Bentley Applied Research Seminar 2020

Session I Digital Twin for Resilient Infrastructure (2:00 PM - 4:00 PM, Tues, Sept. 15, 2020)

1. **Augmented Intelligence (AI) for Resilient Infrastructure Digital Twins**. Dr. Zheng Yi Wu, Bentley Fellow, Bentley Systems, Incorporated, Watertown, CT

Abstract: While Digital Twin (DT) and Artificial Intelligence (AI) go mainstream hand in hand, the essence of AI is to augment the intelligence of DT. This talk will briefly recap our previous efforts and elaborate the on-going applied research endeavors in applying AI to address various challenges with augmented intelligence, instead of artificial intelligence, and enable the users to improve the near real-time operation management for resilient infrastructure.

2. **Convergence of Sensing, Data Analytics, Infrastructure Design/Engineering, and Human Studies for Resilient, Healthy, and Equitable Communities.** Dr. Jie Gong, Associate Professor & Ms. Mengyang (Iris) Guo, Civil and Environmental Engineering, Rutgers, New Jersey State University

Abstract:
Changing climate, intensified nature disasters, and pandemics are ever increasing threats today facing American people, much of them are further beset with social injustice. In this talk, we will discuss our ongoing research effort in using digital technologies such as sensing, data analytics with integrated social and domain knowledge considerations to assist people to cope with these growing social crises. More specifically, we will first talk about how spatial sensing, AI assisted information extraction, and damage modeling can be used to improve the readiness of coastal communities during pandemics. We will also talk about how urban mapping and modeling, transportation asset modeling, and advanced simulation can be used to protect vulnerable populations amid COVID-19. A common thread among these studies is the quest to obtain deep understanding of the stressors, whether they are natural or social oriented as well as designing human centered smart city solutions to mitigate these stressors.

3. **Multimodal Information Integration for Indoor Navigation Using a Smartphone**. Dr. Zhigang Zhu, Herbert G. Kayser Professor, Computer Science, Grove School of Engineering, City University of New York (CUNY), NY

Abstract: It is challenging for travelling public, especially the underserved populations including those with visual impairment, to easily navigate through large and complex facilities such as transportation hubs, sports arenas and exhibition halls. Supported by both the National Science Foundation and Bentley, we have proposed an accessible indoor navigation solution with smartphones. The solutions integrate information of floor plans, Bluetooth beacons, Wi-Fi/cellular data connectivity, 2D/3D visual models, and user preferences. Hybrid models of interiors are created in a modeling stage. Multimodal data are collected, as the modeler walks through the building, and is mapped to the floor plan. Client-server architecture allows scaling to large areas by lazy-loading models according to beacon signals and/or adjacent region proximity. During the navigation stage, a user with the designed mobile app is localized within the floor plan, using the multimodal information. User interfaces for both modeling and navigation use visual, audio, and haptic feedback for targeted users. A prototype of iASSIST, an iOS assistive application built around ARKit will be demonstrated, which provides turn-by-turn navigation assistance using accurate real-time localization over large spaces without the installation of expensive infrastructure.

4. **Infrastructure Digital Twins of Power Distribution System for Resilient Community.** Dr. Wei Zhang, Assistant Professor, Mr. Xiaolong Ma, Mr. Jintao Zhang and Mr. Dongping Zhu**,** Ph.D. Candidates, Dept. of Civil and Environmental Engineering, University of Connecticut, Storrs, CT

Abstract: Power distribution system usually experiences severe damages during extreme weather events, which could significantly affect community residents' daily lives. In the present study, digital twins for the power distribution system is established to enhance community resilience. Based upon 3D point cloud data (LiDAR datasets) and photogrammetry (e.g., digital images from Google street view or cameras installed on UAV), the critical design parameters could be updated for the digital twins of the power distribution system. ContextCapture is employed to construct the reality model with the photos taken from different angles and a filtering algorithm is developed to smooth the surface of the model. For the laser scanning method, point cloud data is classified as pole objects and wire objects, which are then transformed into reality model using the piecewise model growing method. 3D reality model is then converted into a finite element analysis model by assigning material properties and types of connection between different elements. For the distribution network, the finite element model is generated based on the parameters and properties recorded in the database from the 3D reality model. Therefore, infrastructures digital twins for the power distribution system are established and could be updated with new 3D modeling data as well as operational data from utility companies. Different resilience options, such as tree trimming and replacement of poles, can be assessed for various weather events. Reliable decisions for resilience enhancement, therefore, could be achieved and reflects current conditions of physical infrastructure.

