Social Comparison in Crowds: A Short Report

Gal A. Kaminka Natalie Fridman

The MAVERICK Group*
Computer Science Department
Bar Ilan University, Israel
{galk,fridman}@cs.biu.ac.il

ABSTRACT

Modeling crowd behavior is an important challenge for cognitive modelers. We propose a novel model of crowd behavior, based on Festinger's Social Comparison Theory, a social psychology theory known and expanded since the early 1950's. We propose a concrete framework for SCT, and evaluate its implementations in several crowd behavior scenarios. Results from task measures and human judges evaluation shows that the SCT model produces improved results compared to base models from the literature.

1. INTRODUCTION AND BACKGROUND

Models of crowd behavior facilitate analysis and prediction of human group behavior, where people who are in close geographical space are affected by each other's presence. The phenomena that was observed in crowd by psychologists is its homogeneous nature. People in the crowd often acting in a coordinated fashion, as if governed by a single mind [8]. However, this coordination is achieved with little or no verbal communications.

Existing models of crowd behavior, in a variety of fields, leave many open challenges. In social sciences and psychology, models often only offer qualitative descriptions and do not easily permit algorithmic replication. For example, Le Bon explains the homogeneous behavior of a crowd by two processes: (i) *Imitation*, where people in a crowd imitate each other; and (ii) *Contagion*, where people in a crowd behave differently from how they usually behave, individually.

In computer science, computational crowd models tend to be simplistic, and focus on specific crowd behaviors (e.g, flocking). Henderson modeled pedestrian movement as movements of gaskinetic fluids [6]. Helbing et al. [4, 5] developed a model that takes into account interactions between the individuals and the physical environment. Blue and Adler [2] used cellular automata. The focus of all of these is on local interactions; each simulated pedestrian is a particle or an automaton, whose next action or behavior is determined by its local surroundings.

We propose a novel model of crowd behavior, based on Social Comparison Theory (*SCT*) [3], a popular social psychology theory that has been continuously evolving since the 1950s. The key ideas in this theory is that humans, lacking objective means to evaluate their state, compare themselves to others that are similar.

While inspired by SCT, we remain deeply grounded in computer science; we propose a concrete algorithmic framework for SCT, and evaluate its implementations in several crowd behavior scenarios like pedestrian movement and imitational behavior. The results from experiments are promising, and support the general applicability of the SCT model.

2. A MODEL BASED ON SCT

According to social comparison theory [3], people tend to compare their behavior with others that are most like them. To be more specific, when lacking objective means for appraisal of their opinions and capabilities, people compare their opinions and capabilities to those of others that are similar to them. They then attempt to correct any differences found.

We believe that social comparison theory may account for some characteristics of crowd behavior [8]. Using social comparison, people may adopt others' behaviors (*Imitation*). Festinger notes [3]: "The drive for self evaluation is a force acting on persons to belong to groups, to associate with others. People, then, tend to move into groups which, in their judgment, hold opinions which agree with their own". Another implication of SCT is the formation of homogeneous groups (*Contagion*). Festinger writes [3]: "The existence of a discrepancy in a group with respect to opinions or abilities will lead to action on the part of members of that group to reduce the discrepancy".

To be usable by agents, SCT must be transformed into a set of algorithms that, when executed by an agent, will proscribe social behavior. A first step towards this goal has been taken by Newell, which describes SCT as a set of axioms [9]:(i) When lacking objective means for evaluation, agents compare their state features to those of others; (ii) agents compare themselves to those who are more similar; comparison increases with similarity; (iii) agents take steps to reduce differences to the objects of comparison.

We take another step towards the modeling of social comparison theory. Each observed agent is assumed to be modeled by a set of features and their associated values. For each such agent, we calculate a similarity value $s(x)$, which measures the similarity between the observed agent and the agent carrying out the comparison process. The agent with the highest such value is selected. If its similarity is between given maximum and minimum values, then this triggers an action o by the comparing agent to reduce the discrepancy. In order to close the gap, we use a gain function $g(o)$ for the action o, which translates into the amount of effort or power invested in the action. For instance, for movement, the gain func-

---

[*] This research was supported by IMOD.

AAMAS'07 May 14–18 2007, Honolulu, Hawai'i, USA.

tion would translate into velocity; the greater the gain, the greater the velocity.

$$g(o) = \frac{S_{max} - S_{min}}{S_{max} - s(c)}$$

The process is described in the following algorithm, which is executed the comparing agent.

1. For each known agent x calculate similarity $s(x)$
2. $c \leftarrow \texttt{argmax}\ s(x)$, such that $S_{min} < s(c) < S_{max}$
3. $D \leftarrow$ differences between me and agent c
4. Apply actions to minimize differences in D.

3. MODELING PEDESTRIAN MOVEMENT

We evaluate the use of our SCT model in accounting for pedestrian movement phenomena, like lane formations in bidirectional movement and movement in groups. To implement the model for pedestrians movement experiments, we used NetLogo [10]. We simulated a sidewalk where agents can move in a circular fashion from east to west, or in the opposite direction. The SCT-based movement pattern of agents (pedestrians) is as follows: Each agent follows an initially set direction. It chooses moving in this direction, unless blocked. If forward movement is indeed blocked, the agent will choose the lane based on SCT algorithm above.

