Semantic Modeling of Reusable Crowd Entities for Virtual Worlds

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Abstract

Extensive behavioral models, advanced motion planning algorithms, and remarkable physics systems have all contributed to the recent success of crowd simulation. Due to the fact that many crowd simulation solutions are tailored toward just certain settings and situations, several specialized tools and techniques have arisen. Challenging to alter for new use. In order to effectively use this solution across a wide range of situations, virtual environments, and interactions with the entities present in these settings, a more abstract strategy that prioritizes the reuse and configuration of crowds is required. In this article, we offer semantic crowds, a new method that makes it possible to recycle the same crowds for almost any setting and have them make meaningful use of the objects there without any adaptations. Minimizing the agents' knowledge of what items do and how to utilize them allows them to interact independently in any virtual environment. This data is instead embedded in the objects themselves and queried by the agents in accordance with their goals.

1. Introduction

Games and simulation systems for training and education are only two examples of the growing importance of real-time crowd simulation. Both casual and serious video games will come under fire if they depict deserted or sparsely inhabited towns or other settings. Crowd simulation has come a long way in recent years, with improved realism achieved via the use of sophisticated behavioral models, intricate motion planning algorithms, and amazing physics systems. These advancements aren't without their drawbacks; however, since most crowd simulation methods are either too general and abstract, or too specialized and 'hard-wired,' focusing on just a small subset of possible environments and situations. The former is more likely to produce rote, "canned" behavior, whereas the second produces ad hoc, specialized groups that are only useful in very specific contexts. In both situations, there is a plethora of unique approaches and tools at our disposal, making it challenging to adapt them to new circumstances.

A new strategy, one that emphasizes community definition, configuration, and reuse, is needed to avoid these problems. Semantic crowds is a method we suggest in this article that makes it possible to

Define and reuse the same crowds for nearly any environment, allowing them to make meaningful use of whatever objects are there in that environment without any adaptations. We suggest that crowd profiles need to transcend beyond basic geometry to include semantics if they are to be effectively used in a wide range of situations and virtual settings. Semantics is the study of meaning in language, computing, and psychology. Signification in spoken exchanges. The study of the meaning of virtual worlds and the entities inside them is known as virtual world semantics. [1]. Entities, in this sense, include everything and everything that possibly exist in a given universe. Therefore, entities in semantic virtual worlds 'know' not just their physical properties and construction, but also their qualities, roles, functions, services, etc. They may greatly enhance the quality and diversity of player or crowd-sourced agent interactions with an avatar [2].

We reduce the amount of data in the agents about what things do and how to utilize them so that the agents in a semantic crowd may interact credibly and autonomously in any virtual environment. Instead, the objects themselves serve as data repositories, which agents may access depending on their specific goals. We combine a number of previously published ideas, findings, and techniques for specifying crowd and agent behavior. The most interesting aspect of our approach is that once defined, the same crowd may be deployed to any number of virtual settings, and the agents inside it will always show believable but highly varied behaviors without requiring any re-wiring on the part of the developers. That is to say, we are essentially reusing such crowds. The paper will proceed as described below. We begin with a literature review on the topic of virtual crowd and environment specification. (Section 2). Next, we expand on the fundamentals of semantics, focusing on its role in defining populations and ecosystems. (Section 3). Then, in Section 4, we present the demographic and agent ideas important to the semantic crowd model, and we detail the key components of our prototype system, such as the crowd editor, which gives high-level editing options for constructing crowd profiles. (Section 5). In the last section, we make some conclusions about the potential and adaptability of semantic crowds via the use of two illustrative examples. (Section 7).

2. Related Work

In this chapter, we take a look back at some of the research done on how to best depict and generate digital crowds and settings.

