ICCBEI 2019

4th International Conference on Civil and Building Engineering Informatics

November 7-8, 2019, Sendai, Japan

Program and Book of Abstracts

ICCBEI 2019

4th International Conference on Civil and Building Engineering Informatics

Organizers

Asian Group for Civil Engineering Informatics (AGCEI)

Committee on Civil Engineering Informatics,
Japan Society of Civil Engineers (JSCE)

Supporters

Japan Construction Information Center

Miyagi University

Sponsors

Gold Sponsors:

Forum 8 Co., Ltd.
Kajima Corporation
Applied Technology Co., Ltd. and Autodesk Inc.
Sendai Tourism, Convention
and International Association (SenTIA)

Silver Sponsors:

Chodai Co.,Ltd
Chuo Fukken Consultants Co.,Ltd.
JIP Techno Science Corporation
Shimizu Corporation
Trion Corporation
Obayashi Corporation
Yachiyo Engineering Co.Ltd

GREETINGS FROM THE CHAIR OF ICCBEI 2019

We are very pleased to hold the International Conference on Civil and Building Engineering Informatics (ICCBEI 2019) in Sendai City, Miyagi Prefecture, Japan. The organizer of ICCBEI, Asian Group for Civil and Building Informatics (AGCEI), was developmentally organized from the series of Asian Construction Information Technology Roundtable Meeting sponsored by Japan Society of Civil Engineers (JSCE) and Japan Construction Information Center (JACIC). AGCEI is the sister organization of the International Society for Computing on Civil and Building Engineering (ISCCBE), which holds the International Conference on Computing in Civil and Building Engineering (ICCCBE) in the even number years. AGCEI decided to hold the international conference in the Asian and Pacific region in the odd number year and held the conference in Tokyo in 2013, then Tokyo in 2015, and Taipei in 2017. ICCBEI 2019 is the fourth conference, which is the first conference outside of Tokyo in Japan.

In a decade, information and communication technologies (ICT) have advanced continuously and more rapidly. Various new technologies such as 3D scanning using drones, computer vision, IoT sensors and actuators, robot and machinery control, and so on have been developed and applied to civil and building engineering. Also, artificial intelligence (AI) has been able to analyze big data generated by accumulating a large amount of information and replace human knowledge and cognition. Furthermore, the information or data-centric concept has evolved, and the information and data are becoming a core in linking for Cyber-Physical Systems. In every phase in the lifecycles of building and infrastructure, building information modeling(BIM) is becoming increasingly important as the core for storing information. In this trend, “informatics” in the title of the conference is becoming a key academic area in civil and building engineering, and we should make further progress.

In response to our Call for Papers, 78 abstracts were submitted, and our international scientific committee has finally accepted 62 full papers after rigorous reviews. These accepted papers will be presented at the conference. The papers can be categorized into nine academic categories without industrial/ technical category: Building and Construction Information Modeling, AI and Data Analysis, Image Processing and Computer Vision, Visualization and XR(VR/AR/MR), IoT/Sensors and Monitoring, Laser and Image Scanning, Facility and Infrastructure Management, Computational Mechanics/Engineering, and Information and Process Management. As these categories show, the papers target innovative topics in civil and building informatics. We hope that ICCBEI 2019 and the publication of the proceeding will contribute to the development and dissemination of Civil and Building Engineering long into the future. We also invite three key persons in Civil and Building Engineering as keynote speakers. We hope that the discussion in ICCBEI 2019 will contribute to the development and dissemination of Civil and Building Engineering long into the future.

Furthermore, the Sendai area where ICCBEI 2019 will be held was affected by the disaster of the large earthquake in 2011. Especially, the coastal area was heavily hit by Tsunami, and some cities were flown out. Many reconstruction projects in the coastal area are underway, and many applications of ICT are tried. We hope that our discussions at this conference will be useful for the reconstruction of disaster areas.

Finally, we hope that you enjoy the conference.

Koji Makanae

Chair, Organizing Committee of ICCBEI 2019
Chair, Committee on Civil Engineering Informatics,
Japan Society of Civil Engineers (JSCE)
Professor, Miyagi University, Japan

ICCBEI 2019 TIME SCHEDULE

[Day 0] Pre-event and Reception

November 6 (Wed)	
13:00-16:40	[Pre-event] JACIC Session (Japanese Program) *pre-entry required (Studio Theater on 7th Floor)
17:30-19:30	Reception at Crepuscule Cafe on Ground Floor in Sendai Mediatheque

[Day 1] ICCBEI 2019

November 7 (Thu)		
9:00-	Reception *Entrance of Sendai Mediatheque will be open at 9:00	
9:30-9:45	Opening Ceremony (Open Square on Ground Floor, Sendai Mediatheque)	
9:45-10:30	Keynote Lecture-1 (Open Square on Ground Floor, Sendai Mediatheque) Prof. Kincho H. Law (Stanford University) "Information and Communication Technologies (ICT) in Civil and Building Engineering"	
10:30-10:45	Coffee Break (Coffee Space in Open Square on Ground Floor)	
10:45-12:00	Session A (Studio Theater on 7th Floor)	Session B (Meeting Room A/B on 7th Floor)
	[AI1] AI and Data Analysis-1	[XR] Visualization and XR(VR/AR/MR)
12:00-13:00	Lunch (1F Coffee Space in Open Square on Ground Floor)	
13:00-13:40	Keynote Lecture-2 (Open Square on Ground Floor, Sendai Mediatheque) Prof. Katharina Klemt-Albert "Digitalization in AEC – German perspectives from strategy to implementation"	
13:40-15:05	Session A (Studio Theater on 7th Floor)	Session B (Meeting Room A/B on 7th Floor)
	[AI2] AI and Data Analysis-2	[FM] Facility and Infrastructure Management
15:05-15:20	Coffee Break (Coffee Space in Open Square on Ground Floor)	
15:20-16:35	[CV] Image Processing and Computer Vision	[IS] Industrial/Technical Session
16:40	Meet at OpenSquare for Dinner	
16:45-	Bus for Dinner Departure at Sendai Mediatheque (15 minutes trip)	
18:00-20:00	Dinner at Sendai Castle Ruins “Honmaru Kaikan”	
20:00	Bus Departure at Sendai Castle (back to Sendai Mediatheque and Sendai Station)	

[Day 2] ICCBEI 2019

November 8 (FRI)		
9:00-	Reception *Entrance of Sendai Mediatheque will open at 9:00	
9:20-10:20	Session A (Studio Theater on 7th Floor)	Session B (Meeting Room A/B on 7th Floor)
	[BM1] Building and Construction Information Modeling(BIM/CIM)-1	[CME] Computational Mechanics/Engineering
10:20-10:35	Coffee Break (Coffee Space in Open Square on Ground Floor)	
10:35-11:50	[BM2] Building and Construction Information Modeling(BIM/CIM)-2	[IOT] IoT, Sensors, and Monitoring
11:50-13:00	Lunch (1F Coffee Space in Open Square on Ground Floor)	
13:00-13:45	Keynote Lecture-3(Open Square on Ground Floor, Sendai Mediatheque) Dr. Jack C.P. Cheng "Creation, Integration and Management of BIM Information"	
13:45-14:00	Coffee Break (Coffee Space in Open Square on Ground Floor)	
14:00-15:00	Session A (Studio Theater on 7th Floor)	Session B (Meeting Room A/B on 7th Floor)
	[BM3] Building and Construction Information Modeling(BIM/CIM)-3	[LIS] Laser and Image Scanning
15:00-15:15	Coffee Break (Coffee Space in Open Square on Ground Floor)	
15:15-16:15	[BM4] Building and Construction Information Modeling(BIM/CIM)-4	[IPM] Information and Process Management
16:15-16:30	Break	
16:30-16:45	Closing Ceremony Best papers and Best Presentation Awards, Closing, Group Photo	

[Day 3] Excursion *pre-entry required

November 9 (SAT)	
8:50	Meet at Sendai Station East Exit, Chartered Bus Stop
9:00-16:40	Tour to the Matushima Islands and the Tsunami Affected Area Shiogama Shrine, Saura Sake Brewery, Lunch, Zuiganji Temple, Entsu-in Temple, and “Sendai Arahama Elementary School” in Tsunami Affected Area

KEYNOTE LECTURE-1

Information and Communication Technologies (ICT) in Civil And Building Engineering

Prof. Kincho H. Law

Professor, Civil and Environmental Engineering, Stanford University, USA. Email: law@stanford.edu

Abstract: Civil and Building Engineering has had a long and successful history in adopting computing technologies, from computer graphics, CAD, engineering analyses, virtual simulations, to project management. As technologies continue to advance, there are many new opportunities that can take advantage of information science and computing technologies in engineering. Technologies such as building information modeling, virtual reality, computer vision, sensors, Internet and cloud computing, etc., are now being deployed in civil and construction engineering. This presentation will provide an overview of current trends of computing technologies in the AEC domain. Specifically, the discussions will focus on technologies related to building information modeling and enterprise integration, and the applications of Internet of Things (IoT) and machine learning in the civil and building industry.

Profile of Prof. Kincho H. Law

Dr. Kincho H. Law is Professor of Civil and Environmental Engineering at Stanford University. He received his B.Sc. in Civil Engineering and B.A. in Mathematics from the University of Hawaii in 1976, and M.S. and Ph.D. in Civil Engineering from Carnegie Mellon University in 1979 and 1981, respectively. After serving as Assistant Professor at Rensselaer Polytechnic Institute from 1982 to 1988, he joined Stanford University in 1988. Prof. Law's research interests focus on computational and information science in engineering. His research has dealt with various aspects of high performance computing; sensing, monitoring and control of engineering systems; legal and engineering informatics; smart manufacturing; web services, cloud and Internet computing.

Prof. Law was the recipient of the ASCE Computing in Civil Engineering Award in 2011. He has received a number of best paper awards from ASCE, ASME, IEEE and Digital Government Society; these include Best Paper (on Data Analytics for Advanced Manufacturing) at IEEE Big Data Conference in 2016, Best Paper at the ASME Manufacturing Science and Engineering Conference in 2015, Best Paper in the ASCE Journal of Computing in Civil Engineering in 2014, Best Research Paper (on Resilience and Smart Structures) at the International Workshop on Computing in Civil Engineering in 2013, Best Research and Practice Paper at 6th International Conference on Electronic Governance in 2012, Meritorious Paper at the 4th International Conference on Electronic Governance in 2010, Best Research Paper at the 9th International Conference on Digital Government Research in 2008, and others. Prof. Law was elected Distinguished Member of the American Society of Civil Engineers in 2017, Fellow of the American Society of Mechanical Engineers in 2017, Life Member of the American Society of Civil Engineers in 2018, and Senior Member of the Institute of Electrical and Electronics Engineers in 2019.

KEYNOTE LECTURE-2

Digitalization in AEC– German perspectives from strategy to implementation

Prof. Katharina Klemt-Albert

Professor for Construction Management und Digital Engineering, Leibniz Universität Hannover, Germany. Email: klemt-albert@icom.uni-hannover.de

Abstract: Germany has recognized the potential of the BIM method and is proceeding to develop necessary guidelines and framework conditions at national level as well as implementation acts. This process is driven by the Federal Ministry of Transport and Digital Infrastructure (BMVI) and the Federal Ministry of the Interior, Building and Home Affairs (BMI). In 2015, BMVI published the phased plan Digital Planning and Building as a strategy for the introduction of BIM for federal traffic infrastructure. The plan describes the step-wise path to the gradual introduction of BIM in the area of responsibility of the BMVI. Selected transport infrastructure projects of the road, rail and waterways are currently carried out as pilot projects. Federal institutions are pursuing an open exchange of data (OpenBIM). An examination of the application of BIM in building construction projects of the Federal Government with an estimated investment volume of EUR 5 million or higher is demanded by BMI. Starting in 2020, both ministries will run the national BIM competence center in order to coordinate the BIM implementation as well as to act as a service hub of BIM-related knowledge and technology transfer.

In addition, guidelines and instructions for applying the BIM methodology are developed and issued by major German private and public companies. They include BIM execution plans (BEP) and employer's information requirements (EIR) as well as legal designs (contract) and tender procedures. Noteworthy here is, for example, Deutsche Bahn as a major public contractor in the infrastructure sector, which has developed specifications for the application of the BIM method for railway projects. The federal project company in the field of road infrastructure, DEGES, has published guidelines and templates for road construction. Other private companies have proceeded in a similar manner. These guidelines include specifications for framework conditions, such as processes, roles and project standards, as well as BIM use cases, such as specifications for collaboration and information requirements (including platform concepts and integrated communication tools). Specific and crucial roles both on employer's and contractor's side (e.g. BIM manager and BIM coordinator) are defined to guarantee satisfying project execution due to BIM use.

All sectors require a solid, consistent and state-of-the-art training and education of engineers and specialists. This is executed both in the public and the private sector. Legal entities both on national and state level can and must be partner of (regional) economies in order to support especially SMEs in the change process. The Institute of Construction Management and Digital Engineering (ICoM) is a leading German educator not only on the university level, but also transferring knowledge to working professionals from beginner to expert levels via use of new methodical approaches as well as their digital laboratories (X-Lab). Innovative methods of education (e.g. blended learning and virtual reality) find their way into the educational programs. Post-educational, certified courses for professionals and specialists round off academic qualification.

Profile of Prof. Katharina Klemt-Albert

Prof. Dr.-Ing. Katharina Klemt-Albert leads the Institute for Construction Management and Digital Engineering at Leibniz University Hanover since 2016. Her focus in research and teaching is on digital transformation and digitalization of the building and construction industry. She started her academic career studying civil engineering at Ruhr University Bochum. In 2001 she received her doctorate with distinction from Technical University of Darmstadt in cooperation with Northwestern University/USA. Professor Klemt-Albert is an experienced leader and manager of mega projects in Germany and worldwide. For 14 years, she held positions of high responsibility at Deutsche Bahn AG, most recently as Member of the Board of an international engineering company with 1,500 employees. Her personal interest has always been the development and implementation of technical innovations. Her work focuses on the integration of science and practice. Major research topics at her institute are GreenBIM, Digital Methodologies in AEC, Digital Construction and Major Projects. Professor Klemt-Albert is honored as one of Germany‘s Top 25 most influential women in engineering. She won the prize for excellence in teaching of Leibniz Universität Hannover. She initiated several BIM networks such as the BIM Cluster Lower Saxony, a statewide association of government, industry and academia. Furthermore, Professor Klemt-Albert is founder and CEO of albert.ing GmbH, which offers engineering services and consulting in digital construction.

KEYNOTE LECTURE-3

Creation, Integration and Management of BIM Information

Dr. Jack C. P. Cheng

Associate Professor, Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong. E-mail: cejcheng@ust.hk

Abstract: Building information modeling (BIM) technology is increasingly used in various architecture, engineering, construction and operations applications. BIM is even compulsory for public projects in some countries and regions like UK and Hong Kong. This leads to the opportunities yet challenges to the availability, representation, use and management of building information models. In this presentation, the generation and representation of building information models will be discussed firstly. In specific, model requirement definition and advanced approaches based on machine learning and AI to automatically generate building information models from point cloud data will be presented. Secondly, examples and lesson learnt of integrating BIM information with other technologies such as GIS, Internet of Things and robotics will be presented. Thirdly, this presentation will discuss the storage, sharing and management of building information models and associated information in a multi-user, collaborative environment. Potential opportunities and challenges of relevant technologies and infrastructures such as blockchain and common data environment will be discussed.

Profile of Dr. Jack C. P. Cheng

Dr. Jack Cheng is an Associate Professor of Civil and Environmental Engineering, Director of the RFID Center, and Associate Director of the GREAT Smart Cities Institute at the Hong Kong University of Science and Technology (HKUST). He obtained his PhD degree from Stanford University. His research interests include BIM, Internet of Things (IoT), computer vision and deep learning, construction informatics, construction and facility management, green and low carbon buildings, and sustainable construction. He is currently the Chair of the Hong Kong Construction Industry Council (CIC) BIM Standards (Phase 2) Task Force, Chair of ASCE Global Center for Excellence in Computing, Chairman of Autodesk Industry Advisory Board (AIAB), President-Elect of ASCE Hong Kong Section, and Honorary Treasurer of Hong Kong Institution of Building Information Modeling (HKIBIM). He is a Professional Member of HKIBIM, CIC Certified BIM Manager, and Certified Carbon Auditor Professional (CAP). He has received the Construction Industry Outstanding Young Person Award in 2019 and the Young BIMer of the Year Award in 2014 from the CIC. He has co-authored over 200 referred journal and conference publications.

PARALLEL SESSIONS

[Day 1] 10:45-12:00

Session A (Studio Theater on 7th Floor):

[AI1] AI and Data Analysis-1

Chair: Prof. Kei Kawamura (Yamaguchi University)

[AI1-1] NLP-based Method for Auto-Correcting Public Constructions Data
Meng-Lin Yu (National Taiwan University of Science and Technology), Hao-Yung Chan (National Taiwan University of Science and Technology), Meng-Han Tsai (National Taiwan University of Science and Technology)

[AI1-2] Analysis of Power Usage and Building Residents Relationships for Energy Savings Using Social Network Analysis
Ru-Guan Wang (National Central University), Chien-Cheng Chou (National Central University)

[AI1-3] As-built Detection of Steel Frame Structure Using Deep Learning
Ryu Izutsu (Osaka University), Nobuyoshi Yabuki (Osaka University), Tomohiro Fukuda (Osaka University)

[AI1-4] Video-based Construction Vehicles Type Recognition
Chen-Hsuan Wang (National Taiwan University of Science and Technology), I-Tung Yang (National Taiwan University of Science and Technology), Meng-Han Tsai (National Taiwan University of Science and Technology)

[AI1-5] GA-based Optimization for Construction Sequence of Precast and Cast-in-place Concrete Components
Songyang Li (Tsinghua University), Zhiliang Ma (Tsinghua University)

Session B (Meeting Room A/B on 7th Floor):

[XR] Visualization and XR(VR/AR/MR)

Chair: Prof. Amir Behzadan (Texas A&M University)

[XR-1] Efficient Access to Inspection Data Based on Augmented Reality Using a "BRIDGE - CARD"
Hisao Emoto (KOSEN), Hiroki Komuro (KOSEN), Takehiko Midorikawa (KOSEN), Hideaki Nakamura (Yamaguchi University), Kei Kawamura(Yamaguchi University)

[XR-2] Bidirectional Linking Of 4D-BIM Planning with Virtual and Augmented Reality
Felix Dreischerf (University of Applied Science Erfurt), Habeb Astour (University of Applied Science Erfurt)

[XR-3] Verification About Work Efficiency Improvement by Using an Augmented Reality and Wearable Computer
Satoshi Yamanaka (Obayashi Corporation), Shinya Sugiura (Obayashi Corporation), Ryo Tajima (Obayashi Corporation), Takafumi Yamanaka (Obayashi Corporation)

[XR-4] Visualization of Construction Process by Construction Site Sensing and Digital Twins
Atsushi Takao (Okumura Corporation), Nobuyoshi Yabuki (Osaka University), Kohei Seto (Okumura Corporation), Iwao Miyata (Okumura Corporation)

[XR-5] AR Visualization of Physical Barrier for Wheelchair Users Using Depth Imaging
Rio Takahashi (Kansai University), Hiroshige Dan (Kansai University), Yoshihiro Yasumuro (Kansai University)

[Day 1] 13:50-15:05

Session A (Studio Theater on 7th Floor):

[AI2] AI and Data Analysis-2

Chair: Prof. Nobuyoshi Yabuki (Osaka University)

[AI2-1] Basic Study on Detecting Breaking Sounds of Structural Members by Using Machine Learning
Takeo Izumita (Tokyo University of Science), Masayuki Saeki (Tokyo University of Science)

[AI2-2] Computer Vision-based In-building Human Demand Estimation for Installation of Automated External Defibrillators
Wen-Xin Qiu (National Taiwan University), Albert Y. Chen (National Taiwan University)

[AI2-3] Multi-Dimensional Sequence Alignment for Context-Aware Human Action Analysis of Body-Sensor Data
Nipun Nath (Texas A&M University), Amir Behzadan (Texas A&M University), Prabhat Shrestha (Texas A&M University)

[AI2-4] Application of Intelligent Systems in the Underground Excavation Industry: A Short Review
Mohsen Ramezanshirazi (Sapienza University of Rome), Mohammad Norizadeh Cherloo (University of science and technology), Orod Zarrin

[AI2-5] Determination of Automated Construction Operations from Sensor Data Using Machine Learning
Aparna Harichandran (Curtin University), Benny Raphael (Indian Institute of Technology Madras), Abhijit Mukherjee (Curtin University)

Session B (Meeting Room A/B on 7th Floor):

[FM] Facility and Infrastructure Management

Chair: Dr. Veerasak Likhitruangsilp (Chulalongkorn University)

[FM-1] Steel Bridge Information Delivery Model for Earned Value Management (EVM)
Teruaki Kageyama (Japan Construction Information Center), Nobuyoshi Yabuki (Osaka University)

[FM-2] A Proposal of Deterioration Prediction Model for Tunnel Lighting Facilities Using Markov Stochastic Process
Noriaki Maeda (Yamaguchi University), Kei Kawamura (Yamaguchi University)

[FM-3] VRP-based Model for Lane Marking Assessment with MRU Vehicle
Yu-Chun Lin (National Taiwan University), Si-Ting Liao (National Taiwan University), Chieh Wang (National Taiwan University), Albert Y. Chen (National Taiwan University)

[FM-4] The Gateway to Integrating User Behavior Data in "Cognitive Facility Management"
Jinying Xu (The University of Hong Kong), Weisheng Lu (The University of Hong Kong), Jing Wang (The University of Hong Kong)

[Day 1] 15:20-16:35

Session A (Studio Theater on 7th Floor):

[CV] Image Processing and Computer Vision

Chair: Dr. Lei Hou (RMIT University)

[CV-1] Study on Automatic Chalk Marks Recognition for Concrete Tunnel Inspection Using Deep Learning
Yao Zhang (Yamaguchi University), Kei Kawamura (Yamaguchi University), Cuong Nguyen Kim (Mientrung University of Civil Engineering), Koji Oshikiri (Ricoh Company, Ltd.), Taro Kikuchi (Ricoh Company, Ltd.)

