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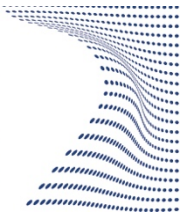

Abstract of Doctoral Dissertation
Doctoral Program in Civil and Environmental Enginering (31th Cycle)

Development of Virtual Cities Models during emergencies

Alessio Vallero
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Supervisors
Prof. Gian Paolo Cimellaro,Supervisor
Prof. Giulio Ventura, Coordinator
Prod. Stephen A. Mahin. Host Supervisor

Doctoral Examination Committee:
Prof. Alan O'Connor , Referee, University of Dublin - Trinity College
Prof. Franco Bontempi , Referee, Università degli studi di Roma 'La Sapienza'
Prof. Anastasios Sextos , Referee, University of Bristol
Prof. Mario De Stefano , Referee, Università degli studi di Firenze
Prof. Enrico Spacone , Referee, Università degli studi 'G. d'Annunzio' di Chieti

Politecnico di Torino
March 22, 2019

ABSTRACT

Buildings are vulnerable to natural disasters, such as earthquakes, man-made disasters and mass causalities events. Within a short time, large numbers of people attempt to evacuate those buildings despite any damaged infrastructure, inadequate communications and limited resources. For this reason, Building Evacuation is an important application field of Agent-Based Modeling (ABM), a class of computational models that attempt to capture the behavior of individuals within an environment.

The objective of this paper is to develop simplified ABM simulations and sensor based catastrophe management techniques to demonstrate the effort that reliable damage scenarios, human behavior and risk analysis can bring in the field of Emergency Management, making simulations closer to reality. Several steps are taken to build a valid analytical framework. First, human behavior and panic models were developed by taking into an account the variations that anxiety can bring to the decisional capacity. Initially the model has been created according to a simplified version of the Extended Belief, Desires and Intentions framework and was based on a survey that has been run both in Italy and in the United States of America. The questionnaire design involved the inclusion of social desirability bias mitigation tools and a leader-follower behavior of an agent respect to the group formation, helping seriously or not seriously injured people and the research of missing individuals. Through this model, agents have been evaluated taking into an account their feelings: the sight of an emergency exit, the injury status and the nearby presence of family and friends. Structural analysis results were implemented on PACT (Performance Assessment Calculation Tool, by FEMA) in order to create the damage scenarios in terms of percentage of injured people and obstacles created by collapsed components and integrate its application into the model. Then, Evacuation simulations have been developed with the use of Repast HPC (software tool by Argonne National Laboratory), damage scenarios and two refined human behavior and panic models to define, at best, an escape path for each agent.

The results show that the inclusion of human behavior and structural damage increase the evacuation time, due to the interactions between agents and the damaged environment. If the population increases, more groups are formed and more people get injured, so each agent can be confused and spend more time in helping or finding someone: that is the real reason of the constant increase of evacuation time in these simulations.

In recent years, Micro Electro-Mechanical Systems (MEMS) accelerometers have proven to offer a suitable solution for Structural Health Monitoring (SHM) in civil engineering applications. Based on the well promising preliminary outcomes of this research, their application to the dynamic identification of existing, full-scale structural damages is then discussed, giving evidence of their

potential via comparative calculations towards past literature results. Being able to limit the occurrence of disasters by preventing damage and continuously monitor buildings, leads the proposed ABM model to simplify its application by limiting the implications of structural damage and to obtain optimal evacuations levels. In this regard, this work focused on the study of a building monitoring technique that uses sensors equipped with a very high precision digital accelerometer, through which it is possible to compute the natural period of the structure in stationary conditions, thus estimating presence of damage and therefore allowing to compare the data collected from a building before and after an earthquake, obtaining not only an early warning system, but also a risk assessment technique.

The obtained results proved that the problem of the increased evacuation time obtained with the proposed ABM model has been addressed and that the use of sensors to monitor structural damages before and after catastrophic events and the creation of an enhanced risk assessment web platform drastically raised the probability to obtain a simplified ABM model that includes limited damages and can be executed in acceptable time.

Keywords: *Resilience, infrastructure, agent-based modeling, building evacuation, emergency, structural damage, performance, sensors, risk assessment, early warning*.