Virtual Environments

Not only can virtual worlds store geometric data, but also data about things, such as what they can do and how agents may interact with them. Common terms for a VE that provides such data include "Intelligent Virtual Environment" [3], "Informed Environment" [4], and "Semantic Virtual Environment." Natural setting [5]. The concept of virtual environments suited for behavioral animations is proposed by Thomas and Domitian [6]. With this information, AI-controlled virtual characters may simulate human activities in a city, such as walking or driving a vehicle. Badawi and Donikian [7] offer an informed environment based on items that provide a summary of interactions to which they might be exposed via the idea of synoptic objects. The objects may represent the interaction process to any agent employing them using a set of seven fundamental actions. Successfully proposing to provide semantics to virtual objects, "smart objects" [8] dealt with many of the conceivable user interactions in a virtual environment. Those functions, together with animation and strategic planning, are what inspired their creation. Using the semantics and functioning of digital goods inside a VE, Gutierrez, Vexo, and Thalmann [9] offer an object representation. Each item in a VE application is more than just a static 3D geometry; it is a living, breathing organism with a wide range of possible appearances and behaviors. This allows the object's dimensions and capabilities to be dynamically scaled and adapted to suit a variety of contexts. Artificial intelligence studies suggested ontologism to address the problem of inaccessible knowledge repositories [10]. Objects and their relationships to one another are the focus of ontologism. Grimed et al. [11] offer a semantic-based architecture for simulation using this idea to establish a global knowledge base. Of coordinated bodies of mind. Agents may utilize the data to improve interactions with objects and other agents. The attributes of the interactive objects are retrieved and organized using object taxonomy. Likewise, ontologism is used to establish social ties among agents so that they may demonstrate morally sound behavior.

Jiang et al. [12] provide a semantic model consisting of a geometric level, a semantic level, and an application level for expressing multi-layered complex settings. To aid in visualization and to help extract semantic information that will feed the next semantic level, the geometric level stores a 3D representation of the world. Semantic information of an environment may be identified or queried using structural and topologic maps, as well as height maps, which are all part of this level. The topmost layer (the application level) must provide effective communication between humans and their surroundings. They employ a modified version of Treuille et al.'s [13] crowd model in their research.

Crowds

Since the dawn of behavioral animation, scientists have investigated the dynamics of virtual communities. Both agent-based and force-based models are common in the academic literature. The first method takes the form of modeling virtual agents, each of which is capable of independent action and interaction with the others. The secondary force-based models are a technique that allows for more global control and can manage large populations. The results of these techniques more closely resemble particle animation than human animation when applied to crowd simulations. This section provides a summary of the methods currently used to create crowd models.

Two important articles are examples of agents-based model: Tu and Terzopoulos [15] constructed schools of artificial fishes with synthetic vision and environmental sensing, while Reynolds [14] recreated flocks of bird-like creatures, or boids, achieving lifelike motion by utilizing just basic local rules. Both publications solely modeled relatively small groups of people, ignoring the effects of increasing population densities. Another example of agents-based models was offered by Musse and Thalmann [16], who suggested a method with hierarchically structured crowds with varied degrees of autonomy. In this concept, behavior is determined by a set of rules that apply to the data that can be found in groups of people, such as their worldviews, mental states, and goals. Multi-layer agent behavior control using rules and Finite State Machines was introduced by Ulicny and Thalmann [17] in their model for crowd simulation. Farenc et al. [18] provide a paradigm that depicts the cooperation between smart items, intelligent settings, and the digital mob. This paper discusses swarms of simulated individuals whose actions were dictated by inanimate items and who could interpret their surroundings and adapt accordingly. The virtual agents in this example were less independent and more subject to their surrounding conditions. The model described by Abaci et al. [19] describes an enhanced version of smart objects for AI and planning purposes, with an emphasis not on large groups of people but on small groups of virtual agents.

3. Semantics

We provide further detail on the semantics necessary for both virtual environments (3.1) and agents in this section. (3.2).

Semantics for Virtual Environments

Objects in virtual environments are often characterized by their attributes, appearance, and, increasingly, physics. Furthermore, an object may display some fundamental behavior, as described by scripts that might, for instance, dictate how to move, what animation to trigger, or how to interact with other objects. Something else. We created a semantic model that serves as a common information repository for these parts. "A virtual environment populated with entities (either objects or agents) that are enriched with semantics" [25] is how we characterize a semantic gaming world. The uniformity of the world's data is made possible by these semantics. This holds true not just for how something seems on the outside, but also for how it acts on the inside and how it interacts with other things. When more entities act realistically, there are more paths to victory for both players and agents. Assuming these things were defined correctly, agents may enjoy a snack, purchase food from a local store, or place a restaurant order to satiate their hunger, for example. Our semantic paradigm centers on entities (real-world things or locations), the properties of which are represented by attributes. Objects in the real world are made of a certain material, for which we may define a set of characteristics. Such entities allow for the expression of many connections, which may be utilized for things like the automated generation of floor plans [26], room layouts [27], and consistent buildings [28].