[CV-2] GA-CNN Based Automatic Crack Detection and Classification Method for Concrete Infrastructures
Cuong Nguyen Kim (Mientrung University of Civil Engineering), Kei Kawamura (Yamaguchi University), Yao Zhang (Yamaguchi University)

[CV-3] As-built Modeling of Steel Structures Using Symmetry
Takuya Suzuki (Nihon University), Tomohiro Mizoguchi (Nihon University)

[CV-4] A Review of Research on Advanced Autonomous Technologies for Bridge Inspection
Rina Hasuike (Gifu University), Koji Kinoshita (Gifu University), Lei Hou (RMIT University)

[CV-5] A Performance Evaluation of Feature Detectors and Descriptors for Unmodified Infrastructure Site Digital Images
Natthapol Saovana (Osaka University), Nobuyoshi Yabuki (Osaka University), Tomohiro Fukuda (Osaka University)

Session B (Meeting Room A/B on 7th Floor):

[IS] Industrial/Technical Session

Chair: Prof. Teppei Ishiuchi (Miyagi University)

[IS-1] Collection Data Using New Tool to Satisfy Specifications
Yasushi Kawanai (Japan Construction Information Center)

[IS-2] Educational Activity Aimed at Improving Productivity in Japanese Construction Industries Through 3D-CAD
Yasuyuki Kikyo (Japan Construction Information Center)

[IS-3] Improvement of Electronic Bidding Core System
Hiroyuki Ishiwata (Japan Construction Information Center)

[IS-4] Integration of 3D Models of Structures and Geological Composition as an Underground Infrastructure Model
Toshiaki Hakoda (JGC Corporation), Syoichi Nishiyama (OYO Corporation), Takaki Omori (Nikken Sekkei Civil Engineering Ltd.), Isao Shiozaki (Engineering Advancement Association of Japan), Mamoru Narusawa (ESCA-SC), Nobuyuki Yabuki (Osaka University)

[Day 2] 9:20-10:20

Session A (Studio Theater on 7th Floor):

[BM1] Building and Construction Information Modeling(BIM/CIM)-1

Chair: Prof. Zhiliang Ma (Tsinghua University)

[BM1-1] Research on BIM Based Infrastructure Platforms with International Standards
Katsunori Miyamoto (Japan Construction Information Center)

[BM1-2] A BIM-based AR Application for Construction Quality Inspection
Nai-Wen Chi (National Taiwan University of Science and Technology), Yi-Wen Chen (Moldex3D Co., Ltd.), Shang-Hsien Hsieh (National Taiwan University), Jen-Yu Han (National Taiwan University), Lung-Mao Huang (Reiju Construction Co., Ltd.)

[BM1-3] Application of BIM Technology on Virtual Mock-up and Implementation for General Contractor in Construction
Rodrigo Samuel Ortiz Chaparro (National Taipei University of Technology), Yu-Cheng Lin (National Taipei University of Technology)

[BM1-4] Deep Learning-based Scan-to-BIM Framework for Complex MEP Scenes Using Laser Scan Data
Chao Yin (The Hong Kong University of Science and Technology), Boyu Wang (The Hong Kong University of Science and Technology), Jack C.P. Cheng (The Hong Kong University of Science and Technology)

Session B (Meeting Room A/B on 7th Floor):

[CME] Computational Mechanics/Engineering

Chair: Prof. Masayuki Saeki (Tokyo University of Science)

[CME-1] Evaluation of Pile Performance in Different Layers of Soil Investigating Pile Behavior by OpenSeesPL
Orod Zarrin (The University of Newcastle), Mohsen Ramezanshirazi (Sapienza University of Rome)

[CME-2] Development of Static and Dynamic Modeling Approaches Using Frame Models for City Seismic Response Analysis
Pher Errol B. Quinay (University of the Philippines Diliman), Aileen Rachelle Fader (Wallcrete Company, Inc.), Franz Marius Carangan (Al Abbar Aluminum Philippines, Inc.)

[CME-3] Structural Shape Grammars Used in Intelligent Generation Design of Discrete Structures
Xianzhong Zhao (Tongji University), Ruifeng Luo (Tongji University)

[CME-4] Numerical Evaluation of Seismic Response of Anchorage Foundation Installed in Switchboard Cabinet
Sang-Moon Lee (Gangneung-Wonju University), Woo-Young Jung (Gangneung-Wonju University), Ga-Ram Kim (Gangneung-Wonju University)

[Day 2] 10:35-11:50

Session A (Studio Theater on 7th Floor):

[BM2] Building and Construction Information Modeling(BIM/CIM)-2

Chair: Prof. Brian Guo (University of Canterbury)

[BM2-1] Conversation-based Building Information Delivery System for Facility Management

Kuan-Lin Chen (National Taiwan University of Science and Technology), Meng-Han Tsai (National Taiwan University of Science and Technology)

[BM2-2] Development of a New District in the State of Hessen "FlexQuartier" Project

Jose Alberto Lagunes Ronzon (Technische Hochschule Mittelhessen), Moritz Hofmann (Technische Hochschule Mittelhessen), Milena Potpara (Technische Hochschule Mittelhessen), Dirk Metzger (Technische Hochschule Mittelhessen), Joaquin Diaz (Technische Hochschule Mittelhessen)

[BM2-3] Process Re-engineering in Owner Organizations to Improve BIM-based Project Delivery Using Requirements Management Platform

Ali Motamedi (École de technologie supérieure), Sylvain Vaudou (École de technologie supérieure), Romain Leygonie (École de technologie supérieure), Daniel Forgues (École de technologie supérieure)

[BM2-4] A Framework for Visual BIM-based Maintenance Management in MRT Stations

Yi-Shian Huang (National Taipei University of Technology), Yu-Cheng Lin (National Taipei University of Technology)

[BM2-5] Modeling the Last-mile Problem of BIM Adoption

Jing Wang (the University of Hong Kong), Weisheng Lu (the University of Hong Kong), Jinying Xu (the University of Hong Kong)

Session B (Meeting Room A/B on 7th Floor):

[IOT] IoT, Sensors, and Monitoring

Chair: Prof. Hiroaki Date (Hokkaido University)

[IOT-1] Framework for a BIM-based Real-time Evacuation Guidance System in Smart Buildings

Kayla Manuel (Osaka University), Nobuyoshi Yabuki (Osaka University), Tomohiro Fukuda (Osaka University)

[IOT-2] Development of a Method to Detect Earthquake-Related Changes in Images Taken by CCTV Cameras Surveying Civil Infrastructure

Arata Konno (Ministry of Land, Infrastructure, Transport and Tourism), Hirotaka Sekiya (Ministry of Land, Infrastructure, Transport and Tourism), Hideyuki Ashiya (Ministry of Land, Infrastructure, Transport and Tourism)

[IOT-3] A Human Following Robot for Assisting Tunnel Inspectors

Chia-Hsing Ho (Turing Drive Inc.), Yo-Ming Hsieh (National Taiwan University of Science and Technology)

[IOT-4] A Building Structural Health Management System by BIM and IoT Collaboration

Narito Kurata (Tsukuba University of Technology), Kenro Aihara (National Institute of Informatics), Takahiro Konishi (Applied Technology Co., Ltd.), Hirofumi Yamaoka (Applied Technology Co., Ltd.), Shinichi Kondo (Applied Technology Co., Ltd.)

[IOT-5] Development of an Anomaly Detection System of Road Signs Using Mems Accelerometers

Naomasa Haibara (Tokyo University of Science), Masayuki Saeki (Tokyo University of Science)

[Day 2] 14:00-15:00

Session A (Studio Theater on 7th Floor):

[BM3] Building and Construction Information Modeling(BIM/CIM)-3

Chair: Prof. Shang-Hsien (Patrick) Hsieh (National Taiwan University)

[BM3-1] BIM-based Wall Framing Calculation Algorithms for Detailed Quantity Takeoff
Chavanont Khosakitchalert (Osaka University), Nobuyoshi Yabuki (Osaka University), Tomohiro Fukuda (Osaka University)

[BM3-2] BIM-Supported Compliance Verification of Performance-based Car-park Ventilation Design
Johannes Dimyadi (Compliance Audit Systems Limited), Robert Amor (University of Auckland)

[BM3-2] The Study of Automatic CIM Models Development for Infrastructure Projects
Tzu-Tin Huang (National Taipei University of Technology), Yu-Cheng Lin (National Taipei University of Technology)

[BM3-4] An Automated BIM-integrated System for Change Order Cost Impact Evaluation
Veerasak Likhitruangsilp (Chulalongkorn University), Tantri Handayani (Universitas Gadjah Mada), Nobuyoshi Yabuki (Osaka University), Photios Ioannou (University of Michigan)

Session B (Meeting Room A/B on 7th Floor):

[LIS]Laser and Image Scanning

Chair: Prof. Yoshihiro Yasumuro (Kansai University)

[LIS-1] Automatic Indoor Environment Modeling from Laser-scanned Point Clouds Using Graph-Based Regular Arrangement Recognition
Hayato Takahashi (Hokkaido University), Hiroaki Date (Hokkaido University), Satoshi Kanai(Hokkaido University)

[LIS-2] Detecting Building Facade Deteriorations: Evaluation of 3D Laser Scanning and Image-Based Reconstruction Approaches to Determine Feasible Sttings in Data Collection
Zhuoya Shi (NYU Tandon School of Engineering), Semiha Ergan (NYU Tandon School of Engineering)

[LIS-3] Automated UAV Route Planning for Bridge Inspection Using BIM-GIS Data
Yang Zou (University of Auckland), Molood Barati (University of Auckland), Enrique Del Rey Castillo (University of Auckland), Robert Amor (University of Auckland), Brian H.W. Guo (University of Canterbury), Jiamou Liu (University of Auckland)

[LIS-4] Measuring Railway Facilities by Using Two Mobile Laser Scanners Directly Above the Rails
Kohei Yamamoto (PASCO Corp.), Nobuyoshi Yabuki (Osaka University)

[Day 2] 15:15-16:15

Session A (Studio Theater on 7th Floor):

[BM4] Building and Construction Information Modeling(BIM/CIM)-4

Chair: Prof. Weng Tat Chan (National University of Singapore)

[BM4-1] Simulation and Optimization of Utility Tunnels Construction as Linear Projects
Mohamed Sherif (The American University in Cairo), Abdelhamid Abdallah (Helwan University), Khaled Nasser (The American University in Cairo)

[BM4-2] Integrating BIM into Green Residential Building Assessment: A Case Study
Fatma Abdelaal (University of Canterbury), Brian Guo (University of Canterbury), Yang Zou (University of Auckland), Mazharuddin Syed Ahmed (Ara Institute of Canterbury)

[BM4-3] Enhanced Underground Utilities Management Integrated CIM Technologies
Sheng-Lun Zhuo (National Taipei University of Technology), Yu-Cheng Lin (National Taipei University of Technology)

[BM4-4] Developing Efficient Mechanisms for BIM Model Simplification
Jack C.P. Cheng (The Hong Kong University of Science and Technology), Keyu Chen (The Hong Kong University of Science and Technology), Weiwei Chen (The Hong Kong University of Science and Technology)

Session B (Meeting Room A/B on 7th Floor):

[IPM]Information and Process Management

Chair: Prof San-Ho Lee (Yonsei University)

[IPM-1] A Feasibility Study for LDAP Certification in Collaboration with Exiting Accounts in RDBMS
Yoshiyuki Yokoyama (Japan Construction Information Center)

[IPM-2] Semantic Modeling of Building Construction Emission Knowledge
Wenkai Luo (RMIT University), Guomin Zhang (RMIT University), Lei Hou (RMIT University), Malindu Sandanayake (Victoria University)

[IPM-3] Application and Analysis of System Architecture Model for Construction Project
Tatsuru Tomii (Kokusai Kogyo Co., Ltd.), Koji Makanae (Miyagi University), Raj Kapur Shah (Liverpool John Moores University)

[IPM-4] Smart Construction Objects (SCOs): A New Theory of Smart Construction Is Born?
Weisheng Lu (The University of Hong Kong), Yuhan Niu (Construction Industry Council), Chimay Anumba (University of Florida)

Organization of ICCBEI 2019

Asian Group for Civil Engineering Informatics (AGCEI)

Board of Director

President:

Nobuyoshi Yabuki, Osaka University, Japan

Members:

Weng Tat Chan, National University of Singapore, Singapore
Atsushi Fukasawa, Japan Construction Information Center, Japan
Shang-Hsien (Patrick) Hsieh, National Taiwan University, Taiwan
Jun Shang Kuang, The Hong Kong University of Science and Technology, Hong Kong
Sang-Ho Lee, Yonsei University, Korea
Veerasak Likhitruangsilp, Chulalongkorn University, Thailand
Zhiliang Ma, Tsinghua University, China
Koji Makanae, Miyagi University, Japan
Xiangyu Wang, Curtin University, Australia

Committee on Civil Engineering Informatics, Japan Society of Civil Engineers (JSCE)

Chair:
Koji Makanae, Miyagi University, Japan
Vice Chair:
Katsutoshi Yasui, Obayashi Corporation, Japan
Osamu Okamoto, Ibaraki National College of Technology, Japan
Secretary General:
Hiroaki Mori, Chuo Fukken Consultants Co., Ltd., Japan
Members:
27 Standing Committee Members and Other Sub-committee members.

Supporters:

Japan Construction Information Center

MIYAGI UNIVERSITY

Committees of ICCBEI 2019

Organizing Committee:

Chair:
Koji Makanae, Miyagi University, Japan
Vice Chair:
Nobuyoshi Yabuki, Osaka University, Japan
Members:
Yoichiro Chiba, Pacific Consultants International Group, Japan
Hiroshi Fukumori, Shimizu Corporation, Japan
Teppei Ishiuchi, Miyagi University, Japan
Hirotoshi Ito, Eight-Japan Engineering Consultants Inc., Japan
Hirofumi Matsuda, Trion Corporation, Japan
Hiroaki Mori, Chuo Fukken Consultants Co., Ltd., Japan
Masaki Sawa, Hazama Ando Corporation, Japan
Yoshihide Sekimoto, University of Tokyo, Japan
Masato Shiozaki, Mitsui Sumitomo Construction Co., Ltd., Japan
Ko Ueyama, CTI Engineering Co., Ltd., Japan
Katsutoshi Yasui, Obayashi Corporation, Japan

International Scientific Committee:

Chair:
Nobuyoshi Yabuki, Osaka University, Japan
Vice Chair:
Koji Makanae, Miyagi University, Japan
Members:
Robert Amor, The University of Auckland, New Zealand
Weng Tat Chan, National University of Singapore, Singapore
Albert Y. Chen, National Taiwan University, Taiwan
Jack C. P. Cheng, The Hong Kong University of Science and Technology, Hong Kong
Hiroshige Dan, Kansai University, Japan
Tomohiro Fukuda, Osaka University, Japan
Lei Hou, Royal Melbourne Institute of Technology, Australia
Patrick Shang-Hsien Hsieh, National Taiwan University, Taiwan
Satoshi Kanai, Hokkaido University, Japan
Teppei Ishiuchi, Miyagi University, Japan
Kei Kawamura, Yamaguchi University, Japan
Jun Shang Kuang, The Hong Kong University of Science and Technology, Hong Kong
Sang-Ho Lee, Yonsei University, Korea
Veerasak Likhitruangsilp, Chulalongkorn University, Thailand
Vincent Yu-Cheng Lin, National Taipei University of Technology, Taiwan
Wilson W.S. Lu, The University of Hong Kong, Hong Kong
Zhiliang Ma, Tsinghua University, China
Tomohiro Mizoguchi, Nihon University, Japan
Kantaro Monobe, Tohoku Gakuin University, Japan
Ali Motamedi, École de Technologie Supérieure, Canada
Tatsunori Sada, Nihon University, Japan
Masayuki Saeki, Tokyo University of Science, Japan
Raj Kapur Shah, Liverpool John Moores University, UK
Yoshihiro Yasumuro, Kansai University, Japan
Xiangyu Wang, Curtin University, Australia
Yang Zou, The University of Auckland, New Zealand

Book of Abstracts

"Proceeding of the 4th International Conference on Civil and Building Engineering Informatics" (*ISBN978-4-600-00276-3*)
can be downloaded from
https://www.iccbei2019.com

AI1-1

NLP-BASED METHOD FOR AUTO-CORRECTING PUBLIC CONSTRUCTIONS DATA

Meng-Lin Yu[1], Hao-Yung Chan[2], Meng-Han Tsai[3]

1) Graduate Student, Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan. Email: m10705510@mail.ntust.edu.tw
2) Ph.D. student, Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, Taiwan. Email: d10705005@mail.ntust.edu.tw
3) Assistant Professor, Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, Taiwan. Email: menghan@mail.ntust.edu.tw

Abstract: This research developed a term dictionary in the construction area for increasing segmentation quality of auto-correcting the data in the public construction cost estimate system (PCCES) data. According to the administrative rules in Taiwan, all the information, such as bidding price, construction time, construction material, etc., of infrastructure projects need to be recorded into the PCCES. The database with enormous amounts of historical data allows the government to have statistical analysis and learn from the historical experience. However, in the database, most of the data is stored as non-structural formats, mainly texts, which makes analyzing those data a tedious and time-consuming work. Therefore, this research aims to structuralize the non-structural data in the PCCES database through natural language process (NLP) methods. We construct a dictionary to eliminate inconsistency of terms and common names automatically. This dictionary contains the terms and common names used in the field of civil engineering in Taiwan to facilitate the use of NLP parsing and classification to correct erroneous data.

Keywords: natural language processing (NLP), public construction cost estimate system (PCCES), Chinese segmentation

AI1-2

ANALYSIS OF POWER USAGE AND BUILDING RESIDENTS RELATIONSHIPS FOR ENERGY SAVINGS USING SOCIAL NETWORK ANALYSIS

Ru-Guan Wang[1] and Chien-Cheng Chou[2]

1) Graduate Research Assistant, Information Technology for Disaster Prevention Program, Department of Civil Engineering, National Central University, Taoyuan, Taiwan. Email: rubyw666@gmail.com
2) Professor, Information Technology for Disaster Prevention Program, Department of Civil Engineering, National Central University, Taoyuan, Taiwan. Email: ccchou@ncu.edu.tw

Abstract: Reducing carbon footprints in the building sector can be achieved by altering power consumption behavior of building residents. Due to the influence of today's declining birth rate and population aging, the structure of human society is changed, requiring the identification of key persons active in a community to persuade the others into saving electricity. This research aims at applying the technique of social network analysis (SNA) to a publicly available smart meter data set for building residents in Germany. Traditionally the head of a community can serve as the role of broadcasting energy-saving information, although its effectiveness varies with different circumstances. In the proposed SNA-based approach, the German data set is firstly examined and pre- processed, such as augmenting building occupancy data and relationships among residents. Then, different SNA indexes are explored in order to derive a generalized procedure for such identification of key persons. More sustainable societies can be established if key persons of a community can be identified and get involved by using the proposed approach. Energy-saving information specific to each type of home appliance can be broadcast effectively and efficiently so that building residents can persuade easily.

