The Impact of Cultural Differences on Crowd Dynamics (Extended Abstract)

Natalie Fridman
MAVERICK Group
Computer Science Dept
Bar-Ilan University, Israel
fridman@cs.biu.ac.il

Avishy Zilka
MAVERICK Group
Computer Science Dept
Bar-Ilan University, Israel

Gal A. Kaminka
MAVERICK Group
Computer Science Dept
Bar-Ilan University, Israel
galk@cs.biu.ac.il

1. INTRODUCTION

Accurate models of crowd dynamics are an important challenge for agent-based social simulations. Unfortunately, existing models of physical crowds do not yet account for cultural factors. In this extended abstract, we briefly summarize our results in treating culture as a first-class object in models of physical crowds. Specifically, we examine the impact of cultural differences on crowd dynamics in pedestrian and evacuation domains.

In the pedestrian domain we relate culturally-aware simulation to pedestrian data which we recorded from videos of pedestrians in five different countries: Iraq, Israel, England, Canada, and France. We characterize these cultures along five individual-level parameters: personal spaces, speed, avoidance side and group formations. We use established crowd-level quantitative measures (e.g., flow, number of collisions, and mean speed) to identify crowd-level effects. We also show that the model can faithfully replicate the observed pedestrian behavior in these videos.

In the evacuation domain, we examine individual cultural parameters (documented in social science literature) as to how seriously people treat possible threats, their tendency to notify others, and their tendency to form groups. We then use the simulations to explore the impact of these on the resulting crowd behavior (measured quantitatively in evacuation time, panic levels, etc.).

2. BACKGROUND

In social psychology there is an extensive research on the cultural differences in micro level interactions among groups of people, but it only rarely addresses the effect of these differences on macro-level crowd phenomena (e.g., pedestrian flow). Cultural differences have been found in variety of human behaviors such as in different pedestrian dynamics [5, 6, 8], evacuation behavior [1] and more.

Work on computer modeling of collective behavior has been carried out in other branches of science, in particular for modeling and simulation. Researchers are developing computational models for simulation of collective behavior in order to be able to predict the resulting macro level behavior from micro level interactions [3, 7, 10]. However, to the best of our knowledge, existing computational models for crowd behaviors do not yet account for cultural differences.

This work follows on our earlier work on modeling pedestrians, validated against human crowd data [4]. It also builds on our work on the ESCAPES [11] agent-based simulation. ESCAPES is a an evacuation simulation, incorporating for individual and social factors. Neither of these earlier works accounted for cultural differences.

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3. PEDESTRIAN CULTURES

In modeling pedestrians, and based on the literature, we focus on the following individual (micro-level) cultural parameters: personal space ([2, 5, 6]), base walking speed ([8], avoidance side ([9]) and group formations (in particular gender-heterogeneity, size, and shape [10]). We quantitatively measure these in movies taken in five different cultures: Iraq, Israel, England, Canada and France. Overall, we collected over a hundred hours of pedestrian footage in different locations. For the purposes of the analysis, we used a total of 45 minutes. Each movie was analyzed by two different subjects and we used the mean value for each measure in our results. For lack of space we only report here that indeed the five countries differ from each other in these four cultural parameters.

We used an agent-based simulation to examine the effect of the presented above four cultural factors on macro-level pedestrian dynamics. We ran extensive simulations with the above values, totaling over 100 hours of simulation. All results below are the averaged value over 30 trials. We examine the impact of each of the cultural parameter and also the effects of mixing individuals with different cultural parameters in the same physical crowd on crowd dynamics. In this extended abstract we summarize a small subset of preliminary results.

First, an important question is whether the fidelity of the simulation is sufficient to support conclusions as to human crowds. Thus we examined whether the simulation can produce similar behavior to that of the observed human pedestrian crowd. To carry out the comparison, we recreated the initial settings in four of the videos in simulation. Specifically, we set the density of the pedestrian crowd (how many pedestrians per unit area); we set the individual parameters of agents and groups per the measured quantized values from the videos. Then we quantitatively compared the macro level measures (flow and mean speed) generated by the simulation to those of the crowds in the videos.

