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REMOTE SENSING FOR MONITORING URBAN SAFETY AND ENVIRONMENT

By

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Monitoring of urban safety and environment requires measurements of a wide variety of variables covering physical, chemical, biological, or geographical aspects. Furthermore, it needs to regularly observe extensive areas. A comprehensive and efficient monitoring system may not be realized with conventional ground observation methods only.

Remote sensing is an observation tool to identify objects or measure their characteristics without directly contacting them. Recent developments in remote sensing technologies have been remarkable and very rapid. Observations with one meter spatial resolution and one nanometer spectral resolution from space are also realized. These may provide an efficient tool to observe a wide range of land surface, atmosphere and ocean variables over extensive areas at regular intervals.

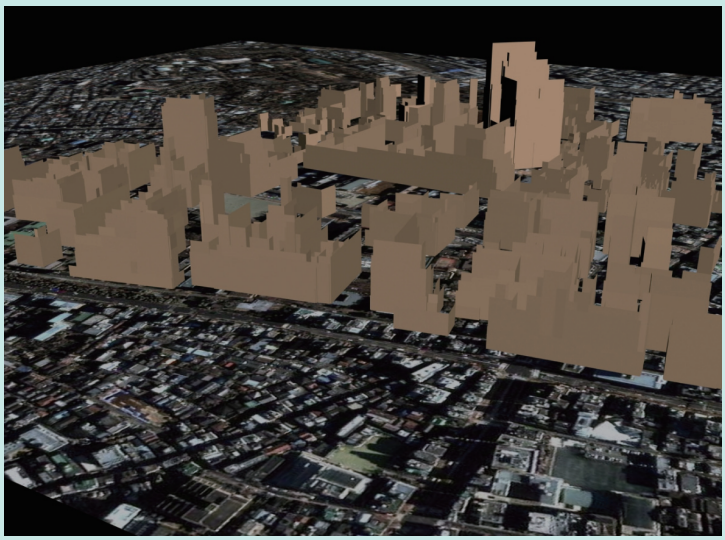
In this article, new technologies in remote sensing are surveyed, and their applications are introduced, with emphasis on the monitoring and assessment of urban safety and environment.

REMOTE SENSING

Remote sensing utilizes electromagnetic radiation as a media for the measurement. The measurement principle in remote sensing is based on the fact that all matter reflects, absorbs, penetrates and emits electromagnetic radiation in a unique way with respect to wavelength. This unique characteristic of radiation is called spectral signature of matter, and it enables to identify objects, or quantify their characteristics.

In remote sensing, the reflected or emitted electromagnetic radiation from a target is detected by a device called a "remote sensor." Cameras or scanners are typical examples of these. A vehicle to carry the sensor is called a "platform," and satellite or aircraft are usually used. Remote sensing from satellites or aircraft enables us to observe a wide range of variables over extensive areas at regular intervals.

The performance of a remote sensor is determined by various specifications including spectral range, spectral resolution, spatial resolution, observation width (swath), or obser-



3-D city model of Hongo Campus, The University of Tokyo, obtained from IKONOS and ALS data

vation frequency. Different types of remote sensor have been developed with respect to these specifications. The table on top of this page summarizes the specifications of typical remote sensors used for environmental and disaster monitoring. High spatial resolution sensors such as LANDSAT TM, SPOT HRV, or IKONOS are used for local or regional observation, whereas low spatial resolution, but wide coverage and high observation frequency sensors such as NOAA/AVHRR, ADEOS/OCTS, and TERRA/MODIS are used for continental or global scale vision.

