Simulating Collective Evacuations with Social Elements

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Abstract. This work proposes an agent-based evacuation model that incorporates social aspects in the behaviour of the agents and validates it on a benchmark. It aims to fill the gap in this research field with mainly evacuation models without psychological and social factors such as group decision making and other social interactions. The model was compared with the previous model, its new social features were analysed and the model was validated. With the inclusion of social aspects, new patterns emerge organically from the behaviour of each agent as showed in the experiments. Notably, people travelling in groups instead of alone seem to reduce evacuation time and helping behaviour is not too costly for the evacuation time as expected. The model was validated with data from a real scenario and demonstrates acceptable results and the potential to be used in predicting real emergency scenarios. This model will be used by emergency management professionals in emergency prevention.

Keywords: Social Contagion, Agent Based Model, Evacuation Simulation.

1 Extended Summary

Most of the evacuation simulation tools consider physical characteristics of the environment, ignoring behaviour and personality of people [13, 10, 9]. Including psychological and social factors in evacuation simulations could make these models more realistic and better in their predictions to ultimately save more lives. For example, observations of actual emergencies show that people tend to be slow to respond to evacuation alarms (taking up to 10 minutes) and take the familiar route out instead of the nearest exit [1, 5]. As part of the EU Horizon 2020 project IMPACT[1], this work proposes and validates an evacuation simulation incorporating these social factors: helping behaviour, groups, age and gender, familiarity, response time and social contagion.

Three existing evacuation simulation models incorporate social and psychological factors, namely FIRESCAP [2], EXODUS[2] [4] and Multi-Agent Simulation for Crisis Management (MASCM [6]). [9]. These models focus more on the physical constraints and factors such as walking speed, walkways, stairways etcetera to find the optimal flow of the evacuation process. The models include evacuation leaders, evacuees going to the nearest group or social psychological attributes and characteristics for each agent,

[1] http://www.impact-csa.eu/
[2] http://fseg.gre.ac.uk/index.html

such as age, sex, breathing rate, running speed. What is missing is group decision making and social interaction, which is included in the proposed model.

The evacuation dynamics were modelled using an agent-based model with the beliefs-desires-intentions and network-oriented modelling approaches [8, 11], and implemented in the Netlogo multi-agent language [12]. Simulation experiments with different factors and levels were designed to determine: (1) if there are significant differences between the improved and initial model version; (2) in how far the model corresponds to reality; (3) the effects of the social features (helping and group formation) on the evacuation time.

Results showed that the current model demonstrates clear improvements over the initial model in terms of Evacuation Time, Falls and Social Influences in the agent`s behaviour. Although the experiments presented in this work show the influence of social aspects individually, more experiments have to be conducted to analyse effects of combination of them. The cross relations between social effects and more complex environments might be explored, e.g. environments with pillars or multiple rooms. The validation results were as expected and close to reality: all three model variations performed less than 7,11% to 14,77% (between 42 and 86 seconds) of difference from the benchmark's total evacuation time, which is a good TAT according to [Owen], and the curves of acceptance show values close to the prescribed boundaries, establishing the model's validity. For the future, it is recommended to apply new benchmarks over the model, increasing the confidence about the model`s results. Finally, the simulation experiments analysing the influence of Helping and Groups demonstrated interesting patterns useful for future security protocols. Social Contagion effect creates faster evacuation time as expected, because information about the need for evacuation spreads faster than without social contagion. The more people are familiar with the environment: (1) the faster evacuation time and (2) the less falls. These results are a combination of a phased evacuation (less congestion) with more people spread through the environment going to the nearest exits, what leads to less falls as well, and social contagion (the decision to evacuate can spread faster), resulting in faster response and evacuation time. In case of Helping, evacuation time increases only for low crowd density environments. For high crowd density environments the Helping effect is minimised for other effects that grow in importance like blocking of paths due to a number of people. Groups of two people reduce the evacuation time and as more people are added to a group this effect is reduced until it disappears. To conclude, the model has advantages over others that don`t consider social effects in collective behaviour to evacuation scenarios, presenting reasonable results and can be used to predict real scenarios. As next steps, new social aspects will be incorporated and more benchmarks will be applied to it.

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