How does the computational speed of pedestrian models depend on the characteristics of the simulated scenario?

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Abstract Pedestrian models have many applications and there are also many different pedestrian models. But which model is best suited for which application? In addition to validity, the computational speed of a pedestrian is a key factor determining a model's applicability. This contribution presents how the computational speed of commonly used pedestrian models depends on the characteristics of the simulated scenario and what this means for which model is suitable for what application.

Keywords Model speed, Pedestrian models, Computational complexity, Model speed versus simulation scenario characteristics

Introduction

The computational speed of a pedestrian model is a key characteristic that determines the applications for which it is suitable. Can a model, for example, be used for real-time applications, where it needs to run faster-than-real-time? Or, can the model be used in simulation studies that need to deal with a lot of uncertainty in the input, which requires many simulations to be run? Many types of pedestrian movement dynamics simulation models have been developed in the last decades, and multiple studies (e.g., [1]) have reviewed the validity of these models. Hence, for this key characteristic, we have much insight into which types of models are well suited for which types of applications and why. For computational speed, this is unfortunately not yet the case.

To reduce this gap, we analysed how the computational speed of many different pedestrian model types depends on the simulated scenario. This analysis provides insight into how different characteristics of a simulation scenario, such as the size of the walkable space or the distribution of pedestrians over the space, affect a model's computational speed. This provides a first indication of what types of pedestrian simulation models are likely to be more suitable than others for certain types of simulation scenarios and why this is the case. Furthermore, this analysis provides important insights into what scenario characteristics should be included and tested when testing the computational speed of a particular model.

Our analysis consists of two steps. First, we identify the so-called pedestrian model archetypes. These capture the fundamental characteristics and features of a type of pedestrian model from a computational speed point of view. Accordingly, we use our recently developed APS (Assess Pedestrian model Speed) framework [2], in particular the test case creation procedure, to analyse how what scenario characteristics impact the speed of the pedestrian model archetypes and how it impacts their speed.

Pedestrian model archetypes

A pedestrian model archetype captures how the algorithm (the loops, data structure operation etc.) of a type of pedestrian model computes a simulation step. We identified a wide variety of commonly used pedestrian models and analysed how their basic algorithms differ from a computational point of view. From this analysis, we distilled six different pedestrian model archetypes that we present in Table 1.

We also identify variations of each basic archetype. For example, microscopic models that use discrete space, cover a wide range of models that share some basic characteristics, such as being a microscopic model using discrete space. But they also vary with regard to other characteristics, for example, in the update scheme they use. We capture these minor variations, from a computational perspective, in the identied variations. For each basic archetype and variation thereof, we describe their algorithm by pseudocode. This pseudocode forms the basis of the analysis.

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Table 1: An overview of the six basic pedestrian model archetypes covering all three major pedestrian model classes

Microscopic models	1. Continuous space
	2. Discrete space
Mesoscopic models	3. Both continuous and discrete space and discrete time
	4. Discrete space in the form of cells and continuous time
	5. Discrete space in the form of a network and continuous time
Macroscopic models	6. Cell-based

Results

We apply the test case creation procedure (from the APS framework) to the pseudocode of each archetype and variation to obtain the scenario characteristics that impact each of them. We identified a total of 11 characteristics that impact the speed of one or more model archetypes. These are the following:

1. Walkable space size
2. Global density
3. # obstacles
4. Population heterogeneity
5. Spatial distribution pedestrians
6. Network complexity
7. Spatial distribution pedestrian classes
8. Spatial distribution obstacles
9. # Destinations
10. Movement base case
11. Scenario layout

Our analysis also reveals what the relationship is between these 11 characteristics and the model archetypes and variations. Table 2 presents an example of these detailed results. We observe that it depends strongly on the type of model what scenario characteristics impact its speed and how. Some scenario characteristics, like the walkable space size, impact all models in a similar way. Namely, as the space increases (whilst the density remains constant) the models become slower. Others, such as the global density, affect most models but not in the same way. The density affects the cell- and network-based models differently than, for example, the microscopic models. And then there are characteristics, like the number of obstacles of the population heterogeneity, that only impact the speed of a few models.

Table 2: The impact of four scenario characteristics whereby − indicates a negative relationship, 0 the model is not affected by this characteristic and +− the effect can be positive or negative depending on the value of the characteristic. The archetypes are identified by their number presented in Table 1.

Variable	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
Size walkable space	−	−	−			−
Global density	−	−	−	+−	+−	0
# Obstacles	−	0	0	0	0	0
Population heterogeneity	0	0	0	−	0	−

The results highlight the importance of using scenarios with different characteristics to test the speed of pedestrian models. That is, testing the speed of models whilst varying only one characteristic provides limited insights into their speed. Also, it can produce biased results when comparing models using a limited set of scenarios because not all characteristics impact each model or impact each model in the same way.

Furthermore, the results provide an indication regarding which type of model is particularly suitable for what sort of scenario from a computational speed perspective. For example, the results indicate that a microscopic model using continuous space (no. 1) is not particularly well suited for scenarios with lots of obstacles compared to all other models because it is the only model negatively affected by this scenario characteristic.

Lastly, we note that we study only one factor that determines the speed of a pedestrian model, the scenario characteristics. The model itself and the specific implementation of the model are both major determinants of the speed of the model. Therefore, the results only provide an indication regarding the suitability of a model type for a certain scenario. By applying the APS framework to particular implementations of models more detailed insights can be obtained.

Bibliography

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