

Simulation of Pedestrian Agent Crowds, with Crisis

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1.1. Introduction

Multiple application areas have an interest in pedestrian dynamics. These range from urban design of public areas to evacuation dynamics to effective product placement within a store. In Hoogendoorn et al [Hoogendoorn 2002] multiple abstractions utilized in simulations or calculations involving pedestrian agents include (1) cost models for selected route choice, (2) macroscopic pedestrian operations, and (3) microscopic behavior. A variety of mathematical and computational techniques have been used in studying aspects of pedestrian behavior, including regression models, queuing models that describe pedestrian movement from one node to another, macroscopic models that make use of Boltzmann-like equations, and microscopic approaches. Microscopic approaches include social force models and cellular automata models. The 'social force' models can involve ad hoc analogies to physical forces. For example, a floor may be viewed as having a 'repulsive' or 'attractive' force, depending on the amount of previous pedestrian traffic. Cellular automata models are based on pedestrian walking rules that have been gleaned from observations, such as those developed from Blue and Adler [2000].

Entities that constitute 'pedestrians' have undergone some development. Still [2000] includes additional rules on his cellular automata 'agents' in his modeling of crowd flow in stadiums and concourses. The agents in 'El Botellon' [Rowe and Gomez, 2003] have a 'bottle and conversation' tropism which was inspired by social phenomenon of

crowds of people “wandering the streets in search of a party”. This work modeled city squares as a set of nodes in a graph. Agents on a square acquire a probability of moving to another square; this probability lessens if there are other agents or a bar in the agent’s current square.

We are interested in agents that are more reflective of ‘real people’ who are pedestrians in an urban area, with goals that reflect the reason for their presence in the city. In the course of their trip to the urban area, a fire (or some other crisis) occurs. With such agents, there is no single original goal location. While some of the pedestrians want to keep as far away from the fire as possible, others might be assessing their personal business needs versus their safety needs. Their different considerations and responses should reflect their personalities, beliefs, and logical assessments.

We adopt a software agent approach to the modeling of pedestrian agents in crowds. The pedestrian agents that we have developed incorporate cognitive and locomotive abilities, and have personality and emotion. The locomotive abilities are based on a translation of the Blue and Adler [2000] cellular automata rules into a software agent framework. Our model utilizes the OCC appraisal model which allows for emotional effects in decision making. Note that our emotion list involves a slight extension from those of the OCC list. Our pedestrian software agent design also includes a belief structure into each agent that is consistent with their personality. The Five Factor personality model [Digman, 1990] provides the framework. These affective features are integrated into the agent’s cognitive processes.

Such a pedestrian software agent is hybrid in the sense that it also has physical locomotion ability. We note that coupling of psychological models with individual pedestrian agents in order to investigate crowd behavior is relatively new. In addition to our work, reported upon here and in Lyell and Becker [2005], we note the work of Pelechano and colleagues [2005]. In their work, they couple previous work on behavior representation and performance moderators with a social force model

We also include police officer agents as part of the simulation framework. These officer agents do not incorporate a psychological / emotional framework. Rather, they encapsulate rules that reflect their training and characteristics ; however, they do have the locomotive capabilities consistent with the other pedestrian agent types. The pedestrian software agents are hosted in an agent-based development and execution environment. After an initial prototype effort, we are in the process of developing a simulation framework in which to host pedestrian software agents; this will facilitate studies of pedestrian agent crowds.

The paper is organized as follows. Section 2 discusses our earlier work and results from the prototype effort. Section 3 discusses our current effort on the simulation framework.

1.2. Early Work: The Prototype Effort

The focus of the prototype effort was three-fold: (1) incorporate both personality and emotion and locomotion frameworks into a pedestrian agent model, (2) conduct validation studies, and (3) conduct initial crowd simulation experiments. We briefly report on results in this section. Further details are found in Lyell and Becker [2005].

1.2.1. Pedestrian Agents, Personality Caricatures, Goals and Locomotion

For the initial effort, we considered three personality types, two of which were caricatures, for use in pedestrian agents. An excessively, extremely fearful (neurotic) personality, an excessively open, extremely curious personality, and an agreeable, social personality were utilized. Both the curious and the fearful (neurotic) personalities were designed to be caricatures.

