocity on the mean drop diameter of dispersed phase. Conditions: $Q_{aq}=9.0\times10^{-3} \text{ m}^3/\text{h}$, $p_{Hin}=1.2\sim2.0$ (Nd), $p_{Hin}=0.6\sim1.8$ (Dy), $p_{Hin}=0.3$ (Fe) . (b) The effect of volume flow rate of aqueous phase on the mean drop diameter of dispersed phase. Conditions: $n=2.4\times10^4$ 1/h (Nd,Dy), $n=3.6\times10^4$ 1/h (Fe), $p_{Hin}=1.2\sim2.0$ (Nd), $p_{Hin}=0.6\sim1.8$ (Dy), $p_{Hin}=0.3$ (Fe)



Fig. 5 (a) The effect of stirring velocity on the specific interfacial area. Conditions: $Q_{uq}=9.0\times10^{-3} \text{ m}^3/\text{h}$, $pH_{in}=1.2\sim2.0$ (Nd), $pH_{in}=0.6\sim1.8$ (Dy), $pH_{in}=0.3$ (Fe) . (b) The effect of volume flow rate of aqueous phase on the specific interfacial area. Conditions: $n=2.4\times10^4$ 1/h (Nd,Dy), $n=3.6\times10^4$ 1/h (Fe), $pH_{in}=1.2\sim2.0$ (Nd), $pH_{in}=0.6\sim1.8$ (Dy), $pH_{in}=0.3$ (Fe)

3.2.2. Extraction rate

Extraction rate of metal M,
$$R_{\rm M}$$
, is expressed as,
 $R_{\rm M} = Q_{\rm org,out} C_{\rm M,org,out} - Q_{\rm org,in} C_{\rm M,org,in}$ (8)

Figure 6 shows the effect of n and Q_{aq} on R_M . The R_M s of Dy and Nd increased as n and Q_{aq} . As mentioned above, a increased with n to enhance the extraction. While Q_{aq} had little influence on a, $C_{M,aq,out}$ increased with Q_{aq} to make $C_{M,org,out}$ larger, as a consequence causing larger R_M . The R_M of Fe decreased as Q_{aq} . These results indicate that the extraction rates of Dy or Nd, and Fe were controlled by the diffusion and chemical reaction steps, respectively, as reported in the previous study[2,3]. Figure 7 shows the effect of pH in the aqueous feed, pH_{in} , on R_M . The R_M s of Dy and Nd increased with pH_{in} because the extraction reaction should be enhanced with an increase in pH_{in} , as shown in Fig. 2.

3.2.3. Yield

Yield of metal M, $Y_{\rm M}$ is defined as,

$$Y_{\rm M} = \frac{Q_{\rm org,out} C_{\rm M,org,out}}{Q_{\rm org,in} C_{\rm M,org,in}}$$

Figures 8 and 9 show the effects of the operating conditions on $Y_{\rm M}$. $Y_{\rm M}$ increased with an increase in *n* or $p H_{\rm in}$ because $R_{\rm M}$ increased as these values. The $Y_{\rm M}$ decreased as $Q_{\rm aq}$ increased because the residence time of solution decreased.

(9)



Fig. 6 (a) Effect of stirring velocity on the extraction rate. Conditions: $Q_{aq}=9.0\times10^{-3} \text{ m}^3/\text{h}$, $p_{Hin}=2.0$ (Nd), $p_{Hin}=1.0$ (Dy), $p_{Hin}=0.3$ (Fe), (b) Effect of volume flow rate of aqueous solution on the extraction rate or yield of several metals. Conditions: $n=2.4\times10^4$ 1/h (Nd,Dy), $n=3.6\times10^4$ 1/h (Fe), $p_{Hin}=2.0$ (Nd), $p_{Hin}=1.0$ (Dy), $p_{Hin}=0.3$ (Fe)



Fig. 7 Effect of *p*H in the aqueous feed on the extraction rate. Conditions: $n=2.4\times10^4$ 1/h, $Q_{aq}=9.0\times10^{-3}$ m³/h.



Fig. 8 (a) Effect of stirring velocity on the yield. Conditions: $Q_{aq}=9.0 \times 10^{-3} \text{ m}^3/\text{h}$, $p_{Hin}=2.0$ (Nd), $p_{Hin}=1.0$ (Dy), $p_{Hin}=0.3$ (Fe), (b) Effect of volume flow rate of aqueous solution on the yield. Conditions: $n=2.4 \times 10^4 \text{ 1/h}$ (Nd,Dy), $n=3.6 \times 10^4 \text{ 1/h}$ (Fe), $p_{Hin}=2.0$ (Nd), $p_{Hin}=1.0$ (Dy), $p_{Hin}=0.3$ (Fe)



Fig. 9 Effect of *p*H in the aqueous feed on the yield. Conditions: $n=2.4\times10^4$ 1/h, $Q_{aq}=9.0\times10^{-3}$ m³/h.

3.2.4. Experimental mass transfer coefficients

Overall mass transfer coefficients based on the aqueous phase, $K_{M,aq}$, was defined as,

$$R_{\rm M} = K_{\rm M,aq} \left(C_{\rm M,aq,out} - C_{\rm M,org,out} / m_{\rm M} \right) a V \tag{10}$$

Here $m_{\rm M}$ and $K_{\rm M,aq}$ were expressed as,

$$m_{\rm M} = \frac{K_{\rm ex,M}C_{\rm RH2,org,out}^3}{c_{\rm H+,aq,out}^3}$$
(11)
$$\frac{1}{K_{\rm M,aq}} = \frac{1}{k_{\rm M,aq}} + \frac{1}{m_{\rm M}k_{\rm M,org}}$$
(12)

where $k_{M,aq}$ and $k_{M,org}$ represent the local mass transfer coefficients in the aqueous and organic phase, respectively. Here it was assumed $k_{M,aq}$ and $k_{M,org}$ were constant and independent of the operating conditions and metal ion spiceis. Then both coefficients were decided by fitting with all experimental results, and the obtained values were listed in Table 6. The effects of m_M on $K_{M,aq}$ is shown in Fig. 10. The solid line is drawn by Eq. (12), and the dotted lines show $K_{M,aq}$ when the mass transfer resistance lies only in either phase. In the range of large m_M , the diffusion in the aqueous phase was ratedetermined, while in the range of small m_M , the diffusion in the organic phase was rate-determined.



Fig. 10 Relation among distribution ratio and overall mass transfer coefficients based on aqueous phase

3.2.5. Theoretical mass transfer coefficients

The mass transfer coefficients in the dispersed drops and continuous phase were estimated by the following general simple models. The local mass transfer coefficients in the continuous and dispersed phases were estimated by the Ranz-Marshall [4] and penetration models [4], expressed as,

$$Sh = 2.0 + 0.6Re^{1/2}Sc^{1/3}$$
(13)

$$k_{\rm d} = -\frac{d}{3t} \ln\left\{\frac{6}{\pi^2} \sum_{l=1}^{\infty} \frac{1}{2^2} \exp\left(-\frac{l^2 \pi^2 Dt}{d^2}\right)\right\}$$
(14)

where Sh, Re and Sc are Sherwood, Reynolds and Schmidt numbers, and D is the diffusion coefficient in the organic phase, calculated by the Wilke-chang equation [4], respectively. The diffusion coefficient of lanthanum in the aqueous phase [5] and the properties of water at 298K are shown in Table 7. The relative velocity of the dispersed drops in the continuous phase was calculated as terminal velocity in gravity field [6]. The association parameter in Wilke-chang equation was set as 1~2, and molecular volume was $322 \times 10^{-6} \text{ m}^3/\text{mol}$, cited from the previous study [7]. The properties of the organic phase used for the estimation were listed in Table 8. The theoretical local mass transfer coefficients obtained by these equations were listed in Table 6 together with the results experimentally obtained. The respective $k_{M,aq}$ s and $k_{M,orgs}$ experimentally and theoretically obtained were almost same as each other. Then the estimation could fully express the extraction rate of these rare earth metals in this measurement range. This estimation method might be applicable for the design of the extraction vessel for the separation of rare earth metals.

Table 6 Loca	mass transfer coefficient
--------------	---------------------------

	$k_{\mathrm{M,aq}}$	$k_{\rm M,org}$					
(a)Experimental	7.0×10 ⁻¹	4.0×10 ⁻³					
(b)Theoritical	1.5×10 ⁻¹	5.4×10-3					
Table 7 Material pro	Table 7 Material properties for calculation theoretical $k_{M,aq}$						
Density of aqueous phase	se, ρ_{ag} [kg/m ³]	997					
Viscosity of aqueous ph	0.89						
Diffusion coefficient in	aqueous phase, D	$aq[m^2/s] = 6.2 \times 10^{-10}$					

Table 8 Material properties for calculation theoretical $k_{M,org}$				
	PC-88A	Kerosene		
Molar weight [kg/mol]	0.31	0.28		
Viscosity [mPa/s]	35	2.3		

4.Conclusion

In the case of batch-wise extraction, metals were largely extracted in large pH of aqueous phase, and extraction equilibrium constant could be determined for each metals.

In the case of continuous extraction, interfacial area increased by increase of stirring velocity and decreased by increase of volume flow rate of aqueous solution. Rare earth metals largely extracted by increase of contact interfacial area and driving force for diffusion, on the other hand extraction of Fe could be accelerated by only increase of contact interfacial area. Extraction rate of rare earth metals is determined by diffusion in both aqueous and organic phase, while the extraction rate of Fe is seemed to be determined by chemical reaction. The experimental local mass transfer coefficients based on experimental results are almost good agreed with theoretical calculated values.

Nomenclature

C: concentration [kmol/m³], *m*: distribution ratio [-], *V*: volume *n*: stirring velocity [1/h], *Q*: volume flow rate [kmol/m³], *R*: extraction rate [kmol/h], *Y*: yield [-], *K*: overall mass transfer coefficient [m/h], k = local mass transfer coefficient [m/h], d_{32} =sauter mean diameter of dispersed phase [m], \emptyset : dispersed phase holdup [-], *a*: specific interfacial area [m²/m³], K_{ex} : extraction equilibrium constant [-]

<Subscripts>

0: initial state, eq: equilibrium state, aq: aqueous phase, org: organic phase, in: inlet solution, out: outlet solution, d: dispersed phase,M: Metal, RH2: extractant as dimer, H+: hydrogen ion, Nd: Neodymium, Dy: Dysprosium, Fe: Iron

References

[1] Robert E. Treybal., LIQUID EXTRACTION 2nd edition, (1963)

[2] K. Takahashi, et.al, Chemical Engineering Science, 57, 469 (2002)

- [3] Hideo Matsuyama, et.al, Hydrometallurgy, 24, 37 (1990)
- [4] 城塚 正, 化学技術者のための移動速度論, 275 (1966)

[5] E.L. Clussler, Diffuison 3rd edition, 162 (2002)

[6] 藤田 重文, 化学工学演習 第2版, 182 (1979)

[7] Eiji Kamio et.al, Chemical journal, 139, 93 (2008)

Fe-Ce catalysts for N₂O decomposition

Student number: 13M18190 Name: Huiting WANG Supervisor: Hirofumi HINODE

Fe-Ce 系触媒による亜酸化窒素の直接分解

王 卉婷

本研究では、工業生産過程等の人為的発生源から排気された N₂O の分解を目的に、Fe-Ce 系触媒を機械的混合法及び含浸法で調製し、N₂O 分解に対する触媒活性を評価した。また、 調製条件である触媒調製方法、CeO₂の種類及び酸素の有無による触媒活性の変化を検討した。 調製した触媒の中で、Fe₂O₃②/CeO₂③(1:5)触媒は最も高い触媒活性を示し、酸素がな い場合、N₂O は 450 ℃において 100%の N₂O 分解を達成した。酸素を導入すると、N₂O の 分解温度は高温側にシフトしたことがわかった。

1 Introduction

Nitrous oxide (N₂O) is one of the powerful greenhouse gases with a life time of about 150 years in the atmosphere, and a net greenhouse effect about 310 times and 21 times of the Global Warming Potential per molecule of CO₂ and CH₄, respectively [1]. Moreover, N₂O is also identified as a contributor to the destruction of ozone layer in the stratosphere. The abatement of N₂O emissions from industrial plants (adipic acid production, combustion process, etc.) is probably the most feasible by implementing catalytic processes [2]. Therefore, it is important to study the decomposition of N₂O from the environmental point of view.

Various catalysts have been studied for N_2O decomposition. Catalysts containing iron oxides, are the subject of studies as potential N_2O decomposition catalyst. Combination of CeO_2 with other metal oxides often affects the mobility of oxygen on their surfaces, thus in some cases, modifies the element's redox ability and catalytic performance [3].

In our laboratory, Fe/TiO₂ catalysts using impregnation method and TiO₂-CeO₂ catalysts using manual mixing method for N₂O decomposition have been studied [4-5]. The addition of CeO₂ improved the catalytic activity of TiO₂. Considering both of the researches, in this work, the decomposition of N₂O over Fe-Ce catalysts was investigated.

2 Experimental

2.1 Catalyst preparation 2.1.1 Manual mixing method

Fe-Ce catalysts were prepared by manual mixing method. Fe₂O₃ (Kanto Chemical Co., Inc.) and three types of CeO₂ (JRC-CEO-1, JRC-CEO-2, JRC-CEO-3, Japan Reference Catalyst) were used.

 Fe_2O_3 and CeO_2 were mixed manually in a mortar using small amount of ethanol. The mixture was then calcined at 400°C for 5 h under air flow.

In order to reduce the pressure drop, the catalysts were pelletized, crushed and sieved into 0.71 mm to 1.00 mm particles prior to activity test.

2.1.2 Impregnation method

Catalysts were also prepared by impregnation method. Three types of CeO₂ (JRC-CEO-1, JRC-CEO-2, JRC-CEO-3, Japan Reference Catalyst) were used as supports. The characteristics of each CeO₂ were shown in Table 1. The precursor of metal is Fe(NO₃)₃ • 9H₂O (Kanto Chemical Co., Inc)

Table. 1 CeO₂ type used in the experiment

CeO ₂ type	Specific surface area(m ² /g)	Purity[%]	
JRC-CEO-1	156.9	99.99	
JRC-CEO-2	123.1	99.97	
JRC-CEO-3	81.4	99.97	

In preparation, CeO_2 was impregnated in an aqueous solution of precursor. Then, the solution mixture was stirred at room temperature for one day followed by drying up for about 12 h at 60°C. After that, the sample was calcined for 5 h under air flow. In order to reduce the pressure drop, the sample was finally pelletized, crushed and sieved into 0.71 mm to 1.00 mm particles, the same as manual mixing method.

The following nomenclatures for the catalyst samples are used. Catalysts prepared by manual mixing method are written as $Fe_2O_3(1)$ -CeO₂(2)(Y:Z) where Y:Z represents the weight ratio between Fe_2O_3 and CeO₂. Catalysts prepared by impregnation method are written as Fe_2O_3 (2) /CeO₂X(Y:Z), where X represents the type of CeO₂ and Y:Z means the weight ratio between Fe_2O_3 and CeO₂.

2.2 Catalytic activity experiment

The catalytic reaction was carried out in a fixed-bed flow reactor under atmospheric pressure. The reactant gas was prepared by mixing N_2O , O_2 and He as a balance gas. The mixed gas of 1000 ppm N_2O , 0%/5% O_2 and He was fed to the catalyst at a flow rate which corresponded to a space velocity of 16000 h^{-1} .

Gas chromatography (GC323w; GL Science Co., with Porapak N, Porapak Q and Molecular Sieve 13X columns) was used to analyze N_2O .

2.3 Catalyst characterization

Characterizations of the catalysts were performed by TG-DTA (TG8120), XRD (MultiFlex), Nitrogen Adsorption (Autosorb1) and SEM (JSM-5310LV) -EDS (JED-2140).

3. Results and discussion

3.1 Catalytic activity of catalysts prepared by manual mixing method

Figure 1 shows the catalytic activity results of Fe_2O_3 (1)-CeO₂ (2) catalysts with different ratios of Fe_2O_3 and CeO₂, prepared by manual mixing method.

Samples were mixed in weight ratio of 1:1, 1:2 and 1:5. Horizontal axis indicates reaction temperature and vertical axis indicates N₂O conversion.



Fig. 1 Catalytic activity of catalysts prepared by manual mixing method for N_2O decomposition

Fe₂O₃① catalyst decomposed 96% N₂O at 650°C. Fe₂O₃①-CeO₂②(1:1), Fe₂O₃①-CeO₂②(1:1), Fe₂O₃ ①-CeO₂②(1:1) and CeO₂② catalysts showed similar activity, 100% N₂O conversion were achieved at 600°C. Among the 5 catalysts, Fe₂O₃①-CeO₂②(1:1) catalyst showed slightly higher activity compared to other catalysts. These results showed that manual mixing method did not change the activity of CeO₂ much.

3.2 Catalytic activity of catalysts prepared by impregnation method

Figure 2 shows the catalytic activity results of Fe_2O_3 (2)/CeO₂ (2) catalysts with different ratios of Fe_2O_3 and CeO₂, prepared by impregnation method. Samples were prepared in weight ratio of 1:1, 1:2 and 1:5. Horizontal axis indicates reaction temperature, and vertical axis indicates N₂O conversion.

Fe₂O₃② catalyst decomposed 98% N₂O at 650°C. 100% N₂O conversion were achieved at 500°C by Fe₂O₃③/CeO₂②(1:1) and Fe₂O₃③/CeO₂②(1:2) catalysts. Fe₂O₃②/CeO₂③(1:5) catalyst showed the best activity among the samples showed in Figure 2, 100% N₂O conversion was achieved at 450°C. Mixed oxide catalysts showed higher activity than pure oxide catalysts of Fe₂O₃ and CeO₂. Moreover, comparing the results of Figure 1 and Figure 2, it was found that catalysts prepared by impregnation method showed higher catalytic activity than catalysts prepared by manual mixing method.



Fig. 2 Catalytic activity of catalysts prepared by impregnation method for N_2O decomposition

3.3 Catalytic activity of catalysts with different types of CeO₂



Fig. 3 Catalytic activity of catalysts with different types of CeO_2 for N_2O decomposition

Figure 3 shows the catalytic activity results of Fe_2O_3 (2)/CeO₂(1:5) catalysts with different types of CeO₂. Three types of CeO₂ (JRC-CEO-1, JRC-CEO-2, JRC-CEO-3 from Japan Reference catalyst) were used. Horizontal axis indicates reaction temperature, and vertical axis indicates N₂O conversion.

 N_2O began to decomposed from 350°C, 100% N_2O decomposition were achieved at 450°C for all the three catalysts. Three catalysts showed similar catalytic activity.

3.4 The influence of oxygen on catalytic activity for N₂O decomposition

Figure 4 shows the catalytic activity results of Fe_2O_3 (2)/CeO₂(3)(1:5) catalyst, which performed the best catalytic activity among all the catalysts discussed. Activity tests were implemented in the presence or absence of oxygen (5%).



Fig. 4 Catalytic activity of Fe_2O_3 (2)/CeO₂ (1:5) catalyst for N₂O decomposition in the presence or absence of oxygen

It is shown that the conversion temperature of N_2O was shifted to higher temperature in the presence of oxygen. This result indicated that the catalytic activity was inhibited by the presence of oxygen. The O_2 could compete with the N_2O in the process of adsorption on active site, reducing the contact of N_2O with the active site; thus reducing the effectiveness of N_2O degradation. [6].

3.5 XRD results 3.5.1 XRD patterns

Figure 5 and Figure 6 show the results of XRD analysis of catalysts with different ratios of Fe_2O_3 and CeO_2 , prepared by manual mixing method and impregnation method, respectively. Both Fe_2O_3 and CeO_2 peaks were detected from the XRD patterns. Increased intensity was observed with increased content of Fe_2O_3 and CeO_2 , respectively.



Fig. 5 XRD patterns of catalysts prepared by manual mixing method



Fig. 6 XRD patterns of catalysts prepared by impregnation method



Fig. 7 XRD patterns of catalysts with different types of $$\rm CeO_2$$

Figure 7 shows the XRD patterns of Fe_2O_3 (2) /CeO₂(1:5) catalysts with different types of CeO₂. CeO₂ peaks became sharper in the sequence of Fe_2O_3 (2) /CeO₂ (1) (1:5), Fe_2O_3 (2) /CeO₂ (2) (1:5), Fe_2O_3 (2) /CeO₂(3) (1:5).

3.5.2 Crystallite size

Table. 2 Crystallite size of catalysts

Catalyst	Crystallite	Crystallite
	size Fe ₂ O ₃	size CeO ₂
	[nm]	[nm]
Fe_2O_3 (1)	59.6	-
Fe_2O_3	26.1	-
Fe_2O_3 $(1:1)$	41.7	7.9
Fe_2O_3 (1)-CeO_2(2)(1:2)	41.7	8.7
Fe_2O_3 (1)-CeO_2(2)(1:5)	34.8	8.5
Fe_2O_3 ⁽²⁾ /CeO_2 ⁽²⁾ (1:1)	20.9	7.7
Fe_2O_3 (2)/CeO_2 (1:2)	18.1	7.9
Fe_2O_3 (2)/CeO_2 (1:5)	10.2	8.5
CeO ₂ ②	-	9.5
Fe_2O_3 (2)/CeO_2 (1:5)	7.6	7.3
Fe_2O_3 ⁽²⁾ /CeO ₂ ⁽³⁾ (1:5)	8.9	10.5

It could be considered that the catalyst with smaller crystallite size showed higher catalytic activity, because small crystallite size could increase the active site exposed to N_2O .

4. Conclusions

Catalysts prepared by impregnation method showed higher catalytic activity than catalysts prepared by manual mixing method. Catalysts prepared by impregnation method showed higher catalytic activity than pure oxides of Fe₂O₃ and CeO₂. Catalysts with different types of CeO₂ showed similar catalytic activity. Fe₂O₃(2)/CeO₂(3)(1:5) catalyst showed the best activity among all the catalysts which have been discussed in this research, 100% N₂O decomposition was achieved at 450°C. By introducing oxygen, the catalytic activity was inhibited and 100% N₂O decomposition was achieved at higher temperature.

References

- [1] S. Kannan, Appl. Clay Sci. 13 (1998) 347
- [2] P. Esteves, Y. Wu, C. Dujardin, M.K. Dongare, P. Granger, Catal. Today 176 (2011)
- [3] S. Imamura, M. Shono, N. Okamoto, R. Hamada, S. Ishida, Appl. Catal. A 142 (1996) 279
- [4] K. Yanagida, Master thesis, Tokyo Institute of Technoligy(2006)
- [5] Y. Fukuchi, Bachelor thesis, Tokyo Institute of Technology(2012)
- [6] S. Suarez, M. Yates, A.L. Petre, J.A. Martin, P. Avila and J. Blanco, Appl. Catal. B64 (2006) 302

An Empirical Analysis of Disclosure Patterns of Environmental Information by Japanese Enterprises

Student Number: 13M18110 Name: Ryoya SUEHARA Supervisor: Naoya ABE

本邦企業の環境情報開示実態の実証分析

末原 諒矢

本論では、近年の環境意識のグローバル化、市民団体の発言力の高まりを受けて変化した企業の環境情報開示について調べた.企業は、報告義務の遵守、自主的開示、質問書に対する返答の3つの義務を負っていると言われる. 本論では、本邦企業の情報開示について、判別分析、ロジスティック回帰分析を用いて実証分析した.結果的に、本 邦企業の前年回答状況、企業機規模、グローバル度、レポート発行経験と質問書への回答状況との関連を確認した.

1 Introduction

Corporate activities have been significantly internationalized with liberalization of finance, relief of trade regulation, and progress of information and communication technology since 1990s. Environmental issues are now needed to be considered more at the global level. Elkington coined the triple bottom line in 1994, meaning that companies should consider three aspects: financial, social and environmental. Moreover, Clean Development Mechanism is defined in the Kyoto Protocol in 1997, firms environmental activities could also affect their financial performance in the future. Thus, Carbon disclosure is getting more and more important for both firms and investors.

There are three types of disclosures: mandatory disclosure, voluntary disclosure, and on-demand disclosure. Mandatory disclosure in Japan is provided by Law Concerning the Promotion of the Measures to Cope with Global Warming. 11,086 firms reported the emissions by their corporate activities.

Voluntary disclosure is a disclosure through sustainability reports usually displayed on a firm's web site. Firms may disclose their non-financial information by publishing a sustainability report following the reporting guidelines. Global Reporting Initiative is one of the most widely used international disclosure guidelines (See Figure 1).

On-demand disclosure is information provision that must be prepared by firms when they are asked to



In Japan, there is a small SRI market accounting for 0.1% of world's SRI market, fewer on-demand disclosure with 47% of response rate compared to 71% (UK) and 69% (US). However, there is high recognition of voluntary disclosure because of the government's encouragement.

2 Objectives

Unlike the other countries, Japanese firms are encouraged to disclose voluntarily by the government. This seems to give a different perception of firms to ondemand disclosure. In order to differentiate the three patterns of disclosure and observe the on-demand disclosure response tendency of Japanese firms, this study aims to:

- 1. To investigate how Japanese firms recognizes the three different disclosure patterns and;
- 2. To identify who disclose and why they disclose the environmental information by means of on-demand disclosure.



Figure 1: Links around GRI



Figure 2: Links around CDP

3 Hypotheses based on the literature review

This study set the following six hypotheses based on the relevant literature review. H_1 is set to clarify the objective 1, and H_2 to H_6 are set to clarify the objective 2.

Sequence

Publishing sustainability report has been a common means for firms to manage their reputation since 1997. On the other hand, reflecting the shallow understanding of SRI, CDP is not well know in Japan. Therefore, this study predicts that firms would more likely to firstly try to publish sustainability report with referring a guideline and then adjust the report to answer CDP's questionnaire afterward.

 H_1 . Firms are more likely to publish a sustainability report before answering CDP's questionnaire.

Response status in previous year

Stanny et al. (2008) reported that the likelihood of disclosure is higher for firms that have disclosed before. The firms' reputation by investors would be worse because of non-disclosure and the firms would even be considered as unable to achieve their emission reduction target if the firm do not disclose. Also, the firms that has disclosed would learn what to measure or how to measure, in order to answer the questionnaire.

 H_2 . Firms responding to the CDP₂₀₁₃ are more likely to respond to the CDP₂₀₁₄.

Total asset

The association between size of firms and disclosure is reported in many literatures (Stanny, 2013, Luo et al., 2012, Matsumura et al., 2014, etc.) Larger firms could maintain good reputation by answering the questionnaire since they receive more media attention than smaller ones. Moreover, larger firms have more financial/human resources and better governance than the smaller ones. Hence, investors concerning SRI would be interested in firms whose activities are stable in terms of environment, social, and governance.

 H_3 . Larger firms are more likely to respond.

Foreign sales proportion

Global firms doing their business in different countries with different environmental regulations and their awareness of environmental risks and opportunities are more likely to respond the questionnaire. Global firms would recognize the opportunity to enter bigger carbon emission trading market.

 H_4 . Global firms are more likely to respond.

Economic sectors

Matsumura et al. (2014) reported the difference of disclosure among sectors. In Japan, telecommunication service sector and materials sector disclosed the information the most. Firms in the telecommunication service only consume electricity and it seem to be easy for them to measure and to disclose. On the other hand, the firms that are energy and chemical intensive would have higher pressure especially from the investors. Responding status would be different among sectors, reflecting the characteristics of the sectors.

 H_5 . Responding status is different from sector to sector.

Report publish experience

Ministry of the Environment has strongly encouraged firms to understand environmental issues since Kyoto Protocol in 1997. Japanese firms have disclosed their non-financial information voluntarily by publishing sustainability reports and putting it on their web sites. Firms that have published sustainability reports are more likely to have higher awareness of environment and have knowledge of reporting.

 H_6 . Firms that have disclosed voluntarily are more likely to respond.

4 Methodology

 H_1 is discussed by using the response time after the recognition of sustainability report and CDP, assuming the base year as a year when firms recognize them first. 1997 is set for sustainability report, and years when firms receive the CDP questionnaire first for CDP in order to see how differently firms respond.

 H_2 to H_6 are tested by using the following binary logistic model.

$$\begin{aligned} \operatorname{Prob}(\operatorname{DISC}) &= \beta_0 + \beta_1 \operatorname{CDP}_{2013} \operatorname{AQ} + \beta_2 \operatorname{SIZE} \\ &+ \beta_3 \operatorname{TFSALEP} + \beta_4 \operatorname{REPORTEXP} \\ &+ \beta_{(5-13)} \operatorname{INDUSTRIES} + \varepsilon \quad (\text{eq.1}) \end{aligned}$$

Where

DISC is one if the firm answered the CDP_{2014} questionnaire and zero otherwise;

 CDP_{2014} is one if the firm answered CDP_2014 and 0 otherwise;

SIZE is the natural logarithm of total assets at the end of fiscal year 2013;

TFSALEP is foreign sales as percent of net sales for fiscal year 2013 net sales;

REPORTEXP is one if the firm have published sustainability report at least once and 0 otherwise;

INDUSTRIES are consumer discretionary, consumer staples, energy, financials, health care, industries, information technology, materials, and telecommunication services. These are variables, which are one if the firm operates in this GICS 1 economic sector and zero

¹Global Industry Classification Standard.

Panel A. Descri	ptive statistics.				
Variables	Mean	1st Quantile	Median	3rd Quantile	Std. Dev.
$CDP_{2013} AQ$	0.44	0.00	0.00	1.00	0.50
SIZE	5.94	5.50	5.84	6.34	0.66
TFSALEP	0.27	0.00	0.19	0.51	0.29
REPORTEXP	0.62	0.00	1.00	1.00	0.49
Panel B. Correl	ation statistics.				
	$CDP_{2013}AQ$	SIZE	TFSALEP		REPORTEXP
CDP ₂₀₁₃ AQ	1				
SIZE	0.33^{***}	1			
TFSALEP	0.28^{***}	-0.10^{**}	1		
REPORTEXP	0.48^{***}	0.16^{***}	0.5	34***	1
deduk dede de con e c		2			

Table 1: Descriptive and correlation statistics.

***, **, *, Significance levels at 1, 5 and 10%, respectively, for two-tailed tests.

Tetrachoric correlation statistics for pairs of binary variables and Pearson correlation statistics for pairs with a continuous variable.

otherwise.

The error term ε is assumed to follow binomial distribution.

5 Empirical Results

Figure 3 shows the response time to CDP and sustainability report. Vertical axis represents the proportion of firms which never participate in CDP/sustainability report publishing, while horizontal axis represents the response time (year). The base year for sustainability report publishing is set at 1997 because of Kyoto Protocol and GRI establishment assuming that firms have come to recognize sustainability report as a way to disclose non-financial information. the base year for CDP participation is set at the year when a firm receive the questionnaire, assuming that firms do not recognize CDP till they receive the questionnaire.

As for sustainability report publishing, the proportion of non-published firms is gradually decreasing over time. It seems that firms tend to publish the report after the recognition, and have gradually been capable of publishing and that sustainability report have been common way to disclose in Japan. On the other hand, as for CDP participation, the proportion of nonparticipating firms reach to 50% just after two years from the recognition, and stay at the same level. Firms are bi-polarized: participating quickly and never answering. It seems that CDP participation is not recognized as a good way to disclose despite its known capabilities.

Number of firms that have complied with both CDP and Sustainability report is 234. 86.8% firms published sustainability reports before participating in CDP. The experience of publishing sustainability report seems to be a higher priority for Japanese firms, this is true even with the fact that the base years were set differently. Therefore, H_1 seems to be correct.

