A Layered Communication Model for Agents in Virtual Crowds

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Abstract

Creating realistic virtual crowds consisting of autonomous agents that display different behavioral characteristics is a challenge in crowd simulation. This work is based on the intuition that modeling inter-agent communication can improve the sense of realism for both individual agents and the crowd. This paper summarizes issues related to development of a communication model for virtual crowds and provides some experimental results.

Keywords: virtual crowd, communication model, crowd simulation, agent communication

1 Introduction

Crowd simulation research efforts have traditionally been focusing on achieving real-time simulation and/or realistic individual behaviors [1]. Various recent works in crowd simulation target a real-time and realistic animation in which individual behaviors differ [2, 3].

An observation which forms the basis of our research, is that real crowds communicate. For example, people evacuating a building talk to each other or read signs. In general, it is possible to say that whether communication takes place or not, and the exchanged information when it does, can affect the decision of an agent. Therefore, we believe that communication is an important concept if the aim is achieving realistic behavior in virtual crowd simulation.

The primary aim of our research is to model communication and study its effects in virtually simulated crowds. In order to do so, we built a virtual crowd simulation framework. Within this framework, a layered communication model is implemented. It is important that we consider a limited definition for communication which is inter-agent, deliberate exchange of information.

2 Related Work

There are two extensive surveys about virtual crowds: Pelechano et al. [1] and Thalmann et al. [4]. One approach to achieve heterogeneity in a virtual crowd is to use physiological and psychological models [2]. The common aim in the field is to improve the realism of the crowd without introducing too much complexity.

Shannon and Weaver developed one of the earliest models of communication [5]. There are, in general, eight major components to this model and its derivations, which are often referred to as transmission models. These components are: Source, Message, Transmitter, Signal, Channel (Carrier), Noise, Receiver, and Destination. Transmission models have the advantage that they are simple, general, and quantifiable. However, these models are far from adequate to model real-world human communications [6].

An interesting model was developed by Schramm during mid 50s [7]. In some sense, Schramm's model tries to incorporate human behavior in communication process. There are two major additions to Shannon and Weaver's model: *feedback*; and *field of experience (FoE)* which represents a communicator's beliefs, values, and experiences as well as learned meanings both as an individual or part of a group.

There are several works that consider communication related issues for computer controlled agents and/or crowds made up of such agents. Sun et al. [8] present a framework for distributing conversations among a virtual crowd. The three part system (CAROSA + HiDAC + MACES) in [1] includes implementation of a simple communication facility between agents.

There are many efforts on modeling human conversation which can be collectively grouped under the field called Embodied Conversational Agents (ECAs). Researchers of ECAs try to address all visible aspects of conversation because the main aim is generally to develop computer controlled agents that can carry out a conversation directly with a human. However, this group of literature is not directly related to our work because of our wish to concentrate on exchange of information in a crowd and its effects on behaviors. We did not come across any work with similar intentions; to the best of our knowledge, our work is original in this respect.

3 Simulation Framework and Communication Model

We initially tested our model with a building evacuation scenario. The environment is represented as a Cell-Portal Graph (CPG) [1]. A two-level agent navigation capability was implemented. The high-level (global) navigation consists of a CPG search to determine a path from current cell to the goal cell. The path produced by the search is converted to a list of intermediate target locations. Then, the low-level (local) navigation uses a navigation mesh for the agent to reach next intermediate target without colliding with other agents. In addition, each agent has a number of physiological (preferred speed, etc.) and psychological attributes (traits in OCEAN personality model), and memory (a personal CPG, a list of known hazards, and another list for recent communications).

Layer	Function
3. FoE	Encoding & decoding w.r.t. agent's FoE
2. N-logue	Controls dialogues (or multi-logues)
1. Audiovisual	Perceiving or producing of auditory or visual signals

Table 1: Layered communication architecture

3.1 *Layered Communication Model*

We target designing a model by integrating two particular features of Schramm's model, namely, *feedback* and *FoE* to a transmission model. A layered architecture organizes and simplifies the design. Table 1 shows the architecture we employ. Agents are likely to have different reasons for communicating in different scenarios. One of the advantages for this architecture is that the highest level communication intentions are abstracted away from the lower level communication facilities. It will be easy to introduce new message types at the top layers as they are needed by new scenarios. We tried to keep the numbers of layers as low as possible. But, this design is not taken as complete or final.

Audiovisual Layer: The main responsibility of this layer is to put messages passed from the N-logue layer in a form to be transmitted and transmit it (and vice versa). This layer represents human-like signal sending and receiving, but, modeling realistic human-like agent perception and expression (the issue driving the field of ECAs) is not a contribution of our work. Therefore, this layer is implemented by simple method calls for message passing.

The interfaces between layers take the data packet of the layer above, and all necessary information is embedded in these packets. If the communication is directed to a specific agent, then first, Audiovisual layer tries to locate that agent. Whether the message can be sent depends on the relative positions of sender and receiver and orientation of the receiver.

N-logue Layer: This layer is responsible for slightly higher level tasks about maintenance of a dialog (or multilog). It controls initiation, continuation, and finalization of dialogs. One specific task here is to determine if the intended communication initiates a new dialog. When a new dialog is to be initiated, this layer sends extra messages to establish the dialog before sending the message from FoE layer. Otherwise, the message is to be sent in an existing dialog. This time, the status of the dialog is checked and the message is sent when it is this agent's turn. Hence, this layer also keeps track of the status of the dialogue and turn taking. Completion of dialogs needs additional messaging as well.