Keywords: Social network analysis; smart meter data analytics; energy conservation.

AI1-3

AS-BUILT DETECTION OF STEEL FRAME STRUCTURE USING DEEP LEARNING

Ryu Izutsu[1], Nobuyoshi Yabuki[2], and Tomohiro Fukuda[3]

1) Master Course Student, Division of Sustainable Energy and Environmental Engineering, Osaka University, Suita, Japan. Email: izutsu@it.see.eng.osaka-u.ac.jp
2) Ph.D., Prof., Division of Sustainable Energy and Environmental Engineering, Osaka University, Suita, Japan. Email: yabuki@see.eng.osaka-u.ac.jp
3) Ph.D., Assoc. Prof., Division of Sustainable Energy and Environmental Engineering, Osaka University, Suita, Japan. Email: fukuda@see.eng.osaka-u.ac.jp

Abstract: At the construction site, as-built management is generally performed by taking pictures and comparing them with drawings or Building Information Modeling (BIM) models. Since this work is time-consuming and prone to human error, a more accurate and efficient method of capturing the progress is desired. The purpose of this research is to construct a system that can efficiently capture the progress of the construction by detecting each structural steel frame component such as a beam and a column under construction from images taken by a camera. First, we developed a Convolutional Neural Network (CNN) that could detect structural steel frame components under construction from images by fine-tuning the existing Object Detection and Segmentation CNNs. Next, we constructed a system that can capture each structural steel frame member from an image by integrating two constructed CNN models. Finally, we conducted accuracy verification and evaluated the developed system.

Keywords: Convolutional Neural Network, Deep Learning, As-built Detection, Steel Frame, Segmentation.

AI1-4

Video-based construction vehicles type recognition

Chen-Hsuan Wang[1], I-Tung Yang[2], Meng-Han Tsai[3]

1) Graduate Student, Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, Taiwan. Email: m10705506@mail.ntust.edu.tw
2) Chairman, Professor, Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, Taiwan. Email: ityang@mail.ntust.edu.tw
3) Assistant Professor, Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, Taiwan. Email: menghan@mail.ntust.edu.tw

Abstract: This research is an ongoing project that aims to recognize construction vehicles automatically for saving the labor cost. Monitoring the construction vehicle that enters and leaves the construction site can help with tracking the construction progress and recognizing the abnormal vehicles. In modern construction sites, IP cameras have been widely utilized for security purposes. The enormous amounts of gathered videos bring opportunities for us to monitor the construction vehicle without assigning a gate guard. However, although IP cameras can store all the historical images, it is very complicated and time-consuming to calculate the traffic flow of each vehicle type from the surveillance images of the day. Therefore, this research proposed a real-time construction vehicle recognition system. The proposed system contained three major parts: an image recognition algorithm for recognizing the vehicle type, a database for storing the recognition results, and a dialogue system for supplying the structuralized results to the site manager. For the image recognition algorithm, the YOLOv3 algorithm was utilized for processing the video frame by frame and recognizing the vehicle type. The results of the recognition would be analyzed and stored in a structuralized database for further use. Lastly, a chatbot-based dialogue system was developed to provide the site information and push instant warning to the related personnel. After a feasibility test, the unstructured construction video data could be transferred into structured information autonomously. Also, additional labor resources could be saved and thus increase the efficiency of the overall process of construction site management.

Keywords: object detection, object location, image segmentation, YOLOv3 algorithm, dialogue system.

AI1-5

GA-BASED OPTIMIZATION FOR CONSTRUCTION SEQUENCE OF PRECAST AND CAST-IN-PLACE CONCRETE COMPONENTS

Songyang Li[1], Zhiliang Ma[2]

1) Ph.D. Candidate, Department of Civil Engineering, Tsinghua University, Beijing, P.R. China. Email: skuyinlee@gmail.com
2) Ph.D., Prof., Department of Civil Engineering, Tsinghua University, Beijing, P.R. China. Email: mazl@tsinghua.edu.cn

Abstract: To reduce the time and cost, as well as to improve the efficiency and safety of precast concrete construction, the construction sequence of precast concrete (PC) components and cast-in-place (CiP) components needs to be optimized. To solve this problem, a Genetic Algorithm-based method is proposed in this paper. Firstly, based on the real project experience and some reasonable assumptions, the construction sequence of PC and CiP components problem is analyzed and several optimization objectives and constraints are summarized. Then a GA- based method to solve the construction sequence problem is implemented, which includes the coding method, fitness function as well as crossover, mutation and selection operations. Finally, a case study is conducted to verify the proposed method. The results indicate that the method can effectively find the optimal solution for the construction sequence of PC components and CiP components.

Keywords: Precast concrete buildings, Construction sequence, Genetic Algorithm, Optimization

AI2-1

BASIC STUDY ON DETECTING BREAKING SOUNDS OF STRUCTURAL MEMBERS BY USING MACHINE LEARNING

Takeo Izumita[1], Masayuki Saeki[2]

1) Master's Student, Tokyo University of Science, Chiba, Japan. Email: 7618503@ed.tus.ac.jp
2) Dr. Eng., Prof., Tokyo University of Science, Chiba, Japan. Email: saeki@rs.noda.tus.ac.jp

Abstract: In case of a large earthquake, it is necessary to grasp the damage state of structures in disaster areas as soon as possible. Therefore, we have been trying to develop a sensor which is able to detect the destruction of structural members.
In this research, we focus on the breaking sound of wood that is easily recorded using a smartphone and is expected to be discerned from any other sounds with the help of machine learnings. As a basic research, first experiments were carried out to record the breaking sounds of woods as well as other sounds such as talking voice, crashing dishes, closing door, etc. Second, Mel Frequency Cepstral Coefficients (MFCC), that is widely used as acoustic features in the field of speech recognition, were calculated by analyzing the recorded samples. Third, Multi-Layer Perceptron (MLP) and Support Vector Machine (SVM) were applied to the MFCCs to categorize them into two groups which were destruction sound and the others. In the analysis, 156 MFCCs were prepared as training data. In case of SVM, about 70% of these data were properly recognized. On the other hand, MLP with one hidden layer gave a success rate of about 90%. In addition, the effect of the selection of training data sets and the MLP models on the success rate was investigated.

Keywords: Mel Frequency Cepstral Coefficients, Machine Learning, breaking sound, damage estimation

AI2-2

COMPUTER VISION-BASED IN-BUILDING HUMAN DEMAND ESTIMATION FOR INSTALLATION OF AUTOMATED EXTERNAL DEFIBRILLATORS

Wen-Xin Qiu[1], Albert Y. Chen[2]

1) Graduate student, Civil Engineering, National Taiwan University, Taipei, Taiwan. Email: r07521505@ntu.edu.tw
2) Assoc. Prof., Civil Engineering, National Taiwan University, Taipei, Taiwan. Email: AlbertChen@ntu.edu.tw

Abstract: To support a better indoor location distribution of automated external defibrillators (AEDs), the real demand, the actual human distribution, should be known. In this research, a computer vision-based process is proposed. The data are collected in the form of image sequences, such as surveillance cameras, in the building. Image based human detection and tracking are applied, and the depth estimation from a deep neural network is utilized to estimate the location of each person. The appearing and disappearing locations are clustered to estimate the node in the indoor traveling network to other spaces in the image. The amount of people are accumulated, for locations in the building, to serve as the demand distribution, and a network based model for AED location optimization can be further integrated.

Keywords: Automated external defibrillators, Human detection and tracking, Depth estimation

AI2-3

MULTI-DIMENSIONAL SEQUENCE ALIGNMENT FOR CONTEXT-AWARE HUMAN ACTION ANALYSIS OF BODY-SENSOR DATA

Nipun D. Nath[1], Amir H. Behzadan[2], and Prabhat Shrestha[3]

1) Ph.D. Student, Zachry Department of Civil Engineering, Texas A&M University, College Station, Texas, USA. Email: nipundebnath@tamu.edu
2) Associate Professor, Department of Construction Science, Texas A&M University, College Station, Texas, USA. Email: abehzadan@tamu.edu
3) M.S. Student, Department of Construction Science, Texas A&M University, College Station, Texas, USA. Email: prabhat1993@tamu.edu

Abstract: Time-motion human data are critical to analyzing activities of construction field crew and their spatiotemporal interactions. A major limitation of the current practice, however, is that the context in which data is collected is rarely incorporated in data analysis. This paper investigates the problem of incorporating context into human activity recognition (HAR). This is achieved by using a multi-dimensional sequence alignment (MSA) method that transforms raw body-mounted sensor data to basic human actions in a one-step process. In this paper, an action is defined as a single, isolated effort (e.g., kneeling, pushing), while an activity refers to an ongoing process over a period of time (e.g., pipefitting, welding). When grouped together, actions performed in a specific sequence form an activity. The designed MSA method enables the recognition of human actions through comparing the similarities between several time series sequences of body-sensor data, thus fusing contextual information on temporal dependency with classification. The method is tested on a publicly available dataset in subject-dependent and subject-independent classifications. It is found that in both cases, the 5-fold cross-validation classification accuracy is >97% which is on par with or higher than the performances achieved in previous studies.

Keywords: Multi-dimensional sequence alignment, machine learning, human activity recognition, smartphone sensors.

AI2-4

APPLICATION OF INTELLIGENT SYSTEMS IN THE UNDERGROUND EXCAVATION INDUSTRY: A SHORT REVIWE

Mohsen Ramezanshirazi[1], Mohammad Norizadeh cherloo[2,] Orod Zarrin[3]

1) Ph.D., Department of structural and geotechnical engineering, Sapienza University of Rome, Italy.Email: Mohsen.ramezanshirazi@uniroma1.it
2) Eng., University of science and technology (IUST). Email: M.norizadeh1369@gmail.com

Abstract: According to the growing trend of the world population, the need for underground transportation is increasing. To satisfy the urban development the use of the underground space acquired increasing importance and consequently tunnels are playing an essential role in the development of urban infrastructures.

A variety of construction methods have been developed for tunneling; in an urban area, the mechanized excavation by using a tunnel boring machine (*TBM*) is the more effective option. Tunnels are constructed under various kinds of geological conditions, different from hard rock to very soft soils. By respect to the number of empirical and semi-empirical methods obtainable for predicting phase in mechanized tunneling, there is a beneficial advantage to using intelligence instrument. This paper aimed to the presented the advantages of inteligence prediction tool with used artificial neural network(*ANN*). The *ANN* crate based on different advance algorithms and data collected from the real Tunnel project. Carry out networks optimization and advantages of the method on time and human resource in projects proposed. The relevant results proved that the capability of this method for prediction and shown good agreements between prediction results .The main aim of this study is to introduce the capable Artificial Neural Networks (*ANNs*) as well as the effectiveness of *ANNs* in order to predict the *TBM* performances employed for tunnel excavation.

Keywords: Intelligent system, *ANNs*, Tunnel Boring Machine, *TBMs*.

AI2-5

DETERMINATION OF AUTOMATED CONSTRUCTION OPERATIONS FROM SENSOR DATA USING MACHINE LEARNING

Aparna Harichandran[1], Benny Raphael[2] and Abhijit Mukherjee[3]

1) Joint Doctoral Candidate, Department of Civil Engineering, Indian Institute of Technology Madras, Chennai, India, and School of Civil and Mechanical Engineering, Curtin University, Bentley, WA 6102, Australia. Email: aparnaharichandran@gmail.com
2) Professor, Department of Civil Engineering, Indian Institute of Technology Madras, Chennai, India. Email: benny@iitm.ac.in
3) Professor, School of Civil and Mechanical Engineering, Curtin University, Bentley, WA 6102, Australia. Email: abhijit.mukherjee@curtin.edu.au

Abstract: Automated construction creates an intricate working environment involving workers and machines. The added complexity of automated construction demands a rigorous monitoring system compared to conventional construction. The first stage of developing such a monitoring system is the identification of construction operations. This paper discusses a methodology for the identification of construction operations from sensor data. The methodology is illustrated using the case study of a coordinated lifting equipment implemented in a laboratory. The data is collected from a small scale structural frame consisting of steel modules in a controlled laboratory condition. The automated system follows a top-down construction method where the major construction operations are performed at the ground level and the structure is lifted upwards in stages. Strain and acceleration measurements were collected from the structure during construction. Each operation is associated with a unique pattern of measurements at each sensor location. The measurement data is used for analysis by support vector classification. Parameters like error penalty (C) and width of Gaussian kernel (σ) were varied to obtain the best prediction results. The results of the analysis show that the linear classification gives better results compared to the nonlinear classification for all operations except coordinated lifting. However, coordinated lifting is the best-predicted operation with an accuracy of 96%. Selection of optimal values of C and σ enhances the accuracy of classification. The features extracted from data seems to highly influence the learning of the algorithm and the performance of prediction. The results show the potential for using machine learning techniques for monitoring automated construction operations.

Keywords: Automated Construction, Construction Monitoring, Machine Learning, Support Vector Machines

CV-1

STUDY ON AUTOMATIC CHALK MARKS RECOGNITION FOR CONCRETE TUNNEL INSPECTION USING DEEP LEARNING

Yao Zhang[1], Kei Kawamura [2], Cuong Nguyen Kim [3], Koji Oshikiri [4], and Taro Kikuchi [5]

1) Graduate Student. Graduate School of Science & Technology for Innovation, Yamaguchi University, Japan. E-mail: i503vg@yamaguchi-u.ac.jp
2) Ph.D., Assoc. Prof., Graduate School of Science & Technology for Innovation, Yamaguchi University, Japan. Email: kay@yamaguchi-u.ac.jp
3) Dr. Eng., Faculty of Highway & Bridge, Mientrung of Civil Engineering, Vietnam. E-mail: nguyenkimcuong @ muce.edu.vn
4) Ricoh Company, Ltd. Japan.E-mail:kohji.oshikiri@jp.ricoh.com
5) Ricoh Company, Ltd. Japan. E-mail:taroh.kikuchi@jp.ricoh.com

Abstract: Current methods of practice for inspection of concrete tunnel typically involve visual assessments and drawing notes conducted manually by trained inspectors. The labor intensive and time consuming natures of manual inspection have engendered research into development of method for automated damage identification using computer vision techniques. Due to the limitation of the information reflected by the current photography technology, in this study, compared with other studies that directly detect cracks from images (Eftychios Protopapadakis et al., 2019; F. Panella et al., 2018; Suguru Yokoyama & Takashi Matsumoto, 2017), the author proposed to identify chalk marks that can be determined to be deformation. In this study, in order to improve the efficiency of tunnel inspection, it verified the automatic recognition of chalk marks in a concrete tunnel with a reasonable accuracy. As a result, a chalk mark classifier using a deep convolutional neural network on deep learning has been generated to detect the existence of chalk marks as a stage study of recognition. The proposed method is evaluated in terms of accuracy, precision and recall is shown.

Keywords: concrete inspection, deep learning, convolutional neural network, image recognition

CV-2

GA-CNN based automatic crack detection and classification method for concrete infrastructures

Cuong Nguyen Kim[1)], Kei Kawamura[2)], Yao Zhang[3)], and Amir Tarighat[4)]

1) Dr. Eng, Faculty of Highway & Bridge, Mientrung of Civil Engineering, Vietnam. E-mail: nguyenkimcuong @ muce.edu.vn
2) Assoc. Prof., Graduate School of Science & Technology for Innovation, Yamaguchi University, Japan. Email: kay@yamaguchi-u.ac.jp
3) Graduate Student. Graduate School of Science & Technology for Innovation, Yamaguchi University, Japan.E-mail: i503vg@yamaguchi-u.ac.jp
4) Assoc. prof, Department of Civil Engineering, Shahid Rajaee Teacher Training University, Iran, tarighat@srttu.edu

Abstract: Automatic crack detection is a main task in a crack map generation of the existing concrete infrastructure inspection. This paper presents an automatic crack detection and classification method based on genetic algorithm (GA) to optimize the parameters of image processing techniques (IPTs). The crack detection results of concrete infrastructure surface images under various complex photometric conditions still remain noise pixels. Next, a deep convolution neural network (CNN) method is applied to classify crack candidates and non-crack candidates automatically. Moreover, the proposed method is compared with the state-of-the-art methods for crack detection. The experimental results validate the reasonable accuracy in practical application.

Keywords: Crack detection, genetic algorithm, convolution neural network.

CV-3

AS-BUILT MODELING OF STEEL STRUCURES USING SYMMETRY

Takuya Suzuki [1], Tomohiro Mizoguchi [2]

1) Master Student, Department of Computer Science, College of Engineering, Nihon University, Fukushima, Japan.
2) Associate Prof., Department of Computer Science, College of Engineering, Nihon University, Fukushima, Japan. Email: mizoguchi.tomohiro@nihon-u.ac.jp

Abstract: As numerous number of civil infrastructures are aging in Japan, new information technologies are required to support efficient and effective maintenance of infrastructures. As-built modeling is one of the techniques that reconstructs 3D model reflecting the current status of the structure from point cloud acquired by laser scanner. Created modes are effectively used in various stages of inspection, such as prior scheduling before inspection and recording of inspection results on the 3D model after inspection. We focus on steel structures in bridges in this work. Many steel members are used in bridge and they are arranged in complicated manner. However, from the viewpoint of function and aesthetics of bridges, steel members are arranged according to the specific rules defined by the designer. For example, steel members are oriented in the vertical direction and are arranged at regular intervals in the horizontal direction. In addition, they are arranged symmetrically in the front-rear and right-left sides of the bridge. Therefore, detecting such symmetry from point cloud and utilizing them in modeling process can improve efficiency of as-built modeling, the quality of the 3D reconstructed model, and robustness to the absence of point cloud, compared with the conventional methods in which each steel member is modeled individually. In this paper, we propose a new method for reconstructing high-quality 3D model of steel structures of bridges from laser scanned point cloud enhancing symmetry. The method first detects multiple planar reflection symmetry which dominate the large portion of bridge by shape matching. The next step detects each steel members efficiently by simplifying point cloud based on voxelization, extracting skeleton structure, and evaluating point distribution using principal component analysis. Then the members arranged in symmetrical positions and posture are grouped together, and finally 3D template models are fitted to the group members simultaneously under symmetry constraints. Experimental results demonstrate good performance of our proposed method.

Keywords: Terrestrial Laser Scanner, As-Built Modeling, Symmetry.

CV-4

A REVIEW OF RESEARCH ON ADVANCED AUTONOMOUS TECHNOLOGIES FOR BRIDGE INSPECTION

Rina Hasuike[1], Koji Kinoshita[2], Lei Hou[3]

1) Ph.D. Candidate, Department of Civil Engineering, Gifu University, Gifu, Japan. Email: w3912010@edu.gifu-u.ac.jp
2) Dr. Eng., Associate Professor, Department of Civil Engineering, Gifu University, Gifu, Japan. Email: kinosita@gifu-u.ac.jp
3) Dr. Eng., Senior Lecturer, School of Civil Engineering, RMIT University, Melbourne, Australia. Email: lei.hou@rmit.edu.au

Abstract: Nowadays, many of these infrastructure projects are having serious aging issues, and therefore, timely inspection and repair works are crucial to ensure these structures are safe to use. So far, bridge inspection has been conducted primarily based on visual inspection by human inspectors. However, the downside of visual inspection is apparent. Firstly, conducting visual inspections can be quite time-consuming, especially in large and complex bridge structures; and secondly, this method cannot well address occupational health and safety issues such as working at height. Under this consideration, applying advanced autonomous technologies such as Unmanned Aer- ial Vehicles (UAVs) and image processing techniques to support human inspectors has attracted growing interest in the industry. In this study, a literature review was conducted with a focus placed around identifying the best practice of current technological approaches and proposing the futuristic research directions for technological re- finement and improvement. Methodically, this study examined the publications over the past 20 years, i.e., from 1999 to 2018, and leveraged the tool of CiteSpace to derive significant review findings on UAV and defect detec- tion research.