Table 2 provides results of logistic models for determinants of answering the questionnaire. In model 1, all variables are statistically significant at more than 5% level. In model 2, the difference between sectors is not statistically significant. In model 3, all variables are statistically significant at more than 10% level. AIC of model 1, 2, and 3 are namely 215.57, 225.06, and 211.6. A model with lower AIC is better model. Therefore, model 3 is the most straight forward model. As a result, H_2 , H_3 , H_4 , H_6 are supported, while H_5 is not.



6 Conclusion

The likelihood of disclosure is higher for firms that (1)participated in CDP in a previous year, (2)are larger, (3)are more global, and (4)have published sustainability report. Moreover, Japanese firms tend to disclose voluntarily (publishing sustainability report) before on-demand disclosure (CDP participation).

Non-financial information disclosure has been adopted by firms as a way to maintain good reputa-

	Table	2: Binary log	it regressions.			
Independent variables	Moo	lel 1	Mod	el 2	Mod	lel 3
Independent variables	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.
Constant	-8.06^{***}	2.06	-11.79^{***}	3.00	-8.91^{***}	2.17
$CDP_{2013}AQ$	5.47^{***}	0.42	5.51^{***}	0.44	5.16^{***}	0.42
SIZE	0.86^{**}	0.33	1.33^{**}	0.43	0.92^{**}	0.34
TFSALEP	1.81^{**}	0.70	1.34	0.82	1.45^{*}	0.72
REPORTEXP					1.10^{*}	0.44
INDUSTRIES						
Consumer Discretionary			0.85	1.28		
Consumer Staples			1.57	1.39		
Energy			0.52	2.09		
Financials			0.25	1.21		
Health Care			1.40	1.40		
Industrials			0.82	1.27		
Information Technology			1.47	1.35		
Materials			2.37	1.32		
Telecommunication Services			-0.34	2.39		
Number of observations	49	97	49	07	49)7
Chi-squared	479	0.23	487	.74	485	.63
degrees of freedom	:	3	12	2	4	L
<i>p</i> -value	0.	00	0.0	00	0.0	00
Log-likelihood value	-10	3.78	-99	.53	-10	0.58
Pseudo-R-squared	0.8	326	0.8	35	0.8	33
AIC	215	5.57	225	.06	211	1.6

The dependent variable is one if the firm responds to the CDP_{2014} questionnaire.

***, **, *, Significance levels at 1, 5 and 10%, respectively, for two-tailed tests.

tion. On the other hand, investors request comparable data to make investing decisions. Environmental, social and governance (ESG) and social responsible investment (SRI) are the factors that motivate them to share the interest in the disclosure. However these do not seem to be understood deeply by both investors and firms in Japan.

Kolk et al.(2008) suggested that CDP progressed much less with regard to the cognitive and value dimensions. Collecting comparable data is also important for policy makers and research institutions. Since Japanese environmental policies have tried to encourage firms' voluntary action and seem to end up with high adoption of sustainability report publishing and bi-polarization in CDP participation, it is important to make high public recognition of SRI.

Data used in this research is limited to top 500 firms in Japan and does not reflect the others. Also, this research only focused on the characteristics of firms that disclosed although in reality firms' activities are influenced by external factors such as depressions, disasters and so on.

The variables used in this research can predict which type of firms are more likely to respond in a next year, but can not increase firms' response to on-demand disclosure because those only represents firms characteristics that can not change easily. In order to motivate firms to disclose their environmental information, investigating the true determinants behind the variables used in this research could be considered for further study. Also, to consider the external factors, using dynamic models could be applied.

References

- John Elkington. 1997. Cannibals with Forks: The Triple Bottom Line of Twenty-First Century Business. Capstone, Oxford.
- [2] Wooldridge, M., J.. 2010. Econometrics analysis of cross section and panel data 2e 565-576, The MIT Press: Cambridge, Massachusetts.
- [3] Stanny, E. (2013). Voluntary disclosure of emissions by US firms, Business Strategy and the Environment 22, 145-158.
- [4] Luo, L., Lan, Y., & Tang, Q. (2012). Corporate incentives to disclose carbon information: Evidence from the CDP Global 500 Report, *Journal of International Financial Man*agement & Accounting, 23:2.
- [5] Stanny, E., & Ely, K. (2008). Corporate environmental disclosures about the effects of climate change, *Corporate Social Responsibility and Environmental Management* 15, 338-348.
- [6] Matsumura, E., Prakash, R., & Vera-Munoz, S.. (2014). Firm-value effects of carbon emission and carbon disclosure. *American Accounting Association* 89, 695-724.
- [7] Kolk, A., Levy, D., & Pinkse, J. (2008). Corporate responses in an emerging climate regime: the institutionalization and commensuration of carbon disclosure, *European Accounting Review* 17, 719-745.
- [8] CDP. (2014). CDP Japan 500 Climate change report 2014.

Evaluation of Durability of Prestressed Concrete by Investigating Beam Specimens Exposed to Marine

Environment for 40 years

Student Number: 13M18095 Name: Takuya KURAMOCHI Supervisor: Nobuaki OTSUKI

40年間海洋環境に曝露された梁供試体を用いたプレストレストコンクリートの耐久性評価 倉持 卓弥

40 年間海洋環境に曝露された緊張方式、曝露環境、持続載荷荷重、緊張力、鋼材種類が異なるプレストレストコンクリート梁供試体を用いて耐久性評価をした。結果、激しい腐食環境で長期曝露後でも最大曲げ引張り破壊耐力が初期設計時の 断面計算値以上残存していること、プレストレストコンクリートにとって重要である有効プレストレス力が PC 鋼材の腐食 が認められない状態では、設計値以上残存していることから総じて健全な構造性能を有していると評価できた。

1. Introduction

Performance of concrete structures have been degraded after construction. Unfortunately, the experimental data after long term exposure are only few. Especially, regarding Prestressed Concrete, it is not clear how PC structures can retain soundness under severe condition for long term exposure, especially marine environment would be considered most severe condition for Prestressed Concrete from the view point of corrosion of steels.

Mainly, for Prestressed Concrete, ultimate bending strength and effective prestress are the most important mechanical properties to prove soundness. It is assumed that corrosion of steels would significantly affect to ultimate bending strength and effective prestress because corrosion of steels can reduce cross section area of them, and bonds strength between steels and concrete.

In this study, the objective is set as to evaluate durability of prestressed concrete exposed to marine environment for 40 years by investigating specimens having several conditions.

2. Experimental works

The study flow of this research is shown in figure 1.



Figure1: Study flow

2.1 Specimens

PC beam specimens had been exposed to marine environment for 40 years up to last year. Then, in this 1 year, they have been on atmospheric condition. Specimens having several conditions shown in table 1 were investigated. There are mainly 5 parameters, types of prestress, types of PC steels, continuous loading condition, exposure condition, initial tensioning force for PC steels.

Mixpropotion of concrete is shown in table2. Concrete of all specimens in this study have same mixproportion. Cement type is high-early strength portatmospheric cement.

PC strands are 2 types, for pre-tensioning PC, the one is SWPR2 φ 2.9mm, the other one is SWPR7 φ 12.4 according to JISG3536.

For post-tensioning PC, PC tendon is SBPR80/95 φ 17mm according to JISG3109.

No.	Mark	Types of Prestress	Types of PC	Loading condition	Exposure condition	Tensioning Force	Remark			
1	R1A3	we have been	TRANSPORT R	REAL AND A CONTRACT	No. 6 NO. 1 SAME	Tidal	No. 21 Star	Server Stevens		
2	R1B2		Chandra	No Load	Submerged sea		cracked			
3	R1C2	Sec. 19	Strands:	in the dealers	Atmospheric	0.8 ду	Contraction in			
4	R2A4	1000 10000	SWPR202.9	Cracking Load	A CONTRACTOR OF THE OWNER OWNE		cracked			
5	R4A1	Pre-	Pre- nsioning Strands: SWPR7φ12.4 No Load	Design Load	a Hitsanda		- 100			
6	T1A3	tensioning		1.10.10.10.10.10.10.10.10.10.10.10.10.10	R. C. BREAK	0.8σу				
7	U1A2	HALP HE		Tidal	0.6 <i>o</i> y	Galvanized, cracked				
8	V1A2			SWPR/012.4	SVVPR/012.4	SWPR/012.4	SWPR/012.4	PR/012.4		100
9	W1A2	100 F 100	210 (18 J.8.9)	a of straf	S126 10 11 187	0.4 0 y				
10	01A4	1.11	10.00	120000	Tidal	0.000				
11	01A5	Post-	T	No. Lond	lidal	0.05-	cracked			
12	O1B2	tensioning	Tendon: φ17	No Load	0	0.85 0 y	cracked			
13	O1B3			(1 1	1011111111	Submerged sea		cracked		

Table1: Parameters of specimens

Table2: Mix proportion of concrete

W/C	Slump Air s/a Maximum		Maximum Unit weight(kg/m			1 ³)		
(%)	(cm)	(%)	(%)	size(mm)	W	C	S	G
37	5±1	4±1	40.5	20	167	460	710	1080

2.2 Method

2.2.1 Observation of concrete surface

The simplest non-destructive investigation of corrosion of steels in concrete is observation of concrete surface, especially focusing on cracks and leakage of rust leachate. So in sketch, cracks and leakage of rust were drawn.

2.2.2 Examination ultimate bending strength

To examine ultimate bending strength, the loading test was implemented with controlling load. In this study, 4types of specimens, No4, 7, 11, 12, were examined.

Outline of loading experiment is shown in Figure2. The span was determined on assumption of destructive mode as steels would be yield due to tensile stress and concrete at the edge of loaded side would be collapsed due to compressive stress.



Figure2: Outline of loading

2.2.3 Measurement of effective prestress by released

stress methods

1) Stress release by cutting core method ¹⁾:

By cutting core of concrete, the effective prestress is

estimated due to releasing the stress of concrete.



Figure4: Principle of cutting core method

2) Stress release by cutting strands method²):

By cutting strands, the effective prestress is estimated due to releasing the stress of strands. This method can directly measure strain of strands, so it does not need to consider concrete property in the equation. To prove the value of cutting core method, cutting core method had been executed.



 $\sigma_{se} = -E_s \cdot \Delta \varepsilon_{se}$

where,

 $\begin{aligned} &\sigma_{se}: \text{effective stress by strand} \\ &E_{sc}: \text{Young's modulus of strand} \\ &\varepsilon_{se}: \text{released strain of strand} \end{aligned}$

Figure5: Principle of cutting strands method

Depending on the characteristics of both methods, in cutting core method, many points can be measured on one specimen, so distribution of effective prestress can be obtained. On the other hand, in cutting strands method, only few points can be measured because this method damages concrete so much.

2.2.4 Prediction of the time of cracking

The time of cracking (end of progressive period) is very important and meaningful because performance of concrete is drastically declined after cracking.

At first, the time of cracking was estimated by using equation developed by Yokozeki et al³⁾.

$$Wcr = -1.841\varphi(\varphi - 8.661) + 145.1\alpha - 1.194 +3809A - 0.8351 + 10.60X - 72.30$$

Where $W_{cr}(mg/cm^2)$: critical amount of rust to induce cracking, φ : Creep coefficient, α : volume expansion rate coefficient, A: angle of corrosion(usually 360°), X: function of shape(=c/ θ)

Besides, the time of corosion happened(end of incubation period) was estimated based on calcularion of Japan Society of Civil Engineers.

For those results, progressive period and incubation period were estimated.

3. Results and disscusion

3.1 Observation of concrete surface

The result of observation is shown in the column of remark in table1. 6 specimens had cracks in 13 specimens. Specifically all specimens, the number was 3 in 3, exposed to submerged zone were observed having cracks according to a line of bar arrangement.

The other noticeable case of having crack was post-tensioning. 3 out of 4 specimens had cracks, in addition those 2 of 3 having cracks had been exposed to submerged sea. The reason might be supposed that deterioration of edge might accelerate corrosion of steels on other area because a plate, a pipe and so on metal parts of anchorage are likely to be corroded. Actually even specimen No.10 (does not have cracks) had much corroded edge parts were confirmed. Thus, an edge of post tensioning type needs much care. However, the remarkable point is that PC tendons were not corroded. The corroded part was only steels.

Those left 2 cases having cracks were the case of galvanized and cracking load. About the case of galvanized, the meaning of galvanized is to be corroded in stead of steels. So there would be possibility that those cracks were happened with corrosion of zinc. In the case of cracking load, the effect of continuous load should be the reason. However, in the case of design load, it could not be observed cracks, even though the design load had been bigger than the cracking load.

3.2 Examine ultimate bending strength

The results are shown in Figure3. In the figure, vertical axis means load and horizontal axis is displacement at a center of span. The horizontal colored dotted lines mean the ultimate bending load by calculation on concrete design of cross-section. The actual ultimate bending load, measured on experiment, was over the value of calculation. In other cases also, the actual ultimate bending load was confirmed as it was over calculated velue.

Therefore, the ultimate bending load was retained as beyond the value of calculation, so from the viewpoint of ultimate bending load, the PC beams are soundness in any case.



Figure3: Load-displacement

3.3 Measurement of effective prestress by released stress methods

According to all results, effective prestress can be remained as same or over value as design. Besides, the both results by 2 methods can indicate almost same value. Therefore, the result of cutting core must have reliability based on the result of cutting strands. Remarkable notice are shown below focusing on parameters.

1) Influence of exposure condition

In Figure5, the results of both methods, cutting core and strands, are shown. Vertical black dotted line means a center of specimen. Vertical axis means estimated effective prestress, and horizontal axis means distance from left edge of a specimen. Green vertical dotted line means the transfer-length in design. About transferlength, in pre-tensioning PC, prestress can be transferred by strength between concrete and strands. So at the edge of a specimen, effective prestress should be 0, then with some length from edge of a specimen, prestress can be obtained as design value. Red horizontal line means design value right now taking account of loss of effective prestress due to shrinkage and creep of concrete and relaxation of steels. Dots are the results of cutting core method and asterisks are the results of cutting strands method. In this figure, to compare the effect of exposure condition, the results of specimens' No. 1, 2, and 3 are combined into 1 graph. The result of No1. Exposed to tidal zone is colored red. The result of No2. Exposed to submerged zone is colored blue. The result of No3. Exposed to atmospheric is colored yellow.

About the maximum value, the value of atmospheric condition was above design value and biggest one amount these conditions. Then the value of tidal condition was above design value. The value of submerged zone condition was below design value.

Regarding transfer-length, the results of atmospheric condition is clearly remained as beyond design value as long distance from center of the

specimen comparing to others. So there would be possibility that effect of corrosion can make transferlength longer. Here, the condition of steels of the specimen exposed to atmospheric was significantly better comparing to specimens of tidal and submerged zone with referring to results of corrosion weight and observation of corrosion on surface of steels (Observation of steels' surface are shown in figure7).





(Top; Tidal, Middle; Submerged zone, Bottom; Atmospheric)

Hence, there is possibility that corrosion may affect to transfer length in a case of pre-tensioning type.

2) Influence of types of introduced prestress

3

R1C2

17.1

In Figure8, the results are shown. In this figure, to compare the effect of types of introduced prestress, the results of specimens' No. 1 and 10 are combined into 1 graph. No.1 the result of pre-tensioning PC is colored red. No.10, the result of post-tensioning PC is colored blue.



Remarkable difference is those distribution of effective prestress. As mentioned earlier, Pretensioning PC needs transfer length to introduce prestress to concrete, so the shape of the distribution is like a bow curve as the value of center of specimen is as top. By contrast, the shape of distribution of the results of post-tensioning PC is liner around design value. Post-tensioning PC does not need transfer-length because prestress is introduced by force of compressive stress due to an anchorage of PC tendon.

For this reason, post-tensioning PC is better against chloride attack than pre-tensioning by taking the effect of transfer-length into account.

However, as mentioned in 3.1, an edge of post-tensioning need special care because a plate, a pipe and so on metal parts are likely to be corroded.

3.4 Prediction of the time of cracking

In this study, degradation process was classified like in fgure9. End of progressive and incubation periods are predicted as mentioned earlier in 2.2.4. The results of strands in pre-tensioning are shown in table3 and also results of steel bars are in table4. For those results, all prediction can relate to the result of observation of concrete surface, certainly No2, 4, and 13 are observed having cracks on surface of concrete.



Figure9: Degradation process by chloride attack

Specimens Corrosion		cimens Corrosion Corrosion speed Critical amount of rust to		Period of	Incubation period	Bemark	
No	Mark	weight(mg/cm ²)	(mg/year)	induce cracking(mg/cm ²)	craccking(year)	Propagation period	Reinark
1	R1A3	58.8	1.38	88.7	61.7	16.9 44.8	
2	R1B2	123.3	1.52	88.7	17.3	16.9 0.4	cracked
3	R1C2	17.1	1.05	88.7	108.1	23.2 84,9	
4	R2A4	156,4	0.77	88.7			cracked
5	R4A1	59.9	0.07	88.7	Over 110		

Table3:	Period	of cra	ckina.	Strands	SWPR2

Table4: Period of cracking, Steels

Spec	cimens	Corrosion	Corrosion speed	Critical amount of rust to	Period of	Incubation period	Demark			
No	Mark	weight(mg/cm ²)	(mg/year)	(mg/year) induce cracking(mg/cm ²) craccking(year)		ng/year) induce cracking(mg/cm ²) craccking(year) Pro		induce cracking(mg/cm ²) craccking(year) Propagation period	Propagation period	d
6	T1A3	54.2	54.2 0.12			17.8				
9	W1A2				48.8	31.0				
10	01A4			55.3						
13	O1B3	95.4	4.56	1.3 Samela	31.2	17.8 13.4	cracked			

Each period is shown in figure10. Focusing on effect of exposure condition, In the case of strands SWPR2, the result of R1C2(atmospheric condition) shows long-term until cracking comaparing to others. The result of tidal condition(R1A3) shows longer-term until cracking than submerged zone condition(R1B2). Moreover, in the case of steels, tidal condition specimens(T1A3, W1A2, O1A4) show longer-term than submerged zone condition(O1B3). Usually tidal zone is considered that steels are more likely to corrode than submerged zone from the view point of contents of oxygen. The reason why those conditions, tidal and submerged zone, are contrary with theory would be not so much difference of provided amount of oxygen. In this study's exposure condition, even submerged sea condition is near from surface of water level. So there would be possibility that provided amount of oxygen is not so different in theose conditions.



Figure10: Incubation and propagation reriods

4. Conclusions

- The results of ultimate strength were evaluated above design value, even though after 40 years exposure to marine environment.
- Regarding effective prestress, effective prestress values were evaluated above design value if not much corrosion on PC steels. Moreovere, the influence of corrosion on effective prestress was confirmed.
- Exposure condition affect on the time of cracking so much. Besides, prediction can relate to the results of observation of concrete.

References

- Niitani Kyoji, Watase Hiroshi, Sakata Kenji, Ayano Katsunori: Study on Effective Stress Estimation Method for Concrete Members, Concrete Reseach and Technology, Vol. 20, No.2, pp.27-37, 2009.5
- [2] Yokoyama Kazuaki, Osada Koji, Muroi Tomofumi, Kato Takuya : Study on the remaining pre-stress measurement of the actual PC Bridge by rebar cutting method , Symposium about the Development of the 13th prestressed concrete, pp.501-504, 2004
- [3] Yokozeki, Okada, Motoyoshi, Tsutsumi: A Rational Model to Predict Service Life of RC Structures in Marine Environment, Forth CANMET/ACI International Conference on Durability of Concrete 1, 1997

Research on Maximum Wind Speed Radius of Typhoon Passing through Japanese Southern Ocean Basin

Student Number: 13M18215 Name: Wenjie WU Supervisor: Hiroshi TAKAGI

日本南方海域を通過する台風の最大風速半径についての基礎的研究

呉 文潔

高潮による人的被害を減軽するためには、数値シミュレーションの予測精度を上げることが重要である.しかし、 その精度に大きく影響するパラメータの一つである台風の最大風速半径の設定は特に難しい.今まで一般的に使わ れてきた加藤の経験式は簡便で有用であるが、推算誤差が大きく、高潮を過小あるいは過大評価する可能性がある. 本研究では、高潮災害が多発する中国の東沿岸域に接近する台風に着目し、その地域に上陸する台風の予測精度の 向上を目指す.このため、日本南方海域において入手可能な気象情報を用いて、従来の手法よりも推定精度の高い 最大風速半径のモデルを新たに提案した.

1. Introduction

Extensive storm surge disasters caused by extremely strong typhoon have occurred frequently in recent years and it is considered that typhoon is likely to become stronger in the future due to climate change. In order to save human's life, it is required to provide the evacuation warning based on an accurate forecast on storm surges. For this reason, enhancement of simulation accuracy will become increasingly important. However, the maximum wind radius (hereafter referred to as Rmax), which is one of the typhoon parameters and has large effect on the simulation accuracy of storm surge, is especially difficult to be chosen.

The information of Rmax is usually not provided from meteorological agencies such as JMA (Japan Meteorological Agency) when they issue typhoon reports or forecasts. Hence, those who carry out storm surge simulation need to estimate the radius by themselves. The empirical formula for estimating Rmax proposed by Kato (2005) has been commonly used among coastal engineers. The Rmax can be estimated according to the pressure on the center of the typhoon. Although this model is simple and useful, the estimation error is not negligible and thus storm surge heights could be underestimated. Therefore, it is necessary to develop a more reliable estimation method of Rmax, which is expected to improve the accuracy of storm surge simulation.

This research focuses on the eastern coastal region of China, particularly Zhejiang Province, where storm surge disasters frequently occurred in the past. A number of meteorological data, which were observed at several observatories in the southern ocean basin of Japan in the past 25 years, have been collected and analyzed in order to improve the Rmax model.

2. Validation of the usage of objective analysis data

To improve the estimation accuracy of Rmax, the model should be developed with reliable data which describe the characteristics of the typhoon correctly. Given that the number of observatories is limited, first the usage of objective analysis data was considered.

2.1 Summary of the objective analysis data

Two types of analysis data were discussed in this research and the summaries are as follows.

(i) ERA-Interim data

ERA is the acronym for ECMWF (European Centre for Medium-Range Weather Forecasts) Re-Analysis and this data can be downloaded from the server of ECMWF.

Table.1 Detail of ERA-Interim data

Data format	NetCDF or GRIB
Period	$1979 \sim about 2$ months prior to present
Time	00,06,12,18 UTC
Area	Grobal
Grid	0.125°× 0.125°

(ii)GPV (MSM) data

GPV is the acronym for Grid Point Value and this data is calculated under MSM (Meso Scale Model) which is a numerical forecast model of JMA. The data used on this research is hourly, composed with objective analysis data as initial value and the forecast data filled at the intervals from the original GPV data by Research Institute for Sustainable Humanosphere and the format is changed to NetCDF.

Table.2 Detail of GPV (MSM) data

Data format	NetCDF
Period	$2002 \sim$ one day prior to present
Time of	~ Feb. 28, 2006: 00,06,12,18 UTC
initial value	Mar. 1, 2006 ~ :
	00,03,06,09,12,15,18,21 UTC
Area	22.4°N ~ 47.6°N, 120°E ~ 150°E
Grid	~ Feb. 28, 2006 :
	longitude $0.125^{\circ} \times$ latitude 0.1°
	Mar. 1, 2006 ~ :
	longitude 0.0625°× latitude 0.05°

2.2 Applicability of the objective analysis data

Five typhoons shown in Table.3 are highlighted as the representative examples of the strong typhoon passing through Japanese Southern Basin and landing on the eastern coastal region around Zhejiang Province. The paths of them are show on Fig1. An assessment was made to identify whether these 2 types of analysis data is applicable to the research considered.

Typhoon	Typhoon period	Central		
No.		pressure		
0413	Aug. 6~Aug. 15, 2004	950 hPa		
0515	Sept. 5~Sept. 13, 2005	945 hPa		
0608	Aug. 5~Aug. 11, 2006	925 hPa		
0712	Sept. 15~Sept. 20, 2007	925 hPa		
1211	Aug. 1~Aug. 11, 2012	965 hPa		

Table.3 Detail of the typhoon examples

2.2.1 Method 1: Pressure comparison at different places in broad area

The data of sea level pressures (SLP) at five locations were used for the applicability test for ERA and GPV. Because the observation data including SLP is available at two Japanese observatories, Naha and Ishigakijima, the comparison was also made between the objective and the observation data.



The comparison yielded the findings as follows:

(1) GPV data is in good agreement with observation data, while ERA data is only reliable in estimating the typhoons when the pressure depression is not significantly large. The error of ERA data appears to reach 30hPa and even larger. Fig.2 shows the comparison result of the pressure at Naha and Ishigakijima when the observed pressure was lowest during the typhoon passage.

(2) At the places where the observation data is not available, the SLP in ERA also shows $20\sim30$ hPa higher than GPV data when the SLP in GPV data depresses under 980 hPa.

ERA data obtained at 6-hours interval appears to be too coarse to estimate the typhoon pressure depression accurately. Therefore, ERA data is considered not appropriate to be used for the purpose of this research.



2.2.2 Method 2: Pressure comparison at the center of the typhoon

Although GPV data is in good agreement with observation data, it has been also pointed out that the central pressure of the pressure field expressed by GPV data is higher than the real central pressure of the typhoon. (Kawaguchi et al., 2007). Thus, the second validation method is to compare the pressures at the center of the typhoons between GPV data and the Typhoon Best Track data.

The comparison shows that GPV data only agrees with Best Track data in the case of T1211, but overestimate the pressures in the other cases. The maximum errors are 12 hPa, 37 hPa, 57 hPa and 33 hPa in the cases of T0413, T0515, T0608 and T0712 respectively. Fig.3 is the comparison result of the central pressure of typhoon 0608 that shows how GPV overestimates the pressures during the period when the center of the typhoon is inside the area of GPV data. It is considered that the GPV data overestimates the typhoon pressure as the grid size is not small enough. Therefore, GPV data is also not appropriate to be used for the purpose of this research.



3. Development of a new estimation method of maximum wind radius

3.1 Selection of the typhoon

Since the analysis data cannot be used to make a comparison to estimate the accuracy of the simulation, only possible data source for the present research could be the observation data at neighboring observatories. There are 10 JMA observatories whose observation data are available inside the research area $(20^{\circ}N\sim30^{\circ}N, 120^{\circ}E\sim132^{\circ}E)$. The criteria for the typhoon selection are as follows:

- ① Typhoon occurred after 1990 when the observation data began to be recorded at every hour (every 3 hours or 6 hours before 1990).
- ② Typhoon passed through the area of 20°N~30°N, 120°E~132°E in conformity to the target area.
- ③ Extremely strong typhoon whose lowest central pressure is under 930 hPa, by which huge storm surge disaster might occur.
- (4) The distance between one or more of the observatories and the center of the typhoon is less than 100km.



Although 621 Typhoons have occurred from 1990 to the present, only 17 typhoons are satisfied with all criteria and decided as the target typhoons. Typhoons, which satisfy the criteria mentioned, are listed on table4 with their central pressures, and the distance to the closest observatories. The name of the observatories from east to west is Minamidaitoujima, Naze. Okinoerabu, Nago, Naha, Kumeiima. Miyakojima, Ishigakijima, Iriomotejima and Yonakunijima. The number in bold indicates central pressures when closest.

Table4 Detail of the research objects

Typhoon No.	Central Pressure (hPa)	Distance (km) to the closet observatories
9019	925→890→ 910 →930	51 (Naze)
9313	930→ 925 →930	19 (Kumejima)

9416	925 →930	47 (Ishigakijima)
9609	930 →925	26 (Iriomotejima)
9918	930	39 (Kumejima)
0314	930 →910 →930	12 (Miyakojima)
0418	925 →930	18 (Nago)
0608	930 →925 →930	63 (Miyakojima)
0613	930→ 920 →930	18 (Ishigakijima)
0704	930	23 (Naha)
0712	930→ 925 →930	7 (Iriomotejima)
0715	925 →930	13 (Yonakunijima)
0815	905→ 925 →930	88 (Yonakunijima)
1011	930	52 (Yonakunijima)
1215	920→910→ 930	4 (Nago)
1216	920→ 930	100 (Naha)
1217	920 →930	32 (Naha)

3.2 Estimation of maximum wind radius by simulation

Myers model (1954) was used to calculate the pressure profiles of the 17 typhoons. The estimated pressures were compared with the observed value to find the value of Rmax for each typhoon at each time period. The procedure is as follows:

- I. Linearly interpolate the Best Track data into the 1-hour interval data.
- II. Search the observatories whose distance to the center of the typhoon is less than 300km.
- III. Estimate Rmax according to Kato's model (2005) and perform the simulation. Compare the estimate pressure to the observed pressure at the places found at step II.
- IV. Repeat the comparison with different settings of Rmax at every 5 km. If the estimate pressure is higher than the observed pressure, raise the value of maximum wind radius, otherwise lower it.
- V. The Rmax calculated by the best estimated pressure that is the closest to the observed data is considered an optimum radius.

3.3 New method for the estimation of Rmax

A new model, which could become an alternative method exceeding the previous models, is proposed.

3.3.1 Correlation with central pressure

Both the empirical formulas of Kato (2005) and Kawai (2005) estimate Rmax according to the typhoon central pressure. To verify the central pressure as determining variable, the correlation between central pressure and the Rmax estimated by the methods mentioned was investigated.

The average of the Rmax shows: 1) an increasing tendency with the rise of the central pressure of the typhoon, which is the same as the plots by two empirical models; 2) a good agreement with Kawai's model, while lower values than Kato's model; and 3) an increasing exponentially with the rise of the central pressure which is the same as Kawai's model, while Kato's model shows a linear trend.

Fig.5 shows each Rmax of the 17 typhoons when each typhoon is the closest approach to the observatory. It is apparent that Rmax estimated in this research shows a lower value than Kato's model and have a wide range differ from typhoon to typhoon even the central pressures are the same. Furthermore, the determination coefficient R^2 is as low as 0.0602, which demonstrates a low correlation between the plots and the regression curve.



Fig.5 The estimated Rmax of the 17 typhoons

3.3.2 Storm force wind radius

The authors focused on another typhoon parameter, storm force wind radius, as an indicator to estimate Rmax. Storm force wind area is the area where the wind speed exceeds 25m/s. Storm force wind area is analyzed as a circle, but for the reason of spatial bias, the radius is expressed by the combination of wide and narrow radius. During a typhoon approaches, JMA forecasts and publicizes this radius along with the other typhoon information. Since the storm force wind radius expresses the size of typhoon, the storm force wind radius is considered to be correlated with Rmax.

Fig.6 shows the correlation between storm force wind and Rmax. For sake of simplicity, storm force wind radius is calculated by averaging wide and narrow radius. For Rmax, the values when each typhoon is the closest approach to the observatory are plotted. The determination coefficient R^2 is as high as 0.579, which demonstrates a high correlation.

The new formula is delivered as follows,

$$r_{0} = a * \frac{(r_{1} + r_{2})}{2} \tag{1}$$

where, r_0 is the estimate of Rmax, r_1 is the wide radius of storm force wind, and r_2 is the narrow radius. *a* is the gradient and equal to the regression coefficient, 0.229. Since the overall range of the samples are inside the range with gradient of $0.172 \sim 0.360$ in Fig.6, it is considered necessary to use these limit values also when do a storm surge simulation.



Fig.6 Correlation between Rmax and storm force wind radius

4. Conclusion

The present paper concluded: 1) the applicability of JMA and ECMWF objective analysis data was investigated, and it was revealed that the resolution of these data does not satisfy the quality for the present typhoon research, 2) correlation between Rmax and the typhoon central shows a low correlation with high variability. This implies that the previous models using the central pressures such as Kato's model should be revisited, 3) correlation between Rmax and the storm force wind radius shows a high correlation will less variability, and 4) a more precise estimation method of Rmax using the storm force wind radius is proposed.