Our model's general behavior is described through services, which we define as "the capacity of entities to perform particular actions" [2]. The needs and outcomes of an activity are the building blocks of that action. The action's consequences are established by its effects, but its feasibility is limited by its prerequisites. A vending machine, for instance, might provide a snack in exchange for a coin, which can be consumed to alleviate hunger.

Semantics for Agents

Our absolute has been updated to include the idea of wishes in order to better model the behavior of agents in a semantic gaming environment. The entity's preferred state, or collection of states, is described by absolute wants, and the set of states that fulfills these needs does not change through time. An agent's goal can be to amass ten coins, for instance. In contrast, an entity's relative wants indicate modifications it would like to make to its current condition. When the entity's state changes, the satisfaction states may also shift. When an agent has the desire to, say, "obtain another hat," that want is satisfied regardless of how many hats the agent currently has. Agents may discover actions whose outcomes affect their present wants by querying their (known portion of) the world. Each action's prerequisites may be used to develop a new want, and the wants' potential fulfillment can be explored by identifying more activities. Because an action's results might include a response (the attempted beginning of another action), agents may take into account the activities of other entities in their investigation.

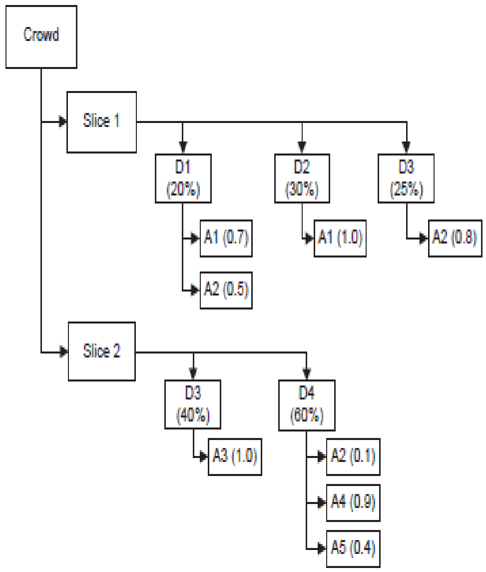


Figure 1: Our agent model's example of a crowd's structure. D denotes the population, whereas A denotes aspirations.

4. Crowds

The crowd and the agent are the two main components of the proposed semantic crowd's strategy. The demographic breakdown and relative abundance of various crowd subgroups are represented in the model. A semantic agent model characterizes the unique actions of each of these groups. After this the crowd model and the semantic agents will each have sections devoted to elaboration.

Crowd Model

The semantic crowd model has two parts—the crowd profile and the crowd socket—that work separately.
Everything about the crowd that is not reliant on its surroundings is described in the crowd profile. The crowd socket sets up everything needed to deploy the crowd in the real world.

Crowd Profile

Our model's demographic profile for a typical user base is discussed below. We start with the agents and work our way up through the ranks of the audience. It's important to remember that according to our definition of crowd; more than one crowd might be at work in any given setting. All of the agents in a given setting are collectively referred to as a population. Commonly used in descriptions of virtual crowds like [29], the term "demographic" refers to a set of agents who have a similar characteristic. What they share depends on the agent model being used. The 'heavy smokers' population, for instance, would include agents who often pause what they're doing in order to light up. At every demography, there is a set of requirements that must be met before an agent may be a part of it; for instance, pickpockets will only emerge at a crowded market. A demographic slice is a demographic description that includes all or almost all of the attendees. In demography, this would be analogous to how agents are spread out in a cross-section of the population. For example, 30% of mall visitors are shopaholics, 40% are grocery shoppers, 16% are impulsive purchasers, 1% is burglars, and the other 12% are just window shoppers. Due to the conditions inherent in the demographics itself, a demographic slice will also include an indication for how to proceed in the event that the demographic is not enabled. In the case of a disabled demography, the slice will be adjusted such that it still covers the same proportion of the audience, or the other demographics will be "enlarged" to fill the void.
A crowd is a set of demographic subgroups plus a "default demographic." An agent may fall into the default demographic if it fits into none of the demographics from the slices; this is because the slices don't have to include everyone in the crowd. A crowd also includes a scattering of agents. There are a few constants that must be present: age (child, adult, or older), gender, and desired movement speed. Additional necessary characteristics may be imposed by the agent model in use. These distributions characterize how qualities are spread out over the population as a whole and are 'overridden' by specific demographics. Figure 1 shows a simplified version of the whole framework of a crowd profile.