Keywords: unmanned aerial vehicles, image processing, bridge inspection

CV-5

A PERFORMANCE EVALUATION OF FEATURE DETECTORS AND DESCRIPTORS FOR UNMODIFIED INFRASTRUCTURE SITE DIGITAL IMAGES

Natthapol Saovana[1], Nobuyoshi Yabuki[2], and Tomohiro Fukuda[3]

1) Ph.D. Candidate, Division of Sustainable Energy and Environmental Engineering, Graduate of School of Engineering, Osaka University, Osaka, Japan. Email: u089147k@ecs.osaka-u.ac.jp
2) Ph.D., Prof., Division of Sustainable Energy and Environmental Engineering, Graduate of School of Engineering, Osaka University, Osaka, Japan. Email: yabuki@see.eng.osaka-u.ac.jp
3) Ph.D., Assoc. Prof., Division of Sustainable Energy and Environmental Engineering, Graduate of School of Engineering, Osaka University, Osaka, Japan. Email: fukuda@see.eng.osaka-u.ac.jp

Abstract: Image registration is a process to match and align a group of images. It is the first step of photogrammetric techniques such as Structure from Motion (SfM) to construct a model. It uses feature detector and descriptor algorithms to detect features inside each image and link these similar feature pairs to solve the unknown variables that is required for further processes. Before using feature detector and descriptor algorithm with a specific knowledge, a performance evaluation of these algorithm is necessary to be conducted because each algorithm has different advantages and disadvantages over specific expertises. Infrastructure project digital images are unique because the structures have similar shapes and smooth surfaces, which can complicate the image registration quality. Moreover, the uncontrolled lighting can further decrease the clearness and sharpness of images. Therefore, it is very challenging to get satisfied output by processing unmodified infrastructure images through photogrammetric techniques. Although these algorithms have various types and directly affect the quality of the model, there are no performance evaluations in the domain of infrastructure images to be seen. This study proposes the performance evaluation of robust feature detector and descriptor algorithms. The evaluation is separated into two categories, which are the feature coverage inside the region of interest (ROI) and the performance of feature matching. The result shows that Oriented FAST and Rotated BRIEF (ORB) can detect the highest amount of features with the shortest amount of time. However, Speeded Up Robust Features (SURF) can better detect features inside the ROI, which may lead to the better output quality. Finally, SURF128, which is SURF that was extended to utilize 128 floats, can finish the entire process at the fastest speed. This study can serve as a suggestion when feature detector and descriptor algorithms have to be chosen to solve questions inside the infrastructure domain.

Keywords: Image registration; feature detector and descriptor algorithms; feature detection; feature matching; infrastructure digital images

XR-1

EFFICIENT ACCESS TO INSPECTION DATA BASED ON AUGMENTED REALITY USING A “BRIDGE - CARD”

Hisao Emoto[1], Hiroki Komuro[2], Takehiko Midorikawa[3], Hideaki Nakamura[4], Kei Kawamura[5]

1) Dr. Eng., Assoc. Prof., National Institute of Technology, Fukushima, Japan. Email: emoto@fukushima-nct.ac.jp
2) Student, National Institute of Technology, Fukushima, Japan. Email: komuro-h@city.iwaki.lg.jp
3) Dr. Eng., Prof., National Institute of Technology, Fukushima, Japan. Email: midorikawa@fukushima-nct.ac.jp
4) Dr. Eng., Prof., Yamaguchi University, Yamaguchi, Japan. Email: nakahide@yamaguchi-u.ac.jp
5) Dr. Eng., Assoc. Prof., Yamaguchi University, Yamaguchi, Japan. Email: kay@yamaguchi-u.ac.jp

Abstract: In Japan, the time has come to rapidly rebuild bridges and other civil infrastructure during this period of economic growth to improve the service life of bridges and to develop long-standing government policy measures to maintain bridges. Normally, bridge inspections are performed by a close visual inspection on site. However, the number of professionals have decreased. For this reason, it is important to efficiently access necessary data on site to save labor. To aid in this, the AR (Augmented Reality) technique has recently been developed.

In order to identify the bridge, a method of accessing data using “marker type” AR technology is employed. As in previous studies, a marker directly pasted on a bridge near a noted condition, such as a crack etc., has been proposed. This is useful for accessing the bridge’s condition data. But the data is not suitable for a bird's- eye viewing of the whole bridge. Instead, it is easy to access whole bridge data using a “Bridge-Card”, functioning like a business card, on which bridge specifications are documented. In this way, the Bridge Card is a marker.

This study aims to efficiently save labor for visual inspections using “bridge-cards”, which are the size of a business card and developed with a bridge inspection support system for smart phones. This system delivers specification data, inspection data, repair and reinforcement data, among other information used by AR when the “bridge-cards” is read by the smart phone. This paper discusses the suitability of the use of a marker, while considering the reality that it is useful to access data off-site, in addition to location-based AR, which requires a bridge site visit.

Keywords: bridge maintenance support system, visual inspection, bridge-card, augmented reality

XR-2

Bidirectional linking of 4D-BIM planning with Virtual and Augmented Reality

Felix Dreischerf[1] and Habeb Astour[2]

1) Ph.D. Candidate, Department of Civil Engineering, University of Applied Science Erfurt, Erfurt, Germany.
Email: felix.dreischerf@fh-erfurt.de
2) Dr.-Ing., Prof., Department of Civil Engineering, University of Applied Science Erfurt, Erfurt, Germany.
Email: habeb.astour@fh-erfurt.de

Abstract: Building information modeling (BIM) currently provides a significant benefit to digitization in the construction industry in and outside of Germany. New techniques such as Augmented Reality (AR) and Virtual Reality (VR) can contribute to the spread of the BIM methodology in the construction industry and it will complement traditional planning and execution methods. Certainly however, these innovative technologies have the potential to simplify the entire planning and execution process.

The BIM methodology, VR, and AR are not well-known nor well applied in Germany. BIM is used in building design, but mostly in pilot projects. It needs to be implemented in the daily workflow. By combining it with new visualization methods, the added value of the BIM methodology will be increased and the process of its implementation will possibly be accelerated.

Today, the linking of BIM with AR or VR is done only in basic features. BIM combined with computer aided planning methods and AR or VR enable new approaches and procedures. This leads to a simplification of planning and execution. That means that the combination of BIM and VR/AR can be one of the most important methodologies in the future of building design. However, this combination and its use cases need to be developed to increase its practicability.

The following paper explains a concept for linking BIM with AR and VR. Therefore, a short overview of these elements and the linking methods is given. The focus of the linking is set on the connection between 3D design and construction schedule. The combination is known as 4D BIM. The result is a concept of connecting 4D BIM with AR and VR.

Keywords: Building Information Modeling, BIM, Virtual Reality, VR, Augmented Reality, AR, 4D, Planning

XR-3

Verification about work efficiency improvement by using an Augmented Reality and Wearable computer

Satoshi Yamanaka[1], Shinya Sugiura[2], Ryo Tajima[3], and Takafumi Yamanaka[4]

1) Chief Engineer, Obayashi CO., Ltd., Tokyo, Japan. Email: yamanaka.satoshi@obayashi.co.jp
2) Manager, Obayashi, CO., Ltd., Tokyo, Japan, Email: sugiura.shinya@obayashi.co.jp
3) Deputy Manager, Obayashi CO., Ltd., Tokyo, Japan, Email: tajima.ryo@obayashi.co.jp
4) Dr. Eng., Chief Engineer, Obayashi CO., Ltd., Tokyo, Japan, Email: yamanaka.takafumi@obayashi.co.jp

Abstract: Conventionally, in construction site, workers used to imagine a structure to be constructed based on a design drawing, and executed construction using an explicit thing such as stake or marking on the site. However, whether they can imagine the finished product accurately depends on the ability of the individual, so work mistakes and rework may occur. Also, there was a problem that it took a lot of time for preparatory work such as installation work of the stake.

In the construction industry in Japan, the labor shortage is getting worse because the number of employees has declined and are aging, but construction investment tends to recover. Even under such circumstances, improvement of work efficiency is required for the entire industry to ensure quality. The use of Information and Communication Technology (ICT) is mentioned as a means to improve work efficiency, and among them we focused on Augmented Reality (AR) technology and Wearable computer and worked to solve the problem.

In this study, we installed the U-shaped drain of berm drainage of 330 meters by using the AR and the wearable computer omitting the installation work of the stake which we have done so far, and the effect by use was verified. In AR, we superimposed a three-dimensional model created from Computer-Aided Design (CAD) software using image recognition method, and adopted “Hololens” it's kind of main display type, among wearable computers which can wear on the head. In addition, automatic tracking type Total Station was used for fine adjustment and position confirmation of the U-shaped drain to be installed. As a result of carrying out the actual construction after the test construction and verifying it, it was possible to shorten the working time by about 48%, and it was confirmed that using this technology contributes to the improvement of working efficiency.

Keywords: ICT, Augmented Reality, Productivity Improvement

XR-4

VISUALIZATION OF CONSTRUCTION PROCESS BY CONSTRUCTION SITE SENSING AND DIGITAL TWINS

Atsushi Takao[1], Nobuyoshi Yabuki[2], Kohei Seto[3], and Iwao Miyata [4]

1) Okumura Corporation, Tokyo, Japan. Email: atsushi.takao@okumuragumi.jp
2) Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University, Osaka, Japan. Email: yabuki@see.eng.osaka-u.ac.jp
3) Okumura Corporation, Tokyo, Japan. Email: kohei.seto@okumuragumi.jp
4) Okumura Corporation, Tokyo, Japan. Email: iwao.miyata@okumuragumi.jp

Abstract: This paper presents efforts to improve the productivity of construction sites by visualizing construction process. As a visualization method, we adopted Digital Twins that combine 3D models and sensing data (construction machinery on-board sensor, AI analysis of cloud camera image). Reproducing the situation at the construction site with Digital Twins made it easier for engineers to understand and analyze the works. Result of the construction site analysis showed the improved efficiency.

Keywords: Digital Twins, Cloud camera, Sensor, 3D model, Visualization

XR-5

AR VISUALIZATION OF PHYSICAL BARRIER FOR WHEELCHAIR USERS BASED ON REALTIME DEPTH IMAGING

Rio Takahashi[1], Hiroshige Dan[2], and Yoshihiro Yasumuro[3]

1) Graduate Student, Graduate School of Science and Engineering, Kansai University, Suita City, Japan. Email: media.englab.tostemkuniv15@gmeil.com
2) Ph.D., Assoc. Prof., Department of Environmental and Urban Engineering, Kansai University, Suita City, Japan. Email: dan@kansai-u.ac.jp
3) Ph.D., Prof., Department of Environmental and Urban Engineering, Kansai University, Suita City, Japan. Email: yasumuro@kansai-u.ac.jp

Abstract: Since Japan is facing the issue of rapid aging society, the number of potential wheelchair users is overgrowing, as more and more seniors need long-term cares. The government has worked on prevailing the barrier-free environment by establishing a law regarding promotion of smooth transfer for elderly and physically disabled people. Holding the 2020 Olympics is also a vital situation for infrastructure development in Japan. Barrier-free maps, for example, are prepared in many communities, but they cover only existences of facilities, e.g., lifts, slopes, and handrails, in major public institutions. Therefore, they miss the details of physical barriers, such as bumps and width clearances on the path, needed for the independent mobility of the wheelchair users. This paper addresses a method to find out physical barriers by using a depth camera to visualize them efficiently through augmented reality, which may be useful for the facility managers. A depth camera acquires 3D point cloud in the target space and checks the existence of interference between the environment and the volume of an actual wheelchair. The proposed system also performs back-projection of the detected barriers onto RGB color video frames for 2D AR representation. The verification of the achieved accuracy of the barrier check, as well as the implementation scheme, are reported in the paper.

Keywords: Augmented Reality, Wheelchair user, Barrier-free, Depth imaging

FM-1

STEEL BRIDGE INFORMATION DELIVERY MODEL FOR EARNED VALUE MANAGEMENT (EVM)

Teruaki Kageyama[1], Nobuyoshi Yabuki[2]

1) Senior Researcher, Research Department, Japan Construction Information Center (JACIC), Tokyo, Japan. Email: kageyamt@jacic.or.jp
2) Ph.D., Prof., the Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University, Japan. Email: yabuki@see.eng.osaka-u.ac.jp

Abstract: Building Information Modeling (BIM) has been widely adopted in the building industry, and its established methods and technologies show enormous potential in benefiting the civil engineering industry. Through the rapid growth of BIM in the civil engineering industry, mandatory use in government procurements, and utilization for improving productivity, the importance of 3D product models in the civil engineering industry is becoming increasingly prominent. The purpose of this paper is to propose for government organizations to implement Earned Value Management (EVM) using 3D product models. Firstly, the government contract process in line with the acts, guidelines and standards are mapped using an Information Delivery Manual (IDM). Next, in order to implement EVM using 3D product models, it is necessary to organize the relationship between the Work Package (WP), the minimum units of the Work Breakdown Structure (WBS), and the government contract units. For this reason, 3D product models with government contract units are defined as Information Delivery Elements (IDE). Finally, by using the Steel Bridge Information Delivery Model (SB-IDM), which has been integrated with the IDE of the steel bridge structure, the usability of EVM is evaluated.

Keywords: BIM for infrastructure, product model, information delivery manual, earned value management

FM-2

A PROPOSAL OF DETERIORATION PREDICTION MODEL FOR TUNNEL LIGHTING FACILITIES USING MARKOV STOCHASTIC PROCESS

Noriaki Maeda[1], and Kei Kawamura[2]

1) Graduate School, Doctor Course, Sciences and Technology for Innovation, University of Yamaguchi, Yamaguchi, Japan. Email: g005wc@yamaguchi-u.ac.jp
2) Dr Eng., Assoc. Prof., Sciences and Technology for Innovation, University of Yamaguchi, Yamaguchi, Japan. Email: kay@yamaguchi-u.ac.jp

Abstract: Asset management systems (AMS) are powerful tool for maintenance of civil infrastructures. The management system model consists of the four steps cycle model that is PDCA(Plan-Do-Check-Action) in the total quality management system. This paper proposes a deterioration prediction model on the management system for tunnel lighting facilities. The model is a time-based Markov stochastic process for predicting the deterioration of health degree of a tunnel unit. The tunnel unit is equivalent to all of tunnel lighting facilities in a tunnel.

Firstly, this paper explains a characteristics of the Markov stochastic process model applied to the deterioration prediction of a tunnel unit. Secondly, the deterioration of health degree of a tunnel unit is formulated by solving the master-equation of Markov stochastic process. Then, the applicability and validity of the deterioration prediction model is shown by illustrating numerical examples using visual inspection data of existing tunnels. Finally, the paper indicates how the model functions in AMS.

Keywords: AMS, tunnel lighting facilities, Markov stochastic process, deterioration, prediction, health degree, master-equation, inspection

FM-3

VRP-BASED MODEL FOR LANE MARKING ASSESSMENT WITH MRU VEHICLE[1]

Yu-Chun Lin[1], Si-Ting Liao[2], Chieh (Ross) Wang[3], and Albert Y. Chen[4]

1) Master Student, Department of Civil Engineering, National Taiwan University, Taipei, Taiwan. Email: r06521515@ntu.edu.tw
2) Master Student, Department of Civil Engineering, National Taiwan University, Taipei, Taiwan. Email: r07521501@ntu.edu.tw
3) R&D Staff, Energy and Transportation Science Division, Oak Ridge National Laboratory, Knoxville, TN, USA. Email: cwang@ornl.gov
4) Associate Professor, Department of Civil Engineering, National Taiwan University, Taipei, Taiwan. Email: albertchen@ntu.edu.tw

Abstract: Evaluation of lane marking conditions has advanced from visual and/or manual inspections, which can be unsafe and time-consuming, to mobile assessments using vehicle-mounted devices that allow transportation agencies to collect retroreflectivity data at a large scale in a safer and efficient manner. However, cost-effectively routing and operating these mobile retroreflectivity units (MRUs) at a large scale can be a unique challenge. This study proposes a vehicle routing problem (VRP) based model to optimize the routing of MRUs. The model takes into account the additional costs of daily and weekly operations of MRUs, such as remounting the device and traveling between tasks.

Keywords: vehicle routing problem (VRP); pavement markings; mobile retroreflectivity unit (MRU)

FM-4

THE GATEWAY TO INTEGRATING USER BEHAVIOR DATA IN "COGNITIVE FACILITY MANAGEMENT"

Jinying Xu[1], Weisheng Lu[2], and Jing Wang[3]

1) Ph.D. Candidate, Department of Real Estate and Construction, The University of Hong Kong, Hong Kong. Email: jinyingxu@connect.hku.hk
2) Ph.D., Assoc. Prof., Department of Real Estate and Construction, The University of Hong Kong, Hong Kong. Email: wilsonlu@hku.hk
3) Ph.D. Candidate, Department of Real Estate and Construction, The University of Hong Kong, Hong Kong. Email: jingww@connect.hku.hk

Abstract: In the face of current predicaments of facility management (FM), the concept of cognitive FM is proposed with a view to providing active intelligent management of a facility. In order to achieve such cognitive FM, how to integrate user behavior data into a cognitive FM system has to be solved. This paper serves as method guidance for it by putting forward the idea that location can serve as a gateway for the integration. Ultra-wideband (UWB) is recommended as the device layer to construct the 3D local positioning system for the cognitive FM system after comparison between different local positioning technologies from the accuracy, scalability, and cost dimensions. The way to bridge the user behavior data with facilities through coordinate transformation and location/distance computation is briefly introduced. Such of a uniform 3D coordinate system with high accuracy and scalability for FM situation can provide a common language for communication and computational applications. Finally, application scenarios for various facilities such as commercial building, office building, hospitals, warehouses, airports, and transportation stations are discussed.

Keywords: Facility management, cognitive system, data integration, user behavior, local positioning system, UWB.

BM1-1

RESEARCH ON BIM-BASED INFRASTRUCTURE PLATFORMS WITH INTERNATIONAL STANDARDS

Katsunori Miyamoto[1]

1) Senior Researcher, Construction Information Research Institute, Japan Construction Information Center General Incorporated Foundation (JACIC), Tokyo, Japan. Email: miyamotk@jacic.or.jp

Abstract: The Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) released the "action plan for the overseas development of infrastructure systems" in 2016. In consideration of this plan, we support the acquisition of the international standards in addition to the Japanese domestic design standards originating in global activity to promote original Japanese construction technologies and knowhow to minimize risks for differences in design concepts between the standards.

Therefore it is becoming increasingly important to participate in international BIM standards meetings to share information and study the major benefits of initiating the international standards related to BIM for infrastructure. These benefits enables 3D collaborative design to improve the efficiency of the construction production system through managed infrastructure lifecycle innovation and facilitates communication by using a standardized format for 3D data modeling, adding the attribute shape and materials information to enable data interoperability between each phase of the production processes of the infrastructure systems.

In this paper, we considered a new method for solutions for civil infrastructure platforms based on the international standards that will maximize efficiency and productivity of public works. While watching the trends of ISO and other international standards, we tried this new method to save time, costs, and human resources, and to improve safety and the production process while working on its standardization. The purpose of this paper is to provide information to introduce a BIM-based framework using the Industry Foundation Classes (IFC) model in consideration of a use case and tools from various Information and Communication Technology (ICT) at construction sites. In order to confirm the amendment results, we applied BIM to a complex, model-related geography and geological 3D model at the time of disaster restoration by utilizing JACIC's complimentary Photog- CAD® and performing case studies of investigations on small-scale areas and short-term lifecycles in a conceptual model.