5. References

- Kato, F. (2005): Study on risk assessment of storm surge flood, Technical Note of National Institute for Land and Infrastructure Management, No.275, p10. (In Japanese)
- [2] Kawai, H., Honda, K., Tomita, T., Kakinuma, T. (2005): Characteristic of Typhoons in 2004 and Forecasting and Hindcasting of Their Storm Surges, Technical Note of the Port and Airport Research Institute, No.1103, pp. 3-12. (In Japanese)
- [3] Kawai, H., Kawaguchi, K., Ohkama, T., Tomoda, N., Hagimoto, Y., Nakano, T. (2007): Simulation of Storm Surge in Seto Inland Sea with Wind Field Estimated by Empirical Typhoon Model and Mesoscale Model, Proceedings of Coastal Engineering, JSCE, Vol.54, pp. 286-290. (In Japanese)
- [4] Takagi, H., Kashihara, H., Esteban, M. Shibayama, T. (2011): Assessment of future stability of breakwaters under climate change, Coastal Engineering Journal, World Scientific Ltd., Vol.53, No.1, pp.21-39.

Separating global warming and urbanization effects to rainfall during summer

Student Number: 13M18072 Name: Natsumi KAWANO Supervisor: Manabu KANDA

地球温暖化と都市温暖化が夏季降雨に及ぼす影響

河野なつ美

本論文では、領域気象モデルWRFに擬似温暖化手法と都市パラメータを適用し、地球温暖化と都市化の影響が 夏季降雨に及ぼす影響について統計的に考察した。その結果地球温暖化影響によって、広域な収束発散場が形成 され雨域が分散された。対して都市温暖化は建物影響を含むことによって都市域の雨が強化された。一方で将来 気候における都市温暖化影響は、現在気候と同じ都市パラメータを使用したため地球温暖化の影響よりも小さく、 雨域に大きな違いは見られなかった。

1 Introduction

Climate change due to global warming is a major concern worldwide¹. Among the triggering factors of global warming are anthropogenic heat and greenhouse gas emissions. These factors are largely linked to urbanization. Urban Heat Island (UHI)², a phenomenon when urban areas have higher air temperature than its surrounding rural areas, is an obvious proof of urbanization's impact to warming. The effects of UHI (e.g. localized heavy rainfall, heat stress) not only the surrounding weather but is also directly tied to human lifestyle and health. For example, frequent localized heavy rainfall, due to UHI, may lead to flooding within the city³. Flooding can lead to economic problems, infrastructure damages, and diseases. Due to the stagnation of heat in urban areas, casualties due to heat stress may rise and quality of sleep will worsen⁴. In the future, urban population is expected to rise which may lead to a more intense UHI. The UHI intensity would be enhanced during night time by 20% in future climate⁵. Pseudo Global Warming (PGW) analysis suggest extreme hot days in metropolitan area would double that of now⁶. Furthermore, the effect of global warming is larger than urbanization effect under the future land use scenario and PGW method7. So far, modelling future climate assume constant and homogeneous urban parameters thus lacking the analysis on the actual contribution of urban areas to global climate change. Also, only future temperature fields and UHI intensity were analyzed. In urban areas, localized heavy rainfall cases have been detected but its modelling coupled with realistic urban parameters were mostly for hindcasting studies. Past localized heavy rainfall in Tokyo were simulated using realistic urban^{8,9}. Long term rainfall trends using weather models with realistic urban parameters are still lacking.

This study aims to conduct one month simulations using PGW method with the emphasis on actual urban effects using realistic parameterizations and distribution. In this study, two one case studies were conducted for Nagoya and Kanto region. First, land use and global warming effects were mentioned by using future land use scenario and PGW method. Second, the separate influences of climate change and urbanization to rainfall was determined.

2 Methodology

2.1 Model description

In this research, Weather Research and Forecasting (WRF) Model Version 3.3.1 was used.

In future climate case, the ensemble average¹⁰ of downscaled 4 global circulation model (GCM) outputs (CSIRO, MIROC, MRI, GFDL) were used as basic datasets. Due to ensemble averaging, distinct fluctuations from each GCM was neglected. Japan Meteorological Agency (JMA) 3-hr Mesoscale Model products were used as initial and boundary condition.

2.2 Nagoya simulation

WRF simulations were conducted for August 2011 (current case) and 2090s (future case). One-way nesting with two domains was used. First domain covered whole of Japan and second domain covered Aichi prefecture. The domain resolutions were 25-km, 5-km and 1-km.

Two future land use distribution were considered for Nagoya (Fig1). One is denoted centralized case, the other is the decentralized case. Centralized case has one large urban which is centered Nagoya city. However, decentralized case has four urbanization areas that are centered Nagoya, Yokkaichi, Toyohashi and Gifu. Total urban area is conserved between these two urban scenarios.



Fig 1 Future land use scenario (left: centralized, right: decentralized)

2.2 Tokyo simulation

For Kanto region, simulations were conducted for August 2010 (current case) and 2090s (future case) without changing the urban parameters for the future. It is to be noted that the 2090s simulation background is not the same with Nagoya. The 2090s simulation's base year is 2010. First domain covered whole of Japan and second domain covered Kanto region. The resolutions were 5km and 1km for first and second domain, respectively. And urban parameter was considered in this simulation.



Fig 2: Simulation area for Kanto

2.3 PGW method

The PGW method¹¹ is used to predict the future climate of a region using dynamical downscaling. Instead of immediate downscaling of future forecasts from the GCM, this method is forecasting future climate relative to an existing past climate condition. First, a PGW dataset is needed which is calculated from the difference of average monthly climatologies in 2090s and 2000s. The GCM used to calculate climatologies in 2090s came from the Intergovernmental Panel on Climate Change (IPCC) AR3 A1B scenario.

Second, the PGW dataset is added to the past lateral boundary. Figure 4 shows the temperature distribution of the lateral boundary in the future and current cases. The future lateral boundary, sum of current case and PGW dataset, shows a temperature higher than current case by 2 - 3 C. The future lateral boundary was used to downscale future climate.



Fig 3. Pseudo global warming method



Fig 4. Temperature at 2m distribution (Left: current, Right: future)

2.3 New urban parameterization

In this simulation, latest urban parameterizations were coupled with single-layer urban canopy model to consider the urban effects¹². The highlight parameters of this research are as follows;

- (1) Anthropogenic Heat Emission (AHE) and Anthropogenic Moisture Emission (AME) distribution
- (2) Roughness length (z₀) and displacement height (d) distribution
- (3) Sky view factor (V_F) distribution
- (4) Actual urban fraction distribution

Two types of simulations were done, one is URB and the other is VEG. URB included the urban parameters in urban area and VEG excludes the urban effect. Fig 5 showed land use information of

URB and VEG. These settings could consider the urban effect in future and current climate, respectively. URB has the urbanized area (red area) in central Kanto region. On the other hands, VEG case is replaced urban area to glass land (light green area) to exclude the urban effect.



Fig 5 Land use category in URB (left) and VEG (right)

3 Results and Discussion

3.1 Nagoya simulation

Table 1 showed the results of temperature, wind speed and precipitation in all cases. Future temperatures were found to increase by 2.3 C In addition, precipitation was increased in the future for both cases. However, wind speed was not change in future and current climate.

Next, a specific heavy rainfall event was selected for further analysis. Fig 6 showed the total amount of distribution in future and current climate. Heavy rainfall occurred from August 20th to 21st. The rainfall distribution was similar in centralized and decentralized cases. In the future, heavy rainfall area will occur in central Nagoya city while current heavy rainfall will be relocated to Toyohashi city. These results showed that future land use scenario did not affect the rainfall so much. Detailed urban effect should be considered.

Table 1 Statics value of temperature, wind speed and precipitation in 2090s and 2011

	III 20703 u	110 2011				
	Centralized c	ase	Decentralized case			
	2090s	2011	2090s	2011		
Temperature [C]	27.2 (+2.3)	24.9	27.2 (+2.3)	24.9		
Wind speed [m/s]	3.4 (+0.1)	3.3	3.4 (+0.1)	3.3		
Precipitation	1369.7 (+470.1)	899.6	1692.0 (+807.3)	884.7		
[mm]						



Fig 6 Rainfall distribution ((a)Centralized_2090s, (b)Centralized_2011, (c)Decentralized_2090s, (d)Decentralized_2011)

3.2 Kanto simulation

Figure 6 shows the temperature and precipitation distribution in URB_2010 and Observation. Observation data was from AMEDAS in JMA. Nine AMEDAS points were picked up to compare with the current urbanized simulation results (2010_URB) namely, Tokyo, Fuchu, Yokohama, Hachioji, Chiba, Abiko, Kuki, Kumagaya and Tsukuba. URB 2010 and Observation were similar to each other.



Fig 6 temperature and precipitation distribution (Left: URB 2010, Right: Observation)

3.2.1 Global warming effect between 2090s and 2010

In this section, global warming effect is detected by subtracting simulated parameters of future climate and current climate. Fig 7 showed the temperature and precipitation intensity distribution in URB (2090s-2010) and VEG (2090s-2010).

In temperature distribution, future climate temperature is higher than current climate by 2 C However in URB case, higher temperature area shifted northwards. The reason behind this is the differences in simulated pressure gradient between sea and land. In 2090s_URB includes the global warming and urbanization effect, temperature increased on land generating stronger winds than 2010_URB. Wind advects warmer air from urban areas further inland.

As for rainfall, it will decrease in the future above urban areas such as Tokyo. To analyze the rainfall, August 19th rainfall event was chosen.

Fig 8 showed the URB (2090s-2010) precipitation, convergence and divergence fields in 17:00 and 18:00. Future precipitation distribution was more dispersed than current precipitation because of the convergence front from Kashima nada and Tokyo bay. On 17:00, current simulation has strong convergence and divergence spots above the boundary of Tokyo and Kanagawa prefecture. These spots were created by two convergence fronts from Tokyo bay and Kashima nada. However, future scenario simulated a northerm Kashima nada convergence front resulting to an expanded convergence region.

3.2.2Urbanization effect between URB and VEG

In this section, urbanization effect was considered by subtract simulated parameters of URB and VEG. Fig 9 showed the temperature and precipitation distribution in 2090s (URB-VEG) and 2010 (URB-VEG). Temperature fields showed that higher temperature area existed above urbanized areas because of the urbanization. However, future higher temperature area was wider than current area because of the heat island effect as a feedback to global warming.

On the other hands, precipitation distribution was different between future and current cases. In current simulation, more precipitation occurred above the urban area. However, future precipitation did not increase as much.

From fig 10, current simulations reproduced a localized heavy rainfall. URB_2010 simulated a heavy rainfall stationary above the urban area while VEG_2010 rainfall spot moved further west. The reason behind the URB_2010 rainfall pattern is due to the consideration of urban parameters in the simulation. High buildings delayed the sea breeze.



Fig 7 Temperature and precipitation field (left: URB(2090s-2010), right: VEG(2090s-2010))



Fig 8 Rainfall, convergence and Divergence fields



Figure 9 Temperature and precipitation field (left: 2090s(URB-VEG), right: 2010(URB-VEG))



Fig 10 Precipitation distribution on 17:00 and 18:00

In the future, rainfall distribution was similar for both URB and VEG. This suggests that in the future, rainfall will not be sensitive to urban areas. It is to be noted that so far comparisons in this study, urban conditions were not subjected to change between now and in the future. From 100-yr observation data, 3.2 K rise in temperature was observed in Tokyo, which is far larger than the global temperature increase. Real temperature and precipitation increase due to urbanization can be specified further in the future if modifications in urban conditions were also reflected in the future simulations.

3 Conclusion

In this study, global warming and urbanization effect to weather

were estimated using PGW coupled with the latest urban parameterization.

First Nagoya simulation, global warming and future land use scenario were considered. Future temperature and rainfall increased in a centralized urban future and decentralized urban future.

Second Kanto simulation, global warming and urbanization effects were considered using PGW and urban parameterization. In these results, current case simulation and observation data agrees in both temperature and precipitation fields. Global warming affects the temperature and precipitation distribution because of its influence to the convergence front of Kashima nada and Tokyo bay.

Urbanization increases and widens temperature distribution above urban areas. Current urban conditions will increase precipitation above the urban area due to the roughness generated by buildings. However, the effect of urbanization to rainfall in the future becomes less apparent.

Reference

- Sato, Tomonori, Fujio Kimura, and Akio Kitoh. *Journal of Hydrology* 333.1 (2007): 144-154.
- [2] McCarthy, Mark P., Martin J. Best, and Richard A. Betts. *Geophysical Research Letters* 37.9 (2010).
- [3] Yonetani, Tsuneharu. Journal of Applied Meteorology 21.10 (1982): 1466-1471.
- [4] Okano. Y., T. Ihara, Y. Genchi. Journal of Heat Island Institute International Vol.3 (2008): 22-33.
- [5] Hara. M., H. Kusaka, F. Kimura, Y. Wakazuki, 2010, Nagare, 29.5 (2010): 353-361
- Kusaka Hiroyuki, Masayuki Hara, and Yuya Takane. Journal of the Meteorological Society of Japan 90.0 (2012): 47-63.
- [7] Adachi, Sachiho A., et al. (vol 51, pg 1441, 2012). Journal of applied meteorology and climatology 51.11 (2012): 2074-2075.
- [8] Shimoju R., M. Nakayoshi, and M. Kanda, (2010). Journal of Hydraulic Engineering, JSCE, 54., pp349-354
- [9] Nakano, M. Nakayoshi, and M. Kanda, (2013). Journal of Hydraulic Engineering, JSCE
- [10] Kawase, Hiroaki, et al. Journal of Geophysical Research: Atmospheres (1984–2012) 114.D24 (2009).
- [11] Sato, Tomonori, Fujio Kimura, and Akio Kitoh. Journal of Hydrology 333.1 (2007): 144-154.
- [12] Varquez, Alvin C.G, Makoto Nakayoshi, and Takuya Makabe. Journal of Japan Society of Civil Engineers, (2014)

Development and Sustainable management of Construction Authorization Database for the World Heritage Site: Case of Department of World Heritage Luang Prabang, in Lao P.D.R.

Student Number: 13M18103

Name: Natsuko Sakanashi

Supervisor: Shinobu Yamaguchi and Jun-ichi Takada

世界遺産地域のための建築許可データベースの持続的運用と開発: ラオス人民民主共和国 ルアンパバーン世界遺産局のケース

坂梨 菜津子

ルアンプラバーン世界遺産局の建築許可業務を支援するため、建築許可データベースが開発 された。この研究では、建築許可データベース運用に対して生じている問題点を持続的運用の 観点から探ると伴に、改善・評価を行うことを目的とする。問題分析と適用可能技術の比較の 結果、データベースの改善が行われた。ユーザビリティーと管理の観点から評価を行い、デー タベースの管理・運用が日常業務として可能であることが確認された。

1 Introduction

Thanks to its outstanding universal values, town of Luang Prabang was inscribed as the first UNESCO World Heritage Site in Lao P.D.R in 1995. The inscription of world heritage site drew not only international attention and rapid tourism boom, but also unplanned expansion of development. Since 2003, Tokyo Institute of Technology (Tokyo Tech) and Department of World Heritage Luang Prabang (DPL) in Lao P.D.R., have been collaborating for strategic management of the world heritage site by introducing applicable Information and Communication Technology (ICT).

As one of such activities, database management systems were developed with reflecting local conditions. The implemented databases have five characteristics: 1) free and open source software (FOSS); 2) client server architecture; 3) Web-based interface; 4) choice of easyto-learn software; and 5) multi language support. One of the databases, the construction authorization database was created in 2007 to support the authorization process of construction permission [1].

However, it was found that the database encountered several problems in its sustainable use in 2013. This study intends to explore sustainable solutions for the construction authorization database.

2 Research background and research objectives

2.1 Implementation of construction authorization database

In order to support the authorization process of construction permission, the construction authorization database was developed in 2007. The authorization process is to give permission for the construction buildings in heritage conservation areas based on Heritage Preservation and Development Master Plan (PSMV). The authorization process directory impacts on the heritage townscape. In authorization section of DPL, large volume of documents and applications were stored in paper-based media, and they have difficulty in the management of these information. Enoki (2008, p.17) summarized the aim of construction authorization database as follows: [2]

- 1) Memorizing the processes to give construction permission based on authorization work
- 2) Preservation of authorization data as digital for long-term preservation and reduction of physical storage space
- 3) Providing searching and analysis processes for saving time to access information

In the field of cultural heritage preservation, database is commonly used for data archiving. World heritage site is managed and preserved under the heritage management plan and it is expected to follow its plan to keep the heritage inscription. Information related to authorizing renovation of architectural building is highly controlled and thus, only experts are allowed to be involved in managing such information. Therefore, the development of the database for cultural heritage is considered vital to manage accurate information and to be shared among professional concerned. This requires close cooperation between ICT engineers and cultural preservation experts. In DPL, the local ICT team members and construction authorization professionals have played major roles in constructing the database.

However, Okumura (2012) clarified the construction authorization database was not updated since 2009 [3]. Based on the analysis, two solutions were implemented. First, PHP was introduced as alternative of web application of Zope. The support of connecting function between Zope and PostgreSQL ended. Second, "Evernote" was introduced as knowledge management tool in order to access the difficulty of knowledge transfer. In spite of these efforts, through local discussion, interviews in the DPL in August 2013, it was found that the databases still had problems for its sustainable use. Implementation and management of the database is easy to fail without careful planning even in developed country. This study site is located in the least developed country. The issues, which this database was faced, had to be analyzed not only from the database management perspectives but also other perspectives. This research could be seen as the ICT and FOSS for development research. The characteristic difficulties of ICT (such as limited cost, human resources, and infrastructure) and those of FOSS for development project (such as requirement of high ICT skills, and poor user support) also had to been taken into consideration [4] [5].

2.2 Research objectives and significance

This study intends to explore sustainable solutions for construction authorization database. The following three objectives were set: 1) analysis and identification of problems of the current database based on literature reviews and local discussions; 2) development of applicable database reflecting the local context; and 3) evaluation of usability and management of the database.

The significance of this research can be explained by the following two points. First, efficient use of the database is able to enhance the preservation of the town of Luang Prabang. Second, this research is expected to contribute as an example of management of the database in the world heritage site in least developed country. The database is one of the major ICT tools employed in cultural heritage site. However, the management of the database is difficult even in developed countries. Previous research covers useful ICTs implementation, but few researches are available discussing database management for the world heritage site in least developed countries. This action-based research highlights important issues to be considered when developing and managing applicable database for world heritage preservation with reflecting local condition in the least developed country.

3 Methodology

The research processes are divided into the following five steps: 1) analysis of issues and needs; 2) identification of solutions; 3) database improvement; 4) evaluation; and 5) identification of issues for further improvement. Each process was corresponded to the action research methods which is a research being motivated to solve specific problem in the real world.

3.1 Analysis of the current issues and needs

The analysis of the current issues and needs of the database was carried out through literature reviews and local discussions between August 2013 and March 2014. The discussion and interview were conducted with the local ICT team members and authorization section members.

A series of analysis identified the following two problems. First, the database interface is complex. It requires too many types of information and time for data input, so users faced difficulty. Second, lack of knowledge and skills transfer was evident due to high mobility of human resources within the local team. Although the training for ICT use including database development was provided with total of 53.2 weeks from 2005 to 2007 [1], the team members were facing difficulty of transferring the knowledge and skill to new team members. Loss of training materials due to the failure of the hard disk drive in 2007 added more difficulties.

These issues clarified the specific needs to improve the database. First, simplification of data input process with user-friendly interface was required. This database is to be uploaded by authorization section staff members, who have less proficiency in English and ICT skills. Simple interface and Lao explanation especially for solving errors and explanations for data input were found vital. Second, training for database management was necessary. The skills of ICT team required were not up to its expectation to manage the database. The training was one of the important factors to empower management of database by local ICT team.

3.2 Identification of solutions

Based on the analysis, the possible solutions for easyto-use user interface were investigated. This process took three steps: 1) comparative analysis on potential solution; 2) developing prototype interface; and 3) conducting usability test with the prototype.

As a first step, the potential technologies providing user-friendly interface were identified. The possible technologies include introduction of new Microsoft Excel, Libre Office Base which is open source software for database management, and improvement of current Webbased user interface. For the comparative analysis, five perspectives were carefully considered reflecting local conditions for its sustainable use, namely, popularity among users, level of skills of local team, reusability of the current resources, level of ease of development, and cost of software. As a result, the modification of the current web-based user interface was identified as the best solution because of fully utilization of the current level of skills of local team and efficient use of the current resources.

Following the above result, the prototype web-based user interface was developed. The prototype was tested to assess its validity and usability. This prototype has basically same functions with the original one in terms of data input, search, and additional editing. However, this prototype had become simpler reflecting opinions of local staff members. Specifically, data inputting process was simplified with prioritizing collecting attributes from 41 to 10 with Lao language explanation.

A total of 23 cases of usability tests were carried out with the authorization section members. The tests clarified satisfying results, enabling to integrate the construction authorization database into their daily work. Users' evaluation proved that this database has become easier to input, search, and edit information. This prototype was appreciated since DPL staff members with less ICT experiences and English skills could also use the database to efficiently manage a large volume of data. At the same time, additional issues were found including needs for local language modification and better layout of web-based user interface.

3.3 Database improvement

Based on feedback collected through the testing of the prototype, the construction authorization database was improved by ICT team members after training. This process included 1) providing training for database management at the local site; and 2) database improvement.

The training for database management was organized in September and October 2014 for ICT team members. It was organized two hours per day for nine days in English and local Lao language. The contents included following items: 1) Linux OS usage and setting up of server; 2) database management system; 3) structure of Web-based interface which was written by HTML and PHP; and 5) Evernote software. In addition, training of Virtual Machine was also provided. It was considered as an option to make backups of server easier. Training participants installed Linux OS with VMware player on their computer running Windows OS. VMware player is popular commercial Virtual Machine software, but freely distributed. In each training session, handouts and sample source codes were distributed to the participants. Each function of program was understood by executing source codes by participants themselves. And also for the user of the database, staff member of authorization section, the introduction of basic technology used for the construction authorization database was provided.

After the training, database improvement was carried out for three days by local ICT team members. Based on the development of prototype interface and its usability test, the improvement processes were designed including the following three points. First, the original input form required to input too many attribute. It was necessary to prioritize important data. The number of attributes for data input was decreased from 41 to 10. Second, Lao language explanation were added and shown at the same page with English one. The necessary attributes and explanation sentences were translated into Lao language. Third, the user interface has pull down lists for easy data input. To further improve of the usability, the values in pull down lists were arranged in alphabet order.

4 Evaluation

Improved database was evaluated through the usability tests and case trials. The usability test was carried out with authorization section staff members. The case trials tests were performed to evaluate whether database improvement is able to be conducted by ICT team members.

4.1 Usability test

The usability test was conducted in October, 2014 to assess the user interface improved by local ICT team members. The participants were asked to perform the tasks namely, data input and searching with new user



Figure 1: Improved user interface



Figure 2: Original user interface

interface. Right after the usability test, interviews were organized to analyze users' point of view.

Through the usability test and interviews, the following three major advantages were found. First, needed time for data input was shortened. Previously, the time for data input took 30 minutes or more. However, with the improved user interface, an average was four minutes and three seconds. Second, all participants confirmed the searching function was easy to use. The people without high ICT skills can search and find the information easily. Third, it was mentioned Lao language explanation helped data input. Therefore, the staff members of authorization section decided to integrate the database into their daily work.

On the other hands, the issues were also identified such as existence of redundant values in pull down list, and inappropriate order of attributes in input form. Further review of the user interface was necessary. In addition, the user manual needed to be further improved to be able to identify necessary information at a glance.

4.2 Case trials

Case trials and interviews were conducted to evaluate whether the local ICT team members were equipped with skills to improve the construction authorization database reflecting participants' feedback. Three ICT team members were assigned two specific tasks of improving construction authorization database. First task was to change the order of one attribute in input form. Another task was to add the value in pull down list. These tasks were expected to receive continuous request by the users. To attain these tasks, the participants had to understand structure of Web-based interface, basic skills of PHP and HTML, Apache server application, database management system, and database tables.

Through the case trial test and interviews, the following three advantages were found. First, most of the team members were able to complete the required tasks. With this result, it is certain that the local ICT team would be able to improve the user interface as request arrives. Second, all participants mentioned that the training helped the participants to understand how to manage database. The staff member having no knowledge of database management also completed the task and was positive for management of the database after the training. Third, they all agreed that ICT team could improve and take backups of the construction authorization database. The participants were also eager to acquiring more skills and knowledge of the database.

At the same time the issues were clarified. The ICT team members were concerned about how to cope with unexpected errors. For the further sustainable management of the database, more experiences and training sessions are required. ICT team members did not utilize reference materials as expected. To promote better knowledge transfer, it is considered that enhanced knowledge management tool is necessary.

5 Discussion

Through the evaluations, following three advantages of improved user interface were identified.

First, improved user interface satisfied the authorization staff members because of its usability. The required time for data input was dramatically shortened. Easy search function was expected to enhance their daily work. In addition, the staff member having less proficiency of English and ICT skills could also utilize the database. Easy-to-use user interface enhances the use of the database and support the construction authorization process effectively. Second, the construction authorization database was highly accepted among users and managers. Authorization staff members decided to integrate the database into their daily work. ICT team members agreed with management of the database as their daily work. The DPL staff members participated in entire improvement processes, such as identification of issues and needs, and usability test. It was considered that the participation of the processes enhanced the acceptance and ownership of the database among users. Third, through the case trials, it was proved that ICT team members can improve the user interface and create backups by themselves as daily work.

At the same time, it has following three issues. First, ICT team members are concerned about how to deal with unexpected errors. They are not confident enough to face unfamiliar errors. For further sustainable management of the database, the training should be required. Second, the contribution of the training materials for solving lack of knowledge and skills transfer is limited. There is a tendency that the staff members do not refer to the materials. It is necessary to enhance the use of the materials and knowledge management tool, such as developing easy documentation, translation of documents,

reintroducing the benefit of the knowledge management tool. Third, improvement of manual for both manager and user was found necessary. The training materials for database management have to be reorganized for daily use. The user manual has to add more detailed information.

6 Conclusion

In this study, sustainable solutions for construction authorization database were explored. The database was created in 2007 to support the authorization process of construction permission. However, the database encountered the problem in its sustainable use.

Through the analysis of issues and needs of the database, following needs were identified: 1) simplification of data input process with user-friendly interface; and 2) organization of training for the management of the data. After the training for ICT team, improvement of the current user interface took place based on comparative analysis of the solutions and the prototype testing.

Through the evaluations, it was clarified that the improved user interface satisfied the needs of users of the authorization section. From the management point of view, ICT team members acquired basic skills for managing this database through training.

Construction authorization database is now to be integrated into their daily work to promote long-term utilization at DPL. Improved database has become applicable for local use. At the same time additional training opportunities are vital for the local professionals further to enhance their development.

References

- [1] Yamaguchi S. "Application of information and communication technology for promoting sustainable development of the world heritage site", Final research report for Grant-in-Aid for Scientific Research (A) in Grant-in-Aid for Scientific Research (KAKENHI), Fiscal year from 2005 to 2007, 2008.
- [2] Enoki S. "Application of information and communication technology in cultural world heritage site; case of luang prabang, lao PDR", Master's thesis, Tokyo Institute of Technology, 2008.
- [3] Okumura T. "Application of knowledge management system in development project: A case of world heritage site in luang prabang, lao P.D.R.", Master's thesis, Tokyo Institute of Technology, 2012.
- [4] Almamy Touray, Airi Salminen, Anja Mursu. "ICT Barriers and Critical Success Factors in Developing Countries", The Electronic Journal of Information Systems in Developing Countries, 2013, vol. 56, ISSN: 1681-4835.
- [5] Katim S. Touray. "Constrains against the adoption and use of FOSS in developing countries", Linux.com, 2004, [Online], Available: http://archive09.linux.com/feature/35055, (Accessed on January 7, 2015).

MODELING ADVECTION VELOCITY OF SURFACE TEMPERATURE FOOTPRINTS

Student Number: 13M18037 Name: Eiji IWATSUKA Supervisor: Manabu KANDA

表面温度フットプリントの移流速度のモデリング

岩塚 英治

TIV により推定される移流速度と、風速の関係についての理解は未だ不十分である.そこで本研究では、人工芝グ ラウンドにて、TIV 観測を実施した.その後、移流速度と風速の波形を比較した.また、移流速度と風速が線形関 係にあると仮定し、その比例定数が気象パラメータと如何に作用しているかを検討した.さらに、移流速度と多高 度で測定された風速値を比較し、移流速度がどの高度の風速と一致するのかを、気象場を考慮しながら検討した.

1 Introduction

Since the 1990's, rapid development of engineering technology such as computational resource and camera technique brought fluid visualization to the stage where quantitative evaluation can be executed. This impact soon brought extensive contribution to the meteorology field. For example, secondary vortex inside an urban canopy was investigated by Takimoto et al. [1] using PIV (Particle Image Velocimetry). Also, Yagi et al. [2] succeeded measuring turbulent structure 76.2 meters above sea level operating the Doppler lidar. However, outside observation measurement method for horizontal wind velocity distribution is currently still limited. PIV captures flow field of few meter scale, and Doppler lidar's measuring range is few hundred to thousand meters. In other words, method to observe turbulent scale of ten to one hundred meters is still problematic. Within this circumstance, TIV (Thermal Image Velocimetry) technique which is used in this paper can estimate two dimensional wind velocity using the thermal image, and can be the solution [3]. TIV was developed based on researches proposing estimation of wind field relating with surface temperature [4]. It observes excel at the lacking range mentioned above and has successfully contributed to wind estimation near building walls and dust devils [5]. Yet, there has been lack to quantitative discussion on relation between wind speed and advection velocity estimated from TIV. In this study, two-dimensional horizontal advection speed vector observed from thermal camera and wind speed measured by sonic anemometer will be compared. Along with this, new expertise will be given to the height where estimated TIV advection speed and measured wind speed matches (ZTIV).

2 Wind Velocity Estimation Theory Using TIV

Consider a case where the surface is heated and the temperature difference between air and surface is extreme. In this condition, active turbulent organized structure will develop near the surface. As it moves around with the wind flow, heat transfer between surface and air occurs, ending up with a non-uniform surface temperature distribution. This phenomenon is recorded using a thermal camera and capturing the surface brightness temperature image (Fig. 1(b)). Afterwards, by using the high-pass filter and removing



Fig. 1: TIV estimation flow. (a) Visible image of surface.(b) Brightness temperature image of surface. (c) Brightness temperature deviation image of surface. (d) Two-dimensional TIV velocity vector.

the effect of surface color patterns & surface reliefs, brightness temperature deviation is extracted (Fig. 1(c)). Applying the image correlation analysis to the extracted brightness temperature deviation pattern, advection velocity will be derived just like the PIV (Fig. 1(d)). Assuming advection velocity and wind near surface are in linear relationship, multiplying the proportionality constant will end up obtaining the two-dimensional TIV velocity vector. This will be the whole flow of TIV estimation.

