Agent-based Crowd Simulation Tool For Theme Park Environments

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Abstract

Walt Disney Imagineering Research and Development is developing a 3-D agent-based crowd simulation tool for collaboration amongst designers, engineers and operations managers. The autonomous agents in our tool model the realistic behaviors of theme park guests with non-goal driven decision-making, and dynamic queuing, crowding, and grouping behaviors. Agents are based on the same universal logic. However, unique agent behaviors emerge from the variation in parameter settings for population type, personality, and feelings. Validation methods based on visual comparisons and real world data are being used to build and refine the tool.

Keywords: crowd simulation, autonomous agents, human behavior, group behavior, architectural modeling

1. Introduction

Planning for and managing crowds is critical to successful theme park design and operation. Crowding behaviors are greatly impacted by how an environment is setup. Different stakeholders involved in a project's design (designers, engineers, and operators) find it challenging to reconcile what are often conflicting goals between the creative intent and the capacity and operating requirements. A tool for simulating and visualizing guest flow will facilitate collaboration amongst these stakeholders. Simulation tools that enable designers and operators congruently to explore and test multiple configurations before committing the resources to change the physical environment will ensure success and allow the most effective use of construction spending.

Several types of crowd simulation tools have been developed. The most promising for theme park application are based on autonomous agents. Autonomous agents perceive a virtual environment, analyze it, make decisions based on a predefined set of rules, and behave accordingly. Crowd patterns emerge from the combined results of many independent agents operating in the same environment. The models we have researched to date have varying limitations and do not provide the desired range of flexibility for our applications.

Computer engineers are using agent-based simulations to design crowd scenes for movies. They use Massive Software to create compelling and effective displays of crowds, however this type of tool does not aid in analyzing crowd behavior. In addition, at the time we evaluated this solution, simulation time was unrealistic and the ability for agents to communicate was too limited.

In other agent-based models designed for visualizing historical events, agent behavior actions are driven by character location and agents are only able to react to one single point of stimuli at a time [1]. In theme parks environments, multiple stimuli can simultaneously drive guest behaviors. The other challenge with using this model is agent-to-agent interaction is limited.

A simulation of the Pennsylvania Station used a more advanced decision flow chart [2]. With this type of approach, adding new behaviors and updating the decision logic becomes challenging as the number of different stimuli increase.

Many of the available agent-based tools are geared towards modeling emergency egress situations [3]. These models are primarily setup to simulate reactive behaviors in extreme situations and cannot easily be adapted to model desire-driven decision-making.

Different from these methods, we are creating a tool to simulate in real-time, multiple, complex, and realistic non goal-driven crowd behaviors for any given theme park environment. Agents will make decisions based on their personality and surroundings, have the ability to interact with other agents, to queue, crowd and navigate in families.

2. Tool overview

Autodesk Maya was chosen as the platform to build and run the simulations, as it is the current tool used by Disney designers and architects to create and visualize their concepts. The tool is being developed with SpirOps (www.spirops.com), a Private Scientific Research Lab focused on Artificial Intelligence. Behaviors are defined using the SpirOps AI Editor, an editor primarily used for developing video game non-player character behaviors. SpirOps is modifying the editor and adding functionality to meet our needs. They are also implementing the Maya plug-ins used to initialize the simulation. The tool, currently in development, includes four main components: a universal agent, an environment editor, a simulation window, and a scripting language layer.

2.1. Universal agent

The universal agent represents any guest or cast member in the theme park. The logic portion of the construct, the "brains," is the same for all agents. Variations in behavior emerge by varying values in the parameters representing the population type (e.g. age, sex), personality (e.g. shyness, curiosity) and feelings (e.g. hunger, sleepiness). Agents can queue, crowd and stay in groups. The universal agent, represented by a simple walking 3D figure, can perceive objects in the environment within a certain radius.

2.2. Environment Editor

The environment editor is a series of Maya plug-ins that provide the ability to populate the scene and tag different elements of the environment. The tags allow the agent to identify the environment (e.g. attraction entrance, food cart). The editor also allows the user to define the information that will be recorded as an output of the simulation. Any variable (attribute, perception, or logic information) can be recorded during the simulation and used for the concept analysis.

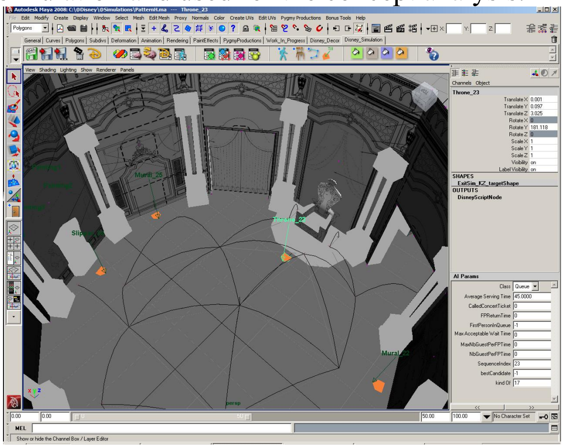

Figure 1: Tool interface

2.3. Simulation window

A real-time OpenGL rendering window displays the simulation animation and provides basic user interaction to edit and view data as the simulation is running.

2.4. Scripting language layer

The scripting language allows the end-user to add a layer of logic to the simulation and to toggle tags on and off given certain events. For example, an additional register should be opened when the lines become too long.