Keywords: BIM, InfraBIM, International Standards, Product Model, Model-Based Design, Cooperative Design

BM1-2

A BIM-based AR Application for Construction Quality Inspection

Nai-Wen Chi[1], Yi-Wen Chen[2], Shang-Hsien Hsieh[3], Jen-Yu Han[4], and Lung-Mao Huang[5]

1) Project Assistant Professor, Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, R.O.C. Email: nwchi@mail.ntust.edu.tw
2) Research and Development Engineer, Moldex3D Co., Ltd., R.O.C. Email: owen0407@gmail.com
3) Professor, Department of Civil Engineering, National Taiwan University, R.O.C. Email: shhsieh@ntu.edu.tw
4) Professor, Department of Civil Engineering, National Taiwan University, R.O.C. Email: jyhan@ntu.edu.tw
5) Assistant Vice President, Reiju Construction Co., Ltd., R.O.C. Email: ko0957@mstc.reiju.com.tw

Abstract: Quality inspection is always an important stage during construction projects. Effective quality control can help construction projects avoid schedule delay and budget overrun. However, effective and efficient construction quality control is always a challenging task. It not only requires experienced inspectors but also various tools such as design drawings, tape measures and cameras to support the on-site quality inspections. In recent years, with the popularity of portable devices, and also the maturity of Building Information Modeling (BIM) and Augmented Reality (AR), it has become possible to integrate the two techniques on portable devices for developing an innovative construction quality control platform. In this paper, a prototype BIM-based AR quality inspection system is proposed. It can assist inspectors to discover the construction errors in the early stage of a construction project by comparing the on-site construction objects (especially for the falseworks) with their corresponding elements in the BIM model. The framework and the user interface of the prototype system are discussed and the application scenarios for improving the current quality inspection procedure are demonstrated.

Keywords: Building Information Modeling (BIM), Augmented Reality (AR), Quality Inspection, Site Inspection

BM1-3

APPLICATION OF BIM TECHNOLOGY ON VIRTUAL MOCK-UP AND IMPLEMENTATION FOR GENERAL CONTRACTOR IN CONSTRUCTION

Rodrigo Samuel Ortiz Chaparro *[1], Yu-Cheng Lin [2]

1) Master graduate student, Department of Civil Engineering, National Taipei University of Technology, No.1. Chung-Hsiao E. Rd., Sec.3, Taipei, Taiwan. Email: rodrigo.ortizchap@gmail.com
2) Professor, Department of Civil Engineering, National Taipei University of Technology, No.1. Chung-Hsiao E. Rd., Sec.3, Taipei Taiwan. Email: yclin@ntut.edu.tw
* To whom correspondence should be addressed. E-mail: rodrigo.ortizchap@gmail.com

Abstract: Building information modeling (BIM), the visual technology that has been constantly used in architectural, engineering and construction (AEC) industry. Some of the major benefits of applying BIM includes presenting and simulating construction operations through 3D illustration, as well as providing an advanced review for construction management. Two dimensional CAD drawings are still widely used for construction projects. However, to avoid misunderstanding of the design concept in projects of larger complexity, construction project teams will require more reliable and detailed information. This study proposes a BIM-based virtual mockup approach for general contractors, to enhance the performance of analysis review for construction management in construction phase of projects. The proposed approach is then applied in the construction phase of a selected project case study to discuss the effectiveness of BIM-based virtual mockup implementation approach in practice. Finally, this study identifies and summaries the benefits, limitations, conclusion, and suggestions for further applications.

Keywords: Building information modeling; BIM; virtual mock-up; general contractor; construction management.

BM1-4

DEEP LEARNING-BASED SCAN-TO-BIM FRAMEWORK FOR COMPLEX MEP SCENES USING LASER SCAN DATA

Chao YIN[1] & Boyu Wang[1], and Jack C.P. Cheng[1]

1) Ph.D. Student, Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong, China. Email: cyinac@connect.ust.hk
2) Ph.D. Student, Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong, China. Email: bwangbb@connect.ust.hk
3) Ph.D., Assoc. Prof., Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong, China. Email: cejcheng@ust.hk

Abstract: Mechanical, electrical and plumbing (MEP) systems play an important role in buildings and civil infrastructure. As laser scanning technology can capture geometric information with a high accuracy, point clouds have been widely used to reconstruct the as-built models of MEP systems. However, due to the complexity of point clouds collected from industrial scenes, processing point cloud data is mostly conducted manually over a long period. In order to speed up the modeling work, this paper proposes an automated BIM model generation framework based on deep learning technique for complex MEP scenes, with noise and heavy occlusion. There are four main procedures in our framework: (1) semantic segmentation: a state-of-the-art deep learning model named PointNet is adapted and leveraged to segment point clouds into four categories; (2) instance segmentation: retrieved point clouds of different classes are further segmented into instances with clustering methods; (3) geometrical information extraction and alignment: for pipes, an algorithm is developed to extract geometric information for pipes; and (4) BIM generation: a BIM model is generated parametrically using Dynamo based on geometric information and alignment parameters. The proposed approach was validated using a real MEP scene. The results show that our proposed framework can satisfactorily provide an automated and robust solution to BIM model generation for MEP scenes using laser scanning data.

Keywords: As-built BIM, SCAN-to-BIM, Point Cloud Processing, Deep Learning, MEP, Laser Scanning

BM2-1

Conversation-based Building Information Delivery System for Facility Management

Kuan-Lin Chen[1], Meng-Han Tsai[2]

1) Graduate Student, Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, Taiwan. Email: m10705504@mail.ntust.edu.tw
2) Assistant Professor, Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, Taiwan. Email: menghan@mail.ntust.edu.tw

Abstract: This research aims to develop a conversation-based building information delivery system as a bridge between equipment maintenance engineers and facility information management platform. At present, most of the new buildings using BIM technology are handed over the managing system to the property management companies. On-site equipment maintenance engineers obtain building model information through these management platforms or emails. However, for an engineer who is on site to repair a particular piece of equipment, there is too much unnecessary model information in the system and it may cause their work to be inefficient. With the development of IT technology, the conversation-based system is more flexible and has been gradually applied in various engineering fields. We developed a conversation-based system through natural language processing (NLP). By collecting and training the query keywords that equipment maintenance engineers often use, this conversation- based system can quickly understand the user's query intent. At the same time, this method integrates various tools for transmitting building information, and equipment maintenance engineers can complete the receiving and querying equipment models in the same interface. In order to verify the effectiveness of this method, we tested several devices in a residential building to analyze the benefits of importing conversation-based system during the FM phase. The results demonstrated that the conversation-based system can correctly identify statements for different sentences but with the same intent and this method can improve the efficiency of equipment maintenance engineers to retrieve building model information.

Keywords: Building Information Modeling, Facility management, Conversation-based system, Natural language processing

BM2-2

DEVELOPMENT OF A NEW DISTRICT IN THE STATE OF HESSEN "FLEXQUARTIER" PROJECT

Jose Alberto Lagunes Ronzon[1], Moritz Hofmann[2], Milena Potpara[3], Dirk Metzger[4] and Joaquin Diaz[5]

1) Master student, Department of Architecture and Civil Engineering, Technische Hochschule Mittelhessen, Giessen, Germany. Email: jose.lagunes.ronzon@bau.thm.de
2) Master student, Department of Architecture and Civil Engineering, Technische Hochschule Mittelhessen, Giessen, Germany. Email: moritz.fabio.hofmann@bau.thm.de
3) Ph. D. student, Department of Architecture and Civil Engineering, Technische Hochschule Mittelhessen, Giessen, Germany. Email: milena.potpara@bau.thm.de
4) Professor, Department of Architecture and Civil Engineering, Technische Hochschule Mittelhessen, Giessen, Germany. Email: dirk.jens.dieter.metzger@bau.thm.de
5) Ph. D. Professor, Department of Architecture and Civil Engineering, Technische Hochschule Mittelhessen, Giessen, Germany. Email: joaquin.diaz@bau.thm.de

Abstract: A new district is planned to be built in Hessen, a state in Germany. This new district is called "FlexQuartier" and it is intended to include residential units and other kinds of floor uses. It is a goal of the Government of Germany to develop new districts with characteristics based on smart city and sustainability principles. The main technology in this project is an innovative High-Temperature Storage System in combination with a battery storage and a water tank storing hot water, this combined with the use of a Quartier Information Model (QIM). This papers explains the steps that are being followed in the beginning of the project (conception phase) and also the steps that will be followed in order to create a model that builds upon itself and can store not only information about the district, but also can help in the design, construction, commissioning and management phases of the project.

Keywords: FlexQuartier, Smart Cities, BIM, QIM, High-Temperature Storage, Interoperability, Sensors, Energy, Facility management.

BM2-3

PROCESS RE-ENGINEERING IN OWNER ORGANIZATIONS TO IMPROVE BIM-BASED PROJECT DELIVERY USING REQUIREMENTS MANAGEMENT PLATFORM

Ali Motamedi[1], Sylvain Vaudou[2], Romain Leygonie[3], Daniel Forgues[4]

1) Ph.D., Assoc. Prof., Department of Construction Engineering, École de technologie supérieure, Montreal, Canada. Email: ali.motamedi@etsmtl.ca
2) BIM Director, CAP INGELEC., Bordeaux, France. Email: sylvainvaudou@hotmail.com
3) M.A.Sc. Candidate, Department of Construction Engineering, École de technologie supérieure, Montreal, Canada. Email: romain.leygonie.1@ens.etsmtl.ca
4) Ph.D., Prof., Department of Construction Engineering, École de technologie supérieure, Montreal, Canada. Email: daniel.forgues@etsmtl.ca

Abstract: BIM-assisted project execution methods are being increasingly adopted by designers and contractors due to client demand and the efficiency gains they provide. However, many owner organizations do not take full advantage of BIM in assessing the quality of deliverables, and do not use digital deliverables during the operation phase. Additionally, although many owner organizations have BIM implementation plans, their design review and data handover processes still follow conventional methods due to a lack of BIM knowledge related to facilities management. Requirements related to Facility Management (FM) operations are usually transferred using traditional methods, and requirement elicitation and management processes often do not consider the BIM potential (such as information provision, automatic data transfer, data quality assurance and control). In this research, the operation of a major provincial government owner organization in Canada, which is one of the pioneers in adopting BIM-based project execution, is analyzed in an observational study to identify process gaps when it comes to benefiting from BIM during the lifecycle. The study showed that although many BIM-based processes are adopted for projects, many core processes on the owner side (such as gathering and communication of FM requirement, data quality control and non-geometric data handover) still follow traditional methods. Using extensive data gathering and use case analysis, process gaps were identified and process re-engineering recommendations prepared. Additionally, the use of a requirements management system is proposed and verified to tackle issues related to requirement documentation and tracing, knowledge preservation, data handover, and data quality assurance and control.

Keywords: BIM, Requirements management, Quality assurance, Facilities management, Process re-engineering

BM2-4

A Framework for Visual BIM-based Maintenance Management in MRT Stations

Yi-Shian Huang [1], Yu-Cheng Lin[2]

1) Master graduate student, Department of Civil Engineering, National Taipei University of Technology, No.1. Chung-Hsiao E. Rd., Sec.3, Taipei, Taiwan. Email: mh70804@gmail.com
2) Professor, Department of Civil Engineering, National Taipei University of Technology, No.1. Chung-Hsiao E. Rd., Sec.3, Taipei Taiwan. Email: yclinntut@gmail.com

Abstract: The long-term operation of MRT station facilities will cause wear and tear. How to improve the maintenance and management is an important issue in MRT station facilities management. In order to improve the efficiency of MRT station facility maintenance and management, this study use the building information model (BIM) visualization technology to discuss the facility management. Although there are many previous studies focused on applications of BIM-based MM works, few studies are focus on the implementation models for BIM-based visual BIM-based maintenance management in MRT Stations. Therefore, the study proposes the framework for visual BIM-based maintenance management special for MRT station in Taiwan. The proposed framework was applied in a selected MRT station in Taiwan for case study to verify our proposed framework and to demonstrate the effectiveness. Finally, the study identifies the benefits, limitations, and suggestions for further applications.

Keywords: Building Information Modeling (BIM), Maintenance Management, MRT Station, Operation Phase

BM2-5

MODELING THE LAST-MILE PROBLEM OF BIM ADOPTION

Jing Wang[1], Weisheng Lu[2], and Jinying Xu[3]

1) Ph.D. Candidate, Department of Real Estate and Construction, the University of Hong Kong, Hong Kong. Email: jingww@connect.hku.hk
2) Associate Professor, Department of Real Estate and Construction, the University of Hong Kong, Hong Kong. Email: wilsonlu@connect.hku.hk
3) Ph.D. Candidate, Department of Real Estate and Construction, the University of Hong Kong, Hong Kong. Email: jinyingxu@connect.hku.hk

Abstract: In recent years, the high expectation of Building Information Modeling (BIM) has increasingly attracted the attention of organizations in developing countries. To catch up with the leading BIM practice, those 'late mover' organizations tend to benchmark and adopt BIM practices that have been proven effective by global leaders. However, the uptake of BIM use is largely stuck by the "last-mile problem". While developers diffusing their standardized or generalized solutions to global users, organizations often find it difficult to adopt such solutions due to the contextual difference between such standardized and generalized BIM solutions and their use environments. This paper aims to firstly define the "last-mile" problem in BIM adoption and then, propose a conceptual model of such problem. In this paper, the last-mile BIM adoption is defined as "a decentralized process involving the linear diffusion of BIM solutions from its source developers to destination users". Synchronizing literature on BIM and last-mile problems in various domains, a last-mile BIM adoption model is proposed by identifying the model components and developing a design framework. This study has both academic and practical implications. It offers a set of formal language to systematically describe the last-mile problem of BIM adoption, leading to an improved understanding of the last-mile process and problems therein. For practitioners, the study facilitates them to analyze last-mile problems and develop strategies accordingly.

Keywords: Building Information Modeling (BIM), last mile, model, adoption, diffusion

BM3-1

BIM-BASED WALL FRAMING CALCULATION ALGORITHMS FOR DETAILED QUANTITY TAKEOFF

Chavanont Khosakitchalert[1], Nobuyoshi Yabuki[2], and Tomohiro Fukuda[3]

1) Ph.D. Candidate, Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University, Japan. Email: khosakitchalert@it.see.eng.osaka-u.ac.jp
2) Ph.D., Prof., Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University, Japan. Email: yabuki@see.eng.osaka-u.ac.jp
3) Ph.D., Assoc. Prof., Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University, Japan. Email: fukuda@see.eng.osaka-u.ac.jp

Abstract: Although an automated quantity takeoff using building information modeling (BIM) is proved to be faster and more reliable than the traditional quantity takeoff method, the information and geometries in a BIM model must be input correctly. Drywall is a wall type that consists of wall framings as a core structure layer and drywall sheets as finish layers. During a tendering phase, the area of each layer of drywall is used for cost estimation. However, during a construction phase, the material quantity of wall framings must be calculated in length in order to purchase the materials effectively. If the wall framings do not exist in the BIM model, construction practitioners have to create them or calculate their length manually. Creating wall framing elements in a BIM model is a time-consuming and error-prone task, especially in a large scale project. The increased geometries in a BIM model also affect the working performance of the software. This research proposes a method that automatically calculates the lengths of vertical and horizontal members of wall framings from the extracted wall surfaces and the input spacing values. The method also eliminates the region of walls that overlap with structural elements such as columns and beams. The validation is done by using an interior construction project as a case study. It showed that the proposed method provides an accurate wall framing quantity when compared with the quantity results from the BIM model that has wall framings and the quantity results from the manual calculation methods. With this method, the wall framing elements do not need to be created in a BIM model for quantity takeoff. The modeling time can be saved while construction practitioners can get an accurate wall framing quantity for purchasing material during a construction phase.

Keywords: Building Information Modeling (BIM), Quantity takeoff, BIM-based quantity takeoff, Wall framing

BM3-2

BIM-SUPPORTED COMPLIANCE VERIFICATION OF PERFORMANCE-BASED CAR-PARK VENTILATION DESIGN

Johannes Dimyadi[1], Robert Amor[2]

1) PhD, CEO, Compliance Audit Systems Limited, Auckland, New Zealand. Email: jdimyadi@complianceauditsystems.com
2) PhD, Prof., School of Computer Science, University of Auckland, Auckland, New Zealand. Email: trebor@cs.auckland.ac.nz

Abstract: Modern regulatory frameworks, such as those enforceable in the UK, Australia, and New Zealand, allow car-park ventilation systems to be designed to comply with performance-based objectives. This has provided designers with the opportunity to propose an alternative solution when prescriptive requirements are either too restrictive or costly to implement. The input data required for computations or numerical simulations to support the performance-based design is often complex and may include the geometry, building usage or activities and building system characteristics, as well as normative compliant-design parameters. Conventionally, this input data is gathered manually from paper-based drawings and other written documentation including normative standards, which is an inefficient and error-prone process. In this paper, we investigate to what extent can simulation input data be generated from the available information shared through the Building Information Modelling (BIM) collaborative process. Additionally, we explore an open standard computable representation of normative requirements that can be used to automate some of the preparatory computations to further complement the simulation input data. An exemplary use case is also described to illustrate the approach.

Keywords: BIM, CO, CFD, car-park ventilation, performance-based design.

BM3-3

The Study of Automatic CIM Models Development for Infrastructure Projects

Tzu-Tin Huang[1] and Yu-Cheng Lin[2]

1) Graduate Student, Department of Civil Engineering, National Taipei University of Technology, Taipei, Taiwan. Email: wchwch8899@gmail.com
2) Professor, Department of Civil Engineering, National Taipei University of Technology, Taipei, Taiwan. Email: yclinntut@gmail.com

Abstract: Building Information Modeling (BIM) has been widely used in civil engineering and construction industry. Its technology has effectively reduced many mistakes of this huge industry and reduced the cost of construction projects. It has established industrial trends for countries all over the world. However, Civil Information Modeling (CIM), is the latest concept in the construction engineering, its application in the is slowly becoming more present in the construction industry. The field of civil engineering construction is relatively large, and the work content in the design and planning stage is highly variable, especially when the model is being constantly updated on the constrcution phase of the project. In this stage CIM engineer encounters many complicated and cumbersome operations and integration of information problem are detected. If complicated projects are built with the limitations of the software itself, improving work efficiency will become a more difficult task. Recently, visualization program design for the application of engineering has gradually become a trend. Visual programming tools can assist the CIM model designs by providing improvement in the solutions of problems encountered in the original construction method. Therefore, this study uses the Autodesk Revit platform combined with Dynamo as a research tool to write programs, import into case application, and study how these two softwares simplify the repetitive work when designing projects. Finally, the research demonstrates the application of the proposed tool into a case of the North Road model guardrail for the design and development of a model with support of automatic generation of elements. With the successful development and implementation of the automation program, this project was able effectively shorten designing and construction time even thought the complexity of the project, reduce human errors and omission. Lastly, this paper will present the discussion of the main benefits, difficulties and limitations by case study as a reference for follow-up research and application will be introduced.

Keywords: Civil Information Modeling, CIM, Automation, Visual Programming, Dynamo.

BM3-4

AN AUTOMATED BIM-INTEGRATED SYSTEM FOR CHANGE ORDER COST IMPACT EVALUATION

Veerasak Likhitruangsilp[1], Tantri N. Handayani[2], Nobuyoshi Yabuki[3], Photios G. Ioannou[4]

1) Ph.D., Assoc. Prof., Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand. Email: Veerasak.L@chula.ac.th
2) Ph.D., Department of Civil and Environmental Engineering, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia. Email: tantri.n.h@ugm.ac.id
3) Ph.D., Prof., Division of Sustainable Energy and Environmental Engineering, Osaka University, Osaka, Japan. Email: yabuki@see.eng.osaka-u.ac.jp
4) Ph.D., Prof., Department of Civil and Environmental Engineering, University of Michgian, Ann Arbor, USA. Email: photios@umich.edu

Abstract: Change orders are inevitable in construction projects and usually have a major impact on project costs. Evaluating change order impacts by using conventional 2D drawings often leads to the inaccurate estimated quantity of modified works, which subsequently yields unreliable impact costs. Building information modeling (BIM) can address such challenges because it facilitates automated quantity takeoff and cost estimating, integrating relevant information, and visualization. Yet, implementing BIM for this purpose requires a well-defined methodology and a well-organized information structure. This paper develops an automated system for evaluating the cost impact of a construction change order. The system analyzes the modified building elements using the model checker and estimates direct and indirect costs of such change order (e.g., demolition and relocation costs). Since the proposed system performs a thorough cost impact analysis with minimal subjectivity, the results are accurate and reliable for all project participants. In addition, the system is equipped with a recording system for tracking the dynamic changing of project costs throughout the construction phase. The system is applied to an actual high-rise building project to illustrate its capability and practicality.