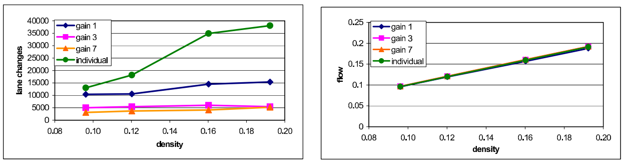
For lack of space, we report here only on a subset of the experiments. In these, each agent has a set of features and its corresponding weight. For simulating pedestrian movement, we used the following features and weights:*Walking direction (weight: 2)*—east or west; *Color (weight: 3)*; and *Position (weight: 1)* in terms of distance and angle. The similarities in different features (f_i) are calculated as follows. $f_{color} = 1$ if color is the same, 0 otherwise. $f_{direction} = 1$ if direction is the same, 0 otherwise. and finally, $f_{distance} = \frac{1}{dist}$, where $dist$ is the Euclidean distance between the positions of the agents. Each agent calculates $s(x)$ according to the algorithm. If the chosen feature for closing the gap is distance, then the velocity for movement will be multiplied by the gain $g(o)$. For other features (which are binary), the gain is ignored.

The rationale for feature priorities, as represented in their weights, follows from our intuition and common experience as to how pedestrians act. Positional difference (distance) is the easiest difference to correct, and the least indicative of a similarity between pedestrians. Direction is more indicative of a similarity between agents, and color even more so.

We contrasted the SCT model with an individual choice model where each agent chooses lanes arbitrarily if forward movement is blocked [2, 5]. The individual choice model was also shown to produce lane formation and is considered to be a base model for pedestrian movement.

In order to evaluate SCT in accounting for lane formation on bidirectional pedestrian movement we perform experiments in which we varied S_{min} and S_{max}, and thus the gain component $g(o)$. As is commonly done in pedestrian movement experiments, we controlled for *crowd density*, calculated as the number of agents divided by the area. We follow the literature in measuring two principal characteristics of pedestrian movement: the total number of *lane changes*, and the *flow* (speed divided by the space-per-agent).

Figures 1(a) and 1(b) show that the number of lane changes in SCT is significantly lower than that of the individual-choice model (one tailed t-test, 0.05 significance level). Moreover, the difference with the individual-choice model increases with an increased gain. However, we see essentially no differences in flow.



(a) Lane changes.

(b) Flow.

Figure 1: Bidirectional pedestrian measurement results.

We also evaluate the SCT model on grouped pedestrians, where agents of the same color move together. To account for the intuition that friends and family walk side-by-side, rather than in columns, we added another feature: The similarity in position along the x-axis and revised features and weights accordingly. In these experiments, all agents move in the same direction and use comparison at all times, and not just when stuck. Gain was allowed to vary per the model, as described above. We examine populations with a different number of colors (5, 10, and 20) and measure the grouping results using *hierarchical social entropy* [1], shown in Table 1. The results of our model are much lower (almost by a factor of two) than those of the individual-choice model.

# Groups	Individual-choice	SCT
5	173.2	**87.4**
10	143.3	**85.8**
20	101.5	**60.1**

Table 1: Grouping measurements of individual-choice and SCT models. Lower values indicate improved grouping.

4. SCT IN IMITATIONAL BEHAVIOR

An attractive feature of social comparison is its hypothesized prevalence in human group behavior, i.e., its generality across different behaviors. Indeed, we believe that the SCT model we presented in this paper is sufficiently general to account for a wide variety of group behaviors. This is in contrast to many existing computational models, that typically focus on specific tasks.

This section provides evidence for such generality by describing the application of the SCT model to the problem of generating imitational behaviors in loosely-coupled groups. Unlike individual imitation, where one agent imitates a role model, crowd imitational behavior spreads across a group of individuals who dynamically select role models for imitation, from the level of observable actions to the level of unobservable internal mental attitudes (e.g., goals). Here, imitation occurs more loosely, as the role models do not necessarily intend to play their role, and indeed may not even know that they are being imitated. Also, the imitators potentially switch their role-model targets from one moment to the next. Psychology literature describes such imitational behavior as one of the keystones of crowd behaviors [8].

To explore imitational behavior, we implemented SCT in the Soar cognitive architecture [9]. Soar was connected to the GameBots virtual environment [7]. Here, multiple agents, each controlled by a separate Soar process (including SCT) can interact with each other in a dynamic, complex, 3D virtual world (see Figure 2).

For lack of space we provide here a very brief overview about implementation of SCT in Soar. The SCT was implemented as secondary parallel thread within Soar. It proposed operators by following the algorithm described previously, though in a way that is adopted for Soar's decision cycle: At every cycle, for each observed agent and for each difference, the SCT process would propose an

Figure 2: Soar agents in the GameBots environment.

operator that would minimize the difference. Then, a set of preference rules is triggered that ranks the proposals based on feature weight. Additional rules prefer the most similar agent (that is still not sufficiently similar). Thus at the end, only one SCT operator is supported.