Specifications of typical remote sensors

Satellite	Sensor	Wavelength (μm or GHz)	No. of bands	Spatial Res. (m)	Swath (km)	Cycle (day)
LANDSAT	TM	0.45-12.5	7	30	180	17
SPOT	HRV	0.50-0.89	4	10-20	60	26
ERS-1	SAR	5.3 GHz	1	20	100	35
JERS-1	OPS	0.52-0.86	4	18	75	44
JERS-1	SAR	1.275 GHz	1	18	75	44
IKONOS	Pan/MSS	is./Near-infrared	1/4	1-4	11	11
ALOS	AVNIR-2	0.42-0.89	4	10	70	46
ALOS	PRISM	0.52-0.77	1	2.5	70/35	46
NOAA	AVHRR	0.58-12.5	5	1000	2700	0.5
ADEOS	AVNIR	0.40-0.92	4	8－16	80	41
ADEOS	OCTS	0.40-12.5	12	700	1400	41
TERRA	ASTER	0.52-11.3	14	15－90	60	16
TERRA	MODIS	0.66-14.2	36	250-1000	2330	16

NEW TECHNOLOGY DEVELOPMENT IN REMOTE SENSING

High-spatial resolution observation

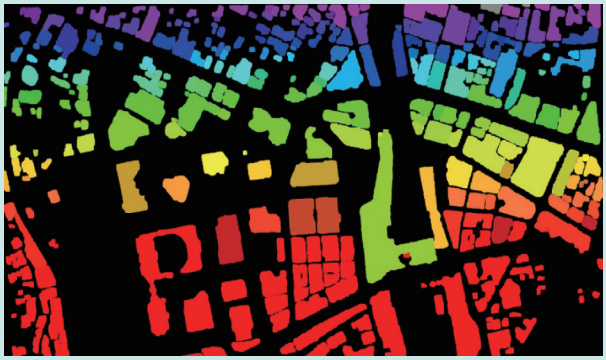
Spatial resolution is one of the most important sensor characteristics in remote sensing. It has been dramatically improved in the last 20 years, and, today, one-meter spatial resolution is realized with satellite sensors. From these images, individual buildings or tree canopies can be identified from space. High spatial resolution observation enables us to retrieve more detailed information on human settlements, land surface characteristics or topography from remotely sensed data. The figure below shows an example of building distribution detected from IKONOS image with one meter spatial resolution over the central area of Tokyo, Japan. In this image very fine spatial structures of the buildings and the roads are identified.

Hyper-spectral observation

Number of spectral channels in conventional remote sensors has been limited to 10 or at most to several tens in satellite and airborne systems. New hyper-spectral sensor systems have the capability of observing land surface in a couple of hundreds of channels. For example, the Hyperion on EO-1 has 256 channels. Airborne sensor systems such as CASI and AVIRIS have more than 200 channels and their spectral wavelength resolution is as narrow as several nanometers. Data from the hyper-spectral sensors have indicated the possibility of observing new urban risk variables, including concrete degradation, or vegetation stress conditions, which could not be observed by the conventional sensors.

Microwave range observation

With optical remote sensing, we can not observe the ground through cloud or haze. Microwave remote sensing has the advantage of all weather observation due to its longer wavelength. This observation capability enables us to monitor land surface conditions regularly even in heavily clouded regions including tropical regions or high latitude regions. A Synthetic Aperture Radar (SAR) is a typical microwave sensor which enables high spatial resolution observation. Microwave remote sensing has also the capability of monitoring precipitation and soil moisture.



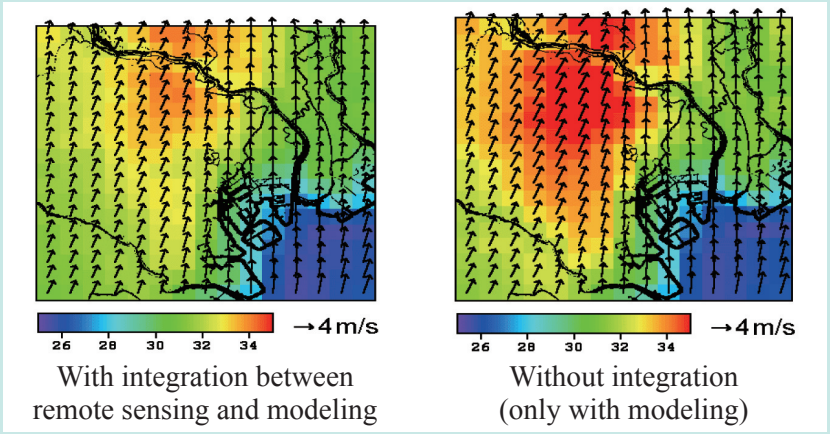
Distribution map of buildings over Shinjuku area, Tokyo, extracted from IKONOS image (color represents the building inventory number)

