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Exploring pedestrian walking through angled corridors

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Abstract

Reliability of many pedestrian modelling and simulation tools is questionable, particularly when used to simulate pedestrian walking behaviors associated with complex geometries such as angled walkways. It is uncertain that existing modeling approaches adequately capture microscopic walking behaviors associated with turning movements with regards to trajectories, speed profiles and acceleration/deceleration patterns. This paper presents preliminary results of a modelling framework that is based on comprehensive experimental data for pedestrian walking behaviors through angled corridors. Numerical simulations indicate that this model reproduces more accurate pedestrian walking behaviors through angled corridors compared to existing approaches.

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1. Introduction

Large crowds can be expected at major public infrastructures not only during special events, such as religious, cultural, or sporting events, but also for daily activities, such as commuting or shopping. It is extremely important to ensure the safety of people in case of an emergency and to guarantee efficient flow of movements in day-to-day situations. In order to achieve these broad objectives, i.e. optimizing designs and management of crowds at public buildings, building designers and crowd managers can utilize pedestrian crowd simulation tools (Gwynne et al. (1999)). These modelling and simulation tools can broadly be classified as macroscopic models and microscopic

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models. While microscopic models are generally implemented through computer simulations, macroscopic models (that mainly use fundamental diagrams) can be implemented either through simulations or hand calculations. Even though the concepts and computation methods are entirely different, both methods are widely utilized to predict evacuation times under various geometrical and network settings (Rogsch et al. (2010)).

Despite popularity of these methods, there are often questions about the reliability of such tools, because they must be calibrated against reliable empirical data to ensure validity before putting them into practice. Rogsch et al. (2009) demonstrated that widely used microscopic commercial software tools, which are based on well-known social force or cellular automata models, fail to predict accurate evacuation times through simple geometries. Thus, the question arises whether those tools and models can predict accurate walking behaviors through more complex geometries such as angled or circuitous walkways. It can be argued that in order to model the realistic walking behaviors associated with complex configurations either the existing models should further be modified or new approaches be explored.

Several approaches in the literature have attempted to simulate pedestrian dynamics associated with rounding corners or angled corridors. The simplest approach is to locate intermediate destinations to change the desired direction and guide the movements through the desired path. For example, Steffen and Seyfried (2009), Höcker et al. (2010) and Zeng et al. (2011) have considered one or several intermediate destinations to plan the desired path beforehand. Chraibi et al. (2013) modelled each agent's direction around the corner through guiding lines and update rules based on the occupancy of those guiding lines by other pedestrians. Other approaches have utilized heuristic based methods (Jian et al. (2014), Kretz (2009)) and various behavioral rules (Guo and Tang (2012)) combined with existing microscopic simulations. However, it is uncertain that these approaches capture the complete situation with regards to trajectories, time-space diagrams, speed profiles and acceleration/deceleration patterns. As a result, the bottleneck effect of turning corridors might have not been represented accurately. Further, many of these models have not been calibrated or validated against empirical data related to walking through angled corridors. Therefore, further studies (empirical and theoretical) are required to understand the effect of turning angle and to model the realistic walking behaviors through angled corridors. In order to address these issues, a novel modelling framework was proposed, which is based on comprehensive experimental data for a range of turning angles, densities and desired speeds. Details of the proposed framework and initial results (i.e. model output for solo) are discussed in this paper.

The paper is structured as follows: The next section will discuss the background and the main steps of model development. This is followed by initial results obtained through numerical simulations. Lastly, conclusions and recommendations for further studies are presented.

2. Model description

2.1. Background

The proposed framework is based on a microscopic, force based, continuous model and can be combined with existing social force models. In order to build and calibrate the model, data were collected through a series of experiments with a group of people walking through corridors of different turning angles at different speeds. Details of these experiments and the data obtained can be found in Dias et al. (2014).

In force based models (Helbing et al. (2000), Shiwakoti et al. (2011)) it is assumed that when an individual is walking in a crowd, he or she is subjected to social and physical forces. Thus, the movement of an individual can be described by the following equation:

$$m_i \frac{d\vec{v}_{i,t}}{dt} = \vec{F}_{desired,i,t} + \vec{F}_{wall,i,t} + \vec{F}_{ij,t} \qquad (1)$$

Where;
m_i = Mass of individual *i*
$\vec{v}_{i,t}$ = Instantaneous velocity of individual *i* at time *t*
$\vec{F}_{desired,i,t}$ = Desired force at time *t* that attracts the pedestrian *i* to the desired destination
$\vec{F}_{wall,i,t}$ = Interaction forces with walls at time *t*
$\vec{F}_{ij,t}$ = Interactions (attractions or repulsions) between pedestrian *i* and *j* at time *t*