Towards an Agent-Based Proxemic Model for Pedestrian and Group Dynamics: Motivations and First Experiments (Extended Abstract)

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ABSTRACT

This paper introduces the first experiments of an innovative approach to the modeling and simulation of crowds of pedestrians considering the presence of groups as a crucial element influencing overall system dynamics. *In-silico* experimental results are discussed in relation to *in-vitro* experiments (experimental observations on the movement of pedestrians and groups).

Categories and Subject Descriptors

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

General Terms

Experimentation

Keywords

pedestrian and crowd modeling, interdisciplinary approaches

1. INTRODUCTION

Crowds of pedestrians can be considered as complex entities from different points of view: the mix of competition for the space shared by pedestrians and the collaboration according to shared social norms, the possibility to detect self-organization and emergent phenomena are all indicators of the intrinsic complexity of a crowd. Models for the simulation of pedestrian dynamics (often adopting agent–based approaches) have been successfully applied to several case studies, off-the-shelf simulators can be found on the market and they are commonly employed by end-users and consultancy companies. However, they generally neglect aspects like (a) the impact of cultural heterogeneity among individuals and (b) the effects of the presence of groups and particular relationships among pedestrians [1]. The aim of this work is to present the motivations, directions and preliminary results of a research effort aimed at the development of an agent–based modeling and simulation approach to pedestrian and crowd dynamics facing these two gaps in the state of the art.

The work is set in the context of the Crystals project[1] whose main focus is on the adoption of an agent-based pedestrian and crowd modeling approach to investigate meaningful relationships between the contributions of cultural studies and existing results on the research on crowd dynamics, and how the presence of heterogeneous groups influence emergent dynamics in the context of the Hajj and Omrah. The yearly pilgrimage to Mecca involves in fact over 2 millions of people coming from over 150 countries, with significant cultural differences. In this context, the definition of groups is adopted as a way to organize and manage flows of pilgrims in several moments and phases. These aspects therefore cannot be neglected when defining models to simulate scenarios in this context. In the paper we present the first experiments in a line of work that is aimed at fruitfully integrating *in-silico* agent–based simulations calibrated and validated by means of, first of all, *in-vitro* experiments on the movement of pedestrians and groups and then also *in-vivo* observations carried out on the field.

2. IN-SILICO EXPERIMENTS

We will briefly introduce here the rationale of a model based on the notion of *proxemics*: the term was introduced by Hall with respect to the study of set of measurable distances between people as they interact [2]. In these studies different situations were analyzed in order to recognize behavioral patterns; one of the most interesting result was the distinction between *physical* and *perceived* distance. While the first depends on physical position associated to each person, the latter depends on proxemic behavior based on culture and social rules. Four types of perceived distances were identified: *intimate distance* for embracing, touching or whispering; *personal distance* for interactions among good friends or family members; *social distance* for interactions among acquaintances; *public distance* used for public speaking.

Starting from these considerations, we defined an agent–based model adopting an approach based on the Boids model [4], in which rules have been modified to represent the phenomenologies described by the basic theories and contributions on pedestrian movement instead of flocks. The defined agent–based pedestrian model, considers thus three main contributions to the movement action: (a) the tendency to move towards a *goal*, (b) the tendency to *stay at a distance from strangers*, (c) the tendency to *stay close to members of your group*. The details of the model cannot be reported here for sake of space, but they can be found in [3]; an important parameter of the model is the distance p representing the threshold under which the presence of a stranger is perceived as repulsive. We realized a sample simulation scenario in a rapid prototyping framework and we employed it to test the model in a simplified real built

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[1] http://www.csai.disco.unimib.it/CSAI/CRYSTALS/

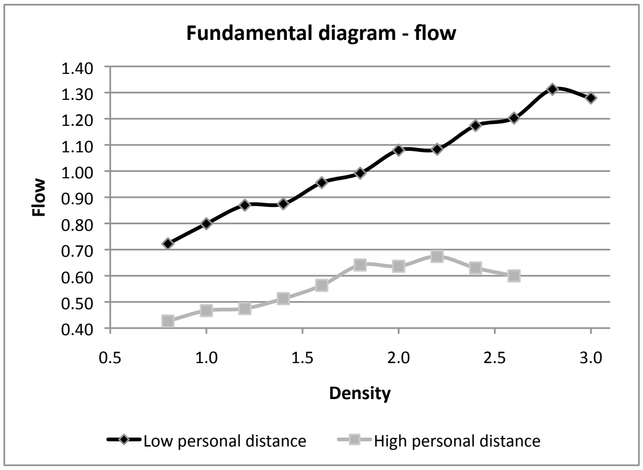

Figure 1: The fundamental diagram for the corridor scenario. The two data series respectively refer to the low end (75cm) and the average value (1m) of personal distance.