3-D Observation

Laser ranging technology enables us to observe the height of the targets from space. For example, Airborne Laser Scanner (ALS) can be used to monitor 3-D structures of buildings and trees with high accuracy. Today integration of high spatial resolution satellite data (e.g. IKONOS) and the topographic data from ALS enables us to produce detailed three dimensional data which is very useful for disaster or environmental assessment in urban areas.

Coupling remote sensing with modeling

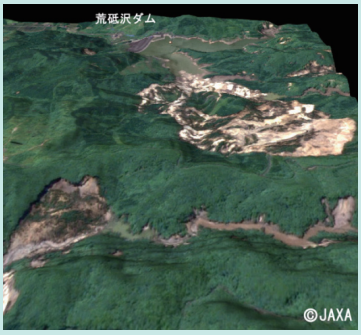
Remote sensing may provide effective information on the current status of environment or disasters, however, it can not predict the future. Physical models are required to predict the future. Recent developments in modeling of atmosphere, ocean and land have been very rapid and model prediction of the earth system has been getting accurate. Still there is a prediction error since the earth system is too complicated to be modeled. Effective integration between remote sensing and modeling may significantly reduce model simulation error since remotely sensed distribution of system parameters may be used for boundary conditioning, assimilation/nudging or validation. There have been studies to integrate remote sensing and modeling to improve model prediction and estimation. The figure on the top left corner of the next page depicts an example of heat island model simulation in Tokyo coupled with remotely sensed land cover distribution. It was shown that the accuracy of the estimated land surface temperature was significantly improved by integrating vegetation distribution observed by satellite data with a meso-scale climate model.



With integration between remote sensing and modeling

Without integration (only with modeling)

Simulation of land surface temperature with integration of remote sensing and modeling



Earthquake damaged area observed by ALOS AVNIR-2 and PRISM (from JAXA website)

APPLICATIONS OF REMOTE SENSING TO URBAN MONITORING

Environment and disaster variables for urban safety monitoring measured by remote sensing range from physical, chemical, biological to socio/economic variables. They also vary from practical/operational to research level. Examples of parameters are summarized as follows.

- Practical level

Land: land surface temperature, topography (Digital Elevation Model), 3-dimensional structures of buildings and vegetations, land cover classification, vegetation classification, vegetation index (Normalized Difference Vegetation Index, etc.), soil index, human habitats

Water: surface temperature, water quality including suspended sediment and chlorophyll, surface wind-vector, sea-ice