3 Experimental Set-Up

The experiment was conducted at an artificial football field in Ti-Tech from September 2nd to 27th, 2013 during clear weather. Surface temperature data at 100Hz were captured by a FLIR SC5000 Thermal camera, which was mounted 49m above ground level (a.g.l.) at the building next to the field. Five sonic anemometers (Kaijo DA600 TR90AH) measured the turbulent velocity components (u,v,w) and the air temperature at 50 Hz at 0.15m, 0.30m, 0.60m, 1.2m, 1.6m a.g.l. inside the camera field-of-view. Total 19 datasets were obtained. Analysis was done by each



Fig. 2: Observation scenery. (a) Aerial photograph of observation site. Trapezoid indicates the shooting area of thermal camera. Sonic anemometer was set inside the circle and Thermal camera was set inside the red square. (b) Sonic anemometer. (c) Thermal camera. (d) Overview sketch of the observation.

observation data as units of 10 minutes. The observation scenery is exhibited in Fig.2.

4 Result

4.1 Spectrum Analysis

Fig. 3 shows spectrum of mainstream wind speed at height 1.6m, and mainstream direction component of TIV velocity. This result was obtained by first, measuring surface brightness temperature at 100Hz. After that, advection velocity of brightness temperature deviation pattern was estimated at 3.3Hz frequency. Next, moving average was taken at 5.0Hz and advection velocity was estimated. A broken and dashed line is noted at 3.3Hz and 5Hz, respectively. The solid line indicates spectrum model of a neutral surface boundary layer which was obtained from Kaimal et al. [6]. A precipitous energy drop can be seen in the frequency range higher than 3.3Hz. In addition, the spectrum is removed in the range higher than 5.0Hz.

Spectrum observed from sonic anemometer in this observation case well matched with Kaimal spectrum model. On the other hand, it didn't match with spectrum obtained from TIV. Mainly three characteristics were recognized from spectrum obtained from TIV velocity. 1) It clearly matched with the spectrum obtained from sonic anemometer in the low frequency domain. 2) Spectrum obtained from TIV velocity is underestimated in high frequency domain. 3) Spectrum obtained from TIV velocity is overestimated in intermediate frequency domain (0.10~1.0 area)



Fig. 3: Frequency analysis of mainstream wind velocity component. Spectrum obtained from mainstream wind speed measured by sonic anemometer is shown in red. Spectrum obtained mainstream direction component of TIV velocity is shown in blue.

4.2 Waveform Comparison between TIV Velocity and Wind Speed

Fig. 4 shows the comparison in one observation case at 0.20Hz sampling frequency. Focusing on the low frequency fluctuation, TIV velocity and wind speed roughly matched. The correlation coefficient between the two velocities were 0.61. On the other hand, focusing on small velocity fluctuation, TIV velocity included spike-like fluctuation which could not be identified in wind waveform. This intermittent spike-like noise well matches with the spectrum peak affirmed in intermediate frequency domain in Fig. 3.



Fig. 4: Waveform graph of velocity. Red line indicates TIV velocity. Blue line indicates wind speed observed from sonic anemometer. (a) Compared at u direction. (b) Compared at v direction.

4.3 Linear Relationship Established between TIV Velocity and near Surface Wind Flow

The fact that TIV velocity and wind speed holds a proportional relationship was known since this TIV method was developed. Theoretically, wind speed will be derived by multiplying the TIV velocity to proportionality constant. However, it is still not yet understood what kind of parameter the proportionality constant (Gradient) relies on. For the current stage, this is obtained by direct comparison of TIV velocity and wind speed.

This section will discuss the weather parameter effect on proportionality constant. Fig. 5 shows TIV velocity and wind speed each plotted at u direction and v direction within 10 minutes (intercept is set to 0). The colored and uncolored circle each indicates 0.017Hz and 0.20Hz sampling frequency. Proportionality constant (Gradient) was 0.72 in this 0.017Hz observation case. When the gradient value is smaller than 1 as shown in this graph, TIV velocity is relatively higher than the wind speed. When the gradient value is larger than 1, the two relation will become opposite.

The relation between proportionality constant (Gradient) and stability for all 19 observation cases in 0.017Hz sampling frequency is shown in Fig. 6. The graph shows that, as stability moves from unstable to near neutral, gradient also shifts from lower to higher value. Result of Fig. 6 can be explained from physical interpretation as below.

TIV velocity tracks the footprints of turbulent organized structures moving near the surface. Usually, when the stability of flow field becomes closer to neutral, buoyancy decreases, causing turbulent organized structures to break into pieces. Then, TIV will only track small turbulent organized structures which will relatively be slower compared to the wind speed (Fig. 7).



 $\begin{array}{c} 1.5 \\ 1.0 \\ 0.5 \\ 0.0 \\ 0.0 \\ 0.0 \\ 0.0 \\ 0.1 \\ 0.2 \\ 0.2 \\ 0.3 \\ 0.4 \\$

Fig. 6: Relation between proportionality constant (Gradient) and stability at 0.017Hz sampling frequency.



Fig. 7: Conceptual diagram of turbulent organized structure (Gradient<1 case). Red arrow indicates TIV velocity. Blue arrow indicates wind speed at height z.

4.4 TIV Velocity Height

Relation between TIV velocity and wind speed includes altitude dependency, which makes it difficult to evaluate with the meteorological parameters. Thus, in this section, we will obtain the height (ZTIV) where 10 minutes averaged TIV velocity and wind velocity matches. In the surface area, outside the buffer region, three-dimensional turbulent organized structures exist (Sott E. et al. [7]). Considering surface brightness temperature pattern as the footprints of turbulent organized structure which has characteristic of rigidbody motion, TIV velocity can be translated as center of gravity speed of the turbulent organized structure. So ZTIV, as defined above, can be interpreted as turbulent organized structure's center of gravity height.

Generally, based on Monin-Obukhov similarity theory, vertical wind speed profile holds logarithmic law. In this case, universal function (4.4.1) is enabled to use as the vertical wind profile model.

$$U = \frac{u *}{k} \Psi_M \tag{4.4.1}$$

 $\Psi_{M} = ln \frac{z}{z_{0}} + ln \frac{(x_{0}^{2} + 1)(x_{0} + 1)^{2}}{(x^{2} + 1)(x + 1)^{2}} + 2(tan^{-1}x - tan^{-1}x_{0})$

Fig. 5: Scatter plot of TIV velocity and wind speed. Colored and uncolored circle each indicates 0.017Hz and 0.20Hz sampling frequency.

$$x = \left(1 - 16\frac{z}{L}\right)^{1/4}, \quad x_0 = \left(1 - 16\frac{z_0}{L}\right)^{\frac{1}{4}}$$

Mainly three type of methods were tested to estimate zTIV. 1) Fitting in the vertical wind profile model equation (4.4.1) based on Monin-Obukhov similarity theory considering roughness length z_0 as constant value for all 19 observation cases. After this is done, z_{TIV} is estimated from inter section point of TIV velocity and model wind profile. 2) Fitting in the vertical wind profile model equation (4.4.1) based on Monin-Obukhov similarity theory considering roughness length z_0 as variable value for each observation case. After this is done, zTIV is estimated from inter section point of TIV velocity and model wind profile. 3) Consider a case when TIV velocity interpose between two observed wind speed points. Calculate the linear equation which passes through two observation wind speed points. After this is done, zTIV is estimated from inter section point of TIV velocity and the linear equation.

Relation of *z*_{TIV} estimated from the three theory above and stability is shown in Fig. 8. The graph of observed wind profile, TIV velocity, model wind profile from



Fig. 8: Relation between zTIV and stability. ZTIV obtained from method 1 is shown in red circle. ZTIV obtained from method 2 is shown in blue rhombus. ZTIV obtained from method 3 is shown in cross mark.



Fig. 9: Observed wind profile, TIV velocity, model wind profile from method 1, and model wind profile from method 2. (a) Highest stability case from Fig. 8. (b) Lowest stability case from Fig. 8.

method 1, and model wind profile from method 2 is shown in Fig. 9(a), (b) each for the highest and lowest stability case. Regardless of the zTIV estimation method, the Fig. 8 graph shows that, as stability moves from neutral to unstable, ZTIV value also shifts from lower to higher value. This result can also be explained from physical interpretation.

Mentioned above, ZTIV value indicates turbulent organized structure's center of gravity height. As the atmospheric stability becomes more unstable, buoyancy increases, which will cause the turbulent organized structure to stretch in longitudinal direction or the turbulent organized structure itself enlarges, ending up with high center of gravity height (Fig. 7).

5 Conclusion

In this research, horizontal surface wind speed distribution in an outdoor artificial turf football field were estimated from a TIV observation experiment that took place during sunny daytime in Sep. 2013. Two dimensional horizontal advection speed vector estimated from thermal camera and wind speed measured by 5 sonic anemometers were compared for all 19 observation cases, each as units of 10 minutes. Proportional relation was then confirmed in scatter plot of advection velocity estimated by TIV and wind speed observed by sonic anemometer. The proportionality constant (Gradient) had strong relation with the atmospheric stability. Also zTIV, the height where TIV velocity & wind speed matches were estimated using three different methods. Relation between zTIV and stability was elucidated.

Reference

[1] Takimoto K., Sato A., Onomura S., Kanda M.:'PIV Measurement of urban canopy turbulence – Intercomparison study between outdoor and indoor urban scale model', *Water engineering paper*, Vol53, 2009

[2] Yagi A., Takimoto K., Fujiwara T., Inagaki A., Fujiyoshi Y., Kanda M. "Estimation of circumferential velocity from observed radial velocity -- Velocity Image Velocimetry (VIV)', *Water engineering paper*, Vol68, 2012

[3] Inagaki, Atsushi, et al.: 'Thermal image velocimetry.' *Boundary-layer meteorology*, 149.1 (2013), pp1-18.

[4] Christen A. and Voogt J. A.: 'Linking atmospheric turbulence and surface temperature fluctuations in a street canyon', *The* 7th *International Conference on* Urban Climate, A3-6, 2009

[5] Inagaki A., Kanda M.: 'Application of Thermal Image Velocimetry for Measurement of near Surface Atmosphere Flows', *Nagare 32*, pp307-312, 2013

[6] Kaimal, J. C., et al.: 'Spectral characteristics of surface - layer turbulence', *Quarterly Journal of the Royal Meteorological Society*, 98.417, pp563-589, 1972

[7] Hommema, Scott E., and Ronald J. Adrian.: 'Packet structure of surface eddies in the atmospheric boundary layer.' *Boundary-layer meteorology* 106.1 (2003): pp147-170.

Estimation of the contained CO₂ emissions from the supply chain of Chinese manufacturing industry

Student Number: 13M18273 Name: Li Tianyue Supervisor: Shinya HANAOKA

中国における製造業サプライチェーンの内包型 CO2 排出量の推計

李 添悦

The excessive CO_2 emissions from manufacturing make China become the largest CO_2 emission country. The objectives of this study are to estimate direct and indirect CO_2 emissions from the supply chain of Chinese manufacturing industry sectors by regions, and to propose the effective solution to CO_2 emissions reduction. Moreover, 5 future emissions scenarios for power generation sector and smelting sector are created. The high-emission upstream sectors in supply chain are proved as the key for CO_2 reduction. Improvement of industrial volume of power generation resources are found as the most effective solutions.

1. Introduction

1.1. Background

Chinese economy develops rapidly since 1980s. During 2000-2014, the average GDP growth rate of China achieves 14.3%. Since 2010, China becomes the second largest economy in the world^[1]. As the side effect of economic boom, China's energy consumption increases rapidly, especially coal. China has been the largest CO₂ emissions country since 2010. At 2013, China expelled 10.3Gton CO₂, accounting for 26.4% of global CO₂ emissions^[2]. China's CO₂ emissions are not only a domestic problem but also a serious global issue. China announced to reduce CO₂ emissions from the upcoming peak no later than 2030, on the COP 20 in 2014.

Industrialization is the key contributor to China's economic growth. China is famous as "World Factory". Manufacturing accounts for 32% GDP since $2000^{[1]}$. Unfortunately, 31% of national CO₂ emissions is the side product of the developed manufacturing^[4]. It is impossible to reduce CO₂ emissions by decelerating the manufacturing development. In order to make CO₂ reduction compatible with economic growth, the mechanism of CO₂ emissions from manufacturing is necessary to be investigated.

1.2. Composition of CO₂ emissions

As illustrated in Fig.1, CO_2 emissions can be estimated by 2 ways, direct CO_2 emissions and indirect CO_2 emissions.

Direct CO_2 emissions of one company, company A for instance, refer to the CO_2 emissions from fuel combustion and industrial process on the production site of company A. But on the production site, company A will demand electricity power or heat, and purchased material or intermediate products from the other companies. In this case, the direct CO_2 emissions from producing the demanded production by company A are the indirect CO_2 emissions of company A. In a word, indirect CO_2 emissions can reveal what kind of demand-product relationships are there among the companies, and how they impact CO_2 emissions.



Fig.1 Supply chain of manufacturing industry

In the context of supply chain among different sectors, one sector demands material from upstream sectors, provides intermediate products to downstream sectors, and sells final products to consumers. Direct CO_2 emissions of this sector consist of the CO_2 emissions from producing both intermediate and final products. The contained CO_2 emissions of this sector are defined as the sum of direct CO_2 emissions from producing final products and indirect CO_2 emissions from all its upstream sectors.

1.3. Literature Review

He (2013)^[4] estimates China's national direct CO₂ emissions during 2000-2010, and direct CO2 emissions of different provinces during 2006-2010. However, He only estimates direct CO_2 emissions by sectors in 2010. Guo et al. $(2010)^{[5]}$ estimates the contained CO₂ emissions of 13 manufacturing sectors in China and America in 2005. The authors don't provide the data in other years, based on a more elaborate sector inventory. Weber et al. $(2008)^{[6]}$ gives contained CO₂ emissions data of 10 sectors in 1992, 1997, 2002 and 2005. The authors don't compare the contained emissions of different sectors, and don't discuss the relationship between sectors and CO2 emissions. Lin et al. $(2010)^{[7]}$ estimate the contained CO₂ emissions of 28 sectors in 1997, 2002 and 2007. Also, the authors estimate the contained emission of 30 provinces in 2002 and 2007. However, the authors don't consider the future emissions variation trend. Furthermore, all these previous studies don't use the newest Input-Output table (I-O table) in 2010 and estimate the future CO₂ emissions by sectors.

1.4. Study Objectives

This study aims to (1) estimate the contained CO_2 emissions by sectors in recent years for 30 provinces; (2) analyze the estimation results of (1), then find the emissions variation trend; (3) investigate the effect of governmental policy, technology innovation, and variation of production volume. Then, estimate the future CO_2 emissions to propose an effective approach to reduce CO_2 emissions.

So far, there are few previous studies concerning the contained CO_2 emissions. Especially, no one has ever analyzed it by sectors and by provinces. Moreover, this study originally estimates the future emissions of key sectors, by hypothesizing 5 scenarios for electricity generation sector and smelting sector. Based on the estimation results, a more detailed and realizable solution can be proposed for CO_2 emissions reduction.

2. Methodology

2.1. Database

There are mainly 3 available databases:

China Energy Statistical Yearbook (CESY) 2000-2010: Energy consumption statistics.

Intergovernmental Paned on Climate Change (IPCC) guideline: Lower heating value and carbon emissions factor.

National I-O tables 2000, 2002, 2005, 2007 and 2010: intermediate and final products of economic sectors in the nationwide scale

Regional I-O tables 2002, 2007: intermediate and final products of economic sectors in 30 provinces.

However, the categories of sector inventories in CESY and I-O tables are different. This study combines these two inventories to make a 16-sector inventory.

2.2. Direct Emissions Estimation

The direct CO_2 emissions can be estimated by the equation below^[8].

 $D_i = \Sigma q_{ik} \cdot j_k \cdot c_k \cdot o \cdot 44/12...$ Eq1 D_i : direct emissions of *i*-th sector, (ton-CO₂)

- *k*: coal, cokes, crude oil, kerosene, diesel, gasoline, natural gas, fuel oil^[8]
- q_{ik} : consumption *i* of k-th fuel, (t)
- $j_{k:}$ lower heating value of k-th fuel, (1000FJ/t)^[8]

 c_k : carbon emissions factor of k-th fuel, (t-C/1000GJ)^[8]

o: oxidation ratio (1.0 de-facto)^[8]

2.3. Contained Emissions Estimation

Contained CO_2 emissions of one specific sector can be estimated by using I-O tables and contained CO_2 emissions intensity.^[9]

I-O table is constructed on the simple idea that goods and services produced by economic sectors should be registered in a table by origin and by destination. Goods produced by economic sectors serve as inputs in other sectors in order to produce their final products also called outputs.

Table 1 Example of Input-Output table

Output	Intermediate Output	Final Output	Total	
Input	$[\mathtt{X}_1, \mathtt{X}_2 \cdots \mathtt{X}_1 \cdots \mathtt{X}_n]$	$[f_1, f_2 \cdots f_i \cdots f_n]$	Output	
Material consumption	AX	F	Х	
$[X_1, X_2 \cdots X_i \cdots X_n]$				
Gross Value added	N			
$[N_1, N_2 \cdots N_i \cdots N_n]$				
Total Input	Х			

X=AX+F OR $X=(I-A)^{-1}$Eq2 $d=[d_1,d_2,\ldots,d_n]$, where $d_i=D_i/x_i$...Eq3 $d_i:$ CO₂ emissions per output of sector i

 D_i : total CO₂ emissions of sector i

 $E=d \cdot X=d \cdot (I-A)^{-1}F$Eq4 E: total emissions of sector i

$$\begin{pmatrix} e_1 \\ \vdots \\ e_k \\ \vdots \\ e_n \end{pmatrix} = d^t (I - A)^{-1} \begin{pmatrix} f_1 = 1 & \cdots & 0 & \cdots & 0 \\ \vdots & 1 & \vdots & \vdots & \vdots \\ f_k = 0 & \cdots & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & 1 & \vdots \\ f_n = 0 & \cdots & 0 & \cdots & 1 \end{pmatrix} \qquad \dots \text{Eq5}$$

 e_i : contained CO₂ emissions intensity (t-CO₂/10k yen) $\sum_j x_{ij} e_i = E_j$Eq6

 E_j : contained CO₂ emissions of sector j

3. Estimation Result

This study estimates the direct CO_2 emissions for 16 manufacturing sectors in 2000, 2002, 2005, 2007 and 2010. Table 2 shows the 16-sector inventory, and Table 3 shows the inventory of the other industries.

	Tabl	le 2	Inventory	of mar	ufacti	ıring	industry	sectors
--	------	------	-----------	--------	--------	-------	----------	---------

Sector 1	Food products, beverages and tobacco
Sector 2	Manufacture of Textile
Sector 3	Manufacture of Textile, Wearing Apparel and Accessories, Leather, Fur, Feather and Related Products and Footwear
Sector 4	Wood and products of wood and cork
Sector 5	Pulp, paper, paper products, printing and publishing
Sector 6	Processing of Petroleum, Coking and Processing of Nuclear Fuel
Sector 7	Chemicals
Sector 8	Manufacture of Non-metallic Mineral Products
Sector 9	Smelting and Pressing of Metals
Sector 10	Manufacture of Metal Products
Sector 11	Manufacture of General and Special Purpose Machinery
Sector 12	Manufacture of Automobiles, Railway, Ship, Aerospace and Other Transport Equipments
Sector 13	Manufacture of Electrical Machinery and Apparatus
Sector 14	Manufacture of Computers, Communication and Other Electronic Equipment
Sector 15	Manufacture of Measuring Instruments and Machinery
Sector 16	Other Manufacture

	Table 3 Inventory of other industries
	Agriculture, Forestry, Animal Husbandry, Fishery and Water Conserva
	Mining and Washing of Coal
i.	Extraction of Petroleum and Natural Gas
1.	Mining and Processing of Metal Ores
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ncy

Sector iii.	Sector iii. Extraction of Petroleum and Natural Gas						
Sector iv.	Sector iv. Mining and Processing of Metal Ores						
Sector v. Mining and Processing of Other Ores							
Sector vi. Production and Supply of Electric Power and Heat Power							
Sector vii. Production and Supply of Gas							
Sector viii. Production and Supply of Water							
Sector ix.	Sector ix. Construction						
Sector x.	Sector x. Transport, Storage and Post						
Sector xi. Wholesale, Retail Trade and Hotel ,Restaurants							
Sector xii. Others							
3.1. Direct CO ₂ emissions							

As shown in Fig.2 the direct emissions keep increasing since 2000. From 2005, the growth rate becomes much faster. The direct emissions in 2010 have doubled that in 2000. During the same period, China's GDP keeps a high growth rate. In 2007, GDP growth rate is even 14%. From 2008, GDP growth rate drop to around 9%. This proves the rapid development of economy, especially that of manufacturing, is the main reason of increasing direct CO_2 emissions. Fig.2 shows that sector 6, 7, 8 and 9 cause much more CO_2 emissions than other sectors,

because these sectors consume much more coal than others.



Sector i

Sector i



3.2. Contained CO₂ emissions

3.2.1. Contained CO₂ emissions intensity

Fig.3 shows that contained CO_2 emissions intensity keeps decreasing since 2000. Technology innovation is supposed to be the main reason. The contained CO_2 emissions intensity of production and supply of electric power and heat power (sector vi) is much higher than other sectors. This sector consumes more fuel than other sectors, especially coal in China.

Sector 6, 7, 8 and 9 have very large contained CO_2 emissions intensity. Recall that these sectors dominate the national direct CO_2 emissions as shown in Fig.2. Since contained CO_2 emissions are composed of direct and indirect emission, their contained CO_2 emissions intensities are inevitably large.

Sector 10, 11, 12 and 13 also have large contained CO_2 emission intensity, as shown in Fig.3. However, they don't significant amount of direct CO_2 emissions. It implies that the indirect CO_2 emissions intensities of these sectors must be large. The reason is that their upstream sector, smelting sector, is a high-emission sector.

There are two reasons why there are some sectors having larger emissions intensity. The upstream sectors in the supply chain suffer from large direct CO_2 emissions intensity. On the other hand, the downstream sector suffers from large indirect CO_2

emissions intensity. In a short word, low-emission sector not only consumes small amount of fuel, but also demands small amount of raw material or intermediate products from those high-emissions upstream sectors.





Fig.3 Contained CO₂ emissions intensity by sectors in different year

Contained CO₂ emissions in the national scale 3.2.2.

Fig.4 shows that the contained CO₂ emissions of 16 sectors keep increasing during 2000-2010, even if the contained CO₂ emission intensities decrease. That's because the production volume increases much faster.

Sector 7 and 9 generate extremely large amount of contained CO₂ emissions. That's because these two sectors in China have excessive production volume. Therefore, they expel enormous amount of direct emissions, as shown in Fig.2. Moreover, the upstream sectors of sector 7 and 9 have large contained CO₂ emissions intensity, which will contribute a large amount of indirect emissions.

The contained emission of sector 6 and 8 are not as large as those of sector 7 and 9. However, Fig.3 shows that these two sectors also have large contained CO₂ emissions intensity. The reasonable exploration is that the production volumes are small. Thereby, a small amount of direct CO₂ emissions are expelled Moreover, their indirect emission benefit from low-emission upstream sectors.

Sector 11, 12, 13 and 14 are usually at the downstream of supply chain. They demand a large amount of materials from high-emissions upstream sectors, such as sector 9., direct and indirect emissions of these 4 sectors are both large due to the large production volumes. Thereby, their contained emission must be large.

It became clear that the contained emissions are determined by a lot of factors, such as the production volume, type of fuel, location in the supply chain, contained CO₂ emissions intensity from the upstream sector.



3.2.3. Contained emissions in the 30 provinces

According to Fig.5 (a) the provinces in the east coast of China have larger amount of contained CO2 emissions. That's because they have more developed manufacturing and larger production volume. In a word, the amount of contained emissions depends on the economic volume.



Fig.5 (a) Total contained CO₂ emissions from manufacturing in 30 provinces at 2002 and 2007(No data in Xizang)

Contained CO₂ emissions (104ton-CO₂)



Fig.5 (b) Contained CO₂ emissions of 16 sectors in 30 provinces at 2002 and 2007 (descending order by GDP in 2007)

As shown in Fig.5 (b) almost all 30 provinces double the contained CO₂ emissions from 2002 to 2007. The contained CO₂ emissions from sector 7 and sector 9 contribute a large emissions share in all 30 provinces. Particularly, sector 14 in Guangdong province has a significant amount of contained emissions. And sector 8 in Fujian province expels a large amount of contained CO2 emissions, compared with those provinces on the same GDP level. In short, the composition of contained emissions also depends on the economic structure.

4. Future CO₂ emissions estimation

This study aims to estimate the peak value of China's CO₂ emissions at 2030, as Chinese government announced in the COP 20 in 2014. This study also aims to estimate the CO₂ emissions at 2050 when CO₂ emissions go down from the peak value. In order to realize the targets, this study hypothesizes the 5 scenarios below.

4.1. **Scenario creation**

Scenario 1: assumes that China's manufacturing will maintain the current growth rate and structure. Meanwhile, it assumes that all the other factors, which affect the contained emissions, don't change. Based on the direct emissions statistics during 2010s, direct emissions can be approximated as a time-variant function. The direct emissions in 2030 and 2050 can thereby be estimated.

This study also estimates the I-O tables and contained CO₂ emissions intensity in 2030 and 2050 by RAS method ^[10], by using the I-O tables in previous 5 years. The estimated direct emissions and I-O tables will be used in the next 4 scenarios.

Scenario 2: This study then picks the power generation sector as subject, since it contributes indirect emissions in almost all other sectors. This study notices that although China relies heavily on coal, the power efficiency of coal lower than those of developed countries. Thereby, this study assumes that the power efficiency of coal will be improved to top level in the word. Then, this study uses the improved power efficiency of coal to estimate the future contained emissions. During the estimation, this study doesn't change the current composition of power generation.

Scenario 3: this study notices that the Chinese government is encouraging the development of green power. The current composition of power generation will change inevitably. This study estimates the refined composition of power generation in the future, then estimates the contained CO₂ emissions in 2030 and 2050. Note that the current power efficiency is still used in this scenario, which is different from scenario 2.

Scenario 4: this study then chooses smelting sector as subject. Smelting sector is well known as the bone of industry, which provides a significant amount of intermediate products and indirect emissions to other manufacturing sectors. Especially, the production volume of China's smelting sector is excessively large and the carbon emissions factor is not low enough. Aforementioned, smelting sector must be the key of CO₂ reduction. From the statistics in recent years, this study estimates the future production volume of smelting sector and carbon emissions factor, then estimates the future emissions.

Scenario 5: combines the assumptions in scenario 2, 3 and 4. This study estimates the future contained CO₂ emissions of smelting sector with a higher power efficiency of coal, less quantity of coal consumption and lower carbon emissions factor. 4.2.

Future CO₂ emissions Estimation Result

The estimation results of all 5 scenarios in 2030 and in 2050 are shown and compared in Fig.6.



Fig.6 Contained CO₂ emissions based on scenario

Clearly, the contained CO₂ emissions of every sector in 2050 are larger than those in 2030. Recall that this study assumes China's economy will maintain a high growth rate in scenario 1. In that case, China's GDP in 2050 will be much larger than that in 2030. Even if other factors are improved, it is too difficult to reduce total emission. Since scenario 1 assumes other factors are not improved, it is reasonable that scenario 1 has the largest amount of CO₂ emissions in all 5 scenarios.

With respect to scenario 1, the contained emissions are significantly reduced in scenario 2 and scenario 3. This reveals that improving of power efficiency of coal and varying power generation composition are very effective to reduce the contained CO₂ emissions.

In scenario 4, sector 9-14 expel less CO₂ emissions with respect to scenario 1, which means smaller production volume and better carbon emissions factor can reduce the contained emissions of smelting sector and its downstream sector. The effectiveness is limited however, if the emissions status of power generation sector doesn't improve.

In terms of CO₂ emissions reduction, scenario 5 is the best. That's because it makes full use of the advantages of scenario 2, 3 and 4. It is worth noting that many sectors only generate slightly more emissions in 2050 than in 2030. This implies that China can almost realize its goal by merely improving the contained CO2 emissions status of power generation sector and smelting sector.

Conclusions 5.

This study estimates the direct and contained CO₂ emissions for every key sector of China's manufacturing in the context of supply chain. It also estimates the future CO₂ emissions by hypothesizing 5 scenarios.

- (1) In the supply chain, those high-emissions upstream sectors, such as smelting sector and chemical sectors, bring more significant impacts on downstream sectors. These sectors should be lock as the key CO₂ emissions reduction targets.
- (2) The high-emissions upstream sectors take large share of total contained emissions in 30 provinces. The economic structure determines the composition of CO₂ emissions. Both the manufacturing volume and structure affect the regional contained CO2 emissions.
- (3) Improving the efficiency of fuel combustion and refining the composition of power generation can reduce contained emissions effectively. They can be the feasible solution to reduce CO₂ emissions in the future. As production volume is controlled in the reasonable range, the contained CO₂ emissions will drop from the peak value after 2030.

References

[1]The World Bank: Data-GDP growth http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG [2]European Commission: CO2 time series 1990-2013 per region/country

http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2013 [3] International Energy Agency: CO2 emissions from fuel combustion highlights, IEA, 2014

[4]He Y,(2013) Chinese energy carbon dioxide emissions control objectives and geographical distribution statistics, [D] [5]Guo j., Zou L.L., Wei Y.M.(2010) Energy Policy, 38, 1389-1397 [6]Weber C.L, Peters G.P, Guan D., Hubacek K. (2008) Energy Policy.36(9).3572-3577

[7]Lin N., Liang R.L., Shimazaki Y., Soma T.(2010) 4,327-337 [8]2006 IPCC Guidelines for National Geenhouse Gas Inventories [9] Nansai K., Kondo Y., Kagawa S., Suh S., Nakajima K., Inaba R., Tohno S.(2012) Environmental Science & Technology, 46(16), 9146-9154.

[10] 丸山佐和子(2009)ノンサーベイ・アプローチによる投入係 数の推計と検証,産開研論集第21号

CORROSION RESISTANCE OF STAINLESS STEEL IN CONCRETE AFTER LONG TERM EXPOSURE IN MARINE ENVIRONMENT

Student Number: 13M18149 Name: Tomohiro Nagata Supervisor: Nobuaki Otsuki

長期間海洋環境で曝露されたコンクリート中ステンレス鋼材の腐食抵抗性 永田 智大

海洋環境での鉄筋コンクリート構造物の使用を考えた際,激しい塩害に対してステンレス鋼材の使用が有効と考えられる が、ステンレス鋼材を使用したコンクリート構造物の長期耐久性は必ずしも明らかでない.このため、本研究では海洋環境 で約30年曝露されたコンクリートとプレストレストコンクリート供試体中ステンレス鋼材の腐食抵抗性と有効プレストレ ス力を評価し、ステンレス鋼材を用いたコンクリート構造物の長期耐久性を評価した.結果、ステンレス鋼材を使用した場 合、コンクリート構造物の潜伏期と進展期の合計期間は50年以上となり長期耐久性が向上すること、SUS430ステンレス鋼 材の腐食抵抗性がエポキシ被覆、Ni、普通鋼材より高くなること、曝露31年後のSUS304ステンレス PC 鋼材を使用した場 合の有効プレストレス力は普通 PC 鋼材を使った場合と同等か大きくなることがわかった.

1. Introduction

For the use of concrete structure in marine environment, severe steel corrosion due to chloride attack is serious. To reduce the risk of deterioration of concrete structure due to steel corrosion for long term, use of stainless steel can be effective. However the long term durability of concrete structure using stainless steel is not clear. Thus in this study corrosion resistance of stainless steel in concrete after long term exposure in marine environment is investigated and discussed to clarify long term durability of concrete structure using stainless steel.

