

Appendix E

Pedestrian flow model NOMAD

At this point, it would be interesting to note that the optimal control model paradigm has also been applied to the microscopic modeling of pedestrian flows (see [28]). In this model overview, it was shown that the walker model describes the individual walking behavior of pedestrians, given the decisions made at the destination choice and route choice level. In the following sections, we will discuss the workings of the latter model. For now, it is sufficient to note that for each pedestrian p the optimal velocity $\mathbf{v}^*(t, x)$ (i.e. speed and direction) has been determined.

Hoogendoorn and Bovy [28] present the conceptual model, where pedestrians are described in terms of a closed feedback control system. This model leads to an optimal control formulation, where pedestrians are assumed to minimize the predicted costs of walking. These costs are determined by among other things the extent to which pedestrians can walk at their desired velocity, the proximity of other pedestrians, walking near to obstacles, and the need to accelerate or decelerate. Furthermore, it is hypothesized that the costs are discounted over time, implying that events in the near future are deemed more important than events that are expected to happen much later. Application of Pontryagin's Maximum Principle establishes the mathematical model describing walking behavior. Besides a control model, predicting the optimal walking behavior of a pedestrian, a physical model describes the effects of physical contact between pedestrians and obstacles.

The walker model is governed by the following ordinary differential equation, describing the behavior of pedestrian p

$$\dot{\mathbf{r}}_p = \mathbf{v}_p \quad \text{and} \quad \dot{\mathbf{v}}_p = \mathbf{a}_p \quad (\text{E.1})$$

with

$$\mathbf{a}_p = \left(\frac{\mathbf{v}_p^* - \mathbf{v}_p}{\tau_p} - \nabla L \right) \quad (\text{E.2})$$

where L denotes the proximity cost incurred by pedestrian p walking close to other pedestrians q , e.g.

$$L = \sum_p A_0 \exp \left[-\frac{1}{R_0} \frac{\mathbf{r}_p - \mathbf{r}_q}{\|\mathbf{r}_p - \mathbf{r}_q\|} \right] \quad (\text{E.3})$$

where $A_0 > 0$ and $R_0 > 0$ pedestrian-type specific parameters. This specification shows that the cost L increases when pedestrians walk closer to each other. The walker model used in the actual simulation model NOMAD is more complex, and features pedestrian anisotropy, grouping behavior, and impatience. The user can set the parameters of these processes. A similar expression is used to describe the way pedestrians walk around obstacles.

NOMAD predicts the effects of special infrastructure on the walking speeds of pedestrians. In case of stairs or grades, the desired speed of the pedestrians is reduced in accordance with the grade of the walking surface or the stairs. The behavior on an escalator is described easily by assuming that the pedestrian will move at the same speed as the escalator.

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