Atmosphere: temperature, water vapor, cloud

Others: precipitation

- Research level

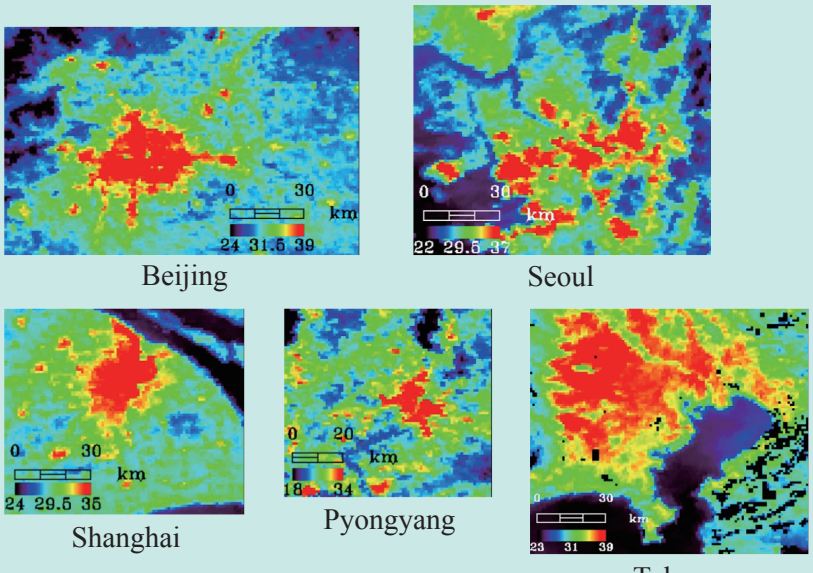
Land: detail land cover classification, detail vegetation classification, soil type classification, soil moisture, LAI (Leaf Area Index), biomass, tree height, canopy structures, NPP (Net Primary Productivity), CO_2 flux (NEP: Net Ecosystem Exchange), chlorophyll/lignin/cellulose in tree canopy

Water: chlorophyll (high accuracy), algae

Atmosphere: CO_2, CH_4, water vapor, ClO, NO_x, SO_x, O_3, aerosols

The figure on the bottom of this page depicts land surface temperature distributions in Asian mega cities obtained from MODIS data. They are critical in assessing urban heat island which has been a serious issue in most of Asian mega-cities.

The figure above shows land surface conditions and 3-D structures over the area damaged by the 2008 Iwate-Miyagi earthquake observed by ALOS AVNIR-2 and PRISM sensors. These variables might not be obtained without new remote sensing technologies.



Beijing

Seoul

Shanghai

Pyongyang

Tokyo

Land surface temperature maps over Asian cities obtained from MODIS data

CONCLUSIONS

Urban safety monitoring with remote sensing has potential advantages as follows:

- it does not disturb the object in measurement
- it can cover extensive areas in a short time
- it can measure parameters in the same spatial and temporal scale for any area of the world
- it can cover land, ocean and atmosphere areas where we can not get into and where we can not do direct observation.

Development of remote sensing technology has been very rapid, and today various types of remotely sensed data are available, ranging from high spatial resolution data for local monitoring to wide coverage data for regional/global monitoring. It is still difficult to realize operational and practical monitoring with only remote sensing or only ground observation. It is expected that an integrated environment and disaster monitoring system for urban safety assessment will be accomplished.

****Executive Director, National Institute for Environmental Studies and former ICUS Professor***

Prof. Sawada: 35 years with remote sensing progress

I started my new post as professor of ICUS on April 4, 2008. Before that, I had been working as Principal Research Coordinator for International Issues in the Forestry and Forest Products Research Institute (FFPRI), an incorporated administrative agency, in Tsukuba. My specialized field is remote sensing and forest information including geographic information system (GIS).

At the age of a sophomore, I read about infrared photography on a newspaper and decided to join the Department of Forestry of the University of Tokyo for studying forest remote sensing. After I obtained my Master's degree there, I started working as a researcher of FFPRI in 1978. I worked also as adjunct and part-time teacher at the University of Tokyo and the University of Tsukuba from 1990 to1994 and 1996 to 2003, respectively.

After developing software systems for processing Landsat images for a few years, I studied radar remote sensing for about a year in the University of California at Santa Barbara. In 1986, the French Government allowed me to stay as a visiting scientist for a year at the International Institute of Vegetation Map of the University of Toulouse.

It is my honor to introduce my research projects in the past on this occasion.

1) Mapping and resource evaluation of natural forests: Very little information on natural forest is available because of the problem of accessibility. Satellite images and aerial photography were used to evaluate typical natural forest resources. Distribution and available volume of trees were determined by integrating remote sensing and GIS data.

2) Development of early detection and early warning system for forest fire: We installed the NOAA satellite receiving system in Indonesia and developed the early detection system for suppressing fires in 1997. Based on this experience, a similar system was set up in Japan to monitor the South East Asian countries. These operational information systems using remote sensing brought us the Ministers Prize of the Ministry of Education, Culture, Sports, Science and Technology of Japan in 2001.