To accomplish this objective, corrosion resistance of SUS430 stainless steel in concrete after 28 years' exposure in marine environment is investigated. Also, those of epoxy coated steel, Ni steel, and normal steel in the same specimen is investigated.

And effective prestress force and corrosion resistance of SUS304 stainless PC steel in prestressed concrete after 31 years' exposure in marine environment is investigated.

There may be few research about the corrosion resistance of stainless steel in concrete after such long term exposure in marine environment.

According to these objectives, in this study 3 examination items are set as shown below.

(1) Lifetime prediction of concrete structure using SUS430 stainless steel

(2) Investigation of corrosion resistance of SUS430 stainless steel through the comparison with those of other steels in concrete after 28years' exposure in marine environment

(3) Investigation of effective prestress force and corrosion resistance of SUS304 stainless PC steel in prestressed concrete after 31 years' exposure in marine environment.

2. Specimens

2.1 Used material

The following shows the materials used in this study.

As mixing water, tap water and seawater are used. As cement, Ordinary Portland Cement (OPC) and High Early Strength Portland Cement (HES) and Blast Furnace Slug powder (BFS) are used. As steel bars, φ 9mm SUS430 stainless steel bar, φ 10mm epoxy coated steel deformed bar, φ 9mm 3.5% Ni replaced steel bar and φ 9mm normal steel bar, φ 7mm SUS304 stainless PC steel bar, and φ 7mm normal PC steel bar are used.

2.2 Overview of specimens

In this study, two types of specimens are used.

(1)Concrete specimen

First one is concrete cylinder specimen (φ 150×300mm) made in 1986. Fig.1 shows the overview of this specimen. In this specimen, 3 steel bars are embedded with cover depth 7, 15, 30mm. And the bottom of this specimen is coated with epoxy resin. Mix proportion of specimens are shown as Table.1. And initial crack is induced to specimens embedded with SUS430 stainless steel, epoxy coated steel and Ni steel.

(2)Prestressed concrete specimen

Second one is prestressed concrete specimen $(150 \times 100 \times 920 \text{ mm})$ made in 1983. Fig.2 shows the over view of this specimen. This specimen was made with flexural crack in the center by loading tool. The anchors of PC steel in the edges of specimens are covered with mortar. Steel type of anchors is the same steel type of PC steel. Mix proportion of specimens are shown as Table.2. And initial prestress force of PC steel is 65kgf/mm2.

These specimens have been exposed in seawater tank which emulates tidal zone.

	Steel type			Unit content[kg/m ³]				$[L/m^3]$		Classic	A 1.	
No		Water type	e W/C	W	OPC	BFS	S	G	AE water reducing agent	Water reducing agent	flow [cm]	Air content [%]
1			0.47	154	270		849	1062	3.2	0.4	7.5	4.3
2			0.48	153	320		795	1078	3.7	0.6	7.8	4.0
3			0.46	148	208	112	783	1094	3.7	0.7	7.6	3.9
4		Тар	0.46	147	144	176	773	1102	3.7	0.8	8.2	3.9
5		water	0.46	147	96	224	761	1110	3.7	0.8	8.6	4.2
6	Normal steel		0.46	146	144	176	768	1110	3.7	0.7	8.0	4.0
7	Normai steer		0.45	145	96	224	759	1118	3.7	0.8	7.4	3.7
8			0.46	146	144	176	753	1126	3.7	0.6	8.0	4.4
9			0.49	158	320		774	1094	3.7	0.7	8.8	4.1
10		Sea	0.48	152	144	176	750	1102	3.7	0.8	8.1	4.6
11		water	0.48	152	96	224	741	1118	3.7	0.9	8.5	4.2
12			0.47	151	144	176	732	1142	3.7	0.8	7.4	4.0
13		Тар	0.48	153	320		795	1078	3.7	0.6	7.8	3.8
14	SUS430 stainless steel,	water	0.46	147	144	176	773	1102	3.7	0.8	8.1	4.2
15	Epoxy coated steel,	See	0.49	158	320		774	1094	3.7	0.7	7.9	4.4
16	Ni steel	water	0.48	152	144	176	752	1118	3.7	0.8	8.3	4.0
17		water	0.46	146	144	176	768	1110	3.7	0.7	7.6	4.2

Table.1 Mix proportion of cylinder concrete specimen

Table.2 Mix proportion of prestressed concrete specimen

Steel Type	Water	W/C	Unit content[kg/m ³]				$[L/m^3]$	Slump	Air	Initial crack
	Туре		W	HES	S	G	AE	flow	content	width [mm]
Normal PC steel	Тар	0.45	160	356	802	1029	1.6	5.9	4.8	0.1, 0.2, 0.3
SUS304 stainless PC steel	water									

3.Experimental results and discussion

3.1 Lifetime prediction of concrete structure using SUS430 stainless steel

In this section, lifetime of concrete structure using SUS430 stainless steel with cover depth 50mm is predicted. In this study, lifetime of concrete structure is defined as shown in Fig.3. To predict these lifetime, chloride ion diffusivity, corrosion threshold chloride ion contents for initiation period, and corrosion rate for propagation period are investigated.

(1)Chloride ion diffusivity and corrosion threshold chloride ion content

To clarify chloride ion diffusivity and corrosion threshold chloride ion content, chloride ion content with cover depth 7, 15, 30mm in concrete specimens No13 with SUS430 stainless steel and No15 with SUS430 stainless steel are investigated. Evaluation method is conform to JIS A 1154. Table.3 shows the result. In tables "OPC tap water" means No13 with SUS430 stainless steel, "OPC seawater" means No15 with SUS430 stainless steel, and by using these data, chloride ion diffusivity is evaluated. Evaluation method is conform to JSCE-G 572. And the equation is used Fick's diffusion



Fig.1 Overview of concrete specimen



Fig.2 Overview of prestressed concrete specimen

equation as shown in Eq.1

 $C(x,t)=C0(1-erf(x/2\sqrt{-}Dc^*t)+Ci Eq.1$ (C: Amount of chloride ion content (kg/m3), x: depth from the exposed surface (mm), t: exposure time (year), C0: Amount of chloride ion content at concrete surface Ci: Initial density of chloride ion content in concrete (kg/m³)Dc: Chloride ion diffusivity coefficient (cm²/year),erf: error function)


Fig.3 Lifetime of concrete structure

Table.3 Chl	oride ion	content in	each o	cover (dep	th
-------------	-----------	------------	--------	---------	-----	----

	Chloride ion	Chloride ion	Chloride ion
	content in 7mm	content in	content in
	covering	15mm covering	30mm covering
	depth[kg/m3]	depth [kg/m3]	depth [kg/m3]
OPC tap water	-	18.4	13.8
OPC seawater	17.6	11.8	-

Table.4	Chloride ion	diffusivity

	Chloride ion	Chloride ion
	content on the	diffusivity
	surface[kg/m ³]	[cm ² /year]
OPC tap water	23.5	1.9
OPC seawater	21.3	0.9

Table.5 Lifetime prediction

Spaaiman	Initiation	Propagation	Lifetime
specifien	period[year]	period[year]	[year]
OPC tap water	25~60	22	58 02
OPC seawater	35~85		30~93

Table.4 shows the chloride ion diffusivity of each specimen.

And in this study corrosion threshold chloride ion content is defined as 13.8~18.4 kg/m³ in OPC tap water, and 11.8~17.6kg/m³ in OPC seawater because SUS430 stainless steel in investigated specimens have corroded.

By using these data, duration that chloride ion content in concrete at 50mm from the surface reaches corrosion threshold chloride ion content is calculated as initiation period of concrete structure using SUS430 stainless steel.

(2) Corrosion amount which makes crack and corrosion rate

To clarify corrosion amount at the beginning of crack, Tottori diagram as shown in Eq.2 is used, and corrosion amount which makes crack is defined as 55.5mg/cm².¹)

Wcr=
$$10(c/\phi)$$
 Eq.2

(Wcr: amount of corrosion product at the beginning of steel corrosion(=55.5mg/cm²) c:cover depth(=50mm), φ:diameter of steel bar(=9mm))

To clarify corrosion rate, corrosion amount of SUS430 stainless steel which is most corroded in OPC specimens is



Fig.4 Frequency distribution of corrosion area



Fig.5 Frequency distribution of maximum corrosion depth of steel in concrete

Table.5 Rate of crack, average corrosion area, and average maximum corrosion depth

	Rate of crack due to steel corrosion[%]	Average corrosion area[%]	Average maximum corrosion depth[mm]
SUS430 stainless steel	0	4	0
Epoxy coated steel	23	12	-
Ni steel	17	6	0
Normal steel	47	26	0

predicted from corrosion depth. And corrosion amount divided by exposure span is defined as corrosion rate. In this study, corrosion rate is defined as 1.7 year/mg.

By dividing corrosion amount which makes crack by corrosion rate, propagation period of concrete structure using SUS430 stainless steel is obtained as 33 years.

(3)Lifetime prediction

Table.5 shows lifetime obtained in this study. In this study lifetime is defined as sum of initiation and propagation period.

From this table initiation period of concrete using SUS430 stainless steel is 25~60 years, and 35~85 years. Propagation period is about 33 years, and lifetime is over 50 years. Generally it is considered that lifetime of concrete using normal steel is about 40 years. Thus use of stainless steel can improve the long term durability of concrete structure.

3.2 Corrosion resistance of SUS430 stainless steel in concrete

In this section corrosion resistance of SUS430 stainless steel in concrete specimen is investigated. To clarify corrosion resistance, corrosion area, corrosion depth, crack of concrete due to steel corrosion are evaluated with image analysis, depth of focus method, visual investigation

(1)Frequency distribution of corrosion area

Fig.4 shows the frequency distribution of corrosion area of steel in concrete. This figure shows corrosion area of SUS430 stainless steel concentrates 0%. On the other hand, corrosion area of other steels spread from low level to high level

(2)Frequency distribution map of maximum corrosion depth

Fig.5 shows the frequency distribution of maximum corrosion depth of steel in concrete. This table shows that maximum corrosion depth of SUS430 stainless steel concentrates below 2mm. On the other hand, corrosion area of other steels spread from low level to high level.

(3)Crack of concrete due to steel corrosion and

Table.5 shows the rate of crack, average corrosion area and average maximum corrosion depth of each steel. This table shows there is no crack in specimens with SUS430 stainless steel and average corrosion area and maximum corrosion depth is smaller than those of other steels. These results show that corrosion resistance of SUS430 stainless steel in concrete is higher than those of other steels in concrete specimen.

3.3 Effective prestress force and corrosion resistance of SUS304 stainless PC steel in prestressed concrete

In this section effective prestress and corrosion resistance of SUS304 stainless PC steel are investigated. To clarify effective prestress and corrosion resistance, effective prestress, corrosion area, corrosion depth are evaluated with loading test and steel cutting method proposed by Niitani², image analysis, depth of focus method.

(1)Effective prestress force

By loading test and steel cutting method, effective prestress of SUS304 stainless PC steel in prstressed concrete is evaluated. According to these test, Average residual ratio of effective prestress force of SUS304 stainless PC steel in prstressed concrete specimens is evaluated as 70%. On the other hand, residual ratio of effective prestress force of normal PC steel is 54%. This result shows residual ratio of effective prestress force of SUS304 stainless PC steel is higher than that of normal PC steel.

(2)Corrosion resistance

Table.6 shows the corrosion area and maximum corrosion depth of each specimen. This table shows that corrosion area and maximum corrosion depth of SUS304 stainless PC steel

Table.6 Corrosion area and maximum corrosion depth

Steel type	Initial crack width[mm]	Corrosion area[%]	Maximum corrosion depth[mm]
SUS304	0.1	5.9	0.2
stainless	0.2	0.7	0.3
PC steel	0.3	2.3	1.4
Normal DC	0.1	27.9	0.9
steel	0.2	38.2	0.6
51001	0.3	19.7	0.7

in prstressed concrete is smaller than that of normal PC steel except the case of initial crack width 0.3mm.

These results show that residual ratio of effective prestress force of specimens using SUS304 stainless PC steel is higher than that of normal PC steel, and average corrosion resistance of SUS304 stainless PC steel is higher than that of normal PC steel except one specimen.

4.Conclusions

In this study the following conclusions are obtained

(1) Corrosion starting period of reinforced concrete using SUS430 stainless steel with cover depth 50mm is predicted as 25~60, 35~85 years, and crack starting period due to steel corrosion is predicted as over 50 years. This period is much longer than general lifetime of that using normal steel.

(2) In the case of concrete after 28years' exposure in marine environment, no crack due to steel corrosion exists in concrete with SUS430 stainless steel, on the other hand crack due to steel corrosion exists in specimen using epoxy coated steel, Ni steel, normal steel. And average corrosion area and maximum corrosion depth of SUS430 stainless steel is smaller than those of other steels. These results show corrosion resistance of SUS430 stainless steel is higher than those of other steels in concrete after long term exposure in marine environment.

(3) In prestressed concrete after 31 years' exposure in marine environment, effective prestress force of specimens using SUS304 stainless PC steel is higher than that using normal PC steel. And average corrosion area of SUS304 stainless PC steel is smaller than that of normal PC steel. But one of the SUS304 stainless PC steel corrodes hard. This phenomena should be investigated in the future.

References

- S. Tottori (2002). Lifetime estimation of concrete structure based on exposure test about steel corrosion in concrete, Doctor Thesis in Kyoto University,2002
- [2] Niitani Kyoji, Watase Hiroshi, Sakata Kenji, Ayano Katsunori: Study on Effective Stress Estimation Method for Concrete Members, Concrete Reseach and Technology, Vol. 20, No.2, pp.27-37, 2009.5

Development of Numerical Model Evaluating Ground Scour behind Coastal Dykes due to Tsunamis

Student Number: 13M18132 Name: Shouhei NAGASE Supervisor: Hiroshi TAKAGI

気液二相津波解析-地盤洗掘連成モデルの構築と現地海岸堤防への適用 永瀬 翔平

津波による堤防の破壊やその背後での洗掘のメカニズムはこれまで十分に解明されておらず,また現地スケールに適 用可能な解析モデルは確立されていない.本研究では既存の流体モデルに地盤洗掘モデルを新たに組み込み,水理模型実 験及び現地の被害状況と比較してその妥当性を検討した.その結果,いくつかの課題は残っているものの,浮遊砂量算定 の係数を調整することで最大洗掘深を精度良く再現できることを示した.

1. Introduction

The 2011 Great East Japan Earthquake and Tsunami caused the devastation of sea dykes, execrated by overflow and scouring behind the structure. Through this experience, the Committee for Technical Investigation on Countermeasures for Earthquakes and Tsunamis of Cabinet Office emphasized that coastal protection facilities need to be further resilient so that a moderate structural performance which contributes to a reduction in tsunami impacts could be sustained even after the dyke has been partially failure. In order to put this into practice, it is necessary to understand failure processes of sea dykes due to a complex mechanism of tsunami overflow and scouring.

In many studies, the failure processes of dykes have been speculated by an investigation through the field investigation. Although small scale hydraulic model experiments to study scouring around dykes have been conducted, a large scale experiment equivalent to actual size has not been made by any research group yet. Regarding the numerical model reproducing scouring, most of the models proposed by other researchers were verified by comparing the results with the phenomenon observed in a small scale model experiment, without further comparison with a large scale model or an extensive scouring around an actual dyke.

The present research investigated failure processes of sea dykes due to a complex mechanism of tsunami overflow and scouring by the field investigation at Ishinomaki City. A numerical model that evaluates scouring behind dykes was developed by using a gas-liquid two-phase numerical analysis, and it was compared with the scouring observed through the field investigation.

2. Field Investigation

The authors conducted a field investigation in Ishinomaki City and measured the scouring depth and elevations around the dyke using a high-precision GPS and leveling staff. The scouring depth reached up to 1.15m, and the hole width was measured at 11.5m at the east side behind the dykes. 4 different failure patterns of dykes appeared:

A) Slab (2.25m width \times 10m long \times 0.25m thick) rotated and backwall (1m height \times 10m long \times 0.25m thick) fell down

B) Slab moved without rotation and backwall fell down

C) Slab moved without failure of the backwall

D) Slab and backwall remained intact

Scouring depth and width around the dykes at the west side of the coast appeared to be shallower than that at the east side. This implies that the incoming tsunami varied in height and direction at different locations even in the same coast.



Fig.1 Extensive scouring behind the dykes at Minamihama, Ishinomaki



Bed material was composed of sands with diameter ranging between 0.5 and 1mm and gravels between 2 and 4mm.

3. Flow characteristics around dykes

In order to understand flow characteristics around dykes when tsunami overflowed, a gas-liquid two-phase numerical analysis and tsunami propagation simulation were performed.

3.1 Tsunami propagation simulation

Delft3D Flow (Ver.3.42) based on a non-linear shallow water equation was applied to the simulation of tsunami propagation from the deep sea to shallow water.

Table.1 Calculation Setting

Item	Outline	ž <u>Central</u> 0100km
Calculation	(a)540m(b)180m	Myagi
area	(c)60m(d)20m	
Time sten	(a)~(c)0.02min	
T into Stop	(d)0.005min	
Tide level	T. D. 10.0	
condition	1.P.+0.0m	
Computation	2011/3/11 14:46:00	
time	~ 16:30:00	
	Input data was	4 * 1 / 100
	created by linearly	Tukushima a
Boundary	interpolating the	Fig 2 Computational damaina
condition	observed tsunami	Fig.5 Computational domains
	elevations at two	point A: East side behind the dykes
	locations	point B: 120m seaward of the dykes
Water level (m)	calculation water mark	point B-WL (m) point B-y direction velocity (m/s) point A-velocity angle(deg) point B-velocity angle(deg) 10 6 10 6 10 6 10 7 10 10 10 10 10 10 10 10 10 10 10 10 10

(i) Comparison calculation value with observed water mark at point A Fig.4 Result of tsunami propagation simulation

3.1.1 Tsunami overflowing the dyke

Fig.4 (i) indicates that the calculation shows a good agreement with the observed tsunami height nearby the dyke. Fig.4 (ii) shows that the tsunami approached almost normal to the dyke (the positive angle is defined as clockwise from 0 degree that aims at the north).

3.1.2 Influence of tsunami reflection from a hillside

Mt. Hiyoriyama is located at about 800m landward of the dyke, likely caused tsunami reflection from its hillside. Fig.6 shows the comparison of tsunami overflow between 2 cases: Case 1 is the actual topography and Case 2 is a hypothetical topography deleting the hill. In Fig.6, both water level and velocity change differently after 15:44:30 between "with" and "without", indicating the influence of reflected tsunami.





Fig.6 Flow condition behind the dyke comparison between 2 topographical cases, with and without the Mt.Hiyoriyama

3.2 Assessment of the dyke failure

An assessment was made to identify how completely the dyke and the ground were damaged and scoured. To do so, ANSYS FLUENT (Ver.15.0) was applied to investigate the tsunami overflow passing the sea dykes for two cases: A: without scouring, B: with scouring of which shape is the same with the cross-section measured by the authors (Fig.2).

Table.2 Calculation Settings f	for vertical 2D	simulation
--------------------------------	-----------------	------------

Computational grid	20cm	
Computation time	Start:2011/3/11/15:39:00	
Computation time	End:2011/3/11/15:44:30	
Time step	0.005sec	
	Water surface elevation at	
Boundary condition	the offshore boundary	
	(See Fig.4(ii))	
Pagia equation	Navier-Stokes equation,	
Basic equation	Continuity equation	
Turbulence model	Standard k- ε	
Free surface analysis	Volume of Eluid Mathad	
model	volume of Fluid Method	



Fig.7 The slab rotation or lift up condition

Fig.7 shows that the concrete slab will not be turned over by the tsunami overflow if without the scouring behind. Given these results, it can be assumed that the dyke was damaged by the tsunami as follows:

1) scouring behind the dyke occurred due to the overflow,

2) as a result of extensive scouring, the backwall turned over,

- 3) erosion beneath the dyke occurred, and
- 4) the slab was rotated by the uplift force

Fig.8 shows the development of turbulent eddies behind the dyke. The second eddy, which appeared when the scouring progressed to some extent, is considered to accelerate instability of the structures.

Table.3 Case Settings

Case	Outline
Case A	No scouring
Case B	Scouring had generated until reflected tsunami arrived



Fig.8 The position of turbulent eddy moving

4. Scouring calculated by previous models

Noguchi et al. (1997) (Eq.1) and Dehghani et al. (2010) (Table.4) derived the relation of scouring depth(ε) and flow condition based by small scale hydraulic model experiments. In order to estimate scouring depth in Ishinomaki, overflow water level and velocity calculated in the previous section were used. However, it was founded that both methods could overestimated scouring depth.

Table.4 Dehghani et al.

	U	
Froud number	h_1/h	ε/Η
0.058 < Fr < 0.076	0.25	0.7
0.058 < Fr < 0.076	0.4	1
0.078 < Fr < 0.093	0.35	0.7
0.078 < Fr < 0.093	0.45	0.8
0.096 < Fr < 0.137	0.5	0.7
0.096 < Fr < 0.137	0.8	1

 $Fr = U/(gh)^{1/2}$, U: velocity, h: dyke height, h_1 : overflow depth, $H = h + h_1$, g: gravity acceleration, $q = Uh_1$

5. Development of numerical model evaluating ground scour

In the present research, a numerical model evaluating ground scouring was developed, and the model accuracy was compared with the model experiment conducted by Hatogai et al. (2012). Finally, the model was applied to reproduce the actual scouring behind the dyke in Ishinomaki.

5.1 Outline of numerical model

The scouring is calculated by Eq.2, using a flexible mesh for the uncovered ground behind the dyke.

$$\frac{\partial z}{\partial t} = \frac{1}{1 - \lambda} \left(\frac{\partial q_B}{\partial x} + q_s - C w_s \right) \cdots \cdots \cdots (\text{Eq. 2})$$

 q_B : bed load, q_s : suspended load, C: suspended sediment concentration, w_s :fall velocity

A conceptual diagram of this model is shown in Fig.9. N and N + 1 indicates the number of neighboring cells. Using the definition in Fig.9, Eq.2 can be re-written as Eq.3. Amount of bed and suspended load, q_B and q_s respectively, can be calculated by Eq.4 presented by Takahashi et al. (2011). In addition, this model includes modification of ground level gradient caused by slope failure, which reshapes the ground to an equilibrium profile.



Fig.9 Conceptual diagram of scouring model

$$\begin{aligned} \frac{\partial z_i}{\partial t} &= \frac{1}{1 - \lambda} \left(\frac{q_{B_{N+1}} - q_{B_N}}{\delta x} + \frac{q_{s_N} + q_{s_{N+1}}}{2} \\ &- \frac{C_N w_{s_N} + C_{N+1} w_{s_{N+1}}}{2} \right) \cdots \text{(Eq. 3)} \\ q_B &= 2.6 \tau_*^{1.5} \sqrt{(s-1)gd^3} \\ q_s &= 1.6 \times 10^{-5} \tau_*^{2} \sqrt{(s-1)gd} \\ \end{aligned}$$

 τ_* : Shields number, *s*: specific gravity of bed material, *d*: diameter of one, δx : distance between neighboring cells

5.2 Model verification with hydraulic model experiment

It was identified that scouring depth could be greatly influenced by the coefficients used in the model. In particular, a coefficient(*a*), which determine amount of suspended load, appears to be one of the dominant factors. Hence, the coefficient was examined in the range of between 2.0×10^{-4} and 5.0×10^{-4} to find a number that best describes the scouring observed in the model test. Consequently the coefficient of $a = 2.0 \times 10^{-4}$ was selected. Fig.10 shows the numerical results with this coefficient along with the model result. Fig.10 also shows that the modification considering slope failure improves the estimation of the ground profile particularly in terms of the location at which the maximum depth appeared.



5.3 Application of the model to coastal dykes in Ishinomaki

Bed materials in Ishinomaki have various diameters. which could result in increasing bearing capacity of Therefore, slope failure will not the soil. instantaneously take place in an actual ground unlike the case of the hydraulic model test. In consideration of this, the analysis for the case of Ishinomaki did not consider the modification of slope failure. It was assumed that bed materials have uniform diameter (0.6mm) in this analysis. The results with the different values of the coefficient *a* is shown in Fig.11. This result indicates that the proposed model could estimate the scouring depth at a reasonable accuracy, though there still remains a number of a drawback. One of the drawbacks is that the scouring immediately behind the backwall tends to be underestimated. This could occur due to inflexibility of the computational grids between the solid grids (structure) and the flexible grids (soil). The usage of more detailed mesh or a gridless analysis such as particle method simulation could contribute to solve this problem, though these methods will pose enormous time and

calculation resource for the simulation.



Case I, Case II, Case III and Case IVare adopted 2×10^{-4} , 3×10^{-4} , 4×10^{-4} , 5×10^{-4} as the coefficient(*a*) respectively.

6. Conclusion

In this research, the following results were obtained.

1) Mechanisms of sea dykes destruction

The failure processes of the sea dykes in Ishinomaki were revealed. The investigation by the field survey and simulation suggests that the turbulent eddy, which appeared when the scouring progressed to some extent, could accelerate instability of the structures.

2) Numerical model evaluating ground scour

The numerical model evaluating ground scour behind coastal dykes due to tsunamis was developed. The proposed model could estimate the scouring depth at a reasonable accuracy, though there still remains a number of a drawback.

7. References

- 野口賢二,佐藤槇司,田中茂信 (1997):津波 遡上による護岸越波および前面洗掘に大規 模模型実験,海岸工学論文集,Vol.44, pp.296-300.
- [2] Dehghani, A.A., Bashiri, H., and Meshkati, S.M.E. (2010): Local scouring due to flow jet at downstream of rectangular sharp-crested weirs, WATER AND GEOSCIENCE 2010, 5TH IASME WSEAS, pp.127-131.
- [3] Takahashi, T., Kurokawa, T., Fujita, M. and Shimada, H. (2011) : Hydraulic Experiment on Sediment Transport due to Tsunamis with Various Sand Grain Size, J.JSCE, Ser.B2, Coastal engineering, Vol.67, No.2, pp.231-235.(in Japanese)
- [4] Hatogai, S., Suwa, Y. and Kato, F. (2012) : Hydraulic model experiments on scour landward of the coastal dike induced by tsunami overflow, J.JSCE, Ser.B2, Coastal engineering, Vol.68, No.2, pp.406-410.(in Japanese)

Phenol Removal by Activated Carbon Using Physical Activation Derived From Exhausted Coffee Grounds

Student Number: 13M18020 Name: Junki IKUTAME Supervisor: Hirofumi HINODE

コーヒー抽出残渣由来活性炭の製造とフェノール除去能

生田目 純希

コーヒー抽出残渣は食品廃棄物であり、コーヒー抽出残渣を炭酸ガス賦活させた活性炭は、ミクロ孔が発達した構造となり、その比表面積は1,303 m²/g であった。コーヒー抽出残渣由来活性炭は、液相からのフェノール除去に非常に効果的であり、Langmuir 型吸着等温式から算出される最大吸着量は、他の文献値を上回る556 mg_{phenol}/g_{cathon}を示した。さらに、100 mg_{phenol}/L フェノール溶液からの除去実験における平衡濃度は3.12 mg_{phenol}/L であり、水質汚濁防止法に定められた排水基準値5 mg_{phenol}/L を満たした。

1 Introduction

Coffee is a very popular beverage in many parts of the world and the second largest commodity in the world after petroleum. Moreover, green coffee trade transaction has been on an upward trend since 1995. Approximately 6,700 kilo tonnes of consumable coffee were exported in 2011^[1]. The extraction process of coffee often generates significant amounts of exhausted coffee grounds (ECG) which represent approximately 50% of the total input mass of coffee feedstock^[2]. Nevertheless, utilization of ECG as a fuel source and as animal feed is restricted due to its high moisture content and chemical composition^[3]. Hence, the effective utilization of ECG needs to be developed.

Approximately 95% of the consumption amount of phenol (C₆H₅OH) have been used for chemical synthesis in Japan^[4]. Discharged wastewater containing phenol from these chemical industries significantly affects the pollution of public water and sewage^[5]. Since phenol concentration in aqueous solution has to be controlled to 5 mg/L or less according to Water Pollution Prevention Law in Japan, it is necessary to remove phenol by some water treatment before releasing the wastewater to environment. Various techniques have been used for phenol removal. Especially, adsorption process is the simplest, the quickest, the most efficient and the most economical alternative for removing phenol^[6]. Among the adsorbents, activated carbon has highly developed porosity, internal and external surface area and it has high removal efficiency towards aromatic compounds such as phenol^[4].

In spite of this, commercial activated carbon is still considered as expensive material in many countries due to the use of non-renewable and relatively expensive raw material (i.e. coal and wood). Therefore, they are environmentally unfeasible for most pollution control applications^[4].

It has been shown by many researchers that lignocellulosic materials, such as coconut shell can become effective raw materials for the preparation of activated carbon^[8]. However, compared to the total amount of coconut and green coffee that Japan had imported in 2011, green coffee was imported approximately 3,000 times as much as coconut^[1]. Due to this reason, more ECG wastes are generated in Japan and therefore, it is more available as a raw material to produce activated carbon.

For these reasons, their use as a raw material for the activated carbon has emerged as a potential alternative for cost reduction and solution for the waste disposal as well. The objectives of this study are to convert ECG into useful activated carbon and to investigate its performance for phenol removal in water matrix.

2 Experimental

2.1 Material

The ECG were donated by the beverage compan y in Shizuoka Prefecture, Japan and ECG with a par ticle size in the range of 1.0 - 2.0 mm were used a s a raw material for preparation of activated carbon. The organic elements (i.e., carbon, hydrogen, nitrogen,

oxygen and sulfur) analysis of the ECG sample wa s conducted using elemental analyzer (Vario EL, Ele mentar).

2.2 Preparation of Activated Carbon

Activated carbon was prepared with different preparation temperature following this procedure: ECG with a particle size in the range of 1.0 - 2.0 mm were loaded in a horizontal mullite tube placed in a tubular furnace (EPKR-12K, ISUZU). Before pyrolysis, the reactor was purged with pure nitrogen gas for 15 min at a rate of 150 mL/min. Pyrolysis was carried out to obtain the biochar at 800°C with a heating rate of 10°C/min under pure nitrogen flow of 150 mL/min. Upon reaching the desired temperature, it was kept for 1 h before switching the gas from N₂ to CO₂ for activation for another 1 h. After switching the gas, physical activation started to obtain the activated carbon at 800°C under CO₂ flow of 150 or 300 mL/min. After physical activation, they were cooled down under pure nitrogen flow, washed with hot deionized water only or 1 N HCl in order to remove inorganic matter and dried at 110°C overnight. After HCl washing, they were washed extensively with deionized water until the pH of the washing solution reached 6.5 - 7. The prepared activated carbon were crushed, sieved and classified into 0.6 - 1.0 mm. The preparation conditions of AC800-1, AC800-2 and AC800-3 is displayed in Table 1.

Table 1 Preparation conditions for AC800-1, AC800-2 and AC800-3

Activated Carbon	Temperature [°C]	CO ₂ flow rate [mL (STP) / min]	Washing
AC800-1	800	150	Deionized water
AC800-2	800	300	Deionized water
AC800-3	800	300	1 N HCl

2.3 Characterization

The surface morphologies of the activated carbon were observed by scanning electron microscope (SEM, VE-8800, KEYENCE).