Crowd Socket

Some information about the physical surroundings is necessary to locate a crowd, whether or whether it is enhanced with semantics. Next, we talk about how the previously described crowds may be placed in real-world settings using the crowd socket aspect of our crowd model. Details are provided below. Are the basic minimum necessary, and may be expanded to enable additional characteristics of the employed agent model(s). Before a crowd can be added to a scene, the sort of entity that will stand in for the agents must be determined. (E.g. a generic human, a police officer or a car). It is possible to specify the object type for each utilized crowd, since a single environment may house numerous crowd kinds at once. Agent attribute distributions in the crowd and demographics may be used to establish attributes of the 'controlled' entities. The origin (or spawn) locations of the agents in the environment should also be given. Specifying a desired spawn rate and the kind of spawn space for each is required. The crowd socket doesn't need a specification for the opposite kind of space, when the agents exit the environment. Since not all exits must be physical doors, they must be described semantically as acts that cause the agent to leave the current context. The decision was made on the basis that exiting should be an active process rather than a passive one, in which just being in the area marked as "exit" would not indicate that the agent intended to depart. Agents may be prevented from spawning by imposing conditions on the spawn area. If there are fewer than 500 agents in the area, for instance, agents will only spawn when the entrance is open.

Semantic Agents

In this subsection, we'll talk about our agent model, the one that really uses the contextual semantics. We address the worldwide thinking process of our agents in addition to the global structure, which includes a statement of the accompanying kind of demography.

Agent Thought Process

As can be seen in Figure 2, our agents' "thought process" may be conceptualized in broad strokes. The actions shown in this flowchart will only occur if the agent in question is given permission to take them. This whole procedure is bypassed if the agent is performing an activity or if the agent is undergoing a certain set of operations.

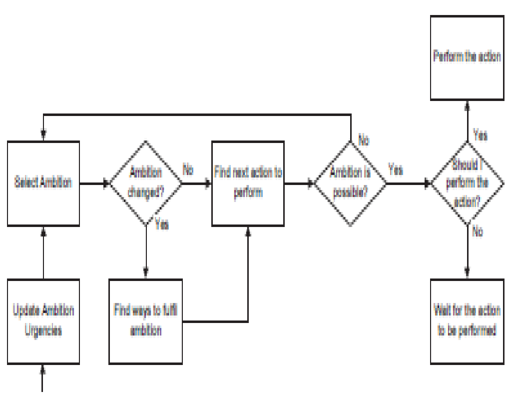


Figure 2: High-level summary of one cycle in the mind of a semantic agent.

Please revise your ambitious needs. The agent first reevaluates all of its present aspirations and chooses those that are viable options. Pick up some ambition. The most pressing goal has been chosen. If the previously chosen aspiration also has a high urgency, the agent may switch to it. The greater the agent's resolve, the greater the disparity between the urgency values may be without the agent switching ambitions.

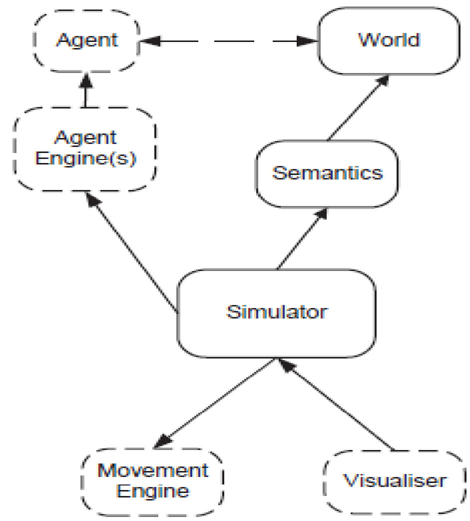


Fig. 3 is a schematic representation of our whole system.

Seek Out Means of Realizing Goals. If the agent's prior desire wasn't the one picked, it will have to figure out how to accomplish its new goal. Its worldview will be questioned by the agent. For entities capable of taking action to fulfill one of its aspirations. Wants for its necessities, and so on, are formed for each of them. When no more potential avenues exist, the search will end.