3) Information for land management of the Mekong River Basin: The Mekong is an international river which flows through China, Laos, Myanmar, Thailand, Cambodia and Vietnam. Because the development of cities and living environment depend on availability of water resources, watershed management is a very important issue. We clarified the environment conditions of the last 20 years using the flux tower data and satellite data, such as NOAA, SPOT and LANDSAT. We were awarded the national order by Cambodian Government for this activity.

These results were applied to estimate carbon fixation of forest for the Kyoto Protocol under the United Nations Framework Convention on Climate Change. As an ICUS member, I would like to promote studies on monitoring of environments under climate change, which have big influence on urban safety.

Fire spread risk map of Japan

(By H. Sawada)

Upgrading the seismic performance of wooden buildings

I got my Ph.D degree from the Department of Architecture, Graduate School of Engineering, the University of Tokyo in 2001. My research interest is wooden structures and wood engineering for buildings.

Japan has a longstanding heritage of wooden buildings. At the same time, Japan is a country beset by earthquakes. Wooden houses in Japan have suffered great damage caused by strong earthquakes.

Many types of wooden buildings were built long time ago in Japan. One of the wooden building category is the detached wooden house. These houses, built especially over 30 years ago, have the problem that they have poor seismic capacity and are damaged by earthquakes. Targets of my research group are the seismic diagnosis and reinforcement methods for existing wooden houses. To clarify the seismic performance of existing wooden houses, we conducted full-scale shaking table tests and evaluated damages of existing wooden houses after earthquakes. At the same time, it is important to create awareness among homeowners about the danger of earthquake so that a good housing stock can be prepared.

In other categories, traditional wooden buildings are not only buildings but also cultural assets in Japan. Traditional wooden buildings like shrines, temples, town houses (Machiya) and folk houses (Nouka) were built by carpenters who were not structural engineers. They built them using empirical, not engineering, knowledge. Recently the seismic performance of traditional wooden buildings is gradually made clear. Even there are some seismic elements that we cannot make clear yet, traditional wooden buildings can be reinforced.

To upgrade the seismic performance of wooden buildings, different ways should be taken according to the category of the buildings. A simplified design method is required for detached wooden small houses and a more sophisticated method could be used for traditional wooden buildings. Researches on both aspects should be made.

(By M. Koshihara)

Full-scale shaking table test

Preservation of districts with groups of historic buildings "Narai-juku"

RC-62 held meeting

The Research Committee 62 (RC-62), "Technologies for Evaluation of Aging Infrastructure Performance Degradation," held its first meeting on June 24, 2008. In order to evaluate present and future performance of infrastructure, knowledge from two or more specialized fields, such as material science, structural engineering, geotechnical engineering, and so forth is necessary. Although these studies have been performed separately in each field, an appropriate methodology for combining these results has not yet been developed. ICUS has established RC-62 in order to consider this problem and regular meetings will be held with the member companies from various specialized fields in civil engineering in order to build relationships and create the environment for joint action. Self-introductions by committee members will be done from the first to the third meetings.

On this occasion, Mr. Kurita and Mr. Inada (Shimizu Corporation), Mr. Sato (Sankyo & Co., Ltd.), Mr. Amano (Hozen Maintenance & Management Engineering Co., Ltd.), Dr. Odabe (Sumitomo Osaka Cement), Mr. Kado (Osmos Technology Association) and Mr. Koike (Geo Search) introduced themselves.

(By Y. Kato)

RC-62 meeting snapshot

14th Open Lecture was held

Recently, people are thinking more often about climate change and getting anxious about how our urban life will be affected by it. Furthermore, the Intergovernmental Panel on Climatic Change (IPCC) was awarded the Nobel Peace Prize last year. For these reasons, ICUS focused on climate change and urban safety issues in the 14th ICUS Open Lecture entitled "How does global warming change urban environment?"

