Resilience assessment of Physical infrastructures and social systems of large scale communities

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Abstract

Community resilience is becoming a growing concern for authorities and decision makers. Resilience is the ability to withstand stress, survive, adapt, and bounce back from a crisis or a disaster and rapidly move on. Current scientific contributions are aimed at understanding disaster resilience and finding new ways to measure it, quantitatively or qualitatively. This dissertation provides new tools for decision-makers to assess the resilience of their communities. The dissertation is divided into three main parts: resilience assessment at the country level, resilience assessment at the community level, and resilience assessment at the Infrastructure level.

At the country level, a novel approach to assess the resilience of countries is presented. The approach is inspired by the classical risk analysis, in which risk is a function of vulnerability, hazard, and exposure. In the proposed analysis, the resilience-based risk is a function of resilience, hazard, and exposure. The methodology is applied to 37 countries for which the resilience is quantified. At the community level, the resilience of communities is tackled by proposing two indicator-based methodologies. The methodologies combine deterministic and probabilistic approaches within a single framework. The first method requires data on previous disasters as an input and returns a performance function for each indicator and a performance function for the whole community as an output. The second method exploits knowledge-based fuzzy modeling for its implementation. A matrix-based interdependency technique that serves as a weighting scheme for the different indicators is also introduced.

In the dissertation, we go in more details when tackling the resilience at the infrastructure level. Resilience can be defined using two main components, the damage incurred following a disastrous event and the restoration time of the system undergone the damage. Therefore, each of the two components is treated separately. For the damage component, two main lifelines, namely water and transportation networks, are tackled. For the water network, a simulation-oriented approach to evaluate the resilience of large-scale water distribution networks is proposed. The failure of the water system occurs when the water flow and the water pressure go below a certain threshold. The resilience of the network is evaluated using two indexes: (1) the number of users without water, (2) the drop in the total water supply. For the transportation network, a resilience

evaluation methodology of large-scale transportation networks is presented. First, the road map of a virtual city is transformed into an undirected graph. Random removal of the roads is applied until the network's failure point is reached. The network resilience is then calculated using the Destruction Spectrum (D-spectrum) approach. Multiple coding algorithms are presented in this chapter to solve several computational challenges. For the other component, restoration time, four main infrastructure systems (water, gas, power, and telecommunication) are considered. A large database that includes damage data for many earthquakes that took place in the last century has been collected from the literature. The database has been used to create restoration curves for the lifelines. The restoration curves have been presented in terms of probability of recovery and time; the longer is the time after the disaster, the higher is the probability of the infrastructure to recover its functions.

Finally, a generic resilience framework to assess the resilience of any engineering systems is presented. The temporal dimension is tackled using the Dynamic Bayesian Network (DBN). DBN extends the classical BN by adding the time dimension. This allows predicting the resilience state of a system given its initial condition. Two case studies are presented in the chapter to illustrate the applicability of the introduced framework. One case study evaluates the resilience of Brazil. The other one evaluates the resilience of a transportation system. The framework can be used to study systems that are not explicitly studied in the dissertation. Although it is probabilistic, the framework is practical and can be used by decision-makers in their day-to-day life.

The results of the dissertation provide valuable insights into the decision-making process regarding the resilience of communities. The solutions proposed by the models are improvements over previous work conducted and could benefit decision makers before, during, and after a disaster. In addition, not only does this research provide benefits to decision makers, but it steps beyond research and offers tools that are readily available for the emergency and infrastructure management communities.