Session 2 Infrastructure Seismic Resilience and Health Performance (2:00 PM – 4:00 PM, Thurs Sept. 17, 2020)

1. **Big Data — A New Research Frontier in Earthquake Engineering.** Dr. Ertugrul Taciroglu, Professor & Chair, Civil & Env. Engineering Department, University of California, Los Angeles

Abstract: Recent advances in performance-based earthquake engineering and existing information technologies provide opportunities to develop extremely granular inventories of the built environment and assess its vulnerabilities to earthquakes as well as other hazards. This presentation focuses on bridges—which are arguably the most critical elements of a transportation network—and delineates the ingredients needed to bring a regional seismic assessment tool to fruition. These ingredients range from site-specific ground motion estimation to automated development of analysis models for bridges using data harvested from publicly available repositories, to damage and economic loss assessment. After identifying the ingredients, an overall framework is articulated for regional risk assessment of transportation networks. An application example is provided to demonstrate the viability of the envisioned approach, and its natural extensions to other areas including structural performance monitoring and rapid post-event assessment are discussed.

2. **Classification of Soft-Story Buildings Using Deep Learning with Density Features Extracted from 3D Point Clouds.** Mr. Peng-Yu Chen, PhD Candidate, Civil & Env. Engineering Department, University of California, Los Angeles

Abstract: Soft-story buildings have been observed to be one of the seismically vulnerable structures during past earthquakes. Identifying these buildings is the first step in seismic risk mitigation efforts for a given urban region's seismic resilience. Many studies have implemented deep learning-based techniques to detect and classify infrastructural damages through images but few of them focused on detecting seismically vulnerable buildings in a city scale. In addition, previously developed models have been trained with well controlled street view images with obvious targets instead of raw images where targets may be blocked. These models may have a high false-positive rate when applied to real-world data. To improve that, this paper develops a method that utilizes density features collected from 3D point-cloud data and generates images describing the point-cloud-density variation along the building height for training convolutional

neural networks to classify soft-story buildings. Point clouds of Santa Monica are collected and split into training, validating, and testing sets based on the ground-truth building footprints. Sensitive ranges of hyperparameters are investigated to obtain the optimal performance.

3. **Physics-Guided Machine Learning for Efficient Occupant Monitoring using Structural Vibrations.** (40 min) Dr. Haeyoung Noh, Associate Professor, Dr. Mostafa Mirshekari, Postdoctoral Research Associate, Civil and Environmental Engine, Stanford University, Stanford, CA

Abstract: Occupant monitoring is an important part of various smart infrastructure systems such as smart health care, security and efficient energy management. To this end, recent literature has introduced a Floor-Vibration-Based sensing for characterizing and monitoring occupants through the floor vibrations caused by their activities. Conventionally, this characterization is based on Machine Learning (ML) and utilizes the vibration responses to extract information about the excitation source. However, due to the structure-dependent nature of floor vibrations, these approaches are inefficient and require extensive amounts of data. In this talk, I 1) introduce this problem in more detail, 2) discuss various inefficiencies related to the use of purely data-driven ML models, and 3) describe how physics-guided learning overcomes those challenges and enables more efficient occupant monitoring. Further, I will discuss some of our collaborations with various nursing homes and hospitals for monitoring patients and the elderly population

4. **Damage Chronology for Spatiotemporal Condition Assessment of Civil Infrastructure Using Unmanned Aerial Vehicles.** Dr. Mohammad Jahanshahi, Assistant Professor of Civil Engineering, Tarutal Gosh Mondal, PhD Candidate, Purdue University

Abstract: This study presents a computer vision-based approach for representing time evolution of structural damages leveraging a database of inspection images. Spatially incoherent but temporally sorted archival images captured by robotic cameras are exploited to represent the damage evolution over a long period of time. An access to a sequence of time-stamped inspection data recording the damage growth dynamics is premised to this end. Identification of a structural defect in the most recent inspection data set triggers an exhaustive search into the images collected during the previous inspections looking for correspondences based on spatial proximity. This is followed by a view synthesis from multiple candidate images resulting in a single reconstruction for each inspection round. Cracks on concrete surface are used as a case study to demonstrate the feasibility of this approach. Once the chronology is established, the damage severity is quantified at various levels of time scale documenting its progression through time. The proposed scheme enables the prediction of damage severity at a future point in time providing a scope for preemptive measures against imminent structural failure. On the whole, it is believed that this study will immensely benefit the structural inspectors by introducing the time dimension into the autonomous condition assessment pipeline.