Each of the agent personality types was supported by an emotion set and a goal set. The goal set included higher level goals, such as “seek safety” or “attend to business goal”. Not each personality type had the same goal set; the caricature personalities each had a sub-set of the possible goals. For example, an extremely fearful pedestrian did not have the “seek safety compassionately” goal as part of its possible goal set.

Concrete actions that could be taken in support of a selected goal were (a) attempted movement to a new (calculated, specified) location and (b) message sending to another pedestrian agent (or agents). Actual movement to a new location utilized the walking rules from Blue and Adler [2000] that had been re-cast into an agent framework.

1.2.2. Verification and Validation Efforts

From the CMU Software Engineering Institute’s web site [CMU-SEI 2006], verification asks “did you build the product right” (meet specs) and validation asks “did you build the right product”. For the verification effort, we “turned off” the cognition in the pedestrian agents and recovered the walking behavior that was found from the Blue and Adler studies [2000]. One aspect, that of spontaneous lane formation of pedestrians moving in the same direction, is shown in Figure 1. This is an example of emergent behavior.

Additionally in verification effort, we also investigated separately the behavior of each of the three agent personality types, and found that they exhibited their expected behavior. Figure 2 shows this for the extremely curious agent type.

The validation effort was in the early work provided by a ‘reasonableness’ check on the results. The next sub-section presents results for one of the initial investigations.

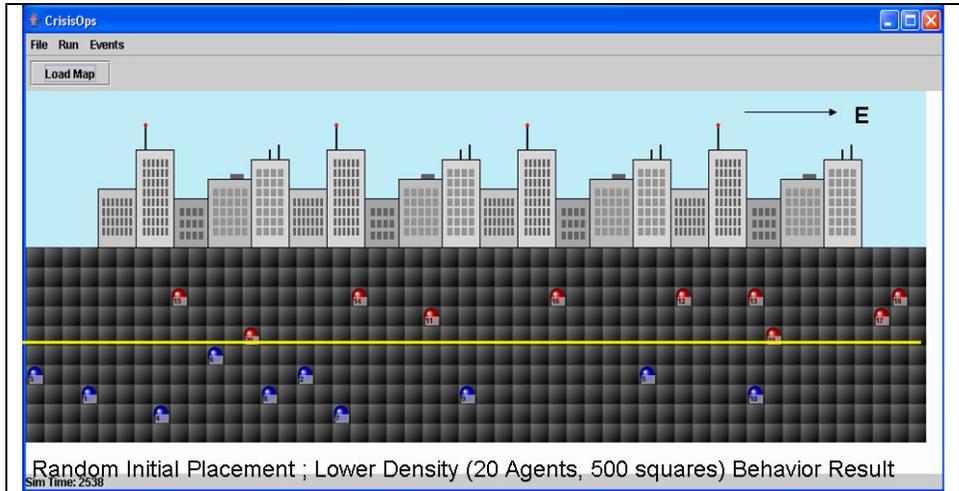


Figure 1: Spontaneous Lane Formation. Westward (red dots) moving pedestrians and eastward (blue dots) moving pedestrians separate into lanes. Not only is there lane formation, the entire westward flow has a sharp boundary from the eastward moving pedestrian flow.

