Modeling Crowd Behavior Based on Social Comparison Theory: Extended Abstract

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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. The results show improved performance over existing models.

1 Introduction and Background

Modelling crowd behavior is an important challenge for cognitive modelers. Existing models, 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. In computer science, models are often simplistic and typically not tied to specific cognitive science theories or data.

Social psychologists observe that people in a crowd act similar to one another, often acting in a coordinated fashion, as if governed by a single mind [1]. However, this coordination is achieved with little or no verbal communication. 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. Some [1] theorize that individual become a part of the crowd behavior when they have "common stimulus" with people inside the crowd. For example, a common cause.

Work on modelling crowd behavior has been carried out in other branches of science, in particular for modelling and simulation. For instance, Blue and Adler [2] use Cellular Automata in order to simulate collective behaviors, in particular pedestrian movement. The focus is again on local interactions: Each simulated pedestrian is controlled by an automaton, which decides on its next action or behavior, based on its local neighborhoods. Helbing et al. [3] focus on simulating pedestrian movement. Each entity moves according to forces of attraction and repulsion. Pedestrians react both to obstacles and to other pedestrians. The study shows that this results in lane formation.

We propose a novel model of crowd behavior, based on Social Comparison Theory (*SCT*) [4], a popular social psychology theory that has been continuously evolving since the 1950s. The key idea in this theory is that humans, lacking objective means to evaluate their state, compare themselves to others that are similar. We propose a concrete algorithmic framework for SCT and evaluate its implementations in several crowd behavior scenarios. We show that these result in improved performance compared to previous approaches.

2 A Model Based on Social Comparison Theory

The research question we address in this paper deals with the development of a computerized cognitive model which, when executed individually by many agents, will cause them to behave as humans do in crowds.

We took Festinger's Social Comparison Theory [4] as inspiration for the social skills necessary for our agent. According to the Social Comparison Theory, 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 the Social Comparison Theory may account for some characteristics of crowd behavior:

Common stimulus between crowd participants. One of the social comparison theory implications is group formation. Festinger notes [4]: "To the extent that self evaluation can only be accomplished by means of comparison with other persons, 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 and whose abilities are near their own".

Imitational behavior. By social comparison, people may adopt others' behaviors. Festinger writes [4]: "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 computerized models, social comparison theory must be transformed into a set of algorithms that, when executed by an agent, will proscribe social comparison behavior. Each observed agent is assumed to be modelled 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 actions (o - with least weight) 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 function 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 executes the comparing agent.

1. For each known agent x calculate similarity $s(x)$
2. $c \leftarrow$ `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 Experiments and Results

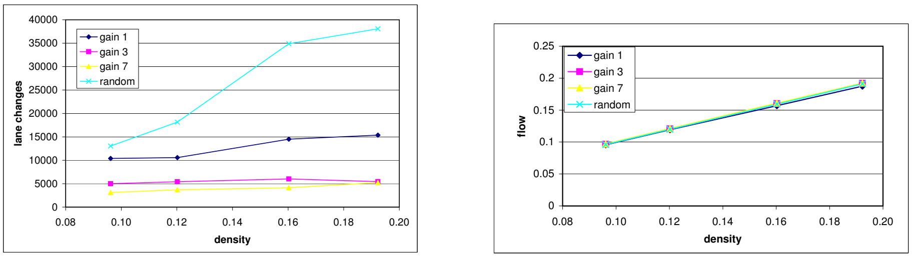
We evaluate our social comparison model as accounting for pedestrian movement phenomena such as lane formations in bidirectional movement, grouping in grouped pedestrians, and behavior in the presence of obstacles. To implement the model for pedestrian movement experiments, we used NetLogo [5]. We simulated a sidewalk where agents can move in a circular fashion from east to west, or in the opposite direction.

For lack of space, we report here only on a subset of the experiments. See [6] for additional details. In these, each agent modelled its peers using the following set of features and corresponding 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.

The rationale for feature priorities, as represented in their weights, follows from our intuition and common experience as to how pedestrians act. 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.

Pedestrian Movement In order to evaluate our model on bidirectional pedestrian movement we perform experiments in which we varied S_{min} and S_{max}, and thus the gain component $g(o)$. In these, we measured performance using two characteristic features of pedestrian movement, used in previous work [3]: The total number of *lane changes*, and the *flow* (average speed divided by the space-per-agent). By varying the number of agents in the fixed space, controlled *crowd density*. Each trial lasted 5000 cycles and was repeated dozens of times. The results are contrasted with a random-choice model [3, 2].

Figures 1(a) and 1(b) show the lane-changes and flow in these experiments. The figures show that there is no reduction in flow and there is significant improvement to the number of lane changes, with an increased gain. For lack of space, we do not show screen shots here, but the results also demonstrate that increased gain causes the agents to group more closely together.



(a) Lane changes.

(b) Flow.

Fig. 1. Individual pedestrian movement experiments.

Grouped Pedestrian Movements We wanted to 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. 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* [7], shown in Table 1. The results of our model are much lower (almost by a factor of two) than those of the random-choice model.

# Groups	Random	SCT
5	173.2	**87.4**
10	143.3	**85.8**
20	101.5	**60.1**

Table 1. Grouping measurements of random-choice and social comparison models. Lower values indicate improved grouping.

4 Summary and Future Work

This paper presented a preliminary algorithmic model proscribing crowd behavior, inspired by Festinger's Social Comparison Theory [4]. Though there is lack of objective data against which the model can be tested, the results are promising and seem to match our intuitions regarding behavior observed in people. We are developing an implementation of the Social Comparison Theory model in the Soar cognitive architecture [8].

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References

1. Allport, F.H.: Social Psychology. Boston: Houghton Mifflin (1924)
2. Blue, V.J., Adler, J.L.: Cellular automata microsimulation of bidirectional pedestrian flows. Transportation Research Record (2000) 135–141
3. Helbing, D., Molnar, P., Farkas, I.J., Bolay, K.: Self-organizing pedestrian movement. Environment and Planning B **28** (2001) 361–384
4. Festinger, L.: A theory of social comparison processes. Human Relations (1954) 117–140
5. Wilensky, U.: NetLogo. Center for Connected Learning and Computer-Based Modeling—Northwestern University; http://ccl.northwestern.edu/netlogo/ (1999)
6. Kaminka, G.A., Fridman, N.: A cognitive model of crowd behavior based on social comparison theory. In: Proceedings of the AAAI-2006 workshop on cognitive modeling. (2006)
7. Balch, T.: Behavioral Diversity in Learning Robot Teams. PhD thesis, Georgia Institute of Technology (1998)
8. Newell, A.: Unified Theories of Cognition. Harvard University Press, Cambridge, Massachusetts (1990)