5. Framework

We've built an interactive editor for the crowd and agent models you saw in the last part. The resultant structure is discussed here. At first, we'll go over the big picture and describe what the system is and how it works. After that, we meet the editors responsible for both of the models.

System Overview

Figure 3 is a schematic representation of our whole system. The items indicated by dashed boxes may be swapped out for modified equivalents. In the next paragraphs, we'll go into further depth about each individual part.

Simulator

The simulator acts as the glue that binds the framework together. Its sole real purpose is to relay information between subsystems and facilitate communication between them. However, the simulation's primary update-loop is located there.

Notifying everyone to check their spawn triggers and see if they need to be updated to add extra agents is the first step. After that, the environment's semantics are brought up to date. After that, the agents' own state is updated, and the location of the agents is updated by requesting a refresh from the movement engine.

Agent Engine(s)

The agent engines handle the agents' updates, making them unique to the agent model in use. In our agent-based paradigm, the engine's main job is to provide update responsibility to individual agents. However, if the agent model necessitates intractable forms of agent-to-agent communication, the corresponding agent engine should manage the semantics. The only thing we've added to our agent engine is the ability to detect behaviors that give agents goals to work toward. The agents themselves could be able to identify this, but that would suggest they are beforehand aware of their own potential goals.

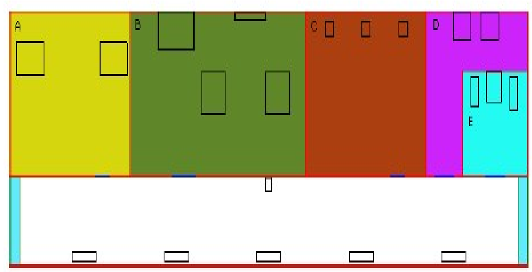
6. Results

Two scenarios have been built and filled by the same group to show the potential and benefits of the suggested technique. The framework is introduced in Section 6.1, and it is then expanded upon in the two scenarios presented in Sections 6.2 and 6.3. The crowd diagram utilized in both cases is introduced in Section 6.1.

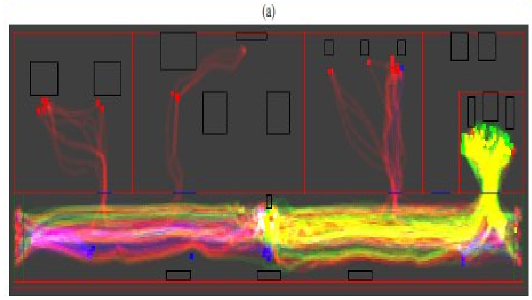
Configuration and Initialization Here, we lay the groundwork by introducing the basic environment, the population that will be utilized throughout the section, and the context-specific parameters that will be used to populate the crowd, as well as the preliminary outcomes of doing so. The Semantics and Organization of the Environment in Section 6.1.1. The setting is meant to evoke the area of an airport just before customs. There are seats for the agents to rest on on one side of the corridor, and a variety of businesses on the other, including a bank (A), hotel (B), café (C), secret chamber with plum trees (D), and arcade hall. (E). There is an ATM built into the lobby's outside wall. Figure 5a depicts one possible floor layout. The left and right sides of the environment serve as entry and departure points for the agents. They may also 'exit' into the hotel, although doing so requires a stay there. The hotel's front desk will accept check-ins using a credit voucher from the bank. Agents need to be registered guests in order to utilize the lobby's comfortable seats. Arcade and coffee shop services need cash, which may be obtained at an automated teller machine or a bank. Plums picked right from the tree are free. Agents have more fun in the arcades, coffee quenches their thirst but makes them use the restroom more often, and eating plums has the opposite effect. Adults and the elderly are the only customers allowed in the bank and café. Congestion Plug. The simplest setup for this setting is as follows. The locations and spawn rates of the spawn areas are defined at the corridor's dead ends. It also defines the unique semantic entity that stands in for the agent. Finally, the number of agents is capped at 50, since any more would quickly produce congestion at the entrances.