The results of flow comparison show fairly low error rates (where the error is measured in percentage of difference between the simulated and the observed values). In two of the France movies, we have 15% and 4% errors, in a *Canada* movie we have 16% error (this was the maximum error across all movies from all cultures), and in `London` we have 10% error. The mean flow error is 11%. The results of mean speed comparison show that in one `France` movie we get 21% error (the maximal error), in `Canada` we have 10% error and in `London` we have 6% error. The mean error for crowd speed is 13%. Note that because the simulation is using low-resolution discrete results (e.g., only three values for speed)

and mean values overall, a perfect match is essentially impossible.

Encouraged by the fidelity results, we examined the impact of different personal spaces among the pedestrians on their number of collisions, and on their mean speed. The preliminary results show that there is a difference in number of collisions between collisions, as we vary the percentage of pedestrians who maintain shorter (*close*) and longer (*far*) personal spaces around them. In homogeneous groups, where everyone maintains *close* or everyone maintains *far*, there are relatively high number of collisions, though the groups do differ between them. Surprisingly, the lowest number of collisions have been found in the 50%-mixed group. The number of collisions is lower than both the homogeneous *close* and *far* groups.

The results also show that agents with *close* personal space have higher mean speed than agents with *far* personal space, although both of the groups were initialized with the same speed individually (so the effect is definitely due to just personal space preferences). Moreover, there is a difference between the *close*- and *far*-homogeneous groups. The differences in mean speed also have been found between the homogeneous groups and the heterogeneous 50%-mixed group.

We also examine the effect of *complete cultures* on crowd dynamics, where a complete culture is defined by a set of values assigned to the cultural parameters, as extracted from the video analysis. To do this, we simulated mixed-culture pedestrians moving on a sidewalk. As an exemplar, we report here on crowds mixing two cultures: Iraq and Canada. We vary the number of pedestrians in the crowd who are initialized with Iraqi cultural parameters, from 0% (homogeneous Canada crowd) to 100% (homogeneous Iraq crowd). We measure the impact of such mixing on the number of collisions, and on mean speed, as above.

The results of the collisions numbers show that in the heterogeneous groups, the higher the percent of Canadian in the population the higher the number of collisions. The lowest number of collisions has been found in population of 20% Canada pedestrians. For example, there is a difference between this population, and the population with 80% Canada pedestrians. Interestingly, the number of collisions in the homogeneous Iraq population jumps up, compared to the 20% Canada crowd.

The mean speed results show that an increased number of Canadian pedestrians in the population leads to higher mean crowd speed (indeed, our human pedestrians analysis shows that the Canada pedestrians had higher mean speed than Iraq pedestrians). The lowest mean speed has been found in population with 80% Iraq pedestrians.

4. EVACUATION CULTURES

Cultural differences have also been found in evacuation domain. Based on our literature survey, we model the following cultural parameters of individual evacuees (evacuating agents): (1) their tendency to notify others regarding an event that have caused them to evacuate, (2) the seriousness with which people (agents) hearing about such an event take it (that is, whether they decide to evacuate too, as a result) and finally, (3) we model the tendency towards evacuating in groups or individually [1]. We then examine the impact of these cultural parameters on the resulting macro level crowd evacuation behavior. Again, for lack of space, we report only on small subset of preliminary results.

We examined the agents' tendency to notify others regarding an event on evacuation rate, with no guards present. The preliminary results show that the more agents communicate, the faster the evacuation time. However, there was no significant difference between agents that pass knowledge of the event to all close neighbors (100% message passing) and agents that pass information to 80% of close neighbors (80% message passing). Thus the evacuation time essentially hits a floor at the level where 80% of the neighbors are informed. We also examined the same settings, except for adding authority figures who act to inform and guide evacuation. The general trend is the same, but the addition of authority figures makes a significant difference in relatively non-communicating agents. For example, the mean evacuation time in population of non-communicating agents (0% notify others) with five guards is cut by almost a half.

5. SUMMARY

We briefly described our first steps to explore the impact of micro-level, individual agent, cultural parameters on macro-level crowd behavior. Building on existing literature which investigates culture in human crowds, we identified important cultural parameters in two physical crowd domains (pedestrian movement and evacuation). We implemented these in established agent-based simulations for these domains, and used the simulations to measure their impact on crowd dynamics. We thus go beyond existing work, which focused on describing cultural parameters of individuals, without investigating their crowd-level effects.

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