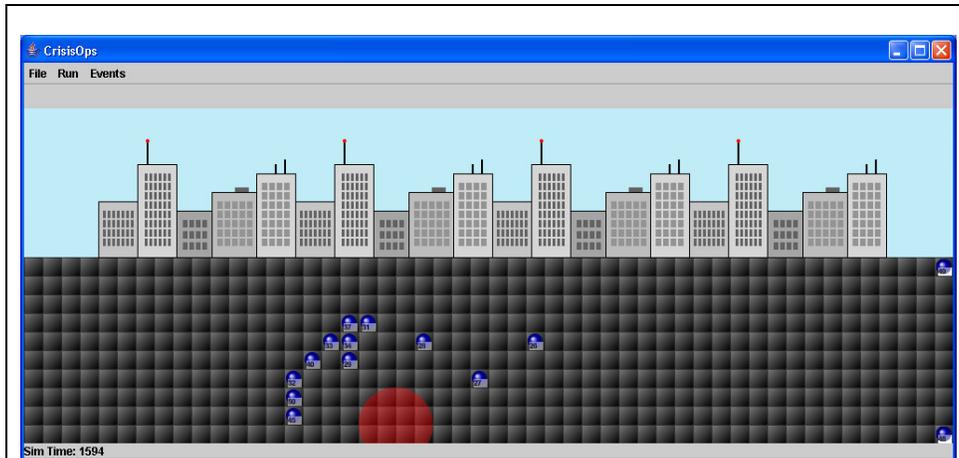
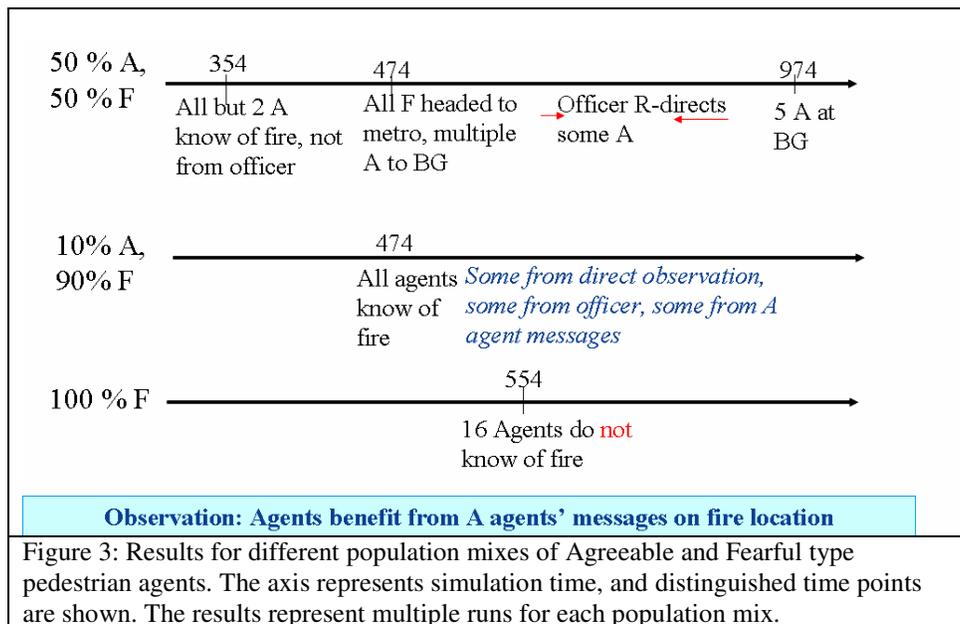


Figure 1: Extremely Curious Pedestrian Agent Behavior : “learning about a fire means viewing a fire”. The agents that are found at the goal sites (right hand side) are those that had traveled past the location before the fire had erupted.

1.2.3. Initial Investigations

We investigated several similar scenarios, each involving different pedestrian agent population mixes and different fire locations. Here, we present the result of one investigation, shown in Figure 3. For each of these initial investigations, the following characteristics held:

- Fearful Agent
 - If learns of fire, will seek safety
 - Never pro-actively helpful with ‘fire exists’ messages
 - Will infrequently respond to direct questions from other agents
- Social/ Agreeable Agents
 - Most complex emotional range
 - Proactively helpful – send ‘fire exists’ messages to nearby agents
- Officer in all cases, moves towards fire, orbits fire, redirects adjacent pedestrians
 - All agent types obey police officer directive to leave area
- City Area Description
 - City Grid 10 cells high, 50 cells wide
 - Agents enter left at metro
 - Business Goals at upper and lower city edge (right)
 - Fire Radius 2, Fire Appears at SimTime 200



1.3. Framework for Simulation of Pedestrian Agent Crowds

1.3.1. Why a Framework?

Among the drawbacks of the initial effort were:

- goal selection (dependent upon the environmental state, the emotional state of the agent, and on the agent's history) was restricted to a single goal,
- caricatures were used for two of the pedestrian agent personality types,
- the developed pedestrian agents were not 'tune-able',
- the urban geometry was too simple,
- it was difficult to simulate 'excursions' on the primary scenario,
- much of the simulation particulars were hard-coded rather than selectable.

A motivation for the development of a simulation framework that allows the study of pedestrian crowds in an urban area with a crisis situation is to enable simulation studies for which the user/analyst does not have to engage in software development. Multiple agent personality types should be provided for use in simulation variations. The urban area design should be configurable. In our current simulation infrastructure development effort, the goal is to support the user/ analyst in devising, executing and analyzing simulations in the domain of pedestrian crowd modeling in an urban environment through the use of simulation framework services. In particular, the user/ analyst will be able to

- develop the geometry of the urban area using a template,
- develop realistic pedestrian agent personalities using templates,
- assign resources to the scenario. The resources include police officer agents.
- construct variations of the scenario, for different simulation investigations.