Keywords: Building information modeling (BIM), change order, variation order, automated cost evaluation, cost impact, claim management

BM4-1

SIMULATION AND OPTIMIZATION OF UTILITY TUNNELS CONSTRUCTION AS LINEAR PROJECTS

Mohamed A. Sherif [1], Abdelhamid Abdallah [2], and Khaled Nasser [3]

1) MSc Candidate, Department of Construction Engineering, The American University in Cairo, Fifth Settlement, Egypt. Email: mohamed_ayman_sherif@aucegypt.edu
2) Teaching Assistant, Department of Architectural Engineering, Helwan University, Cairo, Egypt. Email: abdelhamid.abdullah@aucegypt.edu
3) Ph.D., Assoc. Prof., Department of Construction Engineering, The American University in Cairo, Fifth Settlement, Egypt. Email: knassar@aucegypt.edu

Abstract: The utility tunnels are major features in several projects on different scales ranges from different sizes of campuses like university and hospital campuses to large scale utility tunnels used in mega residential projects and airports. They are usually the housing space for different utilities required for the projects that are on multi- building scale. The simulation of the construction of utility tunneling hasn't received enough attention in research while tunneling in general has been studied significantly. The scheduling and planning of utility tunnels as an example of linear projects are facing big challenges of optimizing the project duration, work balance and utilization of the available resources. Linear Projects consist of several similar elements with repeated activities from one element to the other. This paper will propose a discrete event simulation model to plan the construction sequence of utility tunnels with optimum duration and resources. It also represents a case study as an example for a utility tunnel construction in Egypt.

Keywords: Utility, tunnels, Scheduling, Planning, Linear Projects, Simulation, Modeling, Optimization, Construction, Management.

BM4-2

INTEGRATING BIM INTO GREEN RESIDENTIAL BUILDING ASSESSMENT: A CASE STUDY

Fatma Abdelaal[1], Brian Guo[2], Yang Zou[3], and Mazharuddin Syed Ahmed[4]

1) Ph.D. Candidate, University of Canterbury, Christchurch, New Zealand. fatma.abdelaal@pg.canterbury.ac.nz
2) Ph.D., Lecturer, University of Canterbury, Christchurch, New Zealand. brian.guo@canterbury.ac.nz
3) Ph.D., Lecturer, University of Auckland, Auckland, New Zealand. yang.zou@auckland.ac.nz
4) Ph.D., Ara Institute of Canterbury, Christchurch, Canterbury, New Zealand. mazharuddin.syedahmed@ara.ac.nz

Abstract: Building Information Modeling (BIM) technology provides numerous benefits for green building design and assessment. Recent years have seen attempts to integrate BIM into the commercial and industrial building assessment process. However, research on BIM applications to green residential buildings is limited. Thus, this research aims at investigating the potential of integrating BIM into green residential building rating systems such as Homestar, the green residential assessment system in New Zealand. First, the required data and information to calculate Homestar points has been identified by reviewing the Homestar v4 technical manual, in order to determine the proportion of the design rating points that can be calculated based on BIM functions. Second, the required data were matched against the data available in a BIM model of a case study of a residential building, the building is the first 10 Homestar rating house in Christchurch, New Zealand. The results reveal that 76 of 120 points of Homestar rating credits can be achieved with BIM software, with 100% computable for Density and Resources Efficiency, 67% for Energy, 21% for Water, %17 for Waste, 33% for Management, 100% for Materials, and 67% for Site. Future efforts can be made to develop a fully automated BIM-based green residential buildings assessment framework that can help designers optimize the design and assist the assessors with the rating process. Such a BIM-based assessment framework has a significant potential to simplify the rating process and reduce assessment costs.

Keywords: Building Information Modeling (BIM), Green Building Assessment, Residential Buildings, Homestar, New Zealand, Sustainability.

BM4-3

ENHANCED UNDERGROUND UTILITIES MANAGEMENT INTEGRATED CIM TECHNOLOGIES

Sheng-Lun Zhuo*[1], Yu-Cheng Lin[2]

1) Master graduate student, Department of Civil Engineering, National Taipei University of Technology, No.1. Chung-Hsiao E. Rd., Sec.3, Taipei, Taiwan. Email: z0933957902@gmail.com
2) Professor, Department of Civil Engineering, National Taipei University of Technology, No.1. Chung-Hsiao E. Rd., Sec.3, Taipei Taiwan. Email: yclinntut@gmail.com

Abstract: Civil Information Modeling (CIM) is commonly used in civil engineering projects, such as tunnels, bridges, roads, underground pipelines. CIM can provide a better understanding of engineering problems and onsite status through the visual advantages. The CIM model can present a parameter-based visual effect that once established can effectively achieve communication and coordination. Over the years many adjustments have been made in the existing infrastructure of the pipelines in addition to the new pipelines systems that have been switched. Sometimes, due to an error in the underground pipeline drawings or specifications, unnecessary disasters may occur this would occur because there is not a periodic update in the 2D drawings. In some cases, after the pipeline location is excavated, underground utilities in service could be affected since they were traditionally designed with 2D drawings. If the original pipeline is found during construction or maintenance, 2D drawings will probably show a change or addition, therefore, it will be a difficult task for the construction company to update or verify the precision of the available maps according to the actual situation on site. There are also cases where the current or new pipeline location is not shown or specified in the as-built drawings, making more difficult dinging or other related operations, miscalculation in the construction site for excavation can cause thousands of dollars of over cost and would affect thousands if the drinking water or electricity distribution is affected. This study will use CIM in underground pipeline management applications by building, planning and researching about the processes and standards taken for the underground pipeline models. It is expected that CIM will enable field personnel and construction personnel to keep clear visualization of the underground soil conditions. And explore the benefits, difficulties and restrictions of building a CIM model for underground utilities. Finally, through the 3D model for communication coordination and inspection, and using 3D models and virtual space, through 3D visualization to present pipeline conflicts, review the spatial and spatial needs of facilities and buildings, and analyze the models, and achieve communication between members. Coordinate and integrate the effectiveness of collaboration.

Keywords: Building Information Modeling (BIM), Civil Information Modeling (CIM), Underground Utilities, Underground Pipeline Maintenance.

BM4-4

DEVELOPING EFFICIENT MECHANISMS FOR BIM MODEL SIMPLIFICATION

Jack C. P. CHENG[1], Keyu CHEN[2], Weiwei CHEN[3],

1) Associate Professor, Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong. E-mail: cejcheng@ust.hk
2) Ph.D. Student, Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong. E-mail: kchenal@connect.ust.hk
3) Ph.D. Student, Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong. E-mail: wchenau@connect.ust.hk

Abstract: Building information modeling (BIM), which can provide both geometric and semantic information for users to visualize and interact with each building component, is attracting increasing attention in the architecture, engineering, construction and operations (AECO) industry nowadays. However, complicated and huge BIM models can increase the time for model transfer, increase the computation work load while rendering, and reduce the fluency during visualization and interaction. Therefore, this paper aims to develop efficient mechanisms for BIM model simplification to better utilize large BIM models. This paper mainly focuses on two types of components: walls and cylindrical components. Walls that are connected to each other have a large number of redundant polygons, thus an algorithm is proposed to minimize the number of polygons without altering the walls. Cylindrical components, which have a large amount of redundant polygons on the side surfaces, can be simplified by removing all redundant polygons. Illustrative examples that evaluates the performance of these developed mechanisms are also provided.

Keywords: AR/VR; BIM; Model simplification; Polygon reduction

CME-1

EVALUATION OF PILE PERFORMANCE IN DIFFERENT LAYERS OF SOIL INVESTIGATING PILE BEHAVIOR BY OPENSEESPL

Orod Zarrin[1], Mohsen Ramezanshirazi[2]

1) Centre for Infrastructure Performance and Reliability, The University of Newcastle, Callaghan, NSW 2308 (Australia)
2) PhD Candidate, Sapienza University of Rome, Italy, Mohsen Ramezanshirazi, mohsen.ramezanshirazi@uniroma1.it

Abstract: Pile foundations technique is developed to support structures and buildings on soft soil. The most important dynamic load that can affect the pile structure is earthquake excitation. From the 1960s, the comprehensive investigation of pile foundations during earthquake excitation indicate that piles are subject to damage by affecting the superstructure integrity and serviceability.

The main part of researches has been focused on the behavior of liquefiable soil and lateral spreading load on piles. During an earthquake, two types of stresses can damage the pile head. Inertial load that is due to superstructure and deformation that is caused by surrounding soil. Inertial load and soil deformation are associated with the acceleration developed in an earthquake. The acceleration amplitude at the ground surface depends on the magnitude of earthquakes, soil properties and seismic source distance. According to the investigation, the damage is between the liquefiable and non-liquefiable layers and also soft and stiff layers. This damage crushes the pile head by increasing the inertial load, which is applied by the superstructure. On the other hand, the cracks on the piles due to the surrounding soil are directly related to the soil profile.

In this study, the performance and behavior of pile foundations during different earthquakes are investigated. This investigation has done by OpeenSeesPL in three different layers of soil that contain liquefiable and non-liquefiable layers.

Keywords: Pile, Earthquake, Liquefaction, Non-Liquefiable, Damage.

CME-2

DEVELOPMENT OF STATIC AND DYNAMIC MODELING APPROACHES USING FRAME MODELS FOR CITY SEISMIC RESPONSE ANALYSIS

Pher Errol B. Quinay[1], Aileen Rachelle Fader[2], Franz Marius Carangan[3]

1) Dr. Eng., Assoc. Prof., Institute of Civil Engineering, University of the Philippines Diliman, Quezon City, Philippines. Email: pbquinay2@up.edu.ph
2) Quantity Surveyor-Technical TeaAM, Wallcrete Company, Inc., Quezon City, Philippines, Email: aileenrachellef.wci@gmail.com
3) Junior Structural Engineer, Al Abbar Aluminum Philippines, Inc., Pasig City, Philippines, Email: FranzC@alabbargroup.com

Abstract: Methods that can estimate the city response to seismic events are valuable tools that can assist in disaster risk reduction efforts. With the increasing availability of large computing resources, physics-based approaches that can be used for this purpose are becoming more practicable. This study aims to develop static and dynamic modeling approaches for city seismic response analysis. For both modeling approaches, tools were developed to generate and analyze models that are suitable to the available GIS and BIM data. To check the accuracy of the developed tools, validation tests were conducted by comparing with commercial software that is commonly used in structural analysis and design in the Philippines. Validations for static and dynamic analysis show that the results of the developed tools are within 6% and 8% of the results that were computed using a commercial software, respectively. These results are considered acceptable given the low computation cost per building in the developed approaches. As a demonstrative example, two cities in Metro Manila were considered for scenario earthquake analysis. Low to midrise reinforced concrete structures were analyzed and floor displacements were computed. From these results, maximum responses were obtained and visualized in city-level. Another example was conducted with the aim to compare the computed period of vibration with that of a previous study that performed experiment on a three-story building in Metro Manila. Results show that for the considered standard model of the building, the periods of vibration can be closely estimated by the developed tool.

Keywords: City seismic response analysis, finite element method, static and dynamic analysis

CME-3

Structural Shape Grammars used in Intelligent Generation Design of Discrete Structures

Xianzhong Zhao[1], Ruifeng Luo [2]

1) Ph.D., Prof., College of Civil Engineering, Tongji University, Shanghai 200092, China. Email: x.zhao@tongji.edu.cn.
2) Ph.D. Candidate, College of Civil Engineering, Tongji University, Shanghai 200092, China. Email: lrf@tongji.edu.cn

Abstract: The intelligent construction industry involves three aspects: intelligent generation design, intelligent fabrication, and intelligent operation and service. A conceptual and intelligent generation design method of discrete structures was introduced. The method, based on the computational synthesis, is capable of generating an optimal structure from all alternative ones at the concept design stage to meet the optimization objectives and constraints. This generation method contains three parts: structural shape grammars, structural evaluation, and structural optimization algorithm. Structural shape grammars in this method can generate, optimize and transform discrete structural shapes using geometric topology within the design domain. The characters of structural shape grammars were obtained through existing shape grammars. An innovational tetrahedral shape grammar was presented aiming to improve the adaptability of structural shape grammar in spatial issues. Through classifying the topological relations of five points in space, the tetrahedral shape grammar determines not only the topological transformation rules but also the nodes adding and deletion rules of discrete structure. Besides the topological transformation method, this tetrahedral shape grammar also takes the shape transformation and size transformation into comprehensive consideration. Besides, prospective applications of intelligent generation design method were put forward.

Keywords: intelligent generation design method, spatial shape grammar, tetrahedron topology.

CME-4

Numerical Evaluation of Seismic Response of Anchorage Foundation installed in Switchboard Cabinet

Sang-Moon Lee[1], Ga-Ram Kim[2], Woo-Young Jung[3]

1) Ph.D. Candidate, Department of Civil Engineering, Gangneung-Wonju University, Gangneung-si, Gangwon-do, South Korea. Email: idealmoon@naver.com
2) Master Student, Department of Civil Engineering, Gangneung-Wonju University, Gangneung-si, Gangwon-do, South Korea. Email: kgr3288@naver.com
3) Professor, Department of Civil Engineering, Gangneung-Wonju University, Gangneung-si, Gangwon-do, South Korea. Email: woojung@gwnu.ac.kr

Abstract: In this study, the seismic response of anchor bolt for freestanding equipment, such as switchboard cabinets, at the hydroelectric power plant was presented based on the results of numerical simulations. From the experimental study, shaking table tests were performed to investigate the overall structural behavior of switchboard cabinets and seismic-induced damages including a rocking problem that leads to the deformation occurred at the cabinet bottom were observed during the test. The FE modeling was conducted by using the ABAQUS similar to an actual cabinet panel and 3D dynamic nonlinear analysis was performed using seismic loadings like long-period earthquakes. For validating the proposed FE model, the maximum displacement and the mode shapes were used in the comparison of numerical analysis results and a reasonable agreement was made when seeing in the maximum displacement of the switchboard cabinets. From the analysis, a slight difference was found in the analysis due to the rocking problem which causes cup-like deformation at the bottom of the cabinet during the tests. Finally, using the validated numerical model, the effects of long period earthquake wave on cabinet behavior was analyzed. The Von-Mises stress at the anchor bolt embedded in concrete foundation occurred 1.068 MPa and the horizontal maximum displacement of the cabinet was 24.8 cm. From the basis of this research, there is needed to compare interrelation between nonstructural components such as a cabinet and the seismic waves which have various period in the future research.

Keywords: Switchboard Cabinet, Shaking Table Test, Seismic Waves, Nonstructural Components

IOT-1

FRAMEWORK FOR A BIM-BASED REAL-TIME EVACUATION GUIDANCE SYSTEM IN SMART BUILDINGS

Kayla Manuel[1], Nobuyoshi Yabuki[2], and Tomohiro Fukuda[3]

1) Master Course Student, Division of Sustainable Energy and Environmental Engineering, Osaka University, Japan. E-mail: manuel@it.see.eng.osaka-u.ac.jp
2) Ph.D., Prof., Division of Sustainable Energy and Environmental Engineering, Osaka University, Japan. E-mail: yabuki@see.eng.osaka-u.ac.jp
3) Ph.D., Assoc. Prof., Division of Sustainable Energy and Environmental Engineering, Osaka University, Japan. E-mail: fukuda@see.eng.osaka-u.ac.jp

Abstract: In emergency situations, such as a fire, mass panic can result in many unnecessary deaths. Some deaths are caused not as a result of the fire, but due to the herds of people seeking egress. If alternative exits were made known to those seeking egress, congestion at prominent exits could be alleviated and unnecessary deaths prevented. Current two-dimensional evacuation signs in buildings show a single means of escape and are insufficient because they are static and relying on them for information is inconvenient in a time-sensitive situation. A Building Information Modeling (BIM) model is a semantically rich three-dimensional representation of a building with geometric and semantic data. Integration of this built environment information and Internet of Things (IoT), termed SMART buildings, are commonly used for operation and maintenance purposes. The proposed system integrates BIM and IoT to create an evacuation guidance system to assist users in building egress. The proposed system continuously monitors the current fire situation, the building and its' occupant in order to provide real-time customized instruction from each user's respective location/s to safety. Moreover, should their initial path of escape be obstructed by dynamic events, such as obstructions caused by an escalated fire or inoperative doors, the pre-simulated paths would suggest an alternative route that an egress-seeker should take. Because visibility is low, due to smoke density, egress instruction is given as voice commands to customized wireless earphones so that users can be hands-free to crawl, should the need arise. The system goes through a database of evacuation paths and based on proximity and other factors the evacuation instruction is relayed. The proposed system relies heavily upon knowing where occupants are in the building at all times in order to immediately instruct them from their respective initial positions to a designated exit.

Keywords: Building Information Modeling (BIM), Egress, Dynamic Real-time navigation, Indoor Localization, Smart Buildings, Internet of Things (IoT).

IOT-2

DEVELOPMENT OF A METHOD TO DETECT EARTHQUAKE-RELATED CHANGES IN IMAGES TAKEN BY CCTV CAMERAS SURVEYING CIVIL INFRASTRUCTURE

Arata Konno[1], Hirotaka Sekiya[2], and Hideyuki Ashiya[3]

1) Head, Disaster Prevention and Relief Division, Okayama River Management Office, Chugoku Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Japan. Email: konno-a85aa@mlit.go.jp
2) Ph.D., Head, Information Platform Division, Research Center for Infrastructure Management, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, Japan. Email: sekiya-h92tb@mlit.go.jp
3) Director for Information Engineering Affairs, Electricity and Telecommunication Office, Engineering Affairs Division, Minister's Secretariat, Ministry of Land, Infrastructure, Transport and Tourism, Japan. Email: ashiya-h82ac@mlit.go.jp

Abstract: Following an earthquake, the government's disaster management bureau immediately seeks to clarify the degree of damage to infrastructure. Closed Circuit Television (CCTV) cameras have been deployed and utilized to survey infrastructure on roads and rivers. Use of an automated system to select CCTV cameras in municipal areas where seismic activity has exceeded a preset level (set by the Japan Meteorological Agency) was studied. This system is equipped to obtain images taken by some testing CCTV cameras at regular times to compare images pre- and post-earthquake.

In this paper, we validated a method of detecting regions of change caused by earthquakes using three steps. First, we rendered non-photorealistic images as anomalous by drawing artificial damage after the earthquake. For example, falling objects can be captured by CCTV cameras surveying roads. Second, we validated an optimal number of images so as to remove moving objects such as cars and waving trees. We used the median value of each pixel in the images. Third, we validated algorithms containing parameters to adjust image sensitivity. Accounting for daylight changes, we used a joint intensity histogram of an anomalous image and a normal image. The joint intensity histogram was a two-dimensional combined intensity for the same pixel between anomalous and normal images. We regarded changes outside the constant multiple of the standard deviation of the joint intensity histogram as legitimate.

Using several filters, we removed moving objects with five images for four camera images. Under this condition, it was optimal to regard 10 times the standard deviation as artificial damage for 18 CCTV cameras. We are trying to detect a variety of changes more robustly for more CCTV cameras.

Keywords: support of the early stage after earthquake, Closed Circuit Television, image change detection

IOT-3

A HUMAN-FOLLOWING ROBOT FOR ASSISTING TUNNEL INSPECTORS

Chia-Hsing Ho[1] and Yo-Ming Hsieh[2]

1) Engineer, Turing Drive Inc., Taipei City, Taiwan, Email: chiahsing@turing-drive.com
2) Associate Professor, Department of Civil and Construction Engineering, National Taiwan University of Science and Technology, Taipei City, Taiwan, Email: ymhsieh@mail.ntust.edu.tw

Abstract: Tunnels require regular inspections to maintain their safety. Tunnel inspectors have modern tools such as smartphones and tablets to help them record observations via picture-taking, voice-recording, hand-writing, and text-typing. However, there is a lack of automated ways to obtain localization information inside tunnels. In this work, a person-following robot is developed for assisting tunnel inspectors by providing localization information inside tunnels. The robot contains four essential ingredients: person-detection, self-driving, localization, and communication with smart devices. This paper presents these ingredients and their integration. The developed robot was field tested inside buildings and pedestrian tunnels with success and issues. These results and issues are also presented in this paper.

