Counterflow Model for FDS+Evac Simulations

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Abstract We present a new method for modeling counterflow situations in crowds. Agents, describing individual pedestrians, are set to avoid the moving directions where there is counterflow and prefer the directions with forward flow. In dense counterflow situations, people tend to move shoulder first to occupy less space in the moving direction. If the elliptical cross-section of a human body is considered in a crowd model, the rotational positions in which the agents move affect the counterflow. In our model, agents try to rotate their bodies in certain counterflow situations to move shoulder first. The model is implemented in the FDS+Evac simulation software. Test simulations show that it is able to create rather realistic simulations of counterflow.

Introduction

Counterflow situations are common in moving human crowds. On sidewalks and in large public venues like railway stations, streams of people moving to different directions encounter repeatedly. In evacuation situations, most of the occupants tend to move to the same direction, but counterflow may occur, e.g., when firefighters try to enter the building.

The crowd dynamics model of Helbing *et al.* [1] is widely used and has been found to realistically simulate many phenomena occurring in real crowds. One of the downsides of the model is that agents moving in opposite directions are unable to dodge each other, and thus, unrealistic collisions occur in couterflow situations. Two recent articles [2, 3] present collision avoidance methods that can be added to Helbing's model. Both of these models give realistic appearing results in sparse crowds. However, in these methods, each agent is only able to dodge one other agent at a time, which may cause problems when crowd density increases.

We present a model for counterflow situations, where each agent observes its proximity and selects the moving direction with the smallest counterflow. Agents moving to the same direction create negative counterflow, and thus, the model also makes agents favor the directions with forward flow.

The cross-sectional shape of a human body is elliptical. Hence, the rotational positions of agents may affect counterflow, as agents moving shoulder first occupy less space in the moving direction. We consider this by describing the agents' body dimensions with three overlapping circles and by setting the agents to move shoulder first in certain counterflow situations.

The presented collision avoidance model is implemented in the FDS+Evac simulation software [4, 5, 6].

Counterflow Model

The platform of our counterflow model is the crowd dynamics model of Helbing *et al.* [1], extended by the three-circle representation of agents [2, 4]. Nevertheless, similar approach could most likely also be applied to many other agent-based crowd models.

In the counter flow model, agents frequently update their desired moving directions. Each agent has three options on each update: to go straight ahead, to dodge to right, and to dodge to left. The agents make the decisions by observing the area in front of them and by selecting the direction with the least counterflow. This is done by dividing the area into three overlapping sectors and by giving each sector a score according to locations and moving directions of the agents within the sector. The agents moving to the same direction increase the score of the sector and the counterflow-agents decrease it. On each step, the direction with the highest score is selected and set to be the *desired moving direction* of the agent in the Helbing *et al* model. The range of the sectors varies between 1.5 m and 3 m, according to the velocity of the agent. The features of the model are illustrated in Figure 1.

In situations of strong counterflow, the *desired body angles* of the agents are changed to make them try to move shoulder first. Also the *motive forces* are increased to make the agents more determined in their movement.

Simulation Results

The performance of the counterflow model was tested with FDS+Evac-simulations in the IMO test geometry 8 [6], where a 2 m wide corridor connects two rooms. In the initial situation, 40 agents were located in both rooms and their goal was to pass the corridor to the other room.

Snapshots of the test simulations are presented in Figure 2. When the counterflow model is not applied, the two streams create an impassable jam in the corridor. Using the counterflow model, the flow in the corridor is rather smooth and all agents have passed the corridor in about 50 seconds.

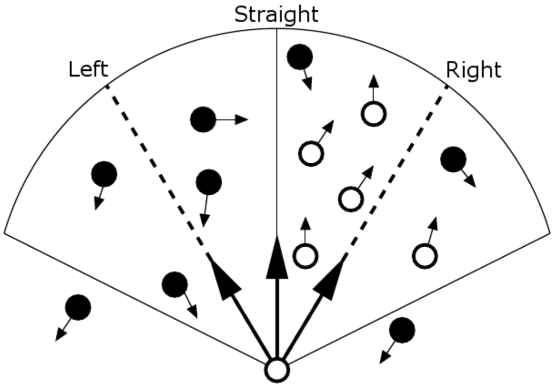

Fig. 1. Illustration of the counterflow model. The agent making the decision is in the origin of the sectors. The large arrows denote the three options of moving direction for the agent. The sectors related to the moving directions are overlapping, as the dashed lines denote the edges of the middle sector and the solid lines the edges of the left and right sectors. The smaller arrows denote the moving directions of the other agents, and thus, the white agents increase the scores of the sectors they are in and the black agents decrease them.

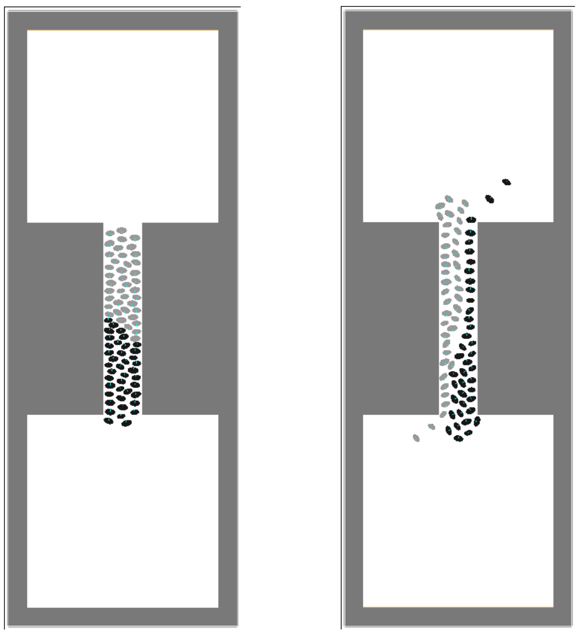

Fig. 2. Simulation snapshots. The counterflow model is used in the right figure. The left figure uses the original model of Helbing *et al*. The gray agents are heading to the bottom room and the black agents to the top room.

Conclusions

In order to realistically model counterflow with the crowd dynamics model of Helbing *et al.,* a method to describe the interaction between agents moving to opposite directions is necessary. We present a short-range model, where agents adjust their walking directions and rotate their bodies to avoid collisions with the oncoming agents.

Test simulations show that the presented model is able to eliminate the unrealistic jams occurring with the original model.

Acknowledgements

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