The variations may include: (a) utilization of different resources (objects or police officers), utilization of different pedestrian population mixes, (c) different densities of pedestrians in the city area, (d) variations in the details of the city area (geometry, buildings, etc.). Of course, all of the simulation variations must be within the scope of "pedestrian agent crowds in crisis, with police officers".

We are in the process of developing a software framework for simulating pedestrian agent crowds in an urban area. The control functionality for the crisis situation may be provided by the police officer agents and their interactions. The major framework elements are shown graphically in Figure 4. These include the aforementioned templates as well as the simulation application (simulation engine), which is layered over the Cybele agent platform. Note that there is an open source version of Cybele [CYB 2006]. Rule engine support for pedestrian agent emotional change and goal selection rules (developed using the agent builder template) is also provided.

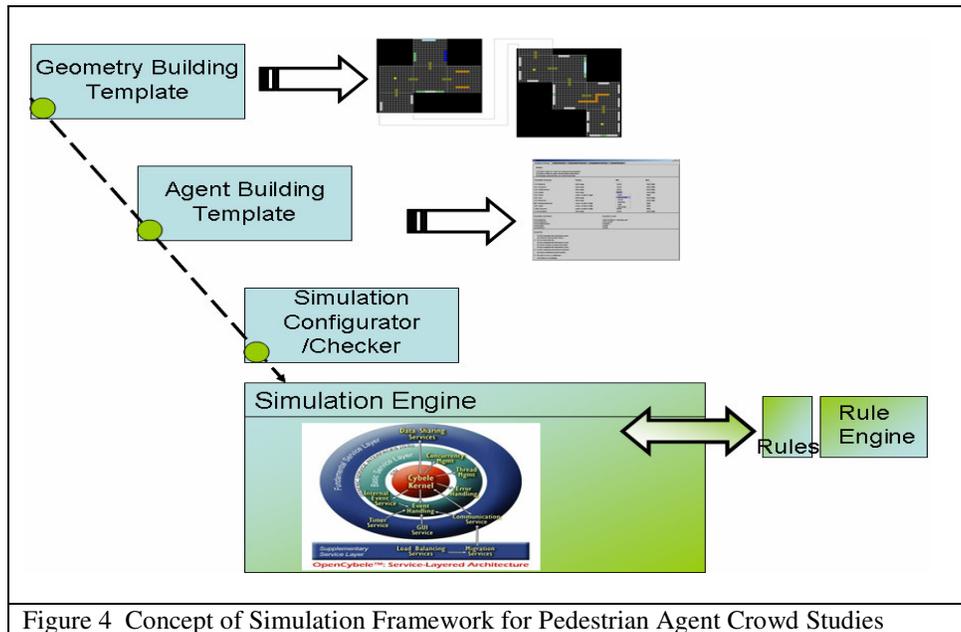


Figure 4 Concept of Simulation Framework for Pedestrian Agent Crowd Studies

1.3.2. Agent Builder Templates for the User / Analyst

One of our challenges has been to develop specific pedestrian agent personalities in such a manner that the personalities are ‘tune-able’, within reason. Guidelines on the extent that parameters may be varied are provided by the template. The psychological framework for the ‘real personality’ agents that underlies the agent builder template had to be developed; details are given in Lyell, Kambe-Gelke and Flo [2006].

The agent builder template presents to the user the aspects of an agent’s beliefs, its allowable emotion set and range for each emotion, and initial emotional status. The emotion elicitors are presented in the context of situations that can occur for this simulation there. The user has the ability to develop rules for goal selection. Rule development is guided by the template. A rule for goal selection involves a situation, with a given context element, and the presence of emotions specified within a range. Lists of allowable situations, contexts, and emotions are presented to the user for potential selection.

The variable elements of the template provide the ‘tune-able’ range for the particular agent personality. The fixed elements have been developed for each of six pedestrian agent personality types that are offered by the agent builder template: (1) Social (2) Egocentric, (3) Troublemaker, (4) Complainer, (5) Good and (6) Generic. Each of these types is consistent with the Five Factor personality model; each of their emotions and responses are consistent with the OCC model.

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