Keywords: localization, person following, robot, tunnel inspection

IOT-4

A BUILDING STRUCTURAL HEALTH MANAGEMENT SYSTEM BY BIM AND IoT COLLABORATION

Narito Kurata[1], Kenro Aihara[2], Takahiro Konishi[3], Hirofumi Yamaoka[4], and Shinichi Kondo[5]

1) Ph.D., Prof., Faculty of Industrial Technology, Tsukuba University of Technology, Tsukuba-City, Ibaraki, Japan. Email: kurata@home.email.ne.jp
2) Ph.D., Assoc. Prof., Digital Content and Media Sciences Research Division, National Institute of Informatics, Chiyoda-ku, Tokyo, Japan. Email: kenro.aihara@nii.ac.jp
3) Corporate Officer, General Manager, Business Strategy Division, Applied Technology Co., Ltd., Kita-ku, Osaka, Japan. Email: ta-konishi@apptec.co.jp
4) IT Consultant, Business Strategy Division, Applied Technology Co., Ltd., Kita-ku, Osaka, Japan. Email: yamaoka@apptec.co.jp
5) BIM Consultant, Business Strategy Division, Applied Technology Co., Ltd., Kita-ku, Osaka, Japan. Email: sh-kondo@apptec.co.jp

Abstract: The authors have developed an autonomous time-synchronization sensing system that holds high- precision absolute time information by using a Chip-Scale Atomic Clock (CSAC) (Kurata, 2016; Kurata, 2018). Even if the CSAC-mounted sensor module/data logger is installed over a wide area and at high density, it is possible to acquire measurement data with time synchronization without relying on a network or a global positioning system (GPS) signal. The CSAC-mounted sensor module as an Internet of Things (IoT) device was installed in an actual building, and a structural health evaluation was performed for each subsequent earthquake (Kurata et al., 2008). A building structural health management system was constructed wherein acceleration data on each floor during an earthquake as measured by the CSAC-mounted sensor module is transmitted to a cloud server by 3G/LTE, and the acceleration, the inter-story drift angle and a structural health evaluation of the building are displayed in 3D model by a Building Information Modeling (BIM). Forge (Applied Technology, 2019; Autodesk, 2019) is employed as a development platform to realize this. This paper gives an outline of the CSAC- mounted sensor module as an IoT device and the building where it was installed, along with case results of seismic observations and inter-story deformation, a proposal for a building structural health management system, and its envisaged future. As a demonstration, an autonomous time-synchronization sensing system as an IoT device was linked with Forge, the BIM cloud expansion support development platform, and the results of a structural health evaluation during an earthquake were shown on a BIM model.

Keywords: Building Management System, Building Information Modeling (BIM), Internet of Things (IoT), Structural Health Monitoring, Earthquake Observation, Time Synchronization, Chip-Scale Atomic Clock.

IOT-5

DEVELOPMENT OF AN ANOMALY DETECTION SYSTEM OF ROAD SIGNS USING MEMS ACCELEROMETERS

Naomasa Haibara[1], Masayuki Saeki[2]

1) Master's Student, Tokyo University of Science, Chiba, Japan. Email: 7618527@ed.tus.ac.jp
2) Dr. Eng., Prof., Tokyo University of Science, Chiba, Japan. Email: saeki@rs.noda.tus.ac.jp

Abstract: It is recognized as an important issue how to efficiently maintain an enormous number of social infrastructures. For example, it is said that there are approximately 10 million road signs in Japan, and they are visually inspected once every five years. The visual inspections take a lot of time and cost. Therefore, we have been trying to develop an anomaly detection system for infrastructures. In this research, as a basic experiment, a road sign was constructed in our university. Then, MEMS (Micro Electronic Mechanical Systems) accelerometers was fixed on the back of the signboard, and the acceleration responses were automatically observed every 4 hours for about 18 months to investigate the daily variation. A single measurement was performed at 100 Hz sampling rate and 3 minutes data length. As a result, it was found that the eigenfrequency of the first mode varied by about
0.01 Hz. We also simulated the damage of the boundary condition which was often seen in damage cases of road signs and examined the change in responses. As reducing the thickness of the root part by about 0.5 mm which corresponded to 12 % decrement of bending rigidity, the eigenfrequency decreased by about 0.016 Hz. Since the change in eigenfrequency was larger than the temporal variation, the anomaly was successfully detected. On the other hand, in the case of 0.1 mm which corresponded to 5 % decrement, the change in eigenfrequency could not be detected because of the small variation. In addition, we also examined the direct density ratio estimation method based on KLIEP (Kullback-Leibler Importance Estimation Procedure) to detect the change point and abnormal value of the anomaly detection index.

Keywords: eigenfrequency, MEMS accelerometer, anomaly detection, road signs, density-ratio estimation, KLIEP

LIS-1

AUTOMATIC INDOOR ENVIRONMENT MODELING FROM LASER-SCANNED POINT CLOUDS USING GRAPH-BASED REGULAR ARRANGEMENT RECOGNITION

Hayato Takahashi[1], Hiroaki Date[2], and Satoshi Kanai [3]

1) Master Course Student, Graduate School of Information Science and Technology, Hokkaido University, Sapporo, Japan. Email: h_takahashi@sdm.ssi.ist.hokudai.ac.jp
2) Ph.D., Assoc. Prof., Graduate School of Information Science and Technology, Hokkaido University, Sapporo, Japan. Email: hdate@ssi.ist.hokudai.ac.jp
3) Ph.D., Prof., Graduate School of Information Science and Technology, Hokkaido University, Sapporo, Japan. Email: kanai@ssi.ist.hokudai.ac.jp

Abstract: In this paper, an automatic regularized 3D modeling method of indoor environments from laser- scanned point clouds is proposed. The method can efficiently create 3D indoor environment models which consist of a floor, a ceiling, and walls with regular arrangements of orthogonal, parallel, coplanar, and regular intervals. In the method, first, a floor and ceiling are extracted by plane fitting and parallelized by the least-square fitting. Then, wall line segments on the ceiling plane are estimated from boundary points on the ceiling. Next, graphs for the wall line segments are successively constructed to recognize the regular arrangements of the walls. In the graph, a node corresponds to one or more wall line segments, and an edge represents regular arrangement relationships between the walls. The resulting graph expresses the simplest regular arrangement relationships of the walls, and modified wall line segments are obtained by the least square fitting of lines to corresponding points under the constraints of the regular arrangements. Finally, a 3D model is created by sweeping the wall line segments along a vertical direction. Experimental results using point clouds from the laser scan simulation of a 3D model and laser scanning of a real indoor environment show the effectiveness of the proposed method.

Keywords: Laser scan, point clouds, 3D indoor environment modeling, regular arrangement.

LIS-2

Detecting Building Façade Deteriorations: Evaluation of 3D Laser Scanning and Image-based Reconstruction Approaches to Determine Feasible Settings in Data Collection

Zhuoya Shi[1], Semiha Ergan[2]

1) Ph.D. Candidate, Department of Civil and Environmental Engineering, NYU Tandon School of Engineering, Brooklyn, NY, USA. Email: zhuoyash@nyu.edu
2) Ph.D., Assist. Prof., Department of Civil and Environmental Engineering, NYU Tandon School of Engineering, Brooklyn, NY, USA. Email: semiha@nyu.edu

Abstract: To identify façade conditions that may cause public injury, many cities mandate façade inspection programs. With around one million aging buildings, New York City (NYC) requires buildings more than six stories to be inspected every five years. Thus, a safe, comprehensive, and objective inspection method is important. Laser scanners can capture as-is conditions rapidly and safely, while terrestrial laser scanners are influenced by the high incidence-angle in capturing detailed crack information at required heights. Images captured through drones or stationary equipment at elevated heights can aid with the height problem by generating point clouds via 3D reconstruction technology; however, is influenced by the accuracy of reconstruction algorithms. The objective of this study is to compare the point clouds obtained from these two modalities of technologies for the visibility and measurement accuracy of cracks and define the settings of equipment in capturing the right quality of point clouds at all floors including six levels and up. The experiments use a series of simulated cracks with different widths and orientations. These cracks were generated at sizes and thresholds indicated in building inspection programs (e.g., Local Law 11/98 in NYC) to understand the capability of two technologies in detecting such thresholds. The root- mean-square error in the measurement of crack lengths as compared to the ground-truth data was utilized to evaluate the accuracy of crack detection using point clouds obtained with these two modalities. Findings are influential for choosing and utilizing technologies at the right settings for effective periodical evaluations of building façades.

Keywords: building façade inspection, 3D laser scanning, 3D reconstruction.

LIS-3

AUTOMATED UAV ROUTE PLANNING FOR BRIDGE INSPECTION USING BIM-GIS DATA

Yang Zou[1], Molood Barati[2], Enrique del Rey Castillo[3], Robert Amor[4], Brian H.W. Guo[5], Jiamou Liu[6]

1) Lecturer, Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand. yang.zou@auckland.ac.nz
2) Research Assistant, Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand. mbar468@aucklanduni.ac.nz
3) Lecturer, Department of Civil and Environmental Engineering, University of Auckland, Auckland, New Zealand. e.delrey@auckland.ac.nz
4) Professor, Department of Computer Science, University of Auckland, Auckland, New Zealand. trebor@cs.auckland.ac.nz
5) Lecturer, Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch, New Zealand. brian.guo@canterbury.ac.nz
6) Senior Lecturer, Department of Computer Science, University of Auckland, Auckland, New Zealand. jiamou.liu@auckland.ac.nz

Abstract: Unmanned Aerial Vehicle (UAV) has been increasingly used for bridge inspection in the past few years and the recent development of 3D bridge models generated by UAV photogrammetry is highly promising for inspection purposes. However, the current practices of UAV-enabled bridge inspection require human control, during which process the UAV is flying close to the bridge location to take high-resolution images according to human commands. To overcome this gap, a novel method to automate the UAV route planning for bridge inspections is proposed, which uses Building Information Modelling (BIM) and Geographic Information System (GIS) data as input to drive the automated UAV flying and operations. The underlying assumptions include, 1) the integrated BIM-GIS system can represent the physical world, and 2) the 3D bridge model generated by UAV photogrammetry can provide highly reliable and accurate data for bridge inspection. Under such route planning, the BIM-GIS system provides the bridge's geospatial and surrounding environment information (e.g. bridge's geometry, elevation, orientation) to guide the UAV flying the shortest path to gather all required information for the bridge inspection according to a novel algorithm. The next stage of this project will validate and test the proposed method for real bridges.

Keywords: Unmanned Aerial Vehicle (UAV), Bridge inspection, BIM-GIS integration, Route planning, Photogrammetry.

LIS-4

MEASURING RAILWAY FACILITIES BY USING TWO MOBILE LASER SCANNERS DIRECTLY ABOVE THE RAILS

Kohei Yamamoto[1] and Nobuyoshi Yabuki[2]

1) PASCO Corp., Japan. Email: kootho1810@pasco.co.jp
2) Ph.D., Prof., Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University, Suita, Japan. Email: yabuki@see.eng.osaka-u.ac.jp

Abstract: To measure three-dimensional shape of the rail is important for the safe operation of trains. Conventional rail track measuring methods tend to be time-consuming, labor-intensive, and error prone. To grasp positions and shapes of railway facilities which are close to the clearance gauge, rapidly, efficiently and precisely, this research proposes a new measurement method by using two mobile laser scanners directly above the rails. In this method, two Mobile Laser Scanners (MLSs) are installed directly above rails so that high-precision point cloud data can be obtained more rapidly than the single MLS method. The point cloud data obtained by two MLSs directly above the rails can be accurately coincided using the position of rail track center lines. The point cloud data of MLSs are compared with the point cloud collected by Terrestrial Laser Scanner (TLS). Finally, this method was applied to the test rail line where two electric poles are installed and it was identified within 0.01m of relative accuracy compared with TLS. The applicability of this method has been verified to both curve and straight tracks.

Keywords: Mobile Laser Scanning, 3D Point Clouds, Registration, Facility Management, Monitoring.

IPM-1

A FEASIBILITY STUDY FOR LDAP CERTIFICATION IN COLLABORATION WITH EXISTING ACCOUNTS IN RDBMS

Yoshiyuki Yokoyama[1]

1) Project Manager, Department of Systems Engineering, Japan Construction Information Center, Minato, Tokyo, Japan. Email: yokoyamy@jacic.or.jp

Abstract: For the purpose of improving productivity, we, JACIC, have been trying to apply a cloud storage product on our already existing application. This idea will have our users use a new login account instead of their existing account to be certified by a cloud storage product. However, since this would put a burden on users by requiring them to keep track of multiple accounts, we have focused on finding a single sign-on solution with LDAP. OpenLDAP, a product that implements LDAP, as well as BerkeleyDB and HierarchicalDB, are used as a back- end system for storing login accounts. However, RDBMS also could have been used at least from its documents. If the RDBMS is attached as the back-end for OpenLDAP, the cloud will be able to access the existing login accounts through an LDAP interface. Thus, users will be certified by the cloud without having to register multiple accounts. However, there are a few OpenLDAP + RDBMS test cases online which have made us hesitate to choose LDAP as our single sign-on solution. This feasibility study shows some points of attention for creating and operating an OpenLDAP + RDBMS environment.

Keywords: single sign-on, OpenLDAP, back-sql, slapd-sql, RDBMS

IPM-2

SEMANTIC MODELING OF BUILDING CONSTRUCTION EMISSION KNOWLEDGE

Wenkai Luo[1], Guomin Zhang[2], Lei Hou[3], Malindu Sandanayake[4]

1) Ph.D. Candidate, School of Engineering, RMIT University, Melbourne, VIC, Australia. Email: s3691927@student.rmit. edu.au
2) Ph.D., Prof., School of Engineering, RMIT University, Melbourne, VIC, Australia. Email: kevin.zhang@rmit.edu.au
3) Ph.D., School of Engineering, RMIT University, Melbourne, VIC, Australia. Email: lei.hou@rmit.edu.au
4) Ph.D., School of Engineering and Science, Victoria University, Melbourne, VIC, Australia. Email: Malindu.Sandanayake@ vu. edu.au

Abstract: Previous works on estimating construction carbon emissions from energy consumption were primarily capitalizing on the quantity of construction materials, equipment and an emission inventory. It is envisaged that with the aid of Building Information Modeling (BIM) technologies that are featured by semantic-rich data and information, the present-day practice of energy and emission estimation can be well improved. Despite an ideal BIM model typically encompasses information that ranges across building design, construction and operation details, a rationale around how to leverage semantic-rich BIM to address building energy consumption and carbon emission topics is still unclear. Under this backdrop, this study is centered on formulating a semantic-rich building energy consumption ontological model that is capable of accurately calibrating the energy consumption and emissions of a building. The formulated model will consider various factors that can affect the calibration and estimation such as materials, fabrication, logistics, processing, and the like.

Keywords: Construction Phase, Ontology, Emission Estimation

IPM-3

APPLICATION AND ANALYSIS OF SYSTEM ARCHITECTURE MODEL FOR CONSTRUCTION PROJECT

Tatsuru Tomii[1], Koji Makanae[2], Raj Kapur Shah[3]

1) Software developer, Kokusai Kogyo Co., Ltd., Tokyo, Japan. Email: tatsuru_tomii@kk-grp.jp
2) Ph.D., Prof., School of Project Design, Miyagi University, Miyagi, Japan. Email: makanae@myu.ac.jp
3) Ph.D., Senior Lecturer, Faculty of Engineering and Technology, Liverpool John Moores University, Liverpool, United Kingdom. Email: r.shah@ljmu.ac.uk

Abstract: In a smart society where physical space and cyber space are integrated. Similarly, the construction project life cycle is being considered to be mutually related on both physical and cyber spaces. The project life cycle becomes complicate when integrating the relationship between physical and cyber space. This paper presents the design of a system architecture model in which the project life cycle is hierarchized, which is based on the scope of each process in the project. Additionally, an analysis of the information technology that supports each process from the scope of this model is also presented. The paper concludes that the proposed model is a useful tool to the construction project life cycle, and it helps to organize the process and system of the project components.

Keywords: System architecture model, V-model, Construction project life cycle, Cyber-Physical systems

IPM-4

SMART CONSTRUCTION OBJECTS (SCOS): A NEW THEORY OF SMART CONSTRUCTION IS BORN

Weisheng Lu[1], Yuhan Niu[2], and Chimay Anumba[3]

1) Associate Professor, Department of Real Estate and Construction, Faculty of Architecture, The University of Hong Kong, Pokfulam, Hong Kong
2) Construction Industry Council (CIC), Hong Kong
3) Dean and Professor College of Design, Construction and Planning, University of Florida, USA

Abstract: Despite of the prolific development of smart systems in the construction industry, the theorizing work of 'smart construction' is rather stagnant. The fundamental concepts, definitions, and models of smart construction are yet to be fully explored. It is against this backdrop that this study seeks to advocate smart construction objects (SCOs) as an innovative concept and the basic elements to define, understand, and achieve a new theory of smart construction. It does so by adopting a mixed-method strategy at the kernel. It establishes the conceptual and deployment elements of SCOs and tests them in two case studies. This study reveals that the concept of SCOs can steer the field of smart construction towards a new theory by (a) enhancing the theoretical lucidity on smart construction, and (b) providing a generalizable framework for realizing it. One elegance of SCOs lies in that they can be adopted and implemented without radically changing the prevailing construction practice and process. Advancing smart construction through this direction can be expected to go more promisingly than existing directions.

Keywords: Smart construction, smart construction objects, theory.

IS-1

COLLECTION DATA USING NEW TOOL TO SATISFY SPECIFICATIONS

Yasushi Kawanai[1]

1) Registered Perfect Engineer (Civil), Director of E-bidding Support Center, Japan Construction Information Center, Akasaka, Tokyo, Japan. Email: kawanaiy@jacic.or.jp

Abstract: As part of E-Bidding Support Center's work with the Japanese Ministry of Land, Infrastructure, Transportation and Tourism (MLIT), our help desk business for e-bidding is partially controlled by the ''performance regulations'' on contract specifications, not amount regulations. The specifications say that the necessary facilities and staff should be prepared for dealing with daily telephone inquiries. This does not involve amount regulations. And the specifications also say that we should avoid making people wait when they call. Instead, immediate responses are requested.

In order to prove that people are not waiting when they call, we need a new data. Therefore, I found a tool to obtain this data and prove that we met this requirement. By using a type of Interactive Voice Response (IVR) system, we can get the data to prove people is not waiting when they call. As a result, we were able to prove that we satisfied the MLIT specifications by the introduction of this system.

Keywords: Interactive Voice Response (IVR), data analysis, MLIT, specifications, performance regulations

IS-2

EDUCATIONAL ACTIVITIES AIMED AT IMPROVING PRODUCTIVITY IN JAPANESE CONSTRUCTION INDUSTRIES THROUGH 3D-CAD

Yasuyuki Kikyo[1]

1) Senior Researcher, Construction Information Research Institute, Japan Construction Information Center, Tokyo Japan. Email: kikyoy@jacic.or.jp

Abstract: In 2014, the Japan Construction Information Center Foundation (JACIC), began a technical and institutional plan about applying CIM. At the same time, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) announced its policy for CIM, but there is no educational organization that provides instruction for 3D-CAD software in the civil engineering field.

We believe it is urgent to develop human resources who can use 3D-CAD software in the construction field. Therefore, we started holding educational activities in Japan called "CIM Challenging Education and Training" as a non-profit service. We developed a special curriculum for 3D-CAD in the construction field with the cooperation of organizations such as buildingSMART Japan. To date, we have held this program eight times from 2015 to 2018.

Keywords: BIM/CIM, develop human resources, 3D-CAD.

IS-3

IMPROVEMENT OF ELECTRONIC BIDDING CORE SYSTEM

Hiroyuki Ishiwata[1]

1) Manager, Systems Engineering Department, Japan Construction Information Center Foundation (JACIC), Tokyo, Japan. Email: ishiwath@jacic.or.jp

Abstract: Most Japanese public procurements were made through paper-based procedures before the year 2000. However, there were some problems with these paper-based processes such as inefficiency, non-competitiveness, and non-transparency. Furthermore, there was a serious issue involving unfairness in transportation costs and time between the participating companies.

