Stochastic Transition Model for Discrete Agent Movements

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Abstract. We propose a calibrated two-dimensional cellular automaton model to simulate pedestrian motion behavior. It is a \( v_{max} = 4 \) model with exclusion statistics and random shuffled dynamics. The underlying regular grid structure results in a direction-dependent behavior, which has in particular not been considered within previous approaches. We efficiently compensate these grid-caused deficiencies on model level.

Keywords: multi-agent, transition matrix, stochastic approach, calibrated model.

1 Introduction

The different model approaches for microscopic person dynamics are based on the particular discipline analogies, ranging from hydro-dynamic models to artificial intelligence and multi-agent systems [1]. The complex dynamic human behavior is induced by individual decisions, which are classified to be of short-range (operational) and long-range type (strategic/tactical). The self-organization of persons is a further essential characteristic of human behavior. In contrast to the social force model [2–4] or the discrete choice model [5, 6] the developed motion model [7–9] is based on a stochastic approach to handle the unpredictable behavior by individual path deviations. The stochastic motion model is an appropriate and fast method for analysis the dynamic pedestrian behavior. However, to derive valid results several simulation runs (>100) have to be performed. The focus concentrates on the evaluation of application oriented simulation scenarios instead of the characteristics of individual interactions or specific pedestrian trajectories.

2 Stochastic Motion Model

The presented motion model is based on a stochastic approach [10], which is comparable to a common cellular automaton. It utilizes a regular grid structure. In contrast to the cellular automaton, the new model is developed on the basis of a fundamental paradigm shift: instead of changing the cell status depending on the status of its surrounding cells (neighbors), the agent is able to move...
over the regular lattice and to enter those cells, which are not occupied by other agents or obstacles (e.g. walls). To describe the motion behavior of an agent, the motion vector is separated into a desired motion direction and a transversal deviation. Using the spatially discrete grid structure and defining three transition states (forward | stop | backward or left | on track | right) the normalized transition probability (p) into these states is generally defined by the following equations.

\[
p^+ = \frac{1}{2} (\sigma^2 + \mu^2 + \mu), \text{ for forward or left}
\]
\[
p^o = 1 - (\sigma^2 + \mu^2), \text{ for stop or on track}
\]
\[
p^- = \frac{1}{2} (\sigma^2 + \mu^2 - \mu), \text{ for backward or right}
\]

In the case of the desired motion direction, \(\mu\) denotes the desired speed and \(\sigma^2\) the corresponding variance. If the transversal deviation is concerned, \(\mu\) is the average and \(\sigma^2\) is the range of the fluctuations. Considering a symmetric transversal deviation (\(\mu_{\text{deviation}} = 0\)) and a connection of desired speed and the corresponding variance (no step backward \(p^- = 0\), so that \(\sigma_{\text{speed}}^2 = \mu_{\text{speed}} (1 - \mu_{\text{speed}})\), the above equations are simplified to the following equations for the desired motion direction and for the transversal motion direction.

\[
p^\text{forward} = \mu_{\text{speed}} \quad | \quad p^\text{stop} = 1 - \mu_{\text{speed}}
\]
\[
p^\text{left,right} = \frac{1}{2} \sigma_{\text{deviation}}^2 \quad | \quad p^\text{on track} = 1 - \sigma_{\text{deviation}}^2
\]

Finally, the motion components are combined to a 3x3 transition matrix \((M_{ij})\) as shown in the following fig. The emphasized cell (marked gray at the figure) contains the transition probability of moving forward without transversal deviations. In fact, the transition matrix possesses a two-dimensional characteristic, but it only defines an one-dimensional transition considering a transversal deviation (1.5-dimensional).

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**Fig. 1.** Generation of the transition matrix due to combination of desired motion speed and transversal motion deviation