Approximately 150 participants attended the lecture. Three well-known professors delivered lectures addressing the followings topics: "what kind of changes our society will cause in the future," "what kind of life adaptation and relief measures are the best solutions," and "what we shall tackle immediately."

Dr. Y. Yasuoka, former ICUS Professor and now Executive Director at the National Institute of Environmental Studies, moderated the lecture, and Prof. Meguro, ICUS Director, gave the welcome speech. Speakers were:

- Prof. Mimura, Ibaraki University and leader author of the IPCC fourth assessment report working group.
- Prof. Hanaki, the University of Tokyo and leader researcher of measures for reducing greenhouse gas emissions.
- Prof. Sawada, former Forestry and Forest Products Research Institute member and currently ICUS Professor. Prof. Sawada is a leader in the field of forest research to tackle global warming.

The closing remarks were given by Dr. Yasuoka. After the Open lecture, a small party was held and attended by approximately 60 people.

(By T. Endo)

Prof. N. Mimura

Prof. K. Hanaki

Prof. H. Sawada

ICUS joins IIS Open House

ICUS jointed the IIS Open House which was held for three days, from May 29 to 31. In this event, our institute is open to the public and experts to share our research outcomes with the visitors. Overall 8,500 people visited Komaba Research Campus. A theme of ICUS was "Towards the Establishment of a Sustainable Urban System."

All laboratory members participated and displayed their panels showing their research activities. Topics included: "Simulation of seismic vulnerability of cities, houses and rooms", "Life-cycle management of port infrastructure", "Sustainable urban infrastructure", "Long term behavior of ground and buried structures", "Concept of disaster intelligence infrastructure", "Building with natural construction materials", "Urban traffic management", and "Satellite observation system for urban ambient environment and disaster." The open house was also an opportunity to introduce the 2007 Annual Report as well as RNUS and BNUS activities. Reports and newsletters were handed to visitors. Almost 250 people visited ICUS exhibition.

(By Y. Kato)

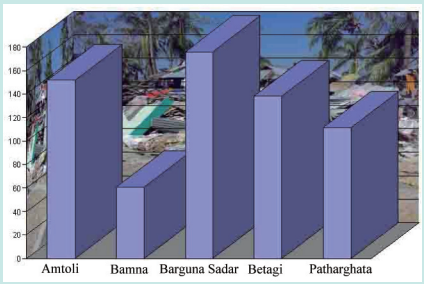
Prof. Sawada explains the principles of remote sensing and its applications to potential future scientists

BNUS Activities

Post Disaster Survey SIDR Cyclone, Bangladesh

A BNUS team visited SIDR affected area (Barguna and Pathuakhali districts) from May 5 to 12, 2008 to make a post disaster survey. The team met local authorities: District Commissioners (DC), Upazila Nirbahi Officers, District Relief and Rehabilitation Officers, Executive Engineers, Assistant and Upazila Engineers of the Water Development Board and Local Government Engineering Department, and NGOs (Bangladesh Red Crescent Society, Cyclone Preparedness Program, and others.)

The authorities shared their experience in tackling the situation during and after SIDR. The team also interviewed local people who were affected by the disaster. Damage data was collected and compiled. On the basis of this data and practical experience, an analysis was performed. The figures below show road damage in different upazila in Barguna.



Comparison of damage at different upazila in Borguna district

Meeting with DC, Patuakhali

Mason Training Manual for Bangladesh

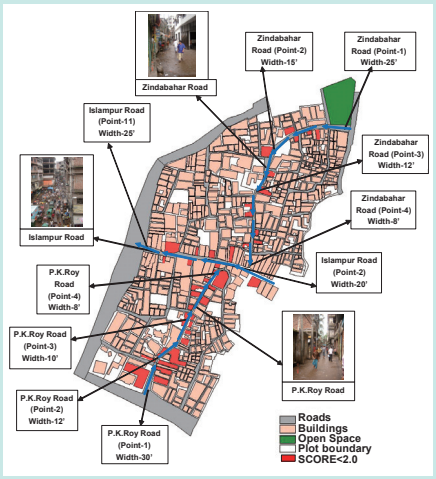
BNUS has developed a manual for mason training in Bangla. Bangladesh has no institution for educating masons. Thus, this is the first step to develop trained masons in Bangladesh. The feature of this manual is that trainer and trainee can store this material and detailed training description.

