Simulating crossing pedestrian flows with a vision-based model of collision avoidance

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Abstract Previous simulations of crossing flows using a vision-based collision-avoidance model reproduced lanes and stripes but showed larger heading adjustments during crossing than the human data. Here we investigate two possible explanations. First, we tested participants walking through a virtual crowd under two density conditions, refit the collision avoidance model, and resimulated the crossing flows data. Our findings reveal little influence of moderate densities on human collision avoidance behavior. Second, we are testing mutual collision avoidance between two participants to determine whether a revised model better approximates the crossing flows data.

Keywords Pedestrian, Collision Avoidance, Modeling, Experiment, Heading Control

Motivation

Individual interactions between pedestrians in a crowd can lead to emergent patterns of collective motion, such as the formation of stripes in crossing flows [1]. In previous research, we found that an empirical, vision-based pedestrian model (Visual SCruM) including only two components, local collision avoidance and a common goal, could reproduce the perpendicular stripes observed in human crossing flows data [2].

However, the simulations consistently overestimated human heading adjustments during the crossing period to avoid collisions. Two hypotheses might explain that result. First, because model parameters were fit to data from participants avoiding a single obstacle moving on a fixed path, it might not scale up to crowds with higher densities. We refer to this as the density hypothesis. Second, the mutual avoidance hypothesis holds that heading adjustments might be smaller in a mutual avoidance scenario when both individuals avoid each other. Here, we present new data in which a participant walked through a crowd of avatars at two densities. Fitting the model parameters to this new scenario only slightly reduced the heading adjustments, inconsistent with the density hypothesis. We are also collecting data on collision avoidance between two participants to test the mutual avoidance hypothesis.

Methods

Crowd Experiment

We designed an experiment to test whether collision avoidance depends on crowd density, for moderate densities that allow for continuous walking. A human participant (N=12) walked in a $12\,\mathrm{m} \times 14\,\mathrm{m}$ area (the VENLab) while wearing a head-mounted VR display. The task was to walk through a virtual crowd (10 avatars) toward a goal while avoiding collisions with the avatars. The crowd had two initial densities (0.42 persons/m^2 and 0.36 persons/m^2) and the avatars walked at different speeds (all $1.0\,\mathrm{m/s}$, all $1.2\,\mathrm{m/s}$, or mixed). Head position was recorded at $90\,\mathrm{Hz}$, and time series of heading and speed were computed.

Fitting Procedure

We fit the parameters of the visual SCruM model to the human trajectory data using an iterative search. For each trial, we initialized the model agent with the initial position, heading, and speed of the participant, and minimized the Root Mean Square Error (RMSE) between the positions of the model agent and the participant.

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Model Validation

We then used the new model parameters from the density experiment to predict the human crossing flows data [3]. In this dataset, a set of participants (N=36 or 38) was divided into two equal groups, which walked through each other at six different crossing angles ($30 - 180\,^{\circ}$, increments of $30\,^{\circ}$), with about 17 trials per angle. Simulations were carried out with model components for a goal, collision avoidance, and alignment. We report the within-subject standard deviation (SD) of heading for the human data and the model, with and without the new fit parameters.

Preliminary Results

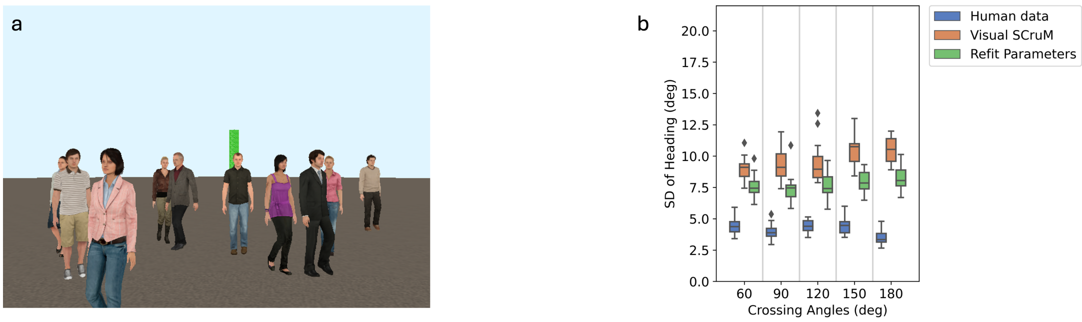

Figure 1: (a) Crowd experiment: A still from the virtual crowd stimuli. The initial positions of 10 avatars were randomly selected from within a bounded area. (b) Crossing flows: Boxplots of heading variation (mean within-subject SD) during the crossing period for human data (blue) and model simulations (previous parameters in yellow, parameters fit to the density experiment in green). Refit model parameters reduce the heading adjustments, but they are still significantly higher than the data.

To test the effect of crowd density, we fit the model parameters to the experiment data in each density condition separately. We then simulated the data in the other density condition and compared the performance between conditions. For the parameters fit to the higher density condition, a t-test found no statistical difference in model performance between the two conditions ($t = 0.34363$, $p = 0.7312$). Similarly, there was no statistical difference for the parameters fit for the lower density condition ($t = -0.85283, p = 0.3939$).

We then fit the model parameters to all the experimental data, and simulated the crossing flows data. The simulated heading adjustments are slightly improved with the re-fit parameters, but are still significantly larger ($p < 0.001$) than the human data (Fig.1). Based on this result, we conclude that the exaggerated heading adjustments in our crossing flows simulations cannot be attributed to the density hypothesis.

We are currently testing the mutual avoidance hypothesis by conducting an experiment in which pairs of participants walk at various crossing angles and avoid colliding with one another. The collision-avoidance model will be refit to this experimental data, and then used to simulate the crossing flow data. The mutual avoidance hypothesis predicts that heading adjustments will be reduced to levels similar to the human data.

Bibliography

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