Information in crowds: The Swarm Information Model

Colin Marc Henein[1] & Tony White[2]

Carleton University. 1125 Colonel By Dr. Ottawa, Ontario. K1S 5B6. Canada.
[1] cmh@ccs.carleton.ca, [2] arpwhite@scs.carleton.ca

One interesting view of crowd modelling is the consideration of crowd effects as being generated from the point of view of individual agents. By modelling individual decisions of agents (rather than generalizing from a population of identical ones) we can represent the heterogeneity inherent in large crowds. The heterogeneous approach allows for different agents to interpret the environment differently (via cognition, memory or other intrinsic factors).

Pelechano et al. [1] have used a psycho-emotional model to consider wayfinding by agents with varying training. Although the results are of interest, jumping from simple models of homogeneous agents to a complex psychological model makes it hard to isolate the effects of heterogeneity. Bandini et al. have designed heterogeneity into their SCA model [2], but we prefer to explore the question incrementally by adding heterogeneity to an existing model, allowing for comparison of behaviours.

The CA model of Kirchner & Schadschneider (K&S) [3] considers individual agent desires to follow locally perceptible gradients. The Swarm Force model [4,5] retains K&S' general approach, but incorporates the physical forces required to reproduce key crowd behaviours. Neither model takes full advantage of the individual-centred approach to explore heterogeneity within the crowd because only location-specific processing is performed (the agents are all basically the same).

In addition to a penchant for homogeneity, previous models have not tended to examine the important effect of the provision of information concerning the overall situation (whether by physical discovery, overhead announcements or inter-agent communication). In our view, timely information about the location and operational status of exits, for example, is of crucial importance in evacuations; different modes of discovery will produce different crowd patterns. Pauls [6] reported that "crowd incidents often exhibit… a failure of front-to-back communication"; information about an unfolding crush at the front of a crowd must be conveyed to those at the rear (with whom damaging pushing forces originate) to prevent disasters.

It is with a view toward examining the effects of heterogeneity and illuminating the importance of information that we here propose the Swarm Information Model (SIM). Its aim is to study crowds of heterogeneous individuals who base their actions on the differing perceptions of the world engendered by unfolding information.

The Swarm Force model and SIM

SIM is an extension of the Swarm Force model [4,5] which in turn is based on K&S' crowd model [3]. The models consist of a rectangular grid of cells, either designated as walls or which hold up to one agent. Agents select and move to an adjacent cell in

Published in Crowds and Cellular Automata.
Lecture Notes in Computer Science v. 4173. pp. 703-706.
2006 New York: Springer. DOI: 10.1007/11861201_83

each time step, and may be forced to remain still should their desired cell be occupied by another agent. Some cells are designated as exit cells, and agents who occupy these cells are considered to exit the model on the next timestep.

The information available to agents for cell selection is restricted to their immediate surroundings, and is dispersed throughout the space through the concept of a *field*: a set of information having a distinct value at each grid cell. K&S define two such fields: the *static field*, whose value is the distance to the closest exit cell, and the *dynamic field,* which allows trail following analogously to ant pheromones. Two sensitivity parameters, k_S and k_D, allow adjustment of the weight agents place on these two fields when selecting the cell they wish to move to next. The cell selection formula of the Swarm Force model is as follows:

$$p_{ij} = N \exp(k_D D_{ij}) \exp(k_S S_{ij}) (1 - \phi_{ij}) \xi_{ij} \quad (1)$$

Here, p_{ij} represents the probability that an agent will select a neighbouring cell (i, j). D_{ij} and S_{ij} represent the value of the dynamic and static fields (respectively) at this location, ϕ_{ij} is the vacancy factor (0 if a cell is unoccupied and 0.5 otherwise), while ξ_{ij} is 0 for walls, 1 otherwise. N is the normalisation number equal to $(\Sigma\, p_{ij})^{-1}$.

Force within the model is a third field whose value on occupied cells is the vector force experienced by the agent on the cell. Force is generated by agents pushing the occupants of desired cells when blocked; is cumulatively retransmitted by agents; when moderate overrides equation (1) as the decision mechanism for cell selection; and, when excessive, injures agents (who then act in all respects as walls).

SIM Explained

SIM departs from the previous models in two major respects. First, it allows for individual agents to perceive the modelled world differently from one another, creating a heterogeneous crowd. Second, it allows for agents to change their view of the world, either under the influence of the new *information field*, or through a simple inter-agent communication mechanism.

Multiple static fields. As with previous models, the basis of agents' view of the world is the static field that, mediated through the k_S sensitivity parameter, motivates agents to move toward points of interest (e.g. exits). To produce different views of the world, the SIM model simply provides a set of static fields rather than a single one. The set of static fields specifies the ways agents can view the world. The additional fields may include points of interest at locations other than real exits (representing blocked exits, or a misinformed agent), and may omit points of interest at legitimate exits (representing exits that are unknown to the agent). The additional static fields are complemented by an agent variable (`current-static`) that tracks which static field is being consulted by that agent.

In short, by allowing the agent access to multiple static fields, different agents have access to different internal maps leading to heterogeneous decision making.

Information Field. The information field is a new field within the model that causes agents to change their view of the world upon visiting certain locations. Like the agent's `current-static` variable, the value of the information field is an index into the set of static fields. Upon entering a cell the agent compares the value of the information field with the agent's internal `current-static`. Should the field indicate a higher index, the agent permanently updates its `current-static` accordingly.