The manual consists of nine chapters, which are: earthquake and its background, site selection, foundation construction (masonry and frame structures), masonry wall building, masonry roof and slab building, quality control, maintenance and reconstruction, and retrofitting. The key role for constructing an earthquake resistant building is generally played by the mason. So, well trained masons are essential.

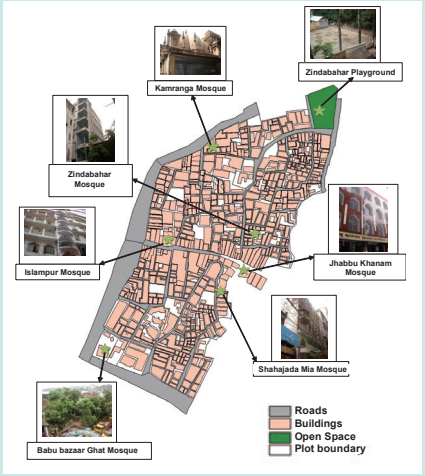
Community Based Earthquake Evacuation Plan for Old Dhaka (Ward No. 68)

The lower portion of Ward No. 68 has been analyzed. Three evacuation paths and seven evacuation centers are identified. The vulnerability of evacuation centers was determined using the FEMA-RVS and Turkish methods. The average road width of Islampur road, P. K. Roy lane, and Zindabahar 2nd lane are 6, 3, and 4.5 meters, respectively. Widening of roads at different points and methods to prevent building collapse are also suggested to ensure effective evacuation. The figures below show the findings of this study.

(By M. Ansary)



Evacuation paths showing road widths at different point



Evacuation centers

RC-58 held two meetings in this trimester

The Research Committee 58 (RC-58) is working under the topic "Business Continuity Management (BCM) Systems Suitable for Japanese Society." Its activities started last year and 13 companies joined this year. The first and second meeting of this fiscal year were held on May 23 and June 17, 2008, respectively.

Last year, the committee members reviewed the existing BCM related literature and made a comparative study. This year, they were divided into three working groups in order to discuss the following topics: 1) the suitable BCM for private companies, 2) the suitable BCM for local governments and 3) suitable methods for evaluating BCM. These three working groups will continue their discussions until the next regular meeting, which will be held in September.

Snapshot of three RC-58 working groups during their discussions and opinion exchange

(By M. Y. Ohara)

RNUS Activities

Liaison meeting at Japanese Embassy

Dr. Tanaka attended the 1st liaison meeting held in Japanese Embassy in Bangkok on June 20, which aims at promoting information exchange and collaborative activities among Japanese organizations working in the field of science and technology. The participants were from the Japan Aerospace Exploration Agency, Japan Society for the Promotion of Science, Japan External Trade Organization, National Institute of Information and Communications Technology, Tokyo Institute of Technology, Osaka University, United Nations Economic and Social Commission for Asia and the Pacific, and AIT.

In this meeting, activities of each organization were introduced and issues in conducting research and education outside of Japan were discussed.

RNUS signed professional consulting services contract

RNUS/AIT team signed a contract for professional consulting services on June 2, 2008 for the project entitled "Seismic Hazard and Vulnerability Mapping of Dhaka, Chittagong and Sylhet City Corporation Areas." This project is a part of the Comprehensive Disaster Management Program (CDMP) of the Government of Bangladesh, supported by the United Nations Development Programme (UNDP), Department for International Development Bangladesh, and the European Commission to increase the level of earthquake disaster preparedness in the important cities in Bangladesh. The project will be executed by a joint venture including consultants, universities, and NGOs.