3. Agent structure

Primary work to date has been to develop and validate the behavior of the universal agent. The model integrates the five layers described by Allen Newell in Unified Theories of Cognition: biomechanical, reactive, cognitive, rational, and social [4]. The main focus has been on studying and developing the decision-making and social behaviors of the universal agents.

Agent Design	Layers of Cognition
Queuing, crowding, grouping	Social
Decision-making: Opportunity	Rational
Decision-making: Motivation	Cognitive
Collision avoidance	Reactive
Mesh and Animation	Biomechanical

Figure 2: Correspondence between the layers of cognition and the universal agent

3.1. Queuing, Crowding, Grouping Behavior

By observing guest actions, we have identified three main categories of behavioral patterns common to all theme park situations: queuing, crowding, and grouping.

Queuing: A queue forms when a limited number of agents can benefit from an object at once. Agents organize themselves in a certain order to wait for access to the object. Queues can be organized (in orderly lines) or disorganized (crowding in front of an entrance).

Crowding: A crowd forms when many agents are benefiting from an object at once (e.g. watching a concert).

Grouping: Less than 1% of guests visit theme parks alone. The gatherings of families and groups have a major impact on crowd flow [5]. Grouping affects the crowd flow of guests moving from one point to the other and the organization of queuing and crowding.

3.2. Decision-making

Decision-making occurs as agents evaluate their interest (value between 0 and 1) to react to each object they perceive. The motivation of an agent is driven by its population type, personality, and feelings. The opportunity for reaction between the agent and a perceived object is based on the object itself and the agent's relation to the object. The interest for each perceived object is a combination of the motivation and opportunity. The agent makes a decision based on the object that has the highest interest. For example, whether a person goes to a specific churro stand depends on how hungry he is, how long the wait is, and how far he is from the stand.

As an element of the environment, the agent itself can also decide to react solely on its feelings. For example, a person will stop and rest if he is too tired.

3.3. Collision Avoidance

Based on its decision, the agent adopts the appropriate response and social behavior. Combining the results of a path-finding algorithm (based on a pre-calculated path-finding mesh) with collision avoidance behaviors, both developed by SpirOps, the agent moves in the appropriate direction.

4. Development and validation

Our agent-based simulation tool is developed to the point where we can run specific models and are ready to begin validation using real theme park data. Running test cases will help confirm the accuracy of the agent brains. The agents' behaviors will be completed and refined through this iterative process.

Initial validation of the emergent crowd pattern will be through visual comparisons to observations. Each behavior independently and/or combined should produce realistic looking crowd flow and social behavior patterns where agents navigate as real humans.

Figure 3: Simulation visualization of Rock 'n' Roller Coaster

Density maps are created with the output of the simulation to help with the visual validation.

Figure 4: Density map of restaurant simulation

Once the simulation visually appears plausible, data from real world scenarios is compared with the results of the simulation. Data comparisons for validation include the overall time spent in the system and the throughput of the location.

Industrial engineers at Disney administer surveys, and observe and count guests in the theme parks to produce annual summaries for different design standard categories (e.g. guest demographics, group size distribution, service times, wait times). This provides the primary information required to initialize the models. Additional data is collected as needed.

Throughout the development, theme park engineers and designers provide direct feedback on the usability and functionality of the tool. The project we are currently simulating is a new attraction for Tokyo Disneyland. Since it is new, there is no current data to refine the behaviors. Therefore, a model of a similar attraction will be constructed and used to validate and refine the agent behaviors. The brains will be transposed to the model of the new attraction, and an in-park test will be conducted to further validate the accuracy of the predictive model. Once the predictive model has been validated, we will run the scenarios being considered for the new attraction to identify the most optimal setup to deliver the creative intent and the required throughput.

The personality, feelings, and behaviors of the agent population are initialized, validated and adjusted based on real world data in a given environment. Therefore, even using visual and data comparisons of current environments, the ability to accurately predict models in new settings is uncertain. Results can be biased on inaccurate relationships between the environment and people's behaviors. For example, a person's interest level for salads at a specific location can appear artificially low if it is driven by the lack of visibility to the salad versus the lack of desire for salads. Using only real world data comparisons may not be sufficient to validate and refine the agent "brains". The tool will benefit as additional validation methods are explored.

5. Conclusion and future research

We believe our tool will provide a robust and valuable method for designers and engineers to plan for and manage crowds within existing and new experiences. Designer and engineer feedback on the usability and functionality of the tool has been positive. Our next step is to complete validation by data comparison (e.g. throughput data, time spent in the different areas of the environment) with a model of an environment similar to the one we want to predict. We will also explore additional validation methods.

The project will also benefit as we integrate more realistic perception features (e.g. vision, hearing) that take into account the interpretation of the environment. The agent should identify when and how much of an object is seen and/or heard and how to interpret the stimuli. The agent's perception can also provide valuable data to inform the design. For example, a restaurant design study using a simple vision system revealed the lack of visibility to the food signs to be the root cause of the queuing chaos.

Cultural differences are another component of human behavior to study. People from different cultures react differently to the same stimuli and have different social organization behaviors. Therefore, incorporating the impact of culture into the tool will be an important addition for modeling projects in Disney's international theme parks.

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