We conducted experiments to evaluate whether SCT can indeed generalize to account for imitational behavior in groups. Unlike the pedestrian movement domain, where clear measures are available for objective measurement of a success of a model (e.g., flow, lane changes), imitational behavior does not have clear standards of evaluation. We therefore rely on experiments with human subjects, which judged the resulting behavior in comparison to completely individual behavior (i.e., arbitrary decisions by each agent, independently of its peers), and to completely synchronized behavior (i.e., all agents act in complete unison).

The hypothesis underlying the experiments was that groups controlled by SCT would generate behavior that would be ranked somewhere in-between the individual and perfect-coordination models, i.e.., that SCT would generate behavior that would be perceived as coordinated, but not perfectly so. To examine this hypothesis, we created three screen-capture movies of 11 Soar agents in action. All movies were shot from the same point of view, and showed the agents in the same environment. In all, the soar agents were fixed to their initial locations, and the only actions available to them was to turn at some angle, or to do nothing.

In all movies, one agent, colored blue, simply turned up to 90° left or right, arbitrarily. All others (red) acted according to one of the models. In one movie (*individual*), the red agents acted completely independently of each other, arbitrarily choosing an angle and turning to it. In another (*unison*), the red agents relied on communications to act in almost perfect synchronization, turning towards the same angle as the blue almost instantaneously (small timing differences resulting from asynchronous responses of the simulated environment). Finally, in the *SCT* movie, the red agents behaved according to the model described above.

The experiments were carried out using 12 subjects (ages: 18–40, male: 6; additional 4 subjects dropped due to technical reasons). Each subject was given a brief description of the appearance of the environment and agents, sometimes aided by a snapshot from a movie (e.g., as in Figure 2). The subjects were told that the purpose of the experiment was to evaluate the use of perception models embedded in the agents; that there was a red-dot—visible to the agents but not to the subject—that moves about on the walls surrounding the group. The agents' goal is to individually locate this dot, and then track it in place by turning around. The purpose of the cover story was to focus the attention of the subjects away from group behavior and imitation, so as to not bias the results. After the description, the movies were shown to the subject. After each movie, the subjects were asked to fill a short questionnaire (described below). The order of presentation of movies was randomly selected for each subject, to control for learning and order effects.

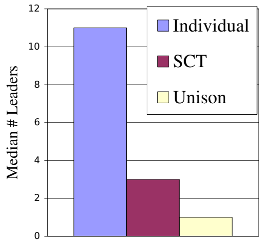


Figure 3: Experiment 5 results (subset).

For lack of space, we will focus here only on a subset of the results. In general, responses to the questions have placed SCT between the individual and unison models (Figure 3). In response to the question "Do you see any leaders? If so, how many?", The median result for the individual was 11 (i.e., every agent is a leader, or in other words, no leader). For the unison model, the median result was 1. For the SCT model, the median result was 3. When asked to qualitative discuss their answer to these questions, many subjects reported on feeling that agents in the movie were organized in several subgroups, that were internally coherent, but not coordinated with the others.

5. SUMMARY AND FUTURE WORK

This paper presented a model proscribing crowd behavior, inspired by Festinger's social comparison theory [3]. The model intuitively matches many of the characteristic observations made of human crowd behavior, and was shown to cover several distinct crowd phenomena. Results from experiments in pedestrian movement and imitation domains are promising, and support the general applicability of the SCT model.

6. REFERENCES

[1] T. Balch. *Behavioral Diversity in Learning Robot Teams*. PhD thesis, Georgia Institute of Technology, 1998.

[2] V. J. Blue and J. L. Adler. Cellular automata microsimulation of bidirectional pedestrian flows. *Transportation Research Record*, pages 135–141, 2000.

[3] L. Festinger. A theory of social comparison processes. *Human Relations*, pages 117–140, 1954.

[4] D. Helbing. Boltzmann-like and Boltzmann-Fokker-Planck equations as a foundation of behavioral models. *Physica A*, 196:546–573, 1993.

[5] D. Helbing, P. Molnar, I. J. Farkas, and K. Bolay. Self-organizing pedestrian movement. *Environment and Planning B*, 28:361–384, 2001.

[6] L. F. Henderson. The statistics of crowd fluids. *Nature*, 229:381–383, 1971.

[7] G. A. Kaminka, M. M. Veloso, S. Schaffer, C. Sollitto, R. Adobbati, A. N. Marshall, A. Scholer, and S. Tejada. GameBots: A flexible test bed for multiagent team research. *Communications of the ACM*, 45(1):43–45, January 2002.

[8] G. Le Bon. *The crowd: A study of the popular mind.* Dunwoody, Ga., N.S. Berg, 1968.

[9] A. Newell. *Unified Theories of Cognition*. Harvard University Press, Cambridge, Massachusetts, 1990.

[10] U. Wilensky. NetLogo. Center for Connected Learning and Computer-Based Modeling—Northwestern University; http://ccl.northwestern.edu/netlogo/, 1999.