Nitrogen adsorption-desorption isotherm at 77 K was determined in Autosorb-1 MP (Quantachrome Instruments). Using the Brunauer-Emmett-Teller (BET) equation, data from the isotherm was used to determine the BET specific surface area (S_{BET} [m²/g]). The total pore volume (V_{total} [cm³/g]) were estimated on the basis of the liquid volume of nitrogen adsorbed at the highest relative pressure ($P/P_0 \sim 0.99$). The micropore volume (V_{micro} [cm³/g]) were obtained by the α_s -plot method ($P/P_0 = 0.40$) and mesopore volume (V_{meso} [cm³/g]) was calculated from the difference between V_{total} and V_{micro} .

commercial granular activated carbon (CAC) manufactured by Wako Pure Chemical Ind., Ltd. ,which was crushed, sieved and classified into 0.6 - 1.0 mm before the above mentioned characterization, was also used for comparison.

2.4 Phenol Removal Test

Special grade reagent phenol (Wako Pure Chemical Ind., Ltd.) was used to prepare the phenol aqueous solutions. All phenol removal tests were carried out in amber polypropylene containers of 250 mL by adding 0.1 g of the activated carbon in a 100 mL phenol aqueous solution with various initial concentrations (50 - 2500)mg_{phenol}/L) and placed on a reciprocal shaker at 70 rpm until achieving equilibrium at room temperature without pH adjustment. An aliquot of the aqueous solution was sampled at various time intervals and the phenol concentration was determined using an ultraviolet-visible spectrophotometer (UV-Vis, UV-1800, Shimadzu) at $\lambda =$ 270 nm. Solutions with concentration higher than 250 mg/L were determined by dilution. CAC which was crushed, sieved and classified into 0.6 - 1.0 mm before the above mentioned tests was also used for comparison.

The adsorbed amount of phenol ($q_e [mg_{phenol}/g_{carbon}]$) was calculated by the following Eq. (1):

$$q_e = \frac{(C_i - C_e)V}{m} \quad (1)$$

where, C_i is the initial phenol concentration [mg_{phenol}/L]; C_e is the equilibrium phenol concentration [mg_{phenol}/L]; V is the volume of the aqueous solution after phenol removal test [L]; m is the mass of the activated carbon [g_{carbon}]

In this study, equilibrium adsorption data were fitted to Langmuir isotherm model. The assumption of Langmuir isotherm model is as follows^{[9][10]}:

- 1. All the adsorption sites are equivalent and adsorption occurs through the same mechanism.
- 2. Adsorbed molecules do not interact.
- 3. The enthalpy of adsorption is independent of how much have been adsorbed amount.
- 4. The surface has a specific number of sites where the solute molecules can be adsorbed.
- 5. The adsorption involves the attachment of only one layer of molecules to the surface (i.e. monolayer).

The linear form of Langmuir model can be expressed by Eq. (2):

$$\frac{C_e}{q_e} = \frac{C_e}{X_m} + \frac{1}{X_m K_e} \quad (2)$$

where, X_m is the maximum adsorption capacity $[mg_{phenol}/g_{carbon}]$; K_e is adsorption equilibrium constant $[L/mg_{phenol}]$

3 Results and Discussion

3.1 Characterization of ECG

The elemental analysis in Table 2 revealed the high contents of carbon and low contents of ash in the ECG.

_	Table 2 Elemental composition of ECG [g/100 g-dry]										
	С	Н	0	Ν	S	Ash					
	53.98	7.46	35.53	2.05	0.18	0.80					

The microstructure of AC800-3 and CAC are shown in Figure 1. The presence of heterogeneous pore structures was dominant and randomly distributed on AC800-3. Although the morphological characteristic of AC800-3 is similar to AC800-1 and AC800-2, that of CAC were significantly different compared to AC800-3 because of different raw material and activation method.



Figure 1 SEM micrographs of (a) AC800-3 (b) CAC

	Ave. Pore Size [Å]	S _{вет} [m²/g]	V _{total} [cm ³ /g]	V _{micro} [cm³/g]	V _{meso} [cm ³ /g]	V _{micro} / V _{total} [%]
AC800-1	20.4	851	0.372	0.355	0.017	95.4
AC800-2	20.8	1061	0.550	0.443	0.107	80.5
AC800-3	21.3	1303	0.694	0.548	0.146	79.0
CAC	17.6	1713	0.775	0.690	0.085	89.0

Table 4 Porosity	properties	of the	activated	carbon
	properties	or une	ucuvucu	curoon

Table 4 represents the porosity properties of AC800-1, AC800-2, AC800-3 and CAC. AC800-3 showed much higher values of S_{BET} , V_{total} and V_{micro} than AC800-2 and AC800-3. However, CAC showed the higher values among the activated carbon. Table 4 also revealed that they mainly consisted of a microporous structure.

3.3 Result of Phenol Removal Test



Figure 2 Effect of contact time on removal of phenol

Figure 2 illustrates the plot of residual concentration of phenol in solution versus the contact time with the adsorbents at the initial concentration of 100 mg_{phenol}/L.

Although CAC showed higher and faster removal performance than AC800-3, AC800-3 made the phenol concentration at equilibrium (3.12 mg_{phenol}/L) satisfy the environmental permissible limit which is 5 mg/L or less.



Figure 3 Langmuir isotherms of phenol removal

The adsorption isotherms of phenol onto AC800-3 and CAC are described in Figure 3. As initial concentration increased, the difference of concentration at equilibrium between AC800-3 and CAC was increased.

Table 5 shows the parameters of Langmuir isotherm model on AC800-3 and CAC. As shown in Table 5, the values of maximum adsorption capacity (X_m) of AC800-3 and CAC are 556 mg_{phenol}/g_{carbon} and 909 mg_{phenol}/g_{carbon}, respectively.

The maximum adsorption capacity values, X_m , reported in literature for phenol removal on different adsorbents are represented in Table 6.

Table 5 Paramiters of Langmuir Isotherm mode	Table 5 I	Paramters of	of Langm	uir isothern	n model
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	X_m [mg _{phenol} /g _{carbon}]	K _e [L/mg _{phenol}]	R ²
AC800-3	556	0.0198	0.998
CAC	909	0.0094	0.987

The best material for phenol removal reported in literature was activated carbon derived from macadamia nut shell. However, the maximum adsorption capacity value of AC800-3 is much higher, which can be associated to its higher surface area and highly developed micropore structure.

Table 6 Summary of maximum adsorption capacity values of phenol on different adsorbents reported in literature

Adsorbent	Maximum adsorption capacity [mg _{phenol} /g _{adsorbent}]	References
ECG activated carbon	556	This study
Macadamia activated carbon	341	[11]
Organobentonite	333	[12]
Rattan sawdust activated carbon	149	[13]
Avocado activated carbon	90	[3]
Coconut shells activated carbon	34	[14]

4 Conclusions

The ECG has great potential to be used as a raw material in the preparation of activated carbon by CO_2 activation. AC800-3 made the phenol concentration at equilibrium (3.12 mg_{phenol}/g) satisfy the environmental permissible limit which is 5 mg/L or less when initial concentration is 100 mg_{phenol}/L. The maximum capacity of AC800-3 was found to be 556 mg_{phenol}/g_{carbon} from Langmuir model equation. The results above clearly indicate that AC800-3 acted as a highly efficient adsorbent for the removal of phenol from water matrix.

References

- [1] FAOSTAT (URL: http://faostat3.fao.org/)
- [2] Adriana S. Franca, Leandro S. Oliveira, Mauro E. Ferreira. "Kinetics and equilibrium studies of methylene blue adsorption by spent coffee grounds". *Desalination*, 249(1), 2009, pp. 267 - 272
- [3] Wen-Tien Tsai, Sii-Chew Liu, Ching-Hsiang Hsieh "Preparation and fuel properties of biochars from the pyrolysis of exhausted coffee residue". J. Anal. Appl. Pyrol., 93(2012), pp. 63 - 67
- [4] 化学物質の初期リスク評価書 Ver 1.0 No.32. NEDO (New Energy and Industrial Technology Development Organization). 2005 年11 月発行.
- [5] PRTR (Pollutant Release and Transfer) information plaza Japan. Ministry of the Environment

(URL: http://www.env.go.jp/chemi/prtr/risk0.html)

- [6] Liana Alvares Rodrigues, Maria Lucia Caetano Pinto da Silva, Manoel Orlando Alvarez-Mendes, Aparecido dos Reis Coutinho, Gilmar Patrocinio Thim. "Phenol removal from aqueous solution by activated carbon produced from avocado kernel seeds". *Chem. Eng. J.*, **174**(2011), pp. 49 - 57
- [7] B.H. Hameed, F.B.M. Daud. "Adsorption studies of basic dye on activated carbon derived from agricultural waste: Hevea brasiliensis seed coat". *Chem. Eng. J.*, 139(1), 2008, pp. 48 - 55
- [8] Mohamed L. Sekirifa, Mahfoud Hadj-Mahammed, Stephanie Pallier, Lotfi Baameur, Dominique Richard, Ammar H. Al-Dujaili. "Preparation and characterization of an activated carbon from a date stones variety by physical activation with carbon dioxide". J. Anal. Appl. Pyrol., 99(2013), pp. 155 – 160
- [9] Amrita Vishwa Vidyapeetham Virtual Lab (URL: http://amrita.vlab.co.in/)
- [10] P. W. ATKINS. "28. 固体表面の過程". アトキンス 物理化学(下). 東京化学同人, 2006, pp. 932 - 935 (第6版 第7刷)
- [11] Liana Alvares Rodrigues, Loriane Aparecida de Sousa Ribeiro, Gilmar Patrocínio Thim, Rafael Reinaldo Ferreira, Manoel Orlando Alvarez-Mendez, Aparecido dos Reis Coutinho. "Activated carbon derived from macadamia nut shells: an effective adsorbent for phenol removal". *J. Porous Mater.*, **20**(2013), pp.619 - 627
- [12] H.B. Senturk, D. Ozdes, A. Gundogdu, C. Duran, M. Soylak. "Removal of phenol from aqueous solutions by adsorption onto organomodified Tirebolu bentonite: equilibrium, kinetic and thermodynamic study". J. Hazard. Mater., 172(2009), pp. 353 - 362
- [13] B.H. Hameed, A.A. Rahman. "Removal of phenol from aqueous solutions by adsorption onto activated carbon prepared from biomass material". *J. Hazard. Mater.*, **160**(2008), pp. 576 - 581
- [14] K.P. Singh, A. Malik, S. Sinha, P. Ojha. "Liquid-phase adsorption of phenols using activated carbons derived from agricultural waste material". *J. Hazard. Mater.*, **150**(2008), pp. 626 - 641

*E-mail: ikutame.j.aa@m.titech.ac.jp,*Phone: 03-5734-3245

Synthesis of Zeolites from Lake Sludge Using Microwave Heating Method and Their Applications as Adsorbent

Student number: 13M18209 Name: Wenjing WANG Supervisor: Hirofumi HINODE

マイクロ波加熱法による湖沼汚泥由来ゼオライトの合成及び吸着材への応用

王 文静

霞ヶ浦は富栄養化が進み堆積汚泥の浚渫が行われているが、従来の埋め立て処理法は埋立地の減少と 軟弱地盤の形成などの問題をもたらしている。本研究では、廃棄物となった湖沼汚泥から吸着機能やイ オン交換性能をもつゼオライトを合成し、堆積汚泥の処理問題を解決し、更に湖沼汚泥を廃棄物未利用 資源として利用し水質を浄化できる再生資源を合成する。ゼオライト合成にマイクロ波を用いて、合成 時間、ゼオライトの特性及び重金属イオンの除去効果に対する影響について検討した。

1. Introduction

Lakes are important sources of fresh water, however contaminants and nutrient salts are easily accumulated because of the closed water systems and human activities around the lakes. One of the most effective methods used to rehabilitate lakes is dredging the sludge. For resource protection, the method of recycling should be considered. According to previous study, lake sludge which contains silica and alumina can be used as raw material to synthesize zeolites by alkali hydrothermal synthesis method^[1]. Zeolites are considered as good cation exchange materials and having good adsorption ability. They are used for heavy metal ions removal in recent years^[1].

The heating method of zeolite synthesis can be done by convection oven or microwave oven. Microwave heating belongs to dielectric heating, an internal heating method. The object to be heated is the heating element during heating. When it is put in the electric field of the microwave, molecules (permanent dipole) are subject to the radio forces. Molecules in electrical neutral state are displaced and polarized. They will vibrate violently according to the frequency of microwave. (In the case of 2450 MHz, 2.45 billion times/sec.)

The advantages of using microwave heating are that the output is easy to control, only 10 min is required to ramp to the target temperature, and after heating, cooling down is done automatically.

Lead ion is a typical heavy metal ion. High toxicity of lead can damage neurological, biological and cognitive functions, especially that of children. Lead poisoning can cause a high degree of intelligence and attention decline, and also affect the growth, vision and athletic ability. High content of lead ion in body can cause anemia and brain and viscera damage, but also lead to coma, convulsions and even death.

There are 23 million people die of lead poisoning worldwide each year. In China, there are several villages in Henan, Yunnan, Shaanxi, and Hunan provinces suffering heavy lead pollution^[2].

In this research, lake sludge was used as the raw material for zeolite synthesis using microwave heating, and the resulting zeolites were applied for lead ion removal, and the performance was evaluated.

2. Experimental

In this study, the sludge from Kasumigaura Lake in Ibaraki prefecture was used. The sludge was dried, crushed and sieved ($-150 \mu m$), and then dried again at about 100°C for 24 hours.

For zeolite synthesis, Box-Behnken design^[3] an optimization method using fewer experiment sets compared to the conventional one, was used to optimize the synthesis condition. The responses in Box-Behnken design are values of cation exchange capacity (CEC). The center run of this design is the synthesis condition we assume to be the optimal one.

In this research, the center run chosen was the one showed the highest CEC value in the previous result, which is NaOH concentration of 2M, temperature of 120° C and Si/Al molar ratio of 1.9.

Synthesis of zeolites

Lake sludge (1.6 g) was treated in different NaOH solution concentration (1, 2 and 3 M, each 8 ml in volume) and put in a Teflon reaction vessel. The mixture is mixed by magnetic mixing for 24 hours or ultrasonic mixing for 3 hours. Afterwards, the teflon vessel was put into a microwave oven and heated at 90°C, 120° C or 150° C for 5 hours. Afterwards, the zeolites were washed with deionized water and dried at 60° C.

Characterization of zeolites

After synthesis, the main phase of zeolite is studied by X-ray diffraction (XRD), morphology is observed by Scanning Electron Microscope (SEM) and cation exchange capacity is measured by Chapman method utilizing Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES)

CEC measurement

Sodium acetate method is used to measure the capacity of exchanging Na^+ to NH_4^+ . Sodium acetate and ammonium acetate solution are used. The concentration of each chemical is 1 mol/L. First do the adsorption of Na^+ for 4 times, in order to make sure all the adsorption sites are filled by Na^+ . Then 99.7% 2-propanol solution is used to wash the sodium ion not adsorbed. After washing, ammonium acetate is used to exchange sodium ion.

Lead ion removal experiment

 $Pb(NO_3)_2$ was used to prepare solution for Pb^{2+} removal experiment. The concentration of $Pb(NO_3)_2$ solutions were adjust from 50 ppm to 600 ppm with volume of 50 ml. The amount of zeolite was 0.05 g.

pH of each Pb(NO_3)₂ solution - zeolite mixture is kept at 5.0 \pm 0.2.

Results and discussion 3.1 XRD analysis and CEC values

According to the XRD analysis, we can know the main phases of zeolites synthesized at different alkali concentrations, temperatures, and Si/Al molar ratios. After optimizing the CEC value using Box-Behnken design, the optimal synthesis condition was obtained.

Table.1 Main phase and CEC values of products obtained using various alkali concentrations, temperatures, and Si/Al ratios

			Magnetic mixing 24 hours			Ultrasonic mixing 3 hours			
¥1	¥2	V2	Main	CEC	Predicted	Main	CEC	Predicted	
~1	~2	~3	phase	CEC	CEC	phase	CEC	CEC	
0	0	0	P1, U,	223.3	234.3	P1. Q	247.5	233.3	
(2M)	(120°C)	(1.9)	Q			, =			
0	0	0	P1, U,	245.9	234.3	P1, Q	237.3	233.3	
(2M)	(120°C)	(1.9)	Q						
0	0	0	P1, Q,	233.8	234.3	P1, Q,	215.2	233.3	
(2M)	(120°C)	(1.9)	U	200.0	201.0	U	210.2	200.0	
1	1	0	F	02.2	67.0	U, A,	145.2	124.1	
(3M)	(150°C)	(1.9)	г,	02.3	07.0	P1, Q	143.5	134.1	
1	-1	0				U, Q,			
(3M)	(90°C)	(1.9)	U, Q,	135.1	109.6	P1	153.3	131.5	
-1	1	0							
(1M)	(150°C)	(1.9)	A,	39.5	64.9	A	26.9	48.7	
-1	-1	0							
(1M)	(90°C)	(1.9)	P1, Q,	152.5	167.8	Q, P1	75.9	87.0	
0	1	1	P1, A,						
(2M)	(150°C)	(2.5)	F,	172.3	166.8	A, P1	68.9	95.6	
0	1	-1							
(2M)	(150°C)	(1.3)	F、P1,U	133.4	128.7	U, P1	155.0	117.7	
0	-1	1							
(2M)	(90°C)	(2.5)	P1, Q	202.1	206.8	P1, Q	94.2	131.5	
0	-1	-1	P1, U,						
(2M)	(90°C)	(1.3)	Q	228.7	234.2	Q, P1	144.2	117.5	
1	0	1	U, P1,			P1, Q,			
(3M)	(120°C)	(2.5)	Q	170.0	190.8	U	205.5	190.0	
1	0	-1	U, P1,						
(3M)	(120°C)	(1.3)	Q	158.9	1/8.8	U	121.1	169.6	
-1	0	1	24.0			A, P1,			
(1M)	(120°C)	(2.5)	P1, Q	232.1	212.2	Q 149.0		100.5	
-1	0	-1	P1, Q,			U, Q,			
(1M)	(120°C)	(1.3)	U	234.3	213.5	P1	113.5	129.0	

Unit of CEC is meq/100 g.

P1: Zeolite P1(Na) – Na₆Al₆Si₁₀O₃₂ · 12H₂O

A: Analcime-C – Na(Si₂Al)O₆ \cdot H₂O

U: Unnamed zeolite – $Na_6[AISiO_4]_6 \cdot 4H_2O$ F: Faujasite-Na – $Na_{14}AI_{12}Si_{13}O_{51} \cdot 6H_2O$

Q: Quartz

The predicted CEC results are calculated from the Box-Behnken design. From this optimizing model the optimal synthesis condition in the case of magnetic mixing 24 hours was NaOH 1.81 M, temperature 109°C, and Si/AI molar ratio 1.3, while the optimal synthesis condition in the case of ultrasonic mixing 3 hours was NaOH 2.31 M, temperature 119°C, and Si/AI molar ratio 1.9.

CEC values were 191.5 meq/100 g and 215.2 meq/100 g, respectively.

In this research, the zeolite showed the highest CEC of 247.5 meq/100 g is zeolite P1(Na) which is synthesized under the condition of NaOH 2 M, 120°C, and Si/Al molar ratio of 1.9 after ultrasonic mixing for 3 hours.

Comparing to the previous result, using microwave heating method, the formation of zeolite P1(Na) was improved. It showed higher CEC than the one synthesized by conventional heating method which showed CEC of 171 meq/100 g. And it is far higher than the commercial zeolite with CEC of 160 \sim 190meq/100 g^[5].

3.2 Morphology of zeolites

The surface images of each type of zeolite were observed by Scanning Electron Microscope (SEM). In this research, 4 types of zeolites are synthesized using microwave heating method.

Fig (a) The SEM image of zeolite P1(Na)(The particle size is about 4μ m).

Fig (b) The SEM image of Unnamed zeolite(The particle size is too small to detect the particle size by SEM).

Fig (c) The SEM image of Faujasite Na(very small particle size).

Fig (d) The SEM image of Analcime C(The particle size is about $17 \mu m$).



Fig 2. SEM images of 4 types of zeolites

3.3 Lead ion removal performance

Determination of removal time was done using 300 ppm, 100 ml of Pb(NO₃)₂ and 0.1 g of zeolite P1(Na) which showed the highest cation exchange capacity.



Fig 3. The effect of removal time

Figure 3 shows that 24 hours is needed to achieve equilibrium.

Langmuir adsorption isotherm

In order to calculate the maximum of removal amount, Langmuir adsorption isotherm was used. Langmuir equation is as follow:

$$Q_e = Q_m \cdot \frac{kC_e}{1+kC_e} \cdot \cdots \cdot \cdots \cdot \mathsf{Eq(1)}$$

And linear equation of Langmuir isotherm is as follow:



Fig 4. Linear plot of Langmuir isotherm

 C_e stands for the equilibrium concentration (ppm) of Pb²⁺ in removal experiment; qe stands for the experimental equilibrium removal amount (mg/g); Qe is the theoretical Langmuir removal amount (mg/g); and Q_m stands for the theoretical isotherm saturation capacity (mg/g).

The plot of experimental data (fig4.) shows that this Pb²⁺ removal experiment fit the Langmuir adsorption isotherm very well with $R^2 = 0.9993$. The theoretical maximum removal amount is 322.6 mg/g, which is much higher than the zeolite

P1 (Na) synthesized by conventional heating method at 55.3 $\mbox{mg/g}^{[1]}$

Figure 5 shows the Langmuir isotherm of synthesized zeolite P1(Na).



Fig 5. The Langmuir isotherm curve

The experimental data fit the Langmuir curve very much.

Dubinin-Astakhov adsorption isotherm

Dubinin-Astakhov adsorption isotherm is usually used to evaluate the adsorption performance from aqueous solutions. By this adsorption isotherm, the maximum adsorption amount and adsorption energy can be calculated.

The equations and parameters are as follows:

$$\varepsilon = R \cdot T \cdot \ln\left(\frac{C_s}{C}\right) \cdot \cdots \cdot \operatorname{Eq}(3)$$

$$q = q_0 \cdot \exp\left[-\left(\frac{\varepsilon}{\sqrt{2E}}\right)^2\right] \cdot \cdots \cdot \operatorname{Eq}(4)$$

$$\ln q = \ln q_0 - \left(\frac{1}{\sqrt{2}E}\right)^2 \cdot \left[R \cdot T \cdot \ln\left(\frac{C_s}{C}\right)\right]^2 \cdot \left[\text{Eq(5)}\right]$$

ε: The adsorption potential (J/mol)

Cs: Initial concentration (mg/L)

- C: The equilibrium concentration(mg/L)
- T: Temperature (K)
- R: Ideal gas constant (J/mol · K)

 $\sqrt{2}$: A correction factor for the adsorption energy q: The amount of a given adsorbate in the

adsorbent under equilibrium conditions (mg/g)

q₀: The maximum amount of the adsorbed species per unit of sorbent (mg/g)

E: The adsorption energy (J/mol)

Eq(5) is the linear form of Dubinin-Astakhov equation. Fig 6 shows the linear plot based on experimental data.



Fig6. Linear plot of Dubinin-Astakhov adsorption isotherm

The plot of experimental data (fig6.) shows that this Pb^{2+} removal experiment fit the Dubinin-Astakhov adsorption isotherm with $R^2 =$ 0.9873. According to this linear plot the theoretical maximum removal amount calculated is 327.1 mg/g.

In Dubinin-Astakhov adsorption isotherm if E = 8 to 16 kJ/mol, the adsorption mechanism belongs to ion exchange. In this research the adsorption energy calculated from linear plot is E = 12.5 kJ/mol meaning that the Pb^{2+} removal belongs to ion exchange.

4. Conclusions

Recycle of lake sludge is successfully done in this study.

By adjusting C_{NaOH} , heating temperature, and Si/Al molar ratio, 4 types of zeolites can be synthesized. Their cation-exchange capacity is as follow:

ZeoliteP1(Na) (247.5 meq/100 g) >Unnamed zeolite (135.1 meq/100 g)>Faujasite Na (82.3 meq/100 g)>Analcime C (39.5 meq/100 g)

Synthesized zeolite P1 (Na) shows higher CEC value than commercial zeolite which is 160 \sim 190 meg/100 g^[5].

Zeolite P1(Na) with highest CEC synthesized after ultrasonic mixing is much higher than the one of 171 meq/100g in previous study.

The internal heating by ionic polarization (Na-OH) and orientation polarization (H₂O) and stirring during heating time are considered to improve uniform heat transmission which results in a better zeolite formation. Another considerable reason is that ultrasonic mixing with frequency of 38 kHz is considered to result in a good alkali treatment. During the treatment the mixture vibrates violently according to the frequency of ultrasonic. Sludge is mineralized well by NaOH during ultrasonic mixing. Si-O-Al structure is well formed from Si and Al, so zeolite P1(Na) structure is formed completely. The more substitution of

Al³⁺ for Si⁴⁺, the more Na⁺ ions are required to bond to adsorption sites. So zeolite P1(Na) is improved in this research.

In Lead removal experiment, 24 hours is enough to achieve adsorption equilibrium. From the Langmuir linear plot, $R^2 = 0.9993$ meaning that this removal experiment fit Langmuir isotherm. Computing by Langmuir isotherm, the maximum of removal amount shows 322.6 mg/g (77.8 meq/100g) which is lower than its CEC value of 247.5 meq/100 g. The ion exchange ratio efficiency is about 31%. It is considered that the removal mechanism belongs to ion-exchange.

Confirming by Dubinin-Astakhov adsorption isotherm, the maximum adsorption amount is 327.1 mg/g with adsorption energy of 12.5 kJ/mol. This adsorption energy value is considered to show this Pb²⁺ removal experiment is accomplished by ion exchange capacity of zeolite P1(Na).

Reference:

[1] Yan Shao, Synthesis of Zeolites from Lake Sludge, International Development Engineering, Tokyo Institute of Technology

[2] Human rights watch, "My Children Have Been Poisoned" May, 2010

[3] Myers, R.H., Montgomery, D.C. & Anderson-Cook, C.M. (2009) "Response Surface Methodology," Third Edition. Chapter 7.

[4] Chapman, H.D., "Cation-exchange Capacity," Method of Soil Analysis(1965)

[5] TSK 東新化成株式会社 ゼオライト成分参考 分析値

Impact on domestic air cargo demand by changing aviation circumstances

Student Number: 13M18089 Name: Ryuuhei KUDOU Supervisor: Shinya HANAOKA

航空環境変化が国内航空貨物需要に与える影響

工藤竜平

本研究の目的は、近年の航空環境変化が国内航空貨物需要に与えた影響を明らかにすることである。まず可能性のある環境変化要因の影響を検討し、その内の GDP、総座席数、一便あたりの座席数を変数として、国内線全体、幹線全体、ローカル線全体の他、特定の4路線について、国内航空貨物量との関係をベクトル自己回帰(VAR)モデルによって分析した。その結果、国内線、幹線、ローカル線全体ではグレンジャー因果性が確認されたが、特定路線の場合は路線毎に異なる結果が示された。

1. Introduction

Recently Japanese aviation circumstances changed greatly. For instance, economic trend which due to Great East Japan earthquake and high exchange rate of the yen and streamlining of Aviation Company because of soaring fuel price. Indeed, main Japanese airlines reported they changes their aircraft from wide body one to smaller one, like Boeing 787 and Boeing 737. These changes are considered to impact on domestic air cargo in Japan in the same way.

Ministly of Land, Infrastracture and Transport (MLIT)^[1] shows the difference in domestic cargo volume between trunk flight routes and local flight routes. Trunk flight routes means air routes between New Chitose (Sapporo), Haneda, Narita, Itami, Kansai, Fukuoka, and Naha airports. And local routes means others routes. And MLIT report current status of many regional airports. In this way there are some papers and reports about each factor and each airport, but there are few papers which use stateistical analysis of domestic air cargo from wide viewpoint and take into account recently aviation circumstances widely.

In this paper, we discuss the impacts on domestic air cargo by aviation circumstances, and choose some factors of impacts, then analyze VAR model and Granger causality between these factors and domestic air cargo demand by whole domestic routes, trunk routes, local routes, and some specific flight routes.

2. Selection of factors to give the impact on domestic air cargo demand

2.1. Discussion on possible factors

I. GDP

GDP reflects to economic trend. General trend of air cargo is similar to GDP, that is, be increasing. Inoue ^[2] and Chang ^[3] have concluded that there are relationships between GDP and international air cargo. Thus we need to analyze the relationship between GDP and domestic air cargo.

II. Distance

In the ranking of domestic cargo volume by route, there are many routes which be linked with Haneda airport and the more the distance from Haneda is longer, the more cargo volume is larger. Therefore we discuss Kyushu region and main airports in Kyushu as case study routes.

- III. Competitiveness with other transport modes
 - Main items of air cargo are document and mechanical parts. Thus air cargo volume is smaller than other transport modes. Indeed air cargo volume is very smaller than that in other transport modes even in case of between Tokyo and Kyushu region [4]. Hence it is difficult to check impacts by changing other transport modes widely. Therefore we investigated specific change of other mode, discounts of highway. 40% discount started from '08 February, 50% discount started from '08 October 30% discount in weekday started from '09 March. And there is 30% discount before this period. When we compare cargo volume in this period, there are impacts on air cargo by 50% discount in midnight and weekday discount, but in this period, global financial crisis happened and it is difficult to distinguish the impact from discount of highway tolls and economic trend. Hence we need to more analysis about whether there is impact by this discounts or not but we are not concerned here with this factor more.
- IV. International transit air cargo volume in domestic route

In case of routes between Kyushu and Haneda, the share of international cargo in domestic air transport is $2\%\sim5\%$ from 2005 to 2013. Recently directly export from and import to Haneda airport but I think the impact of domestic air transport from international cargo is not so big.

V. Expansion of air slot in Haneda airport

The frequency of flight gradually increasing in almost all routes between main airport in Kyushu and Haneda airport ^[1]. Thus offering cargo capacity may increase.

VI. Miniaturization of aircraft

On the other hand, seats per a flight is gradually decreasing. Miniaturization of aircraft may be affect cargo capacity too, so we would like to analyze this factor with offering cargo capacity.

VII. Operation of freighter

Figure 1 is change of air cargo volume of Haneda -Saga route. We can see in this figure that there is not so change when cargo dedicated flight start operation but there is big change when freighter start operation. It suggests that operation of cargo dedicated flight



Figure 1 Cargo volume of Haneda-Saga route

does not have big impact on cargo volume but freighter has impact on it. However flight routes which be operated freighter are not so much, so we have to consider each routes. Thus this is not my concern in this paper.

VIII. Operation hours

Midnight operation is important to increase air cargo for international hub airport but many airports started midnight operation with operating cargo dedicated flight. Thus it is difficult to distinguish effects by midnight operation and by operation of cargo dedicated flight.

IX. Other factors

In addition to these changes, management strategy of Airline Company, like using regional airport as international cargo hub and freighter's stopping at airport affect airport's cargo volume. However these are issue of each airport thus this is not my concern in this paper.

2.2. Factors selection and flight routes

For above results, I would like to analyze to 3 essential factors, GDP, offering cargo capacity, and average size of aircraft. The variables used are: GDP, offering seats to reflect cargo capacity, average seats per a flight to reflect average size of aircraft, and domestic air cargo demand.

We analyze these factors about whole domestic routes, trunk routes, and local routes. And I choose 4 flight routes which between Haneda airport and Sapporo (CTS), Kushiro (KUH), Fukuoka (FUK), and Nagasaki (NGS) airport. Sapporo route and Fukuoka route are trunk routes and Kushiro route and Nagasaki route is local routes. The reason why choose Sapporo and Fukuoka routes is that these routes are the most heavily routes about domestic air cargo. The reasons why choose Kushiro and Nagasaki routes are that these airports are in same region of Sapporo and Fukuoka, Hokkaido and Kyushu and, these flight routes has been decreasing the average seats per a flight. Thus we analyze 7 cases.

