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Validation of pedestrian groups in agent-based simulation

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Abstract

We develop a unique validation method to empirically assess the influence a group model. We apply a computer vision pedestrian trajectory analysis and adapt it to crowd simulation. We determine the probability that collocated virtual pedestrians are travelling in the same group based on their path over time. We use receiver operating characteristic (ROC) analysis to determine the best parameter intervals. A series of experiments is run in a crowded corridor of a virtual airport. The results demonstrate that our method is able to provide crowd modelers a unique description of the influence of the model parameters.

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Keywords: crowd simulation; agent-based simulation; pedestrian groups; validation; calibration

1. Introduction

The majority of pedestrians do not walk alone, but most frequently in small groups, as described by Schultz et al. (2006). Reuter et al. (2012) say that pedestrian groups impact on the behaviour of crowds, and affect evacuation time and flow. However, Köster et al. (2011) and Fehler et al. (2005) underline that groups have played a relatively small part in the conceptualisation of simulated crowds until recently. Furthermore, they question the uncertainties of the process of verifying and validating group behaviour in simulated crowds. Instead of using accepted empirical results from sociology or psychology, crowd modelers are relying on intuition and assumptions to select governing influences of their simulation model. Additionally, to assess the basic reliability of group models, visual aspects are used to manually identify key crowd elements (e.g. distribution of groups). However, this does not deliver important quantifiable output measurements. Both Köster et al. (2011) and Fehler et al. (2005) conclude that this leads to unreliable crowd simulation models, and that further work in the area of group validation is required.

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We advance the research on the validation of pedestrian groups in agent-based simulation. Our main contribution is an experimental validation method for assessing the influence of the group model parameters on the behaviour of agents. To achieve this, we adapt a state-of-the-art pedestrian trajectory analysis technique, as developed and validated through human consensus by Ge et al. (2012), to crowd simulation. This automatically detects small groups of agents travelling together. We evaluate a range of parameters using receiver operating characteristic (ROC) analysis. To our knowledge, no previous work has specifically exploited trajectory information to methodically assess the performance of a group model in crowd simulation. We demonstrate the feasibility of our work on a group model that is inspired by Reynolds (1999) through a series of experiments run in a crowded virtual airport corridor. The results of the experiments give a quantified description of the influence of a model's parameter on the navigational behaviour of groups. We demonstrate that we are able to determine the best set of parameters for the proposed model, and to identify possible problems of agent's behaviour.

This paper is structured as follows. We first discuss previous work done in group modeling, pedestrian trajectory analysis and verification and validation. In Section 3, we discuss our methodology to assess the behaviour of groups in a crowd simulation. We describe a set of experiments in a crowded airport terminal in Section 4. Section 5 details the results of our experiments. Lastly, in Section 6, we conclude this work and discuss future work.

2. Related work

Crowd simulation requires a high degree of fidelity and realism. This is due to related serious application fields, the investigation of the safety of individuals in evacuation scenarios and the assessment of the reliability of architectural design, as described by Thalmann and Musse (2005).

To achieve higher fidelity and increased realism in crowd simulation, an extensive study of the semantics underlying real crowds' motion is necessary. Research demonstrates that the coordination, the communication and the structure of pedestrian groups heavily impact on the flow of crowds. Moussaïd et al. (2010) say that patterns from group organization result from the desire of respective members of a group to communicate with each other. Group members continuously adjust their position to facilitate communication, while avoiding collision with other in-group and out-group individuals. Furthermore, observations of real crowds by Qiu and Hu (2009) suggest that the group size, that is, the number of individuals within a group, is spread as according to a zero-truncated Poisson distribution depending on the considered scenario. However, both Qiu and Hu (2009) and Moussaïd et al. (2010) conclude that there is a need to further study the simulation of the behaviour of groups in pedestrian crowds.

Trajectory analysis provides a deeper insight into pedestrian movement. Seyfried et al. (2005), Oberhagemann et al. (2011), and Helbing and Mukerji (2012) use video algorithms to detect the flow of crowds. Ronchi et al. (2014) analyse people's trajectories in staircases during evacuation. Ge et al. (2012) collect trajectory data of crowds using a multi-object tracking algorithm of pedestrians in surveillance camera videos. All these works conclude that trajectory analysis gives relevant insights into people's interaction. As underlined by Ge et al. (2012), pedestrian trajectory information alone is enough to identify potential groups within a short video sequence. It brings considerable knowledge of the behaviour of individual crowds to researchers, allowing a deeper understanding of the self-organising phenomena resulting from the interactions of many pedestrians.

Fehler et al. (2005) describe validation as an important step in every process that concerns the development of simulation models, which is independent from the actual modeling paradigm used. Models' variables and coefficients have to be set in a way that a structurally correct model produces a valid outcome as verified through scientific foundation. Qiu and Hu (2009) and Moussaïd et al. (2010) underline a model's interrelated input and output dependencies, the size of the possible configuration search space and the additional computational complexity. They agree that quantifiable data is important for measurement comparison with interdisciplinary field data, and to directly compare the simulation output of crowd models.

However, there are uncertainties on how to compare and verify group models in crowd simulation to empirical data, and how to identify governing group model variables and coefficients. Using assumptions and intuition to calibrate model parameters is highly criticized. Köster et al. (2011) say it is crucial to use a methodical approach supported by sociological and psychological insight to validate group models. However, they suggest that model validation is still a challenge and more interdisciplinary is required to tackle this issue.