Like the arrangement of exits and the setup of the static field(s), the information field is a creation of the modeller; working together, these three constructs determine the evacuation scenario being studied. The information field is likely to be fixed at the outset of the model, but it is also possible to change the information field during the course of model execution. This can model, for example, the effect of localized or generalized overhead announcements concerning the situation.

Communication. By providing for direct communication we can use this model to investigate behaviour engendered by informing agents of different views of the world, including misinformation, without physically visiting locations of interest.

If enabled, communication occurs when an agent *a* is blocked from moving due to an agent *b*'s occupation of *a*'s desired cell. Agent *a* provides its `current-static` value to *b*, which updates its own value (if it was lower). Conceptually, communication occurs as an attempt by *a* to get *b* to move out of the way.

Example Scenario. Consider a simple example scenario with two exits, one blocked. Using two static fields we can represent two states of agent "belief", one incorrect in which there are two functional exits (two points of interest: one at an exit, one at a wall cell) and one correct in which there is one functional exit (one point of interest, at the exit). If we wish to model a scenario where agents may run to the blocked exit, find it blocked, then move to the correct exit then we set the information field to 1 throughout the space, and 2 in the immediate proximity of the blocked exit. Agents "see" the blockage of the second exit upon moving into this proximate zone. Upon this movement they update their `current-static` variable to 2, switching to the second static field, and thereby viewing only the true exit as a point of interest.

Scenarios studied and Results

Results are given here for three scenarios. The first scenario is the example scenario just described, with no communication between agents. The second scenario is the same, but with communication. In the third scenario there are two exits, both functional, but one is not well known (only one randomly selected agent knows about the second exit at the outset of the model). There are two static fields; the first field is incomplete (showing a point of interest at only one of the doors) while the second field shows points of interest at both doors. The information field is entirely set to 1, except for a small area proximate to the "secret" exit which is set to 2 (this allows agents who wander close the secret door to "discover" it). Communication is enabled.

The SIM outcomes demonstrate important differences from the Swarm Force and K&S models. In the first scenario agents divided into two crowds based on initial proximity to each point of interest. Agents discovering the blocked exit attempted to turn back toward the functional exit. They were prevented from doing so by naïve agents who were clustered around the blocked exit but outside the proximal information zone; the naïve agents did not know the exit was blocked and so pushed in toward the blocked exit while the knowledgeable agents pushed out towards the functional exit. Stasis resulted. Given appropriate injury thresholds this pattern of force application created injuries along the boundaries between the two crowds.

The second scenario began to unfold as the first with the creation of two crowds. The effect of communication was to allow the first naïve agent between a knowledgeable agent and the functional exit to be converted into a knowledgeable agent. This agent then converted the next naïve agent and so on until a stream of knowledgeable agents was able to move toward the functional exit. As the knowledgeable agents left the proximity of the blocked door, naïve agents were able to move into the space created and continue the information process. Ultimately all agents moved to the functional exit, and all agents became knowledgeable.

There were two broad outcomes of the third scenario. If the one knowledgeable agent was initially attracted to the well-known exit then few agents left by the secret one. If the single knowledgeable agent was initially attracted to the secret exit then through communication engendered by the normal contention for space in a large crowd it informed naïve agents. In this case the knowledgeable agent sponsored a small crowd of individuals to move to the secret exit. Depending on the geometry of the situation it is not necessarily the case that the naïve crowd will ever find out about the secret exit, but if it does then some agents may leave the rear ranks at the well-known exit and move to the secret exit.

Conclusion and Future Work

We have proposed a new model that demonstrates the effects of heterogeneity within crowds and also the results of providing situation-level information. The modelled crowd behaves quite differently from a homogeneous one, displaying non-adaptive effects (like stasis and injuries when numerous agents work at cross purposes due to differing goals). The new model additionally allowed for complex scenarios involving changing goals and unfolding information, characteristic of more realistic situations.

We have not explored adding more dynamic fields, but doing so could result in agents with similar views of the world following each other. Rather than switching between fields, agents could maintain their own distinct k_S and k_D values for each field, changing them dynamically as information is gained. This would allow for declining belief in certain options and consequently a more cognitive model. These interesting points are left for future research.

1. Pelechano,N., O'Brien,K., Silverman,B., Badler.N. (2005) Crowd Simulation Incorporating Agent Psychological Models, Roles and Communication. V-CROWDS '05. Retrieved 26-Apr-06: http://www.seas.upenn.edu/~npelecha/Pelechano_V_CROWDS05.pdf
2. Bandini,S., Federici,ML., Manzoni,S., Vizzari,G (2006). Toward a methodology for situated cellular agent based crowd simulations. *ESAW 2005*, LNAI v. 3963, Springer, 203-220.
3. Kirchner,A., Schadschneider,A. (2002) Simulation of evacuation processes using a bionics-inspired cellular automaton model for pedestrian dynamics. Physica A, 312, 260-276.
4. Henein,CM., White,T. (2005) Agent-Based Modelling of Forces in Crowds. MAMABS05. Lecture Notes in Computer Science v. 3415. Springer, 173-184.
5. Henein,CM., White,T. (submitted) Macroscopic effects of microscopic forces between agents in crowd models. Preprint: http://www.orange-carb.org/~cmh/papers/
6. Pauls,J. (1984) The movement of people in buildings and design solutions for means of egress. Fire Technology, 20, 27-47.