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An agent-based model for earthquake pedestrians' evacuation simulation in urban scenarios

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Abstract

The earthquake risk assessment approach actually ignores human behaviors during earthquake. Nevertheless, simulating pedestrians' motion could be useful to introduce "human" interactions with post-earthquake scenarios. This work proposes an agent-based model for evacuation simulation based on the analysis of videotapes concerning real events. Modifications to the social force model are provided in order to describe typical behaviors. A simulation software is developed for model validation. Tests mainly involve speeds and distances between individuals. The model could be integrated in tools for the analysis of probable pedestrians' choices in different scenarios, and checking solutions for reducing man-environment interferences during the evacuation process.

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Keywords: pedestrian behaviors in disaster; earthquake evacuations simulation; multi-agent model

1. Introduction

The earthquake risk assessment at urban scale is actually based on the definition (Ambraseys (1983)) of three parameters: the site hazard H (Klügel, 2008), the buildings vulnerability V (Federal Emergency Management Agency (2009)) and the exposition E (Chen et al. (1997)). In particular, the exposition parameter E defines only the number of individuals in the scenario and the presence of buildings with historical and artistic value, but does not

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consider human behaviors during both the event and the following evacuation. Nevertheless, human behaviors and by interactions between people and post-event environment represent one of the most influencing element in the inhabitants safety definition. Understanding, defining and simulating human behaviors and rules for pedestrians' motion in these emergency conditions become essential in order to really introduce the "human" factor influence in the risk assessment. Integrated "risk maps" could be designed through the combination of evaluations related to traditional parameters and results of human behaviors analyses. Finally, the community resilience (Cutter et al. (2008)) could be evaluated by analyzing evacuation procedures effectiveness through simulations (Chen et al. (2012)).

This work approaches the problem from this point of view and proposes an earthquake evacuation simulator in order to analyze the influence of behavioral effects, and so to inquiry the E parameter. Firstly, individuals in post-earthquake evacuation move in an environment that is modified by the earthquake. The post-event scenario definition can essentially be founded on correlations between building type and vulnerability (Calvi et al. (2006)), seism intensity and possible grade of damage (Grünthal (1998)) or average damage index (Giovinazzi and Lagomarsino (2004)). In this way, consequent scenarios can be defined by estimating the probable percentage of building within a certain damage level (Federal Emergency Management Agency (2009). Nevertheless, environmental aspects and human behavioral aspects have to be contemporarily considered by a similar simulator. For these reason, two other issues are needed: human behaviors in earthquake evacuation (Alexander (1990)); pedestrians' motion simulation models (Helbing and Johansson (2010), Lakoba et al. (2005)).

A limited number of works investigate earthquake evacuations (Alexander (1990), D'Orazio et al. (2014), Yang et al. (2011)). They are often strictly connected with precise case studies or are based on hypothetical questionnaires (Miyamoto et al. (2011)). The analysis of videotapes related to real earthquake evacuation is rarely performed (D'Orazio et al. (2014), Yang et al. (2011); However, general noticed behaviors concern the inferior limit in event perception (Grünthal (1998)), "pre-movement" phase, cohesion bonds (Alexander (1990)), influence of geographical background (Alexander (1990)), and the so called "fear of buildings" (Alexander (1990)), with frightened people that prefer to run out of buildings during the earthquake. The analysis of average speeds in evacuation is provided (D'Orazio et al. (2014), Hori (2011)). Only some of these studies organize empirical data in order to define a chronological scheme of them during their evacuation process (Alexander (1990), D'Orazio et al. (2014)) and an evacuation simulation model (D'Orazio et al. (2014), Hori (2011)).

Many models can simulate human behaviors and motion in both normal and evacuation conditions by using different approaches (Zheng et al. (2009)). Models can be also distinguished by different definitions of space and time (Lakoba et al. (2005)). In particular, continuous-space models uses a continuous 2-D or 3-D environment description: individuals can move continuously in space and time, and they are guided by different motion approaches (Helbing and Johansson (2010); Hughes (2002)). The "Social Force model" (Helbing and Johansson, (2010), Lakoba et al. (2005), Parisi and Dorso (2005)) takes advantages of these powerful features and founds its motion law on the real evacuations analysis: pedestrians' motion behaviors are defined in terms of attractive and repulsive forces, that are due to the interactions between people and environment, and that lead individuals to achieve their motion goal. Parameters for introducing panic conditions are also suggested (Lakoba et al. (2005)).The Social Force model can be combined with rules-based models (Rabiaa and Foudil (2010)) and discrete models and space representation (Zheng et al. (2009)). However, the original model cannot be applied to earthquake evacuations for the lack of inquiries about this case. Finally, few studies proposes the integration of behavioral simulators in the earthquake case (Hori (2011)).

Behavioral aspects and scenario modifications are jointly considered in our simulation model. For this reason, the agent-based approach (ABM) (Macal and North (2010)) is adopted in order to describe the specific agents and to trace the interactions between them. In addiction, the ABM architecture can be easily combined with "Microscopic dynamics of pedestrian evacuation" approaches (Parisi and Dorso (2005), Zheng et al. (2009)), such as the social force model, with the purpose to produce realistic simulations (Rabiaa and Foudil (2010)).

This paper proposes an ABM model that takes advantages of the social force model for the pedestrians' motion description. Modifications to the social force model are provided in order to include earthquake evacuation behaviors noticed from experimental analysis, including interferences between man and post-earthquake environment. Both ABM and social force model approaches share the same "Lagrangian" methodology (Rabiaa and Foudil (2010)): interactions between agents produce phenomena and quantitative values that are comparable with the