From here, we express G as GDP, C as Cargo Volume, S as Offering Seats, and PS as seats per a flight. Data is quarterly from 1994 to 2013. I obtain GDP data from Cabinet Office ^[5], and aviation data from MLIT^[1]. Here, **PS** are series which divide **S** by frequency of flight thus correlation between **PS** and **S** is possible. Indeed, it should be noted that there is correlation only in Kushiro route.

Methodology 3.1. Outline of VAR model

Vector Auto Regression (VAR) model is Auto Regression model which be augmented to use multi-variables. This model is used for economic forecasting and economic analysis. VAR model is one of Time Series Analysis, thus it is relatively easy to get required data by statistics.

VAR model which has 2 variables and lag 1 is below;

$$y_t = a_y + \lambda_y y_{t-1} + \beta_y x_{t-1} + \varepsilon_{yt}$$
(1)

$$x_t = a_x + \lambda_x y_{t-1} + \beta_x x_{t-1} + \varepsilon_{xt}$$
(2)

Where,

 y_t , x_t : Time series data which refer to the period (t =1, 2, 3,..., T)

 $\varepsilon_{yt}, \ \varepsilon_{xt}$: disturbance terms $a_y, \ a_x$: constant terms

 $\lambda_y, \ \lambda_x, \ \beta_y, \beta_x$: coefficients

This equation means y_t is explained by 1 term ago (lag = 1) values of itself and x_t .

VAR model cannot use when y_t and x_t have Unit Root. When we use VAR model with constant term to these y_t and x_t , it caused Spurious Regression. If we would like to use VAR model to these variables, take a difference of these variables. VAR model in difference (DVAR) is expressed as below;

$$\Delta y_t = a_y + \lambda_y \Delta y_{t-1} + \beta_y \Delta x_{t-1} + \varepsilon_{yt}$$
(3)

$$\Delta x_{t} = a_{r} + \lambda_{x} \Delta y_{t-1} + \beta_{x} \Delta x_{t-1} + \varepsilon_{rt}$$
(4)

$$\Delta x_t = x_t - x_{t-1} \tag{5}$$

And when there is Cointegration between y_t and x_t which have Unit Root, VAR model and DVAR cannot use. In this case, we use Vector Error Correction (VEC) model. VEC model is expressed as below;

$$\Delta y_{t} = a_{y} + \lambda_{y} \Delta y_{t-1} + \beta_{y} \Delta x_{t-1} + \varepsilon_{y t} + \eta_{1} (y_{t-1} + \psi x_{t-1})$$

$$(6)$$

$$\Delta x_{t} = a_{x} + \lambda_{x} \Delta y_{t-1} + \beta_{x} \Delta x_{t-1} + \varepsilon_{x t} + \eta_{2} \left(y_{t-1} + \psi x_{t-1} \right)$$

$$(7)$$

Where,

 $\eta \left(y_{t-1} + \psi x_{t-1} \right)$: error correction term

3.2. Unit root

When series x_t is not stationary but Δx_t is stationary, it is called that x_t has Unit Root. One of typical Unit Roots process is random walk, and that is expressed as below;

$$X_t = \mu + X_{t-1} + \varepsilon_t \tag{8}$$

Where,

 $\mu : {\bf constant \ term}$

In this equation, coefficient of X_{t-1} is 1, so this time series is called as unit root process. Many economic indicators are known as they have unit root.

As an example, we regress G_t (GDP) and R, which is logarithm of below random walk RW to next model;

$$\boldsymbol{R}\boldsymbol{W}_t = 1 + \boldsymbol{R}\boldsymbol{W}_{t-1} + \boldsymbol{\varepsilon}_t \quad \boldsymbol{\varepsilon}_t \sim N(0, 4) \tag{9}$$

$$\boldsymbol{R}_t = \log(\boldsymbol{R}\boldsymbol{W}_t) \tag{10}$$

$$\boldsymbol{G}_t = \boldsymbol{a} + \boldsymbol{b}\boldsymbol{R}_t \tag{11}$$

Where, a: constant term b: coefficient

 G_t has Unit root. Result equation is below;

$$G_t = 12.728 + 0.102 * R_t$$
 (12)
[421.2131] * [12.42666] *
*: 1% significance.

The numbers in the brackets indicate t-values of coefficients. R^2 of this equation is 0.664403 and Adjusted R^2 is 0.660101. Of course there is no relationship between GDP and RW_t , but this result seems meaningful. This is Spurious Regression.

3.3. Cointegration

When 2 variables y_t and x_t have unit root, sometime there are constants a and b which complete equation $ay_t + bx_t$ is stationary. In this case, these variables is said that they have cointegration. Error correction term in equation of VEC means this cointegration. Error correction term expresses error from long-term equilibrium of y_t and x_t , and adjustment factor controls direction and speed of effect from cointegration.

3.4. Granger causality

There are the paper which use VAR model and Granger test for air transport market by Inoue^[2] and Chang^[3]. When forecast from using past y_t and x_t is more applicable than forecast from using only y_t , it is said that there is (short-run) Granger causality from x_t to y_t . When we want to investigate there is Granger causality or not, we examine below equation;

$$y_{t} = \sum_{1}^{p} \lambda_{i} y_{t-i} + \sum_{1}^{p} \beta_{i} x_{t-i} + \varepsilon_{t}$$
(13)

Where, *p*: lag number

If null-hypothesis $\beta_i = 0 \forall i \in p$ is reject by F-test, we think there is Granger causality from x_t to y_t .

Moreover, in case of there is cointegration between variables, there is possibility of long-run Granger causality. The reason why this causality is occur is that cointegration is stationary, thus there is equilibrium in long-run term. When we want to investigate long-run Granger causality, we examine adjustment factor in VAR model is significance or not by t-test. It should be noted that Granger causality is different from causality in general meaning.

4. Result

4.1. Unit root test

Almost all variables are non-stationary in levels but stationary in 1st difference. Exception are C of local routes, S of Kushiro, C of Fukuoka, and S of Nagasaki. C of Fukuoka and S of Nagasaki are stationary in levels and differences, and C of local routes and S of Kushiro are non-stationary in levels and differences. However if I do seasonal adjustment to these data, the results are same of other variables, non-stationary in levels but stationary in 1st differences. Thus we deal with these variables as they have unit root.

4.2. Lag number

We use 4 as lag number. It means these variables refer to 1 year before. Other method to decide lag number is usage of information criterion.

4.3. Cointegration test

We did Johansen's cointegration tests between variables and C about each route. Because we are not certain about intercept of VAR and intercept and time trend of Cointegration, thus calculate all model and adopt the model and number of cointegration which has the smallest Akaike information criterion (AIC). Table 1 is results of cointegration tests. 1st row is air route, 2nd row is examined variable with C, 3rd row is number of cointegration, and 4th row is type of VAR and Cointegration. Table 2 shows classification of VAR model type. 1st row is Number of type, 2nd row is whether there is intercept in examined VAR, 3rd row is whether there is intercept in cointegration, and 4th row is whether there is time trend in cointegration in cointegration.

Table 1 Result of Cointegration test

	Whole Japan			Tru	nk rou	ites	Local routes		
	G	\boldsymbol{S}	PS	G	\boldsymbol{S}	PS	G	\boldsymbol{S}	PS
Coint.	1	0	1	1	1	1	1	1	1
Туре	1	1	5	4	4	5	1	1	4

	CTS		KUH		FKU			NGS				
	G	\boldsymbol{S}	PS	G	\boldsymbol{S}	PS	G	\boldsymbol{S}	PS	G	\boldsymbol{S}	PS
Coint.	0	0	1	1	1	1	1	1	1	1	1	0
Type	4	1	4	4	4	5	4	1	1	4	1	1
G: GDP S: Offering Seats PS: Seats per a flight									ght			

Table 2 Type of VAR and Cointegration

Туре	1	2	3	4	5
Intercept in VAR	No	No	Yes	No	Yes
Intercept in Coint	No	Yes	Yes	Yes	Yes
Trend in Coint	No	No	No	Yes	Yes

	ΔG to	ΔC to	ΔS to	ΔC to	ΔPS	ΔC to				
	ΔU	AG		40	toΔC	ΔPS				
		A) Who	ole Dome	stic rout	es					
Long	*		-	-	*					
Adj.	-0.239	-0.029	-	-	-0.528	-0.016				
Short	**		*	*		*				
		B) Who	ole Trunk	x routes						
Long		*	*		*					
Adj.	-0.085	-0.081	-0.437	0.013	-0.559	-0.064				
Short	*			*						
C) Whole Local routes										
Long			*	*		*				
Adj.	-0.01	0.003	-0.235	-0.127	-0.066	0.222				
Short	**		*	**		*				
D) Sapporo (CTS)										
Long	-	-	-		**					
Adj.	-	-	-	0.01	-0.32	0.01				
Short				**		**				
		E) Kus	hiro (KU	(H)						
Long	**	**		**	**					
Adj.	-0.172	0.013	0.108	0.241	-0.531	-0.02				
Short		**		**	**	*				
		F) Fuk	uoka (Fl	JK)						
Long	*		*		*					
Adj.	-0.272	0.013	-0.393	-0.022	-0.392	-0.069				
Short	*			**						
		G) Nag	asaki (N	GS)						
Long	**	**	*		-	-				
Adj.	-0.091	0.011	-0.229	-0.063	-	-				
<u> </u>	at at a		**	ماد ماد						

Table 3 Result of Granger Causality Test

*(**) denotes statistical significance at 1% (5%) level.

4.4. Granger causality test

Table 3 shows results of Granger causality tests. These cointegrations take 1 for coefficient of C. 1st row is direction of Granger causality, 2nd row is results of long-run Granger causality, 3rd row is adjustment factor of cointegration in VAR model, and 4th row is results of short-run Granger causality.

- A) About whole domestic routes, we see that GDP has short-run and Long-run Granger causality to cargo demand. Offering seats has short-run Granger causality, and seats per a flight has long-run Granger causality to cargo demand. This results suggests that these factors affect cargo demand. This result also suggests that cargo demand affect offering seats and size of aircraft.
- B) About trunk routes, important differences from whole domestic are there is long-run causality from cargo to GDP. This result suggests that cargo affect GDP. And other important point is average size of aircraft has long-run Granger causality to cargo demand as with whole domestic routes.
- C) About local routes, the important point is there is no Granger causality from average size of aircraft to cargo but there are Granger causalities from cargo to offering cargo capacity and to size of aircraft. This result may suggest that it is not true that decreasing of cargo demand in local routes are caused by miniaturization of aircraft but small cargo demand cause small aircraft and few cargo capacity.

From here, we compare each route between Haneda airport with whole trunk routes or whole local routes.

- D) About Sapporo (CTS) route, there is no resemblance with about whole trunk routes, and few Granger causality are confirmed. This result suggests that cargo demand in this route is independent of these factors, or simply my modeling is wrong.
- E) About Kushiro (KUH) route, there are no resemblance with whole local routes in the same way. Important point of this route is there are Granger causalities from size of aircraft to cargo nevertheless these cannot be find in whole local routes.
- F) Only result of Fukuoka (FKU) route are similar to result of whole trunk routes. This result suggests that Fukuoka route is typical route in trunk routes.
- G) Nagasaki (NGS) route are not similar to result of whole local routes. As we can find similar result in Fukuoka route, there are long-run Granger causalities from GDP to each cargo demands. This result suggests that Kyushu region is more affected by economic trend.

5. Conclusions

In this paper, at first we discussed 9 factors to give the impact on domestic air cargo demand and chose 3 essential factors, GDP, offering cargo capacity, and average size of aircraft as factors which have big impact. Second, we analyzed the relationships between these 3 factors and cargo demand in whole domestic routes, whole trunk routes, whole local routes, and 4 specific routes by using VAR model.

Throughout the VAR model analysis, the results represents that these 3 factors affect cargo demand in whole domestic cargo and miniaturization of aircraft affect cargo demand in trunk routes rather than local routes. Furthermore the results to examine each trunk route or each local route are different from the results to examine whole trunk routes or whole local routes. Thus, when we need to consider about each route, we should analyze each route to understand the circumstance of the route clearly.

References

- MLIT, "Annual Statistics of Air Transport", 1994-2013.
- [2]. Inoue, G. and Tansei, K. (2011), "Study on Application of Time-series Analysis to Air Transport Demand Estimation", Technical Note of National Institute for Land and Infrastructure Management, No.652.
- [3]. Chang, Y. and Chang, Y. (2009), "Air cargo expansion and economic growth: Finding the empirical link", Journal of Air Transport Management Vol.15, pp 264-265.
- [4]. MLIT, "Regional Mobility Survey of Cargo" 2000 2012.
- [5]. Cabinet Office. (2014), "Real Gross Domestic Product (seasonally adjusted series)".

Sugar production from agar by recombinant Brevibacillus choshinensis

Student Number: 13M18066 Name: Sanomi KASHIMURA Supervisor: Kiyohiko NAKASAKI

遺伝子組換えブレビバチルスによる寒天からの糖生産

樫村 彩乃美

バイオマスとして紅藻に着目し、紅藻中の寒天からバイオリファイナリーに使用する原料となるガラク トースの生産を試みた。はじめに寒天を分解する2種類の酵素を生産する組換え菌の作製に取り組み、 得られた組換え菌の遺伝子配列を決定することで目的の組換え菌が得られたことを確認した。続いて作 製した寒天分解酵素生産組換え菌により寒天からのオリゴ糖生成、オリゴ糖分解酵素生産組換え菌によ りオリゴ糖からの単糖生成を確認することができた。さらに2種類の組換え菌を混合培養することで、 寒天からガラクトースを生産できた。

1. Introduction

In recent years, biorefinery defined as production of bulk chemicals and fuels such as lactic acid and bioethanol from biomass has attracted attentions. Thus, many studies have been performed on the production of them from biomass, such as lignocellulosic biomass [1], paper sludge [2], and other wastes such as starch and food wastes. Seaweed is proposed as one of the most promising biomass for biorefinery, since it is known to contain no lignin that makes polysaccharides in biomass resistant to hydrolysis.

In particular, red seaweed has high content of fermentable sugar such as glucose and galactose, and thus, it is expected that the hydrolysis and fermentation of the red seaweed can produce various bioproducts, such as ethanol, lactic acid, and succinic acid, with high yields.

Agar is a polysaccharide contained in red seaweed and it is composed of galactose and anhydrogalactose. Two types of enzyme, β -agarase and α -agarase are required for enzymatic hydrolysis of agar because it has 2 types of bond called as β -1, 4 bond and α -1, 3 bond in agar. Firstly agar is degraded by β -agarase into oligosaccharide, and secondly neoagarobiose which is one of oligosaccharides is degraded by α -agarase into galactose and anhydrogalactose (**Fig. 1**). For the production of galactose from agar, commercial β -agarase is available, however it is expensive, and α -agarase is not commercialized. Therefore, the use of some microorganisms that produce β and α -agarase enzyme are considered to be more feasible.



Fig. 1 Degradation of agar by 2 kinds of agarase

In this research, construction of 2 kinds of recombinant *Brevibacillus choshinensis* which contains either β -agarase gene or α -agarase gene and the hydrolysis of agar by the recombinant *B*. *choshinensis* were attempted.

2. Materials & Methods

2.1 Construction of recombinant *B*. *choshinensis* possessing β -agarase gene

A fragment encoding β -agarase gene was amplified from chromosomal DNA of *Cellvibrio* sp. OA-2007 by PCR. This amplified fragment was ligated in pNCMO2 vector for the construction of pNCMO2- β -agarase plasmid. The plasmid of pNCMO2- β -agarase was then introduced into *B. choshinensis*.

After the construction of the recombinant *B*. *choshinensis* that have β -agarase gene, sequence analysis of the plasmid introduced to *B. choshinensis* was carried out to ensure that β -agarase gene was introduced properly.

This recombinant *B. choshinensis* was cultivated on agar medium containing 50mg/L of neomycin at 30°C for 2 days to check the expression of β -agarase gene.

Then, the recombinant B. choshinensis was cultivated in liquid medium containing 50 g/L of neomycin and 50 g/L of agar at 30°C for 0, 1, 3, 5 days in order to produce oligosaccharide from agar. The oligosaccharide produced in the culture of the recombinant B. choshinensis was analyzed by high performance liquid chromatography (HPLC) and thin layer chromatography (TLC). In HPLC analysis, KS-802 was used as column under 50°C and 0.8 ml/min of flow rate. In TLC analysis, the culture of the recombinant B. choshinensis was filtered through 0.45µm membrane filter and spotted on silica plate, and developed using the solvent (butanol: ethanol : distilled water = 3 : 1 : 1). The spots were visualized by spraying with 10% H₂SO₄ in ethanol containing 0.2 % naphthalendiol and heating [3].

2.2 Construction of recombinant *B*. *choshinensis* possessing α -agarase gene

A fragment encoding α -agarase gene was amplified from chromosomal DNA of *Cellvibrio* sp. OA-2007 by PCR. The construction of the recombinant *B. choshinensis* was carried out with the similar method as described in **2.1**, and the sequence analysis of the plasmid introduced to *B. choshinensis* was carried out.

The recombinant *B. choshinensis* was cultivated in liquid medium containing 50 g/L of neomycin and 10 % of oligosaccharide mixture including 16 g/L of neoagarobiose in the mixture at 30°C for 0, 1, 3, 5 days in order to produce galactose. The culture of the recombinant *B. choshinensis* was analyzed by HPLC and TLC under the same condition as described in **2.1**.

2.3 Mixed culture of the two kinds of the recombinant *B. choshinensis*

For the comparison of the enzymatic activity in the different medium, the recombinant *B. choshinensis* with β -agarase gene and the recombinant *B. choshinensis* with α -agarase gene were cultivated individually in MT, LB and MT (without glucose) liquid medium containing 50 mg/L of neomycin at 30°C for 0, 1, 2, 3, 5 days and the OD₆₀₀ of the culture was measured.

The recombinant *B. choshinensis* with β -agarase gene and that with α -agarase gene were cultivated together in MT liquid medium containing 50 mg/L of neomycin and 50 g/L of agar at 30°C for 0, 1, 3, 5 days in order to examine the production of galactose from agar. The culture was analyzed by TLC under the same condition as described in **2.1**.

3. Results & Discussion

3.1 Oligosaccharide production by recombinant *B. choshinensis* possessing β -agarase gene

The result of the sequencing of β -agarase gene introduced to *B. choshinensis* is shown in **Fig. 2**. The sequence was 100 % the same with expected sequence. This result shows β -agarase gene was successfully introduced into *B. choshinensis*.

After the cultivation of the recombinant *B*. *choshinensis* that have β -agarase on agar medium, the pits around the colonies were observed (**Fig. 3**). The formation of the pits indicates that the agar was hydrolyzed by β -agarase expressed in *B. choshinensis*.

Then, HPLC chromatogram of the culture obtained on 0 day and 5 day was shown in **Fig. 4** and TLC chromatogram of the culture obtained on 0, 1, 3 and 5 day was shown in **Fig. 5**. On the HPLC chromatogram, three peaks corresponding to neoagarobiose, neoagarotetraose and neoagarohexose were observed. In addition, on the results of the TLC chromatogram, three spots corresponding to neoagarobiose (designated as 2s), neoagarotetraose (4s) and neoagarohexose (6s) were observed for each medium after 3 days (**Fig. 5**). These results suggested that the recombinant *B. choshinensis* with β -agarase gene produced oligosaccharide from agar.

β-agarase β -agarase β -agarase



Fig. 3 Pits around the colonies of recombinant *B*. *choshinensis* that have β -agarase gene



Fig. 4 HPLC chromatogram on the production of oligosaccharide from agar (A: 0 day sample, B: 5 day sample)



Fig. 5 TLC chromatogram on the production of oligosaccharide from agar (①, ②, ③ and ④ correspond to the culture obtained on 0, 1, 3, 5 day)

3.2 Galactose production by recombinant *B*. *choshinensis* possessing α -agarase gene

The sequence of α -agarase gene is in **Fig. 6**. The sequence was 100 % the same as that of being expected as α -agarase gene. It shows that α -agarase gene was successfully introduced into *B. choshinensis*.

Fig. 6 Result of sequence analysis of α -agarase gene introduced to *B. choshinensis* (Forward)

Then, HPLC chromatogram of the culture obtained on 0 day and 5 day was shown in **Fig. 7** and TLC chromatogram of the culture obtained on 0, 1, 3 and 5 day was shown in **Fig. 8**. On the chromatogram of HPLC, the peak correspond to neoagarobiose was observed on 0day and disappeared on 5day, then appeared the peak of galactose and anhydrogalactose. It indicates that neoagarobiose (2 sugar) was degraded and galactose and anhydrogalactose (AHG) were produced in the culture of the recombinant *B*. *choshinensis* with α -agarase gene. In addition, in the TLC analysis, the spot corresponding to neoagarobiose (2s) was observed on 0 day and disappeared after 1 day, and then the spots of anhydrogalactose were observed (**Fig. 8**). These results suggested that the recombinant *B. choshinensis* with α -agarase gene degraded neoagarobiose into galactose and anhydrogalactose.



Fig. 7 HPLC chromatogram on the production of galactose from oligosaccharide (A: 0 day sample, B: 5 day sample)



Fig. 8 TLC chromatogram on the production of galactose from oligosaccharide (①, ②, ③ and ④ correspond to the culture obtained on 0, 1, 3, 5 day 0, 1, 3, 5 day)

3.3 Galactose production by the mixed culture of two kinds of recombinant *B. choshinensis*

The courses of OD_{600} of the culture of the recombinant *B. choshinensis* with β -agarase gene were shown in **Fig. 9** and that with α -agarase gene was shown in **Fig. 10**. It was found that the growth of the recombinant *B. choshinensis* was the fastest and final cell density was highest in MT medium among MT, LB and MT (without glucose) medium.



Fig. 9 OD₆₀₀ of the liquid medium of the recombinant β -agarase *B. choshinensis*



Fig. 10 OD₆₀₀ of the liquid medium of the recombinant α -agarase *B. choshinensis*

In the TLC analysis of the filtered culture of the two recombinant B. choshinensis in the MT liquid medium containing agar, the spots of oligosaccharides were observed after 3 day cultivation (Fig. 11). This result shows that the recombinant B. choshinensis that have β-agarase produced oligosaccharides from agar. The color intensity of the spot of neoagarobiose (2s) is not high compare to the other oligosaccharides such as neoagarotetraose (4s) and neoagarohexose (6s), because neoagarobiose was degraded into galactose and anhydrogalactose soon after it was produced. And the spots of anhydrogalactose were observed above neoagarobiose spots and became high intensity. Anhydrogalactose and galactose are produced when neoagarobiose are degraded into monosaccharides. Thus, it was considered that galactose was successfully obtained from agar using 2 kinds of agarase produced by the recombinant B. choshinensis.



Fig. 11 TLC chromatogram on the production of galactose from agar

(1), (2), (3) and (4) correspond to the culture obtained on 0, 1, 3, 5 day 0, 1, 3, 5 day)

4. Conclusions

In this study, the recombinant *B. choshinensis* that have β -agarase gene was successfully constructed. By the cultivation of the recombinant *B. choshinensis* containing agar in the medium, oligosaccharides were obtained.

In addition, the recombinant *B. choshinensis* that have α -agarase gene was also successfully constructed. By the cultivation of the recombinant *B. choshinensis* in the medium containing oligosaccharides, galactose and anhydrogalactose were obtained.

Then, galactose was successfully obtained by the mixed cultivation of the recombinant *B. choshinensis* that have α -agarase gene and β -agarase gene cultivated simultaneously in MT liquid medium.

References

- [1] Garde A, Jonsson G, Schmidt AS, Ahring BK. Lactic acid production from wheat straw hemicelluloses hydrolysate by Lactobacillus pentosus and Lactobacillus brevis. Bioresource Technology., 81, 217-223 (2002)
- [2] Nakasaki K., Adachi T. Effects of intermittent addition of cellulase for production of l-lactic acid from wastewater sludge by simultaneous saccharification and fermentation. Biotechnology Bioengineering., 82, 263-270 (2003)
- [3] Yun E. J., Shin M. H., Yoon J., Production of 3,6-anhydro-l-galactose from agarose by agarolystic enzymes of Saccharophagus degradans 2-40. Process Biochemistory., 46, 88-93 (2011)

Prototype of an autonomous energy harvesting system using boost converter

Student number: 13M18014 Name: Ryushi ASAMI Supervisor : Kunio TAKAHASHI

エネルギーハーベスティング用自律型昇圧コンバータの試作

浅見 立志

本研究では、電源の最大出力点を自動で検出・追従し、自分自身の動力を管理する自律型のエネルギーハーベスティン グ装置の制御方法を提案し、試作した。装置が電源の出力を確認し、出力と自身の消費電力を比較するアルゴリズム及び 実現するための回路の設計について述べた。また、試作した装置で実際に出力が変動する熱電素子と太陽電池から蓄電を 行い、最大出力点検出・追従機能の蓄電効率への影響と、スリープ機能を利用したスタンバイ状態の有効性を確認した。

1. Introduction

The energy harvesting means gathering unused tiny and instable energy from the environments, such as a light on small space or exhaust heat [1]. It is significant for application such as autonomous wireless sensor networks [2].

A circuit has been sold that can charge 24[V] batteries from photovoltaic cells with following changes of Maximum Power Point (MPP) of power source and voltage of storage (MPP Tracking, MPPT) in 2013. But the circuit can't always follow MPP, and can't charge from lower power source less than 10[W].

Tanaka proposed an optimization method to store tiny electric energy using boost converter [3] in 2011. Based on the study, we developed a PC-controlled MPPT circuit. It scans MPP of DC power source and follows it. But controlling by PC is unpractical because PC consumes more energy than it harvests.

The purpose of this study is to make a prototype of the autonomous energy harvesting circuit by using micro controller, which charge energy from at least 50[mW] to 1[W].

Suggestion of function of autonomous circuit 2.

The block diagrams of the autonomous system is shown in Fig.1. The schematic of autonomous circuit is shown in Fig.2.

In order to control the boost converter circuit, the controller must get the information of MPP of the power source and the voltage of the storage device $(V_{\rm C})$ because they change momentarily. The energy consumption of the controller must come from its energy storage to work autonomously. Thus, the controller has to judge that the power source has enough power to charge. It is better that the energy consumption of controller is as low as possible, so we have chosen a micro controller as the circuit controller.



..... :Signal flow

Fig.1 Block diagram of autonomous system

The circuit supplies the energy, which preliminarily charged in the storage device, to the micro controller through a voltage regulator. The circuit measures a MPP of the power source (1) and voltage of the storing capacitor $V_{\rm C}$ (2) regularly. As soon as measurement is finished, the controller calculates optimized duty ratio of PWM inverter (3), which Tanaka calculated in his study [3], and emit it to control the circuit to charge the storage devices, or go to sleep mode (4). This study, the measurement of MPP is executed once by 5[s], the measurement of $V_{\rm C}$ and calculation of duty ratio are executed once by 0.5[s].



Fig.3 is the MPP scanning circuit. The power source charges a capacitor in the circuit when connected to this circuit. The controller measures $V_{P.S.}$ and V_1 . V_1 means $I_{\rm P.S.}$, current from the power source. When the circuit is connected to the power source, the capacitor's voltage $V_2 = 0[V]$, and the $V_{P.S.} = 0[V]$ too. But V_2

becomes higher, the $V_{\rm P.S.}$ becomes higher too. The controller continues measuring $V_{\rm P.S.}$ and V_1 and calculating $P_{\rm P.S.} = V_{\rm P.S.} * I_{\rm P.S.}$. The highest $P_{\rm P.S.}$ and its $V_{\rm P.S.}, I_{\rm P.S.}$ are MPP $P_{\rm MP}, V_{\rm MP}, I_{\rm MP}$, and controller records $P_{\rm MP}, V_{\rm MP}, I_{\rm MP}$ as $P_{\rm target}, V_{\rm target}, I_{\rm target}$.

The controller also calculates amount of the chargeable energy and compare it to energy consumption by using $P_{target}, V_{target}, I_{target}$. If the chargeable energy is not large enough compared to the energy consumption, the controller stops the circuit and switch itself into sleep mode to save energy consumption, and regularly wakes up and calculates the chargeable energy again.

3. Prototype and experiment

We made a prototype of the circuit mentioned at section2 (Table.1, Fig.4). And we arranged Tanaka's formula of charging efficiency because of counting energy loss of MPPT, energy consuming of controller, voltage drop of switching FET in efficiency. The arranged formula is shown in

Measured charge efficiency $\eta_{\text{measured}} = \frac{E_{\text{charged}}[J]}{P_{\text{MP}}[W]*T_{\text{total}}[s]} =$

 $\Delta \frac{1}{2}C[F]V_c^2[V]$

$$P_{MP}*T_{total}$$

Theoretical efficiency $\eta_{\text{theory}} = \eta_{\text{charge}} - \frac{E_{\text{loss}}}{P_{\text{MP}}*T_{\text{total}}} a_{\text{safe}}$

$$\begin{split} E_{\text{loss}} &= E_{\text{controller}} + E_{\text{disconnected}} + E_{\text{drop}} + E_{\text{leak}} \\ E_{\text{controller}} &= I_{\text{controller}}[A] * V_{\text{c}} * T_{\text{total}} \\ E_{\text{disconnect}} &= P_{\text{MP}} * T_{\text{disconneced}} \\ E_{\text{drop}} &= V_{\text{drop}} * I_{\text{MP}} * T_{\text{total}} \\ E_{\text{leak}} &= \frac{V_{\text{c}}^2}{R_{\text{div}}[\Omega]} * T_{\text{total}} \\ \eta_{\text{charge}} &= \frac{R_{\text{MP}}V_{\text{C}}}{RV_{\text{C,D}}} * \left(\frac{\tilde{g}_{\text{C,D}}^2 (1 - e^{-(1 - d)T}) (1 - e^{-dT})}{\tilde{T} (1 - e^{-T})} - (1 - d) \tilde{g}_{\text{C,D}} (\tilde{g}_{\text{C,D}} - 2) \right) \end{split}$$

 $E_{\text{controller}}$ contains switching loss ($\eta_{\text{fo}}[4]$). $I_{\text{controller}} = \text{current consumption of the controller}$ $T_{\text{disconneced}} = \text{times}$ without charging because of scanning MPP $V_{\text{dron}} = \text{voltages drop by MPP measure FET}$

 V_{drop} = voltages drop by MPP measure FET R_{div} = voltage dividing resistor a_{safe} = safety factor

Table.1 Parts list				
Power Source	MAX $V_{\rm MP} = 2[V]$			
(Photovoltaic cell)	MAX $I_{\rm MP} = 500[{\rm mA}]$			
Power Source	$R_{\rm MP} = 10[\Omega]$			
(Thermoelectric devices *4)				
Capacitor(storage)	ELNA 2R5D107T *4			
	$V_{\rm MAX} = 10.0$ [V]			
	C = 28.06[F]			
	$R_{\rm C} = 120[{\rm m}\Omega]$			
Controller	Microchip PIC16F1938			
	I _{controller} @4[MHz],5[V]			
	= 1.66[mA]			
MOSFET(PWM)	TOSHIBA TPC6006-H			
	$R_{\rm DS} = 78[{\rm m}\Omega]$			
	$V_{\rm th} = 2.3[V]$			
MOSFET(MPP measure)	ROHM RTF015N03			
	$R_{\rm DS} = 200[{\rm m}\Omega]$			
	$V_{\rm th} = 1.5[V]$			
Inductor	L = 4.74[mH]			
	$R_{\rm L} = 0.2[\Omega]$			
Diode	$V_{\rm th} = 0.5[V]$			
	$R_{\rm D} = 100 [\mathrm{m}\Omega]$			

Resister(voltage dividing)	$R_{\rm div} = 8.8 [M\Omega]$
Resister(current measure)	$R_1 = 1.0[\Omega]$
Capacitor(ADC)	$C_{ADC} = 0.1[uF]$
Regulator (CMOS-LDO)	SII
	S-812C50AY-B-G(5V)



Fig.4 Figure of the prototyped circuit

Using the arranged formula, we measured the charging efficiency of the prototyped circuit in this condition, using a photovoltaic cell as the power source. $V_{MR} = 1.84$ [V]. $I_{MR} = 0.100$ [A]. $P_{MR} = 0.184$ [mW].

$$\begin{split} V_{\rm MP} &= 1.84[\rm V], I_{\rm MP} = 0.100[\rm A], P_{\rm MP} = 0.184[\rm mW], \\ f_{\rm PWM} &= 12.5[\rm kHz], V_{\rm drop} = 0.040[\rm V] \\ T_{\rm disconneced} &= \frac{180[\rm ms]}{5000[\rm ms]} T_{\rm total}, T_{\rm total} = 694[\rm s] \\ V_{\rm C}(\rm before\ charged) &= 6.13[\rm V], V_{\rm C}(\rm after\ charged) = 6.66[\rm V] \end{split}$$

From this, we calculated η_{theory} and η_{measured} . a_{safe} is set as 1.

$$\begin{split} \eta_{\rm theory} &= 90.1\% - (5.8\% + 3.6\% + 2.2\% + 0\%) \cdot 1 = 78.5\% \\ \eta_{\rm measured} &= 75.4\% \end{split}$$

We got almost same efficiencies between the theoretical value and the measured value. From this, we set $a_{safe} = 2.0$ and the theoretical efficiency can be used for judging the controller go to sleep mode or not.