Crowd Characteristics

In all of these examples, the same kind of crowd is used. By doing so, we want to demonstrate how the same group of people may be led to behave in strikingly diverse ways when exposed to virtual worlds that have been supplemented with various meanings. To put it another way, changing the agents' surroundings or behaviors does not require "re-programming" them. Gender is evenly distributed among the agents, but the old and young are overrepresented; only around 15% of the agents will be under the age of 18, while the remaining 70% will be of working age. Average walking pace slows with age, yet people of all ages are similarly focused and easily distracted.



(a)



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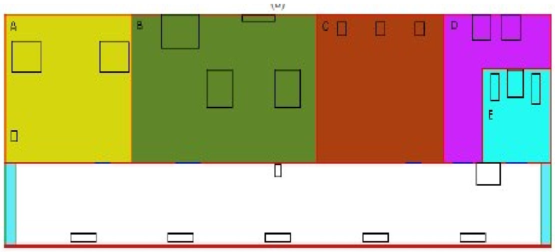

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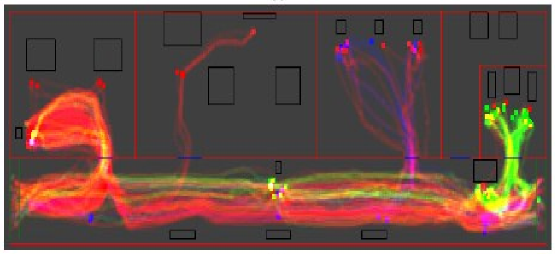
(d)

Figure 5 shows the overall layout as a floor plan (a) and a heat map (b). The heat map (d) and floor layout (c) for Case 1 are shown below. Blue traces represent the elderly, red traces represent adults, and green traces represent children in both heat maps.

Aside from the obvious need to relieve themselves when nature calls, every agent also has a more modest aspiration to depart the surroundings. When the latter occurs, the agent becomes more urgent. Eighty percent of kids are looking for a good time before they go home, while just 10 percent of grownups and zero seniors share that goal. The goal of resting when fatigued is shared by all individuals and the elderly, although the latter tire considerably more quickly. Approximately 75% of the senior citizens and 50% of the adults who visit the area do so in quest of alcoholic beverages, while 50% of the adults who do not want a drink plan to check into a nearby hotel.

Analysis

In Figure 5b, we can see a heat map depicting the simulation of this rudimentary arrangement. The first obvious thing to notice about this map is that the agents aren't eating any of the plums they have access to. However, this is to be anticipated, given the plums have no beneficial impact on the agents' aspirations. There is nothing in the surroundings that may inspire an agent to relieve themselves, hence they never will.

Another overarching fact is that agents will spread out about evenly across the numerous objects providing the same service. As we saw in Section 4.2, agents make decisions about which actions to do depending on the "cost" they anticipate incurring as a result of taking those acts. Since the estimate of projected cost is very simplistic, the item closest to the entrance is not always the one that receives the greatest usage. Several agents can be seen on the heat map sitting on the benches. Only the old agents have used the benches since the typical life span of an agent in the ecosystem is so short. In this instance, the chaise lounges are being underutilized. The lounge chairs are available to any agent who needs a break, but it is much more cost-effective if the agent is already in the check-in process. Agents may avoid the hassle of checking in by just sitting on one of the seats that have been strategically placed throughout the facility. Our brokers focus on a single goal at a time. Agents will prioritize checking into the hotel above getting some rest because of the perceived importance of each task. The coffee shop and the arcade both exhibited similar tendencies. Agents who plan on using both locations will need to withdraw funds from an ATM twice (or visit the bank once) to cover their expenses. But if agents feel they already have enough money to begin meeting their present objective, they will never obtain more. So, the agent may use the ATM to withdraw money before heading to the cafe, and then use it again to withdraw money before heading to the arcade.

7. Conclusions

We presented semantic crowds as a new technique that makes it simple to design crowd templates that can be taken with you and used in almost any setting, where objects are utilized in a natural and meaningful way. To do this, agents probe their surroundings to locate any items that would satisfy its needs. For the purpose of designing crowd templates, we briefly discussed our prototype system, which has an interactive crowd editor with access to high-level editing settings. Finally, we showed how a semantic crowd may change its behavior to fit newly introduced conditions. If you want finer-grained control or more realistic and detailed pathways, you can simply integrate your own bespoke implementations of agent behavior model and motion planner into this crowd reuse modular architecture.

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