RNUS/AIT will be responsible for seismic vulnerability and risk assessment. The scope includes: supervising field survey of more than 20,000 buildings, identifying dynamic characteristics of more than 100 representative buildings, assessing the seismic vulnerability of typical buildings and lifelines by numerical analyses and estimating potential losses from possible earthquake scenarios using the GIS-based software package HAZUS.

(By K. Worakanchana and S. Tanaka)

Changes in ICUS staff

Prof. Sawada and Dr. Koshihara joined ICUS

ICUS welcomes Prof. Sawada and Dr. Koshihara who joined our center on April 1, 2008 as Professor and Associate Professor, respectively. They belong to the Infrastructure Information Dynamics Division.

Prof. Sawada field of expertise is remote sensing and forest information including geographic information system. Dr. Koshihara specializes in earthquake resistance of wooden structures and retrofitting methods. They have introduced their researches in this volume of ICUS Newsletter.

Dr. Ohara is promoted

ICUS would like to congratulate Dr. Miho Ohara who was promoted to ICUS Associate Professor on April 1, 2008 and also started to work as Associate Professor for the Center for Integrated Disaster Information Research (CIDIR), Interfaculty Initiative in Information Studies, The University of Tokyo from June 1, 2008.

CIDIR was jointly established by Interfaculty Initiative in Information Studies, The Earthquake Research Institute, The Institute of Industrial Science (IIS) in April 2008 in order to integrate disaster information research results in the University of Tokyo. She is expected to act as a bridge between CIDIR and ICUS, IIS.

Dr. Ohara graduated from the Department of Civil Engineering, The University of Tokyo and joined ICUS as Research Associate in April 2003. She obtained her Doctor of Engineering Degree in September 2005 from the University of Tokyo.

Her research interests are urban disaster mitigation strategies and education. Recently, she is developing E-learning system for increasing disaster response capacity of the staff members in medical facilities and universities.

(By K. Meguro)

Prof. Haruo Sawada

Dr. Mikio Koshihara

Dr. Miho Ohara

ICUS Activities

・Dr. Kato attended the 1st International Symposium on Life-Cycle Civil Engineering, which was held in Varenna, Italy from June 9 to 16.

・Dr. Tanaka stayed at AIT for his research work and teaching duties at RNUS from April 1 to May 1, May 12 to 24, June 16 to 26, and July 2 to 20.

・Dr. Tanaka visited Hong Kong from May 18 to 19 to hold a research meeting on dynamic traffic operation.

・ICUS organized the 14th Open Lecture entitled "How does global warming change urban environment?" on May 9.

・ICUS joined the IIS Open House from May 29 to 31.

・RC-58 held general meetings on May 23 and June 17, 2008.

・RC-62 held general meeting on June 24, 2008.

Editor's Note

In this trimester, there were two huge natural disasters, one is the Cyclone Nargis hitting Myanmar and the other is the Sichuan Earthquake which occurred in China. Both disasters caused enormous victims and still a lot of people are suffering from refugee life. We would like to express our sincere sympathies to people affected by these disasters. Although the events themselves had huge impacts, problems after the events, such as, troubles and delays in accepting foreign assistance offers, etc. were also revealed. These post-event activities are very important in disaster management, and we have to make efforts in this area, too.

Cyclones and earthquakes are typical natural disasters which cause huge damage in our daily life. However, as our society develops and connects intricately, factors which affect urban safety are also increasing much more than before.

After the retirement of Prof. Yasuoka, who made great contributions to ICUS from its beginning, we welcome new members, Prof. Sawada and Dr. Koshihara from this April. Their researches are introduced in this volume. ICUS is expanding its research field more widely and this variety of activities is the advantage of our center. Taking these opportunities, we would like to keep our organization active and try to tackle new challenges for a better society and urban environment.

(By S. Tanaka)

If you would like to contribute an article to ICUS newsletter or have any comment or suggestion, please contact the editorial committee at icus@iis.u-tokyo.ac.jp

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