We compared the efficiency of the prototyped autonomous circuit and the circuit without MPP scanning. Without MPP scanning, should be input fixed V_{target} , I_{target} preliminarily.

We used thermoelectric devices as a power source energy by utilizing a temperature difference between both sides of the devices (Fig.5), one side is heated by boiling hot water, 360[g] and the other side is cooled by water 100[g] and ice cubes 100[g]. Temperature of the room and water was 18 [degrees]. In this condition, we measured the charging.





scanning which fixed V_{target} , I_{target} to

 $V_{\text{target}} = 1.7[V] \text{ and } I_{\text{target}} = 0.17[A],$

$$V_{\text{target}} = 1.2[V]$$
 and $I_{\text{target}} = 0.12[A]$,

 $V_{\text{target}} = 0.70[V] \text{ and } I_{\text{target}} = 0.070[A].$

Those experimental charging are stopped when the circuit go to sleep mode, or $V_{\rm C}$ turn into decrease.

Fig.6 is the result of charging $V_{\rm C}$. It indicates with the autonomous MPP scanning charged energy the fastest and the most. Adding, it stop charging and go to sleep before $V_{\rm C}$ turn into decrease. Scanning and judging sleep or not works well. Other patterns couldn't judge sleep or not because they couldn't get parameter of actual $P_{\rm MP}$.

From these results, the autonomous circuit contributes charging efficiency from thermoelectric devices well.



Fig.6 $V_{\rm C}$ charged by thermoelectric devices Fig.7 is the result of $V_{\rm P.S.}$ when charging. Autonomous MPP scanning follows MPP time by time.



Fig.7 Output voltages $V_{P.S.}$ of thermoelectric devices We compared the same, using a photovoltaic cell as power source (Fig.8). We light the photovoltaic cell by using halogen lamp with variable stabilized power supply. To change output of power source, we changed voltage of halogen lamp 12[V], 9[V], and 6[V] by 5[minutes].

We experimented 4 patterns, which means with autonomous MPP scanning and 3 patterns of without scanning which fixed V_{target} , I_{target} to

 $V_{\text{target}} = 1.90[V] \text{ and } I_{\text{target}} = 0.28[A],$ $V_{\text{target}} = 1.88[V] \text{ and } I_{\text{target}} = 0.13[A],$ $V_{\text{target}} = 1.80[V] \text{ and } I_{\text{target}} = 0.040[A].$



Variable stabilized power supply

Fig.8 Schematic of a photovoltaic cell experiment Fig.9 is the result of charging $V_{\rm C}$. It indicates with the autonomous MPP scanning don't charge more energy always from photovoltaic cell than without scanning.





One of the reason of the without scanning circuit's efficiency is not less than the autonomous, is shown in Fig.10. $V_{P.S.}$ of without scanning has similar behavior to $V_{P.S.}$ of the autonomous scanning, and it means they tracking MPP without scanning. The autonomous should stop charging and switch to scan circuit, and the loss decrease the autonomous' efficiency.

Another reason is shown in Fig.11. It shows change of Power-Voltage curves of photovoltaic cell. $V_{\rm MP}$ of the photovoltaic cell changes only 100[mV] in contrast $V_{\rm MP}$ of the thermoelectric devices changes more than 1[V]. Amplitude of $V_{\rm P.S.}$ is larger than 100[mV], so changes of $V_{\rm MP}$ does not influenced to efficiency. Photovoltaic cell can approximate as a diode and current source, and so current mainly changes when its generating power changed.

From both reasons, the autonomous circuit doesn't contribute charging efficiency from photovoltaic cells well. But to judge charge or sleep, autonomous circuit needs to get MPP parameters in some way.



Fig.11 Relation between P-V curves of photovoltaic cell and Voltage of halogen lamp

4. Conclusion

This study focuses on prototyping autonomous energy harvesting system. It is suggested that an algorithm of autonomous system, including MPP scanning and sleep mode. The prototyped circuit proved that MPP scanning and sleep mode of the circuit is effective.

From this study, following knowledge are obtained.

- 1. MPP scanning is effective when power source changes its $V_{\rm MP}$, like thermoelectric devices, more than amplitude of switching.
- 2. MPP scanning is not effective as 1. when power

source don't changes its $V_{\rm MP}$, like photovoltaic cells, more than amplitude of switching.

From this study, we can try various kinds of direct current power source for energy harvesting easily. **References**

[1] Energy Harvesting Consortium

http://www.keieiken.co.jp/ehc/ (2015)

[2] ChenGregory. Millimeter-scale nearly perpetual sensor system with stacked battery and solar cells. ISSCC p.288-289, (2010)

[3] Tokyo devices <u>http://tokyodevices.jp/items/113</u> (2013)
[4] Masanori Tanaka "Optimization of control parameters of a boost converter for energy harvesting" Journal of Physics: Conference Series 379 (2012)

ACCELERATION OF THE COMPOSTING BY INOCULATING STRAIN RB1 AND CONTROLLING COMPOSTING TEMPERATURE

Student Number: 13M18155 Name: Hidehira HIRAI Supervisor: Kiyohiko NAKASAKI 酵母 RB1 株の接種と温度制御による高速コンポスト化

平井 秀平

食品残渣のコンポスト化において、有機酸の蓄積は微生物による有機物分解を阻害する。本研究では、有機酸分解能を持つ酵母 RB1 株の接種と、RB1 株の活性を維持するために温度を 40°C に維持する操作を行い、コンポスト化過程で生成される酢酸の蓄積を抑制し、コンポスト化を高速化した。さらに、でんぷん質を 30%、50%含む原料の場合に、温度をそれぞれ2日間、3日間維持すると酢酸の 蓄積が抑制され、温度の維持期間は原料中のでんぷん質の量に依存していることを明らかにした。

1. Introduction

Management of the ever-increasing waste materials produced in our society has become an essential area of study in recent years. Among waste materials, organic fractions such as food waste originating from households, restaurants, and food processing factories can be reclaimed as compost for agricultural use [1]. Composting has also attracted attention as a key technology for recycling organic waste such as food waste. Therefore, much research is currently focused on food waste treatment [2].

One of the significant problems in the food waste composting is that the pH of the food waste decreases because of the decay prior to the composting and another problem is that the pH of the composting material decrease because of the production of the organic acids during the composting. Low pH inhibits microorganism activity and causes a delay of organic matter degradation. Therefore, for the acceleration of the composting, it is necessary to remove organic acids that inhibit organic matter degradation.

Previously, *Pichia kudriavzevii* RB1 was isolated from compost produced from garbage and rice bran mixture in our laboratory and was used as an inoculum that has high degradation activity against organic acids. This study elucidated that the inoculation of *P. kudriavzevii* RB1 accelerated the degradation of organic acids initially contained in the compost raw material [3].

The compost raw material in previous study relatively contained a small amount of starch, whereas

actual food waste contains more starch. Therefore, it is necessary to investigate the effect of inoculating strain RB1 in compost raw material containing more starch than that of previous study.

In this study, it was aimed to achieve the acceleration of the composting period by inoculating strain RB1 in order to promote the degradation of organic acids in compost raw material containing starch.

2. Material & Methods

2.1. Compost material

Material of each composting experiment, Run A, Run B, Run C-1, Run C-2, Run D-1 and Run D-2, were shown in Table 1. Run A, Run C-1, Run C-2, Run D-1 and Run D-2 were with inoculation of yeast strain RB1 at the cell density of 10^5 CFU/g-ds and Run B was without inoculation of RB1.

The rabbit food and rice were mixed at a ratio of 7:3 in Run A, Run B, Run C-1 and Run C-2 and at a ratio of 5:5 in Run D-1 and Run D-2 to representative model of food waste. Four kinds of organic acids, acetic acid, propionic acid, butyric acid, and lactic acid [4], characteristic to the food waste were added to the raw compost mixture to achieve adjusted concentrations of 2.90, 3.02, 2.43, and 12.45 g/kg-ds for acetic acid, propionic acid, butyric acid, and lactic acid, respectively. The mixture of rabbit food and rice, sawdust and seeding material were mixed at a ratio of 10:9:1. Distilled water was added to adjust the moisture content to 60%.

2.2. Composting operation

Schematic diagram of the composting system is shown in Fig. 1. At the start of the experiment, approximately 3kg of the raw compost mixture was put into the reactor, and the temperature of the composting material was set at room temperature, with air introduced from the bottom of the reactor at a minimum flow rate of 45 L/h to maintain aerobic conditions. When the temperature in Run C-1, Run C-2, Run D-1 and Run D-2 reached 40°C by self-heating due to organic matter decomposition, the temperature was controlled at 40°C by increasing the air flow rate to 200 L/h. The period of controlling temperature in Run C-1 and Run C-2 was 1 day and 2 days respectively, and that of Run D-1 and D-2 was 2 days and 3 days respectively. After controlling temperature, the air flow rate was returned to the first value which was 45 L/h. The temperature in all runs reached a final set temperature of 60°C, the temperature was then controlled at 60°C by regulating the air flow rate. In the later stages of composting, if the temperature decreased to below 60°C despite the air feed rate being set at the minimum, the temperature was maintained at 60°C with the heater surrounding the reactor.

The concentration of CO_2 in the exhaust gas from the reactor was measured continuously, and the CO_2 evolution rate was calculated based on the concentration of CO_2 and the air flow rate.

During the composting process, the compost material was turned once daily to ensure uniform organic matter decomposition. At the time of turning, approximately 15 g of compost was withdrawn from the reactor every day. Distilled water was added to prevent the compost from drying out during composting. The period of composting was 10 days.



Fig. 1. Schematic diagram of the composting system.

Table 1.	Compost	material	and	operation	of	each	run
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Run name	Ratio of rice in compost raw material (%)	Inoculation of strain RB1	Period of temp. control (d)
Run A	30	0	0
Run B	30	-	0
Run C-1	30	\bigcirc	1
Run C-2	30	\bigcirc	2
Run D-1	50	\bigcirc	2
Run D-2	50	\bigcirc	3

2. 3. Physicochemical analysis

The compost samples collected every day were measured for pH, moisture content, concentration of organic acids and cell density of mesophilic bacteria, thermophilic bacteria and fungi by dilution plate method. The concentration of organic acids was determined by using a high pressure liquid chromatography (HPLC) system.

The concentrations of the organic acids and the cell density of the microorganism were measured 3 times per sample, and an average of the 3 measurements was used. For each of the organic acids, error bar of the averaged value was calculated as a 95% confidence interval.

2.4. Real-time PCR

The cell density of strain RB1 in the compost samples, Run A (RT-PCR), Run B (RT-PCR), Run C-1 (RT-PCR) and Run C-2 (RT-PCR), was measured by real-time PCR method using the DNA extract from the samples as a template. The primers specific to strain RB1, RB1rtF, 5'-GACTCGCCTGAAAGGGA-3', and RB1rtR, 5'-CTGATTTGAGGTCGAGC-3', were designed and used. The real-time PCR was performed using Smart Cycle[®] II system (Cehpeid, California, USA) and SYBR[®] premix *EX TaqTM* (TaKaRa Biochemicals, Shiga, Japan)

3. Results & Discussion

3. 1. Composting of model food waste containing starch of 30%

The courses of the temperature, cell density of fungi by dilution plate method and real-time PCR method and concentration of organic acids for Run A and Run B are shown in Fig. 2.

The temperature in Run A increased to around 55°C during day 2 and day 3, and then decreased to around 30°C at day 4. After that, the temperature rapidly started to increase again at day 5 and achieved to 60°C, whereas in Run B, the temperature increased rapidly at day 5 and achieved to 60°C at day 7. These results

indicated that inoculation of the compost with yeast strain RB1 could advance the composting process 3 days, in this case where RB1 effectively increased the temperature in the early stage of composting.

The cell density of fungi in Run A and Run A (RT-PCR) increased to around 10^8 to 10^9 CFU/g-ds at day 1, whereas in Run B (RT-PCR), remained around 10^3 CFU/g-ds when the cell density of fungi in Run B increased at day 5. These results indicated that the most of the fungi in Run A was yeast strain RB1 and that in Run B was another fungus. The cell density of fungi in Run A and Run B corresponded to the course of temperature.

Four types of organic acids in Run A with inoculation of RB1 were degraded at day 1 faster than in Run B without inoculation of RB1. The degradation of organic acids in Run A at day 1 corresponded to the increase of the cell density of RB1, which indicated that RB1 promoted organic acids degradation in the early stage of composting.



Fig. 2. The courses of temperature, cell density of fungus and concentration of organic acids for Run A and Run B.

These results also revealed that significant amount of acetic acid in Run A and Run B was accumulated at day 3 and day 7 respectively along with the increase of the temperature. The decrease of the temperature in Run A during day 2 and day 3 was caused by the accumulation of acetic acid which strain RB1 couldn't degrade at day 3 because of decreasing the activity of RB1 along with the increase of temperature. RB1 started to degrade acetic acid at day 5 after the temperature decreased by day 4, and then the temperature reached to 60°C. After that, acetic acid was accumulated again, which inhibited the organic matter degradation by the end of composting. Therefore, it was necessary to keep the activity of RB1 in order to degrade acetic acid produced during composting by strain RB1.

3. 2. Composting of model food waste containing starch of 30% with controlling composting temperature

Temperature control during the composting was performed as a method to keep the activity of RB1.

The courses of the temperature, cell density of fungi and concentration of organic acids for Run C-1 and Run C-2 are shown in Fig. 3. The temperature in Run C-1 and Run C-2 was kept at 40°C for 1 day and 2 days respectively, after that, immediately increased to 60°C. The cell density of RB1 in Run C-1 and Run C-2 was kept at 10⁹ CFU/g-ds at day 3 in Run C-1 and at day 3 and day 4 in Run C-2 when the temperature was controlled at 40°C, and then decreased to non-detectable levels at less than 10^3 CFU/g-ds after the temperature reached to 60°C at day 4 and day 5 respectively. For the concentration of organic acids in Run C-1 and Run C-2, acetic acid was accumulated in both Run C-1 and Run C-2 at day 3 and day 4 after four types of organic acids were degraded at day 1. The concentration of acetic acid in Run C-1 and Run C-2 at day 3 was around 8 g/kg-ds that was less than half of around 24 g/kg-ds in Run A, which indicated that keeping the RB1 activity by controlling temperature decreased the amount of acetic acid accumulation. After controlling temperature, the concentration of acetic acid in Run C-1 increased to around 16 g/kg-ds at day 6, whereas in Run C-2, decreased to zero. This result elucidated that temperature controlling period of 2 days was more effective for decreasing the amount of acetic acid accumulation than that of 1 day.



Fig. 3. The courses of temperature, cell density of fungus and concentration of organic acids for Run C-1 and Run C-2

3. 3. Composting of model food waste containing starch of 50% with controlling composting temperature

The courses of the temperature and concentration of organic acids for Run D-1 and Run D-2 are shown in Fig. 4. After controlling temperature, the temperature in Run D-1 increased and then decreased during day 5 and day 6 because of the accumulation of acetic acid, whereas in Run D-2, increased to 60°C directly after stopping controlling temperature at 40°C. This result indicated that temperature controlling period of 2 days in the composting contained starch of 30% could prevent the accumulation of acetic acid after controlling temperature, whereas in the composting contained starch of 50%, couldn't prevent it. Therefore, it was revealed that the temperature controlling period needs to be determined according to the amount of starch contained in the compost raw material.



Fig. 4. The courses of temperature and concentration of organic acids for Run D-1 and Run D-2

4. Conclusions

In this study, it was achieved the decrease of the amount of acetic acid accumulation with inoculation of yeast strain RB1 by controlling composting temperature, thereby accelerated the composting period. Temperature controlling period needs to be determined according to the amount of starch in compost raw material.

References

[1] Al-jabi, L. F., Halalsheh, M. M., Badarneh, D. M., 2008. Conservation of ammonia during food waste composting. Environ. Technol. 29, 1067-1073.

[2]Abbasiliasi, S., Tan, J. S., Ibrahim, T. A. T., Ramanan, R. N., Vakhshiteh, F., Mustafa, S., Ling, T. C., Rahim, R. A., Ariff, A. B, 2012. Isolation of *Pediococcus acidilactici* Kp10 with ability to secrete bacteriocin-like inhibitory substance from milk products for applications in food industry. BMC Microbiol. 12: 260.

[3] Nakasaki, K., Araya, S., Mimoto, H., 2013. Inoculation of *Pichia kudriavzevii* RB1 degrades the organic acids present in raw compost material and accelerates composting. Bioresor. Technol. 144,521-528.

[4] Sundberg, C., Franke-Whittle, I., Kauppi, S., Yu, D., Romantschuk, M., Insam, H., Jönsson, H., 2011. Characterisation of source-separated household waste intended for composting. Bioresour. Technol. 102, 2859-2867.

MECHANISMS OF WASTEWATER TREATMENT PROCESS IN THE ANAEROBIC-AEROBIC REACTORS SYSTEM

Student Number: 13M18178 Name: Ryutaro BESSHO Supervisor: Kiyohiko NAKASAKI

嫌気・好気槽による廃水処理過程の浄化機構

別所 隆太郎

途上国では、低コストな廃水処理法として、嫌気槽と好気槽を直列に繋げた簡易な浄化槽型装置が多用 されているが、従来からその装置は経験に基づいて設計されており、浄化機構は明らかにされていない。 そのため、浄化機構を明らかにした上での最適装置の設計が求められてきた。本研究では実験室規模の リアクターを用いて人工廃水の浄化過程における有機物濃度変化を解析することで微生物の有機物分 解活性を定量し、また微生物叢を解析することで種菌の効果が薄いことを明らかにした。

1. Introduction

Recently in Philippines, water pollution in rivers, lakes and marshes caused by the pollutant such as industrial wastewater, agricultural wastewater, heavy metals and other materials, have become more serious with economic growth and population increase, thus solutions to the water pollution problem have been desired. In Philippines, the water quality standard and the effluent standard are defined by DENR administrative order No. 34 and No. 35, respectively. Industrial effluent must meet the standard of COD (Chemical Oxygen demand) that are defined against the respective water area.

In order to decrease the COD of the effluent, microbial treatment is widely applied due to its high degradation efficiency and low cost. Microbial treatment can be classified into aerobic treatment and anaerobic treatment by whether air is provided to the microorganisms or not. Aerobic treatment, which is widely applied in Japan and many other developed countries, has high degradation rate, but it is costly due to the necessity of the electrical power for air



Fig. 1. The schematic diagram of the anaerobic-aerobic reactors.

supply whereas anaerobic treatment does not require air supply. In addition, the increase of the cell mass in the anaerobic treatment is smaller than the case of aerobic treatment. Therefore anaerobic treatment cost lower, however, the quality of effluent is inferior to that of aerobic treatment [1].

In developing countries, the anaerobic-aerobic treatment process, where multi anaerobic reactors and an aerobic reactor are used, is applied (Fig. 1). In anaerobic-aerobic treatment, influent are treated flowing through the anaerobic reactor at first and the aerobic reactor at second. Anaerobic-aerobic treatment has a higher degradation rate than anaerobic treatment and takes a lower cost than aerobic treatment.

However the anaerobic-aerobic reactors are designed based on not the mechanisms of the wastewater treatment but the experiences. In this study, the organic compounds consumption rates was quantified and the microbial community was analyzed to examine the effect to add seed at the start of an anaerobic-aerobic treatment and to reveal the mechanisms of the organic compound removal in an anaerobic-aerobic treatment.

2. Materials and methods

2.1. Treatment of synthetic wastewater in the anaerobic-aerobic reactors at laboratory scale

Three kinds of the synthetic wastewater, the organic carbon source of which were 1.39 g/L of sucrose [2], 17 g/L of peptone [3] and 20 g/L of starch [4] were used. The installation for anaerobic-aerobic treatment, which were consisted of 4 anaerobic reactors (R1, R2, R3 and R4) and an aerobic reactor (R5), were prepared at laboratory scale imitating the



Fig. 2. The schematic diagram of the anaerobic-aerobic reactors at laboratory scale.

reactors used in a cassava processing plant in Philippines. The schematic diagram of the reactors is shown in Fig. 2. The volume of the synthetic wastewater was 635 mL for each reactor. Each reactor was filled with the synthetic wastewater and 2 mg/L of seed, NS series TW (Nanosys International, INC., Manila, Philippines) at the start of the treatment. In the treatment, the synthetic wastewater was supplied from the influent tank to anaerobic R1 at a constant flow rate of 2.2, 4.4 and 2.2 mL/min in the case of the treatment of the 3 kinds of synthetic wastewater containing sucrose, peptone and starch as organic carbon source, respectively by peristaltic pump and then the effluent from R1 flowed into R2. The synthetic wastewater flowed through R1, R2, R3, R4 and R5 and finally flowed out as effluent. All the reactors were incubated at 35°C during the treatment. The periods of the treatment of the 3 kinds of the synthetic wastewater containing sucrose, peptone and starch were 30, 12 and 12 days, respectively. The synthetic wastewater containing sucrose, peptone and starch were treated at a HRT of 24, 12 and 24 hours, respectively.

Approximately 10 mL of the sample was taken from each reactor every day for the following measurements. The pH and ORP of the synthetic wastewater in each reactor were measured every day using pH and ORP meter. The COD of the synthetic wastewater in each reactor was measured every 2 days using Reagent Set for Water Analyzer No.44 COD and DIGITALPACKTEST MULTI (Kyoritsu Chemical-Check Lab., Co., Tokyo, Japan)

2.2. Calculation of the COD removal rates by the microorganisms

The curve fitting on the courses of COD were carried out in order to quantify the organic compounds consumption rates by the microorganisms in each reactor during the anaerobic-aerobic treatment. The organic compounds consumption rates by the microorganisms were calculated by the curve fit and the following equation (1); dC_i/dt , C_i and C_{i-1} were given by the curve fit.

$$\left(\frac{dC_i}{dt}\right)_{\text{cons.}} = -\frac{dC_i}{dt} + \frac{F}{V}(C_{i-1} - C_i) \quad (1)$$

where C_i is COD of the i^{th} reactor, F is flow rate of the medium and V is the volume of the reactor

2.3. Microbial community analysis of the synthetic wastewater in each reactors

The DNA of the wastewater sample was extracted using DNA extraction kit, ISOIL for Beads Beating (Nippon Gene Co., Ltd., Toyama, Japan). After purification of the DNA, TaKaRa Ex Taq Hot Start Version (Takara Bio Inc., Shiga, Japan) was used for PCR amplification by using TaKaRa PCR Thermal Cycler Dice (TP600; Takara Bio Inc., Shiga, Japan) with the following primer sets deriving from the 16S rRNA gene: 357FGC, 5'-CGC CCG CCG CGC GCG GCG GGC GGG GCG GGG GCA CGG GGG GCC TAC GGG AGG CAG CAG-3', and 518R, 5'-ATT ACC GCG GCT GCT GG-3' for bacteria. DGGE analysis was carried out using D-code DGGE Complete System (BioRad Laboratories, CA, USA). The PCR product was mixed with an equal volume of $2\times$ gel loading dye (10 mM Tris-HCl at pH 8.0, 20 mM EDTA at pH 8.0, 0.05% [w/v] bromophenol blue, and 70% glycerol) and loaded onto a 10% (w/v) polyacrylamide gel in a 1× TAE buffer (40 mM Trisacetate at pH 7.4; 20 mM acetate, 1 mM Na2EDTA) with a denaturing gradient ranging from 30% to 60%. Using the DGGE image as a reference, the bands of interest were excised from the gel on a Dual Intensity Ultraviolet Transilluminator (Model TDS-20; UVP, CA, USA). Sequencing reactions for the purified DNA bands were carried out with a BigDye Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems, CA, USA), while sequencing was performed using an ABI PRISM 310 Genetic Analyzer (Applied Biosystems, CA, USA). The results of the sequencing analyses were compared to the sequences of the 16S rRNA genes available in the common databases (DDBJ, and GenBank) [3].

3. Results and discussion

3.1. Courses of COD and COD removal rate by the microorganisms in each reators

The courses of COD in the anaerobic-aerobic treatment in the case of sucrose, peptone and starch are shown in Fig. 3. In the case of sucrose, almost no differences were observed among other reactors, which suggested that only R1 had a large COD removal rate and almost no degradation occurred in the other reactors. Thus a HRT of 4.8 hours of R1, was enough for treatment of 500 mg/L of wastewater. In the case of peptone, the differences among the reactors were observed because the loading of supplied wastewater was high than the organic compound consumption; the organic loading rate in the case of sucrose and peptone were 1.91 g/h/L and 0.104 g/h/L respectively. Therefore it was suggested that the organic compounds not degraded in R1 were degraded in R2 and likewise the degradation of organic compounds was occurred in each reactor.

The COD removal rates corresponding to the degradation activity of organic compounds, during the anaerobic-aerobic treatment of the synthetic wastewater containing sucrose and peptone, are shown in Fig. 4. The COD removal rates in the case of sucrose was calculated to be 78.8 mg/L/h on day 12 in R1 by equation (1) and the COD consumption rate by microorganisms whereas the other reactors had almost 0 of COD removal rates. Thus it was revealed that almost only the microorganisms in R1 had the degradation activity when 500 mg/L of wastewater was treated in anaerobic-aerobic reactors at a total HRT of 24 hours. In the case of the peptone, the COD removal rate of R1 was calculated to be 721 mg/L/h on day 12 whereas the COD removal rates in R2, R3, R4 and R5 were 54.7, 249, 42.9 and 126 mg/L/h



Fig. 3. Courses of COD during the anaerobic-aerobic treatment of the synthetic wastewater containing sucrose and peptone.



Fig. 4. Courses of COD removal rates by microorganisms during the anaerobic-aerobic treatment of the synthetic wastewater containing sucrose and peptone.

respectively. Unlike the case of sucrose, the COD removal rates of R3 and R5 on day 12 also had a certain value not negligible as R1, which showed that the microorganisms in the reators in the downstream and the last aerobic reactor degraded acertain amount of organic compounds when the wastewater, the COD of which was high as 4600 mg/L were treated. It was also observed that the COD removal rates of R2, R3 and R4 had a peak around day 5-7, when the COD removal rate of R1 was increasing. It was considered that the organic compounds degradation activity in R1 was relatively low around day 5-7 so that the organic compound supplied into R1 was not degraded sufficiently. Therefore it was suggested that the activity of organic compounds degradation increased in R2, R3 and R4 because the organic compounds not degraded in R1 flowed into the following reactors. The COD removal rate of R5 increased around day 5 and leveled off, which showed that the organic compounds that could not be degraded under anaerobic condition were degraded under aerobic condition.

3.2. Microbial community in the synthetic wastewater

The DGGE images of the seed and day 30 in the case of sucrose, day 8 in the case of peptone and day 6 in the case of starch are shown in Fig. 5. It was confirmed that no changes observed in the band patterns after day 30, 8 and 6 in the case of sucrose, peptone and starch, respectively. Quite different microbial communities could be observed among the 3 kinds of the synthetic wastewater and they were also different from the seed. The analysis based on 16S rRNA gene revealed the closely related sequences corresponding to the characteristic bands in the DGGE image. The phylogenetic tree derived from the 16S



Fig. 5. The DGGE fingerprints of the seed and R1, R2, R3, R4 and R5 on day 30 in the case of sucrose, on day 8 in the case of peptone, on day 6 in the case of starch.

rRNA gene sequences of the characteristic bands observed in the DGGE image and the related species was build based on neighbor-joining method (Fig. 6).

It was revealed that the dominant species were



Fig. 6. Phylogenetic tree derived from the 16S rRNA gene sequences of the characteristic bands observed in the DGGE image and the related species.

different among the 3 kinds of the wastewater. Most of the dominant species were closest to Clostridium sp., which are found in soil, dust, intestines and feces, and was barely contained in the seed. The species, suitable for the condition of the treatment and slightly existed at the start of the anaerobic-aerobic treatment, became dominant and contributed to the degradation of organic compounds. In contrast, the bands of the dominant species in the seed did not appear during the anaerobic-aerobic treatment, therefore it was considered that the most of the added species at the start of the treatment did not contribute to the removal of organic compounds.

4. Conclusions

The COD removal rates, the activity of organic compounds degradation by microorganisms, were quantified, which showed that almost only the microorganisms in the first reactor degraded the organic compounds under the condition of low loading whereas the microorganisms in the second and the following reactors also degraded under the condition of high loading.

The analysis of microbial community revealed that the most of the added species at the start of the treatment did not contribute to the organic compounds romoval in the anaerobic-aerobic treatment whereas the species barely contaied in the seed, which are known to be found insoil, dust, intestines and feces, contributed greatly. Hence it was suggested that the to add the seed at the effect start of anaerobic-aerobic treatment was insignificant.

References

- N. Kataoka, "嫌気性生物処理技術の特徴と発展の流れ Characteristics and Development Chronology of Anaerobic Biotreatment Technology," エバラ時報 No.229, pp. 27-38 (2010).
- [2] A. P. Rollon. (1999) Anaerobic digestion of fish processing wastewater with special emphasis on hydrolysis of suspended solids: Taylor & Francis, Inc.
- [3] S. H. Kwon and K. Nakasaki, "Relationship between changes in microbial community and the deterioration of methane fermentation which treats synthetic peptone wastewater," J. Ind. Eng. Chem., Vol. 21, No. 25, pp. 443–450 (2015).
- [4] S. Roh, Y. N. Chun, J. Nah, H. Shin, and S. Kim, "Wastewater Treatment by Anaerobic Digestion Coupled with Membrane Processing," J. Ind. Eng. Chem., Vol. 12, No. 3, pp. 489–493 (2006).