FoE Layer: This topmost layer represents encoding/decoding tasks and stands for the second feature in Schramm's model. In Schramm's model, encoding/decoding happens with respect to a communicator's FoE. It is the FoE layer's job to transform a communicative intent into a message (or vice versa) w.r.t. the state of the agent. There can be various communicative intentions in different scenarios. Hence, his layer will evolve as new scenarios are used.

3.2 Implementation

`Message` is the most general message type. Together with its subtypes, it facilitates seven message types: UNKNOWN, DIRECTION_REQ, NEXT_ROOM, PATH, CHAT, FAILURE, and HAZARD. A DIRECTION_REQ message is sent when an agent asks about directions. On receiving this message, the obvious response is to try calculating a path to target. But, before doing so, a probabilistic check to ignore the request is done. This is one of two points where agent personality affects communication (The other one will be explained in the next section). The more introvert the agent is, the more likely s/he is to directly respond negatively. If agent does not respond negatively, then s/he tries to calculate a path. If a path can be calculated, a NEXT_ROOM message is sent back. This symbolizes a person directing another to the next room s/he should go to. When the agent cannot calculate a path, a FAILURE message is sent.

The N-logue layer uses an `NloguePacketType` attribute which can be INIT_REQ, INIT_ACK, CONTENT, FINAL_REQ, or FINAL_ACK. Also, the primary data structure in N-logue layer keeps track of dialogs in progress and their statuses (INITIALIZING, IN_PROGRESS, FINALIZING).

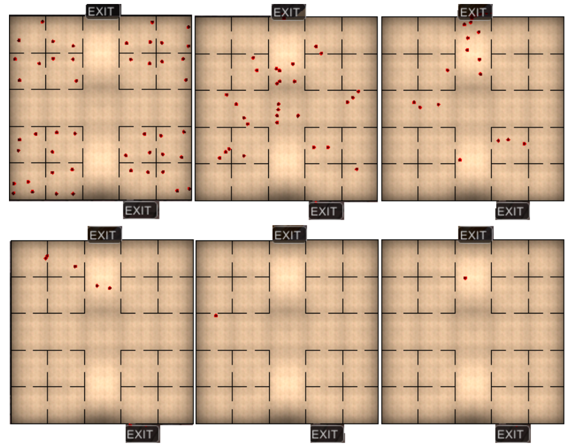

Figure 1: Intermediate frames (1, 91, 181, 271, 361 and 451 left to right, top to bottom) from the simulation. No events. Agents have same average personality.

4 Results

We simulated a building evacuation scenario with 47 virtual agents and with three different settings. Agents can evacuate the building through two doors. None of the agents know the full layout. An agent's CPG includes the room (cell) they are in and rooms that are 1-adjacent to that room. Evacuation behavior is as follows: If an agent can find a path on its own, then s/he follows that path. Otherwise, if there are other agents nearby, a probability that depends on the personality of the agent is calculated. This is the second point where personality affects communication. The agent decides to ask for directions depending on this probability. The more extrovert an agent is, the more likely s/he is to ask. If the agent prefers not to communicate or if others cannot direct her/him, s/he explores the environment improving its CPG in the process.

In the first simulation run, agent personalities are not varied, i.e., all agents have the same medium personality parameters. There are no specific events occurring (Figure 1). Because it is not possible to demonstrate the communications taking place over the course of the simulation with few images, we provided only a top down view in Figures 1 and 2 to demonstrate path planning and evacuation behaviors. The video accompanying this paper shows the communication behavior more clearly.

To be able to show the effect of fully au-

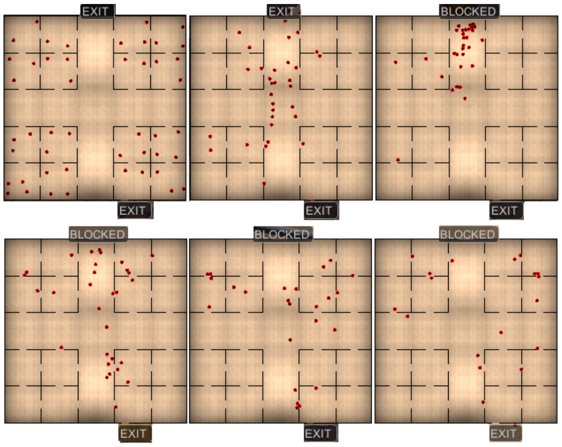

Figure 2: Intermediate frames (1, 91, 181, 271, 361 and 451 left to right, top to bottom) from the simulation. Main door becomes unusable after 20 seconds. Agents have same average personality.

tonomous communication capabilities of agents, the second simulation involves a hazardous event. The main door of the building malfunctions 20 seconds into the simulation so that it cannot be used by agents afterwards. Everything else is the same as the first simulation (Figure 2).

In order to show the effect of personality on communication, the last simulation is run with varying agent personalities. The female characters are assigned extrovert personalities (0.9 in the scale $[-1, 1]$) whereas male characters are assigned introvert personalities (-0.9 in the scale $[-1, 1]$) (cf. accompanying video). Everything else is the same as the second simulation.

The video for the second simulation demonstrates that when the main door becomes unusable, the agents who were targeting this door autonomously begin to form a discussion group. They share information about a new exit route and each individual leaves the group to execute its own plan. When personalities are varied between female and male characters, it is observed that the females tend to communicate more, whereas males appear to be eager to leave the discussion group quickly.

These results should be considered as examples demonstrating usage of our communication model. The model can further be improved with additional message types and/or combined with more advanced autonomous agents. The communication model can be applied to different scenarios which will show its usefulness when agents have other reasons to communicate. We believe that making use of such communication models can create an improved sense of autonomy for agents and heterogenity for the crowd in viewer's eyes, and hence, can improve the realism of the simulated crowd.

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