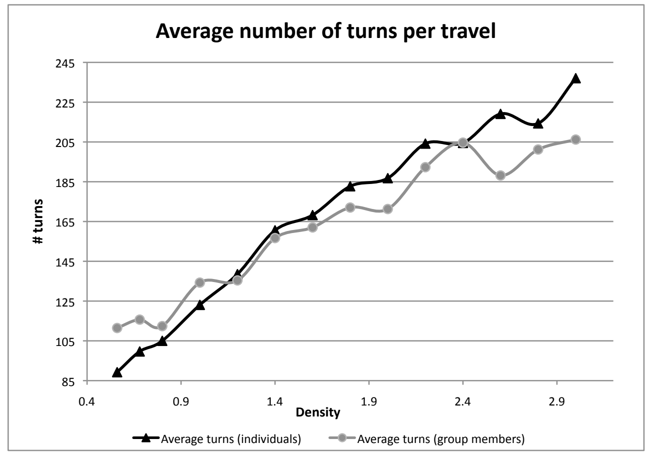

Figure 2: The average number of turns per travel, individuals compared to group members.

environment, a corridor with two exits (North and South); later different experiments will be described with corridors of different size (5m wide and 10m long). We realized a campaign of experiments to verify the plausibility of the model, to calibrate some of its parameters and also to evaluate the effects of the presence of groups. In the experiments, the corridor is populated by two facing sets of pedestrians, respectively heading North and South. Some of the pedestrians are single individuals, others are part of a group: the behaviour of the former is only based on the tendencies to move towards the goal avoiding other pedestrians.

3. SIMULATION RESULTS

We conducted several experiments with the above described model to evaluate the plausibility of the overall system dynamics achieved with such simple basic rules and to calibrate the parameters to fit actual data available from the literature or acquired in the experiments. In particular, we focused on the influence of the proxemic distance p on the overall system dynamics, considering Hall's personal distance and the identified ranges he reported as a starting point. In particular, we considered a high value (1m) and a low value (75 cm) for the proxemic distance p; results are shown in shown in Figure 1. In general, the higher value allowed to achieve good results in low density scenarios, but for densities close and above one pedestrian per square meter the lower value allowed achieving a smoother flow, more consistent with the results available in the literature. The low distance allowed achieving a good balance between flow smoothness, collision avoidance and group cohesion and the results of the simulations employing the low personal distance are consistent with empirical observations discussed in [5] and also with *in-vitro* experiments on pedestrian dynamics conducted in Tokyo in the same environment configuration.

We also analyzed the implications of the presence of groups in the environment. The data generated by *in-silico* experiments, as well as the *in-vitro* observations, do not lead to conclusive results; in low density simulation scenarios, however, the average speed of group members is consistently lower than the one of single individuals. It must be considered that, when compared to individuals, their overall movement has an additional component that sometimes contrasts the tendency to move towards the goal, to stay close to other group members. In high density scenarios, instead, the average speed of group members is generally higher than that of single individuals. This is probably due to the fact that the presence of the group has a greater influence on the possibility of other individuals to move, generating for instance a higher possibility of members on the back of the group to follow the "leaders". Figure 2 compares the average number of turns per complete travel time of individuals and group members (where the turn duration is 100 ms).

4. CONCLUSIONS

This work described the first steps towards an agent–based pedestrians and crowd model considering the influence of groups and cultural heterogeneity in the simulated scenario. In the context of the project the model has been extended and it is now being applied in a more complex scenario and validated with datat from *In-vivo* observations carried out at the 2010 edition of the Hajj.

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