The Japanese government officially announced the "e-Japan Strategy" in 2001 and active application of "information, communication, and technology." For public procurement, an electronic procurement method using the internet was planned. According to the policy, JACIC had developed package software for an electronic bidding system (Electronic Bidding Core System) in 2002. Afterwards, we launched some updates and are now on our latest version, Version 6, released in March 2016. Currently, 800 public organizations have adopted our software.

For 15 years, we worked with several types of IT technology and launched update modules for this software. Then, a serious problem occurred in December 2016 that Java plugin technology will be abolished starting from the future version, Next Java SE Version 9. However, in September 2017, when Version 9 was released, it was announced that the abolition schedule of the Java plugin had been pushed ahead. The majority of Japanese public systems depend on Java plugin technology, and our Electronic Bidding Core System was no exception, so we immediately got to work on an emergency project for our system.

This paper describes that project.

Keywords: procurement, electronic bidding, JACIC

IS-4

INTEGRATION OF 3D MODELS OF STRUCTURES AND GEOLOGICAL COMPOSITION AS AN UNDERGROUND INFRASTRUCTURE MODEL

Toshiaki Hakoda[1], Syoichi Nishiyama [2], Takaki Omori[3], Isao Shiozaki[4], Mamoru Narusawa[5], and Nobuyoshi Yabuki[6]

1) Assistant General Manager, Overseas Infrastructure Project Division, JGC Corporation, Yokohama, Japan. Email: hakoda.toshiaki@jgc.com
2) P.E., JP (Applied Science), General Manager, Social System Business Division, OYO Corporation, Tokyo, Japan. Email: nisiyama-syoichi@oyonet.oyo.co.jp
3) P.E., JP (Applied Science), General Manager, Engineering Division, Nikken Sekkei Civil Engineering Ltd., Email: oomorita@nikken.jp
4) Dr. Eng., General Manager, Geo-space Engineering Center (GEC), Engineering Advancement Association of Japan (ENAA) Email: shiozaki@enaa.or.jp
5) Deputy Manager, Facility Management Department, ESCA-SC, Email: narusawa@esca-sc.com
Ph.D., Prof., Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University. Email: yabuki@see.eng.osaka-u.ac.jp

Abstract: To develop three-dimensional (3D) models as examples of the infrastructure model concept which would be useful for the operation and maintenance or design and construction of underground facilities, we integrated 3D models of the geological composition, the structure and the lifeline facilities (water supply and sewerage system, city gas line, electrical power and communication lines) for the underground mall named ESCA in Nagoya City, Japan. After the integration of the above 3D models, we were able to show the owner, ESCA-SC, that the soil layers were suitable to ensure the stability of the structure. They also checked the 3D models by utilizing the Mixed Reality (MR) system and found the integrated 3D models would be very useful for making a plan for the modification and renovation of their facilities.

Keywords: 3D geological model, underground mall and lifeline, Mixed Reality (MR)

ARCHITECTURE,
ENGINEERING & CONSTRUCTION
COLLECTION

建築、 土木、 施工に対応する
統合 BIM、CIM ツール

AEC COLLECTION は建築、 土木、 施工のほか
これらの分野が相互に関連するプロジェクトに
欠かせない基本ツールをまとめて手頃な
価格で提供します。

コレクションに含まれる主なソフトウェア

- Revit
- Civil 3D
- InfraWorks
- 3ds Max
- Navisworks Manage
- Vehicle Tracking
- Dynamo Studio
- AutoCAD
- AutoCAD Map 3D
- AutoCAD Plant 3D
- AutoCAD Architecture
- AutoCAD Raster Design
- AutoCAD モバイルアプリ

導入のご相談

フリーダイヤル
月 - 金 9:00 - 17:00 (祝日除く)
0800-123-6275

inside-sales-aec@autodesk.com
twitter.com/RevitJapan
facebook.com/RevitJapan
youtube.com/AutodeskJapanBIM

AUTODESK.

次の現場は、宇宙です。

鹿島建設の技術はいま、月に手が届こうとしています。2016年から、鹿島とJAXA(宇宙航空研究開発機構)の共同研究が始まりました。課題は、月や火星での宇宙基地構築を目指して、無人の遠隔施工システムを実現すること。過酷な宇宙空間で建設をするために、機械だけが宇宙へ。地上からの遠隔操作と建設機械の自動制御によって、宇宙での建設を行うのです。それを可能にするのが、鹿島の次世代建設生産システム「A⁴CSEL(クワッドアクセル)」。人間は、タブレット端末であらかじめ指示を出すだけ。あとは複数の建設機械が、自動で働く。人間が行けない危険な現場での作業を可能にし、また、将来の現場の深刻な人手不足を解決するために生まれた技術が、宇宙の可能性をも切り拓こうとしているのです。鹿島が見上げる夜空には、次の現場が浮かんでいます。

100年をつくる会社
鹿島

FORUM8

2002 SOFTIC SOFTWARE PRODUCTS OF THE YEAR WINNER

Virtual Reality Design Studio UC-win/Road VR/FEM/CAD/Cloud UC-1 Engineer's Studio®

Virtual reality design studio

UC-win/Road Ver.14 64bit 32bit

3D real time/virtual reality software UC-win/Road awarded Software Product of the Year, 2002. Advanced software that enables the creation of large scale 3D spaces for all sorts of projects by PC operations and with which you can give variety of presentations in real-time. It can be used as an ideal software in a flexible development environment and for advanced system development.

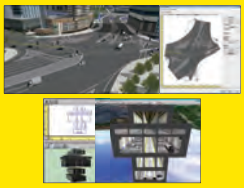
Ultimate :	US$19,200
Driving Sim :	US$12,800
Advanced :	US$9,700
Standard :	US$6,300
Presentation :	US$660

FUNCTION

Utilization of standard data and CAD data

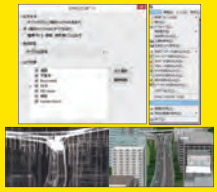
Terrain data and map are included on the database. A 50m topographic mesh(of New Zealand and Japan) and 2500 spatial infrastructure data is included.
Other useful features include a custom terrain feature, a world geographic coordinate system conversion feature,DXF-XML conversion as well as a 3D and 2D terrain editing feature.

Simple and precise creation of complex road structure



Thousands of 3D models available for easy and efficient VR modeling

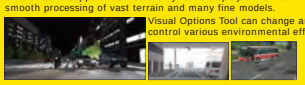
CIM support by DWG tool



Makes drawings of VR space model in 3D and supports CIM.

Large-scale VR support

64 bit native support realizes the dynamic display of LOD and the smooth processing of vast terrain and many fine models.



Visual Options Tool can change and control various environmental effects.

VR space can be manipulated at will in real-time by simple PC operations. Before/After, scripting, and manual driving features all assist presenters.

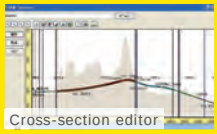
DESIGN

Terrain surface input/Road generation

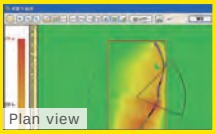
Digital maps available

Rivers, road cross sections

Cutting, embankment, berm



Cross-section editor



Plan view

Railway

Intersection editor

Modeling / Data linkage

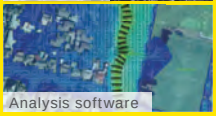
FBX

Point cloud data

DWG/CAD

IFC

Traffic AP



Analysis software

SIMULATION

TRAFFIC SIMULATION

Signal control

Traffic Flow

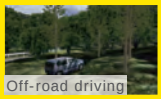
Driving SIMULATION

Set cockpit

Steering rotation

Vehicle Motion Simulator

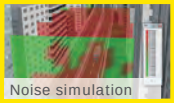
Road attribute



Off-road driving

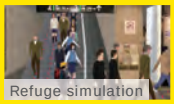
Visualizing analysis results

Crowd flow



Noise simulation

Fluid analysis



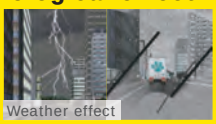
Refuge simulation

Tunami simulation

Debris-Avalanche simulation

Illumination and meteorological effect

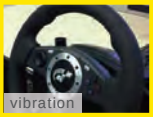
Lighting function



Weather effect

Setting of sound/vibration

Audio system



vibration

System integration

6K digital signage

8DOF Traffic safety simulator

4K 3D Driving simulator

Ver.14 NEW FUNCTIONS

▷Creation of 360-degree video

VR simulation videos created as 3D video can be displayed on VR Head Mounted Display and be published in VR video format

▷Linkage with Eye Tracking Devices

Linkage of eye tracking devices with UC-win/Road allows inspection of driver's gaze-point, and exporting of logs recorded in real-time whilst driving

▷Real-time Linkage with Traffic Simulation Model in VISSIM

Sends UC-win/Road's vehicle data in real-time to VISSIM, which then calculates data of surrounding vehicles and feeds the calculation result to UC-win/Road.

▷Customization of Rendering Process

This pixel color processing is able to be freely customized by using OpenGL shader language GLSL. For example, it can be used for the space analysis function by object segmentation, the deep learning and AI training, and the test data creation.

▷Object Sensor

This function detects objects within a sensor's measurement range and visual field. Version 14 supports the detection of static 3D models, traffic flow models, characters, movable models, road signs, road markings, and cockpit objects.

▷Enhancement of Simulation Real-time Linkage Option

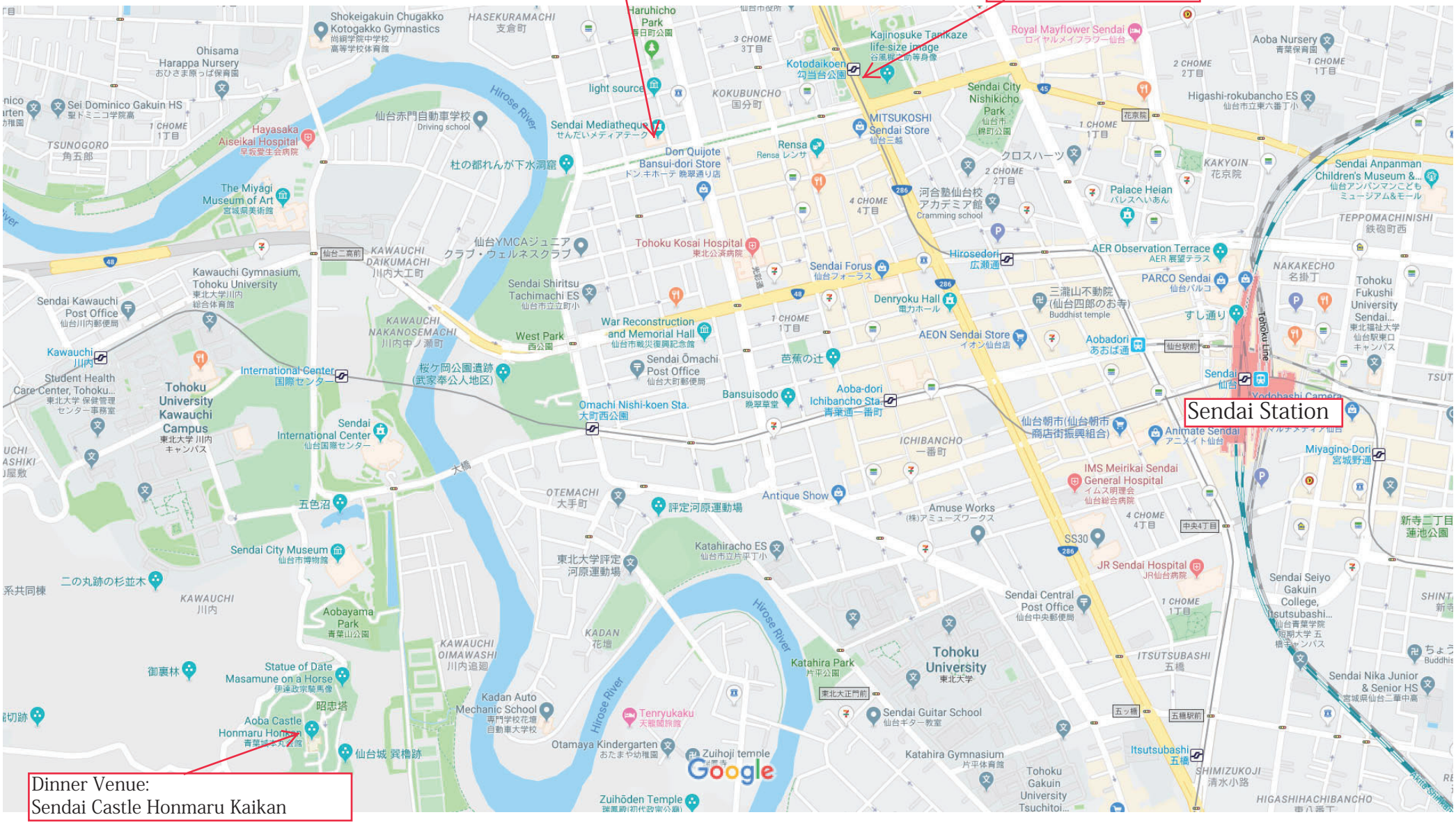
▷Seamless interoperability with more devices

●HTC VIVE Plug-in Ver.3

・Supports newest version of OpenVR API
・Device Model Display function updated
・Linkage with scenario events ・Ability set scenario triggers
・Linkage with VIVE Tracker ・Interface for developers available

●UAV Plug-in Ver.5 ・Supports newest model of DJI Drone

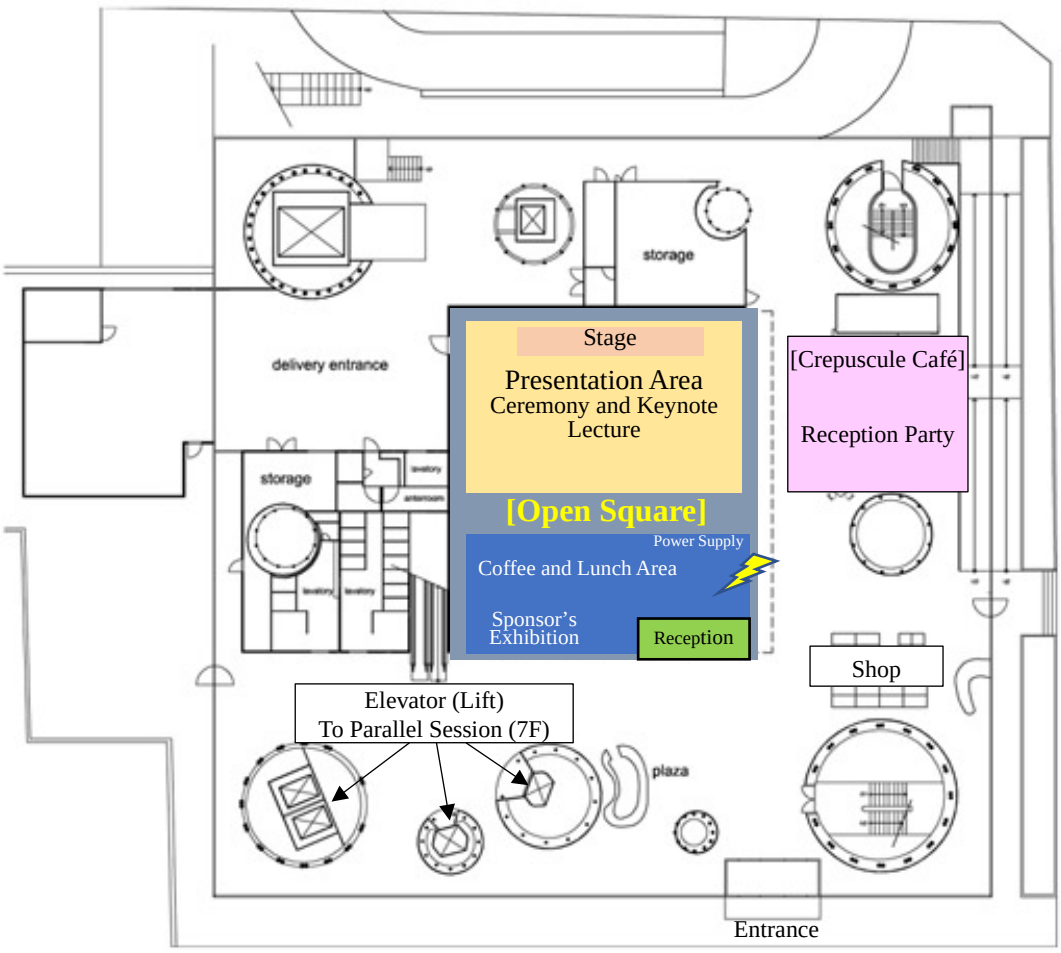
Google Maps Sendai City Map



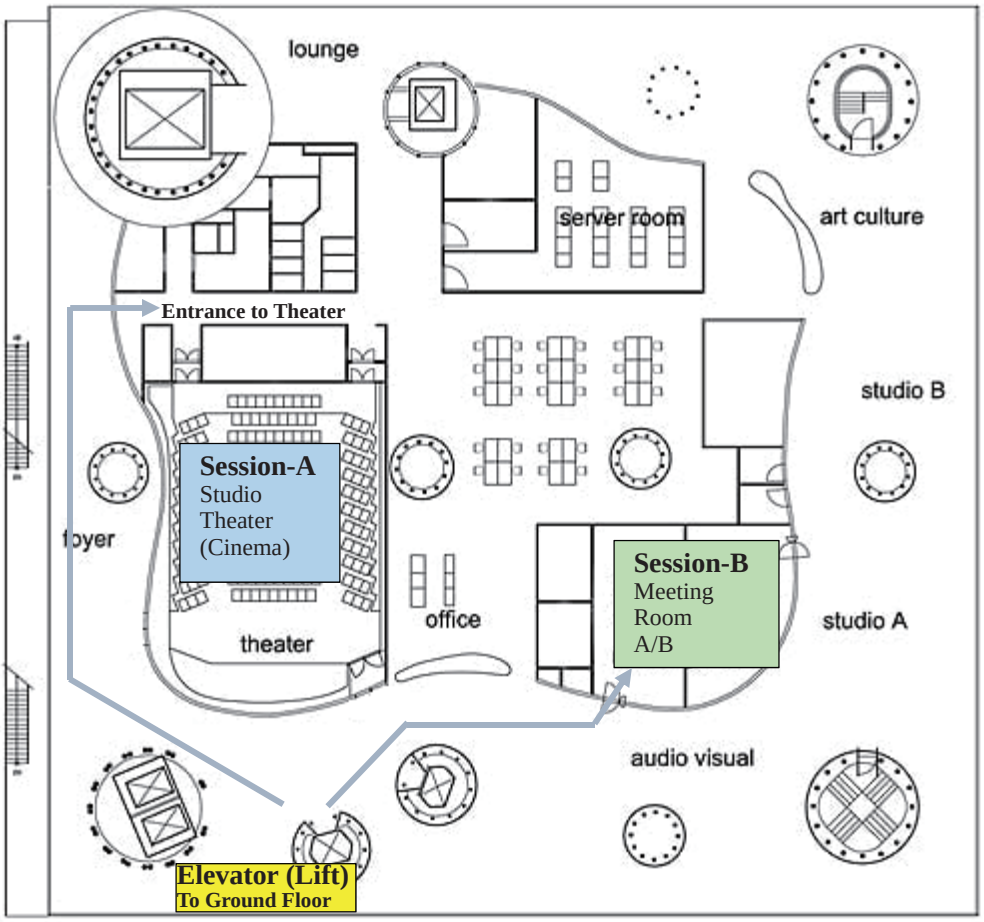
Map data ©2019 200 m

Google Maps Sendai Castle Ruins

FLOOR MAP -Ground(1st) Floor of Sendai Mediatheque



FLOOR MAP - 7th Floor of Sendai Mediatheque



Proceeding of the 4th Interenational Conference on Civil and Building Engineering Informatics
ISBN978-4-600-00276-3
can be downloaded from https://www.iccbei2019.com

Photos are provided by SenTIA

Gold Sponsors:

FORUM 8®

鹿島 KAJIMA CORPORATION

応用技術株式会社 APPLIED TECHNOLOGY CO.,LTD.

AUTODESK.

SenTIA Sendai Tourism, Convention and International Association

Silver Sponsors:

JIPテクノサイエンス株式会社

中央復建コンサルタンツ株式会社

Yachiyo Engineering Co.,Ltd.

CHODAI

SHIMZ

TRION

OBAYASHI

Supporters:

MIYAGI UNIVERSITY

JACIC