Modeling Heterogeneous Speed Profiles in Discrete Models for Pedestrian Simulation

(Extended Abstract)

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ABSTRACT

We present a discrete model extending the floor field approach allowing heterogeneity in the walking speed of the simulated population of pedestrians. Whereas some discrete models allow pedestrians to move more than a single cell per time step, in the present work we maintain a maximum speed of one cell per step but we model lower speeds by having pedestrians yielding their movement in some turns. Different classes of pedestrians are associated to different desired walking speeds and we define a stochastic mechanism ensuring that they maintain an average speed close to this threshold.

Categories and Subject Descriptors

I.6 [**Simulation and Modeling**]: Applications

General Terms

Experimentation

Keywords

pedestrian and crowd modeling, interdisciplinary approches

1. INTRODUCTION

Discrete pedestrian simulation models are viable alternatives to particle based models that employ a continuous representation (see, e.g., [4]) and they are able to reproduce realistic pedestrian dynamics from the point of view of a number of observable properties. The effects of discretisation, however, also imply difficulties in modelling some phenomena that can be observed in reality. This paper focuses on the possibility of modelling heterogeneity in the walking speed of the simulated population of pedestrians by modifying an existing multi-agent model extending the floor field approach [5]. Whereas some discrete models allow pedestrians (or cars, when applied to traffic modelling) to move more than a single cell per time step (as discussed in [2]), in the present work we maintain a maximum speed of one cell per step, but we model lower speeds by having pedestrians yielding their movement in some turns. Different classes of pedestrians are associated to different desired walking speeds and we define a stochastic mechanism ensuring that they maintain an average speed close to this threshold. In the paper we will formally describe the model and we will show the results of its application in benchmark scenarios (single and counter flows in simple scenarios).

2. DISCRETE PEDESTRIAN MODEL

The method described in this paper has been developed on the computational model described in [5]. For reasons of space, we will omit the discussion of this baseline and we will only explain the general characteristics of the discrete environment, fundamental for the understanding of the proposed method for managing speed heterogeneity. The environment is represented by a grid of 40 cm sided square cells. Moore neighbourhood structure is used for describing the agents movement capabilities at each time step. Finally, update of agents intentions and positions at each step are managed with the parallel update strategy, with rules for conflict management based on the notion of friction [3]. The baseline model has been modified in several parts: each agent has a new parameter $Speed_d$ in its $State$, describing its desired speed; for the overall scenario, a parameter $Speed_m$ is introduced for indicating the maximum speed allowed during the simulation. In order to obtain the desired speed of each pedestrian during the simulation, the agent life-cycle is then *activated* according to the probability to move at a given step $\rho = \frac{Speed_d}{Speed_m}$. By using this method, the speed profile of each pedestrian is modelled in a fully stochastic way and, given a sufficiently high number of step, their effective speed will be equal to the wanted one. But it must be noted that in several cases speed has to be rendered in a relatively small time and space window (think about speed decreasing on a relatively short section of *stairs*).

In order to overcome this issue, we decided to consider ρ as an indicator to be used to decide if an agent can move according to an *extraction without replacement* principle. For instance, given $Speed_d = 1.0m/s$ of an arbitrary agent and $Speed_m = 1.6m/s$, ρ is associated to the fraction 5/8, that can be interpreted as an **urn model** with 5 *move* and 3 *do not move* events. At each step, the agent extracts once event from its urn and, depending on the result, it moves or stands still. The extraction is initialised anew when all the events are extracted. The mechanism can be formalised as follows: (i) let $Frac(r) : \mathbb{R} \to \mathbb{N}^2$ be a function which

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Algorithm 1 Life-cycle update with heterogeneous speed

if $Random() \leq \alpha/\beta$ **then**
  if $updatePosition() ==$ true **then**
    $\alpha \leftarrow \alpha - 1$
  else
    $\beta \leftarrow \beta + 1$
  end if
end if
$\beta \leftarrow \beta - 1$
if $\beta == 0$ **then**
  $(\alpha, \beta) = Frac(\rho)$
end if

returns the minimal pair $(i, j) : \frac{i}{j} = r$; (ii) let $Random$ be a pseudo-random number generator in $[0, 1]$; (iii) given ρ the probability to activate the life-cycle of an arbitrary agent, according to its own desired speed and the maximum speed configured for the simulation scenario. Given (α, β) be the result of $Frac(\rho)$, the update procedure for each agent is described by the pseudo-code of Alg. 1. The method $updatePosition()$ describes the attempt of movement by the agent: in case of failure (because of a conflict), the urn is not updated.

