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Satellite-Based Big Data for Resilience of Critical Infrastructures Subjected to Natural and Man-Made Disasters

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Editorial

During natural and man-made disasters, infrastructures are subjected to cyclic combined flexural, axial and shear forces. The safety and serviceability of infrastructures are critical because their failure can have catastrophic consequences. The capacity of infrastructure to recover quickly from disasters is urgently needed and this requires sound decision making. Hence, The Engineering for Natural Hazards (ENH) program at the National Science Foundation encourages research that advances knowledge for understanding and mitigating the impact of natural hazards (earthquakes, tornadoes, hurricanes, tsunamis, storm surge and landslides, etc) on constructed civil infrastructures. Considering civil infrastructure performance over its lifetime, the potential of multiple hazards to the infrastructures is high.

The potential impact of natural and man-made disasters such as earthquakes, tornados, tsunamis, blasting and missile attacks increases significantly for critical infrastructures. Therefore it is extremely important that the resilience of such infrastructures be maintained in order to keep the economic loss to a minimum. Space-borne satellites acquiring information on the earth's surface routinely will provide rich data. Big data is huge and complex data sets, including catch, curation, hunt, sharing, analysis, storage, convey, visualization and private information. Space-borne satellites to acquire information (such as deformation of the infrastructure, water level of flooding, etc) on the earth's surface are needed to critically examine the damage level of the infrastructure.

Combining the finite element analysis results for the targeted critical infrastructures will produce large and complex data sets that can be stored in big data. The critical infrastructures can be visualized as assemblies of various elements. The behavior of a whole structure can be predicted if the behavior of each element is thoroughly understood. Using OpenSees as a framework, a finite element analysis (FEA) program to predict the nonlinear behavior of infrastructures subjected to multi-hazards is developed at the University of Houston. In the formulation, we develop the constitutive relation and various element modules with a model-based simulation approach by taking into account the Cyclic Softened Membrane Model also developed at the University of Houston. To form a FEA program, the constitutive relation modules and the analysis procedure were implemented into a finite element program development framework, OpenSees, developed at UC Berkeley. By analyzing the data collected by satellite after impact and the analytical outcomes of the targeted infrastructures, a resilience methodology can be quickly developed that will be very helpful for the decision makers.

Satellite-based big data can be employed to guide the finite element analysis of critical infrastructures and to evaluate the damage level for resilience purposes. The developed finite element program (Simulation of Concrete Structures, SCS) is able to accurately predict the nonlinear, dynamic behavior of critical infrastructures subjected to natural hazards or man-made disasters using satellite collected data to trace the loading history and to obtain the damage level for resilience purposes. Through finite element analysis and the data collected by satellites in the big data, a robust and effective "resilience methodology" can be developed for the decision makers.

(Figure 1) shows the flow chart of the resilience methodology for critical infrastructures. When disaster occurs, real-time data of the pre-selected critical infrastructures and the surrounding environmental conditions are captured and integrated by the satellite, which will be immediately uploaded to the big data system for further processing. Meanwhile, this satellite-based integrated information, such as environmental conditions, structural deformation status and any other accessible data, will be applied as the inputs for the analysis procedure. Once the satellite-based information is updated, the big data system can provide a rough estimation of the critical infrastructures' damage level and current status based on the previous corresponding data and similar cases in a very short response time.

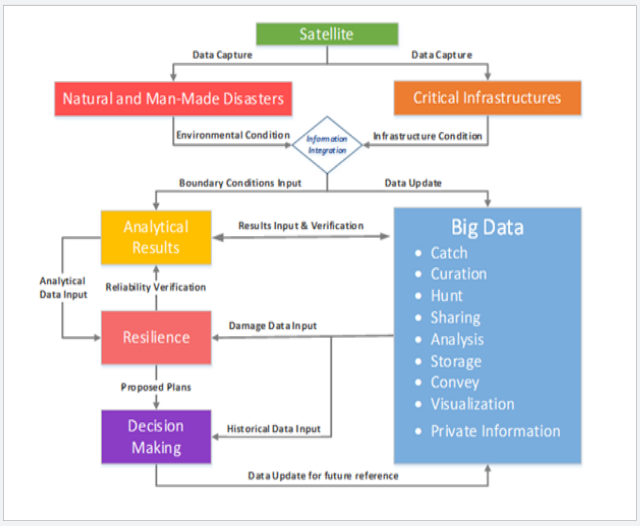

Figure 1: Resilience Methodology for Critical Infrastructures.

On the other hand, with the satellite-based information collected, the FEA program can simulate the real damage status of the infrastructures, which provides much more accurate and reliable results for the following structural assessment purpose. Although the two results are derived using different methods, the satellite-based data can be used to verify the analytical outcomes. Once the analytical results are verified, it will be passed to the resilience program as an important reference data, together with the historical damage records from the big data system, which in turn proposes the most robust and effective resilience methodologies for keeping the economic loss to a minimum.

The proposed resilience plan, which is a highly-integrated methodology containing the contribution and progress from both the FEA program and the Big Data System, will be delivered to the resilience committee for the final decision making, The incredible advantage of these two systems enables the committee to have the most feasible and the most time- and cost-effective method for the disaster recovery. And of course this method will also be uploaded to the big data system for future reference purposes. With more and more cases analyzed and input to the big data system, this continuous developing database tool will be stronger and smarter day by day, case by case. Its self-study character not only helps people to make quick response to any disasters, but also ensures that the best choice can always be made.

The intellectual merit of the proposed work on Satellite-based Big Data for Resilience of Critical Infrastructures is that this research will demonstrate whether sound decisions can be made to provide resilience of infrastructures and hence greatly reduce the economic loss. The impact of the proposed work would be significant, because although the failure of infrastructures can have catastrophic consequences, the simulation tools for the entire process of the proposed concept do not exist. The use of a widely available open-source framework will ensure that this capability can be used by a broad community of engineers and researchers.

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