Chapter VI
Fundamentals of Pedestrian and Evacuation Dynamics

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ABSTRACT

Multi-Agent Simulation is a general and powerful framework for understanding and predicting the behaviour of social systems. Here the authors investigate the behaviour of pedestrians and human crowds, especially their physical movement. Their aim is to build a bridge between the multi-agent and pedestrian dynamics communities that facilitates the validation and calibration of modelling approaches which is essential for any application in sensitive areas like safety analysis. Understanding the dynamical properties of large crowds is of obvious practical importance. Emergency situations require efficient evacuation strategies to avoid casualties and reduce the number of injured persons. In many cases legal requirements have to be fulfilled, for example, for aircraft or cruise ships. For tests already in the planning stage reliable simulation models are required to avoid additional costs for
changes in the construction. First, the empirically observed phenomena are described, emphasizing the challenges they pose for any modelling approach and their relevance for the validation and calibration. Then the authors review the basic modelling approaches used for the simulation of pedestrian dynamics in normal and emergency situations, focussing on cellular automata models. Their achievements as well as their limitations are discussed in view of the empirical results. Finally, two applications to safety analysis are briefly described.

INTRODUCTION

Understanding and predicting the dynamical properties of large human crowds is of obvious practical importance (Schadschneider et al., 2009). Especially emergency situations and disasters require efficient evacuation strategies to avoid casualties and reduce the number of injured persons. In many cases legal regulations have to be fulfilled, e.g. for aircraft or cruise ships. For tests already in the planning stage reliable simulation models are required to avoid additional costs for changes in the construction. But even, if changes in the construction are not possible, simulations can be very helpful for organizational issues like the design of evacuation routes, where full-scale tests are either too expensive or too dangerous.

Multi-Agent Simulation provides a general and powerful framework for understanding and predicting the behaviour of social systems. In this contribution, we describe its application to the dynamics of human crowds, especially their physical movement. The latter restriction allows us to focus on the operational and tactical levels of the agents’ decisions. ‘Operational’ in this context means the proper body motion, i.e. avoiding collisions and the movement within a short time-span (e.g. one second). ‘Tactical’ means that putting this in the well-established BDI-framework (beliefs, desires, intentions), only the intentions (like getting to the closest exit in the case of an evacuation) are explicitly modelled. Desires and beliefs are either neglected or modelled implicitly, e.g. by assuming that everyone wants to get out as fast as possible and representing orientation as following the gradient of a static floor field (for details, please refer to the following sections). Furthermore, the multi-agent paradigm is flexible enough to cover the model extensions that belong to the tactical and strategic realm.

Having said that, the fact that there are such distinct models as cellular automata and molecular dynamics-like simulations used in the field, gives strong hint to the need for a thorough understanding of basic model characteristics, their scope and limitations. This part can be addressed by investigating the models themselves without making reference to empirical data. This is useful but of course not sufficient. Therefore, we will cover the latter in this contribution, too.

In recent years several models of different sophistication have been developed. Macroscopic approaches use a coarse-grained description in terms of densities. In contrast in microscopic models, which are the focus of this review, different agents1 are distinguished. This allows to equip them with different properties reflecting demographics.

In this contribution we will try to give a compact introduction to the most important empirical results and theoretical approaches. All of these are relevant for most agent-based simulations of pedestrian dynamics. We will emphasize the importance of a close interplay of empirical observations and data with theoretical modelling approaches. We demonstrate how the realism of the model dynamics can be improved by taking into account qualitative and quantitative empirical observations. Such validation and finally calibration is extremely important, e.g. for the applications in safety analysis mentioned above.
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