This basic mechanism allows synchronisation between the effective speed of an agent and its desired one every τ steps, which in the worst case (informally when $\frac{Speed_d}{Speed_m}$ cannot be reduced) is equal to $Speed_m \cdot 10^{\iota}$ step, where ι is associated to the maximum number of decimal positions considering $Speed_d$ and $Speed_m$. For instance, if the desired speed is fixed at $1.3m/s$ and the maximum one at $2.0m/s$, the resulting $Frac(\rho) = \frac{13}{20}$, therefore the agent average velocity will match its desired speed every 20 steps.

Additional mechanisms were also added to manage the increase of actual speed that would be achieved by means of diagonal movements: repeated diagonal movements essentially cause the insertion of a *do not move* event in the urn, to avoid achieving an actual speed exceeding the desired one.

3. RESULTS

We carried out a simulation campaign to evaluate the effects of the introduction of this mechanism for the representation and management of heterogeneous speed profiles in the simulated population in reference scenarios in which empirical data can be found in the literature. In particular, we simulated and measured the unidirectional and bidirectional flow of pedestrians in a corridor with varying density. We carried out a set of simulations with a growing number of pedestrians, and therefore density, measuring their average velocities to be compared with fundamental diagrams from the literature [4]. We configured the simulations to include pedestrians with desired speeds of 1.2, 1.4 and $1.6m/s$ according to a gaussian–like distribution (in line with statistics on pedestrian behaviour). The outcome of the simulation leads to results, shown in Figure 1, that are in tune with the empirical data from the literature. Moreover, pedestrians are able to move at the desired walking speed in free flow conditions, whereas with the growth of density differences tend to disappear due to the effect of conflicts. Additional tests were performed and results, omitted here for sake of space, are described in [1].

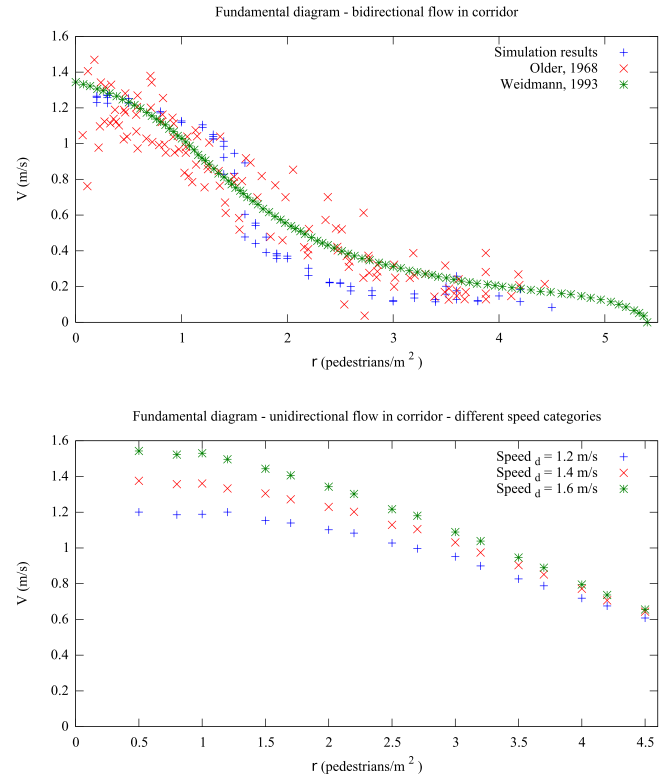

Figure 1: Fundamental diagram related to bidirectional flow in a corridor, on top, and average walking speeds for different types of pedestrians (having different desired speeds) in different density conditions, on the bottom.

4. REFERENCES

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