AGENTS FOR MULTI-USER VIRTUAL ENVIRONMENT (MUVE)

Selina Lam, Ph.D. Candidate,
Department of Architecture, UC Berkeley;
selinalam@berkeley.edu

Gokce Kinayoglu, Ph.D. Candidate,
Department of Architecture, UC Berkeley;
gokce@berkeley.edu

Seung Wook Kim, Ph.D. Candidate,
Department of Architecture, UC Berkeley;
swkim@berkeley.edu

ABSTRACT: Virtual user simulation has been used to simulate and predict the "average" user's response to built environments. However, autonomous agents are seldom used in gaming environments. This is probably to ensure control over the game narrative. Also, the complexity in defining behavioural patterns tailored for the storyboard and the computing resources required make it difficult to incorporate autonomous agents in game environments. In this paper, we address the implementation of autonomous agents in a multi-user virtual environment designed as a game. Instead of the traditionally-used goals and behavioural rules to govern the behaviours of the agents, we used another mechanism, the switch-nodes. Switch-nodes are location-based triggers to control the behaviours of the agents. The nodes could trigger an action, a series of actions, an animation or a mixture of actions and animations. However, as the node system does not prevent conflicts or unreasonable behaviour in the environment, we experienced some challenges even for a narrow range of behavioural needs. Though so, with proper adjustments, careful planning and some creativity, we are able to achieve a "naturally appealing" behavioural pattern without negatively affecting the performance of the overall gaming environment.

KEYWORDS: agents, virtual user, multi-user virtual environment, autonomous.

1. INTRODUCTION

Virtual user simulation is often used to simulate "average" user's response to built environments. Such programs represent not only the perception and cognitive process used by humans when confronted by an environment, but also the judgmental processes they employed (Kalay 2004). This notion makes virtual user simulation a valuable tool for behaviour simulation in which much variance among inhabitants of a certain environment is expected. Common applications of virtual user simulation for behavioral simulation are focused on the following areas:

- Pedestrian simulation
- Crowd and fire egress simulation

These simulations are often aimed at testing the *Level of Service* — to study and predict how people carry out certain activities, such as walking on walkways and through corridors and doors, under normal or emergency situations. In these simulations, virtual users are embedded with predefined schedules or goals. They would interact with one another and the environment according to predefined behavioural rules. In this sense, the behaviours of the virtual users are autonomous. That is, they will react according to the conditions present in the environment rather than any predefined action schedule. Therefore, goals and behavioural rules have to be carefully defined to represent the "natural" human behavioural patterns of the *real* potential users.

Considering the capabilities of current games in representing "natural" human behaviours, it is surprising that agents are seldom used in gaming environments. In game environments, characters can be broadly defined as players and non-playing characters (NPCs). Behaviours of players are controlled by users while those for NPCs are generally predefined in the game engine. The existence and response of NPCs are triggered by the behaviours of players but are not normally autonomous. For example, in a shooting game, NPCs may only "appear" when a player is near by. They will shoot the player when she is at a certain distance. They will disappear again when the player is away. In fact, completely autonomous agents are seldom used in gaming environments. This is probably due to the necessity to ensure excitement in the gaming experience and to maintain control over the game's difficulty. Anyhow, it will not be fun if all the NPCs start chasing for and shooting at the player right at the beginning of the game. Also, the complexity in defining behavioural patterns tailored for the storyboard and the computing resources required make it difficult to incorporate autonomous agents in the game environment.

In this paper, we will address the implementation of autonomous agents in a multi-user gaming environment. These agents act in response to events around the environment, and have some social properties. Meanwhile, we will also address the solutions of minimizing complexity and computing resources so as to maintain a high level performance of the game itself.

2. BACKGROUND

2.1 Virtual user simulation

Virtual user simulation is employed as an evaluation tool to assess the performance of buildings and environments that have not been built. In that case, the buildings and environments can still be modified if the evaluation shows they are deficient in a way. This predictive approach is based on modelling both the environment and the humans who will use it, and simulating their interrelation "in action" much like electrical and mechanical engineers can "run" their designs to see how they perform under certain conditions. In these simulation models, virtual users (agents) have abilities of perceiving, knowing and responding to the environments they are situated. Such cognitive models for general human spatial behaviour simulations have been developed by Archea (1977), Glaser and Cavallin-Calanche (1999), and Kaplan & Kaplan (1982). They typically use discrete event simulation methods, where a generalized algorithm tracks minute-by-minute changes (Kalay, 2004), geometry-based approaches (Glaser and Cavallin-Calanche, 1999), or neural-nets (O'Neill, 1992). The existing computer simulations of environmental behaviour are focused on pedestrian simulation, and crowd and fire egress simulation.

2.1.1 Pedestrian simulation

Some agent-based models are driven by goals, engaging in obstacle avoidance and interaction with other agents. The agents have plans or schedules giving distinct purpose to their trips that drive them to complete some tasks, such as shopping (Haklay, O'Sullivan et al, 2001; Kerridge, Hine et al, 2001). Some other models are derived from various analogies in fluid dynamics and particle systems and also embracing key ideas from the theory of self-organization. All models emphasize the way pedestrians interact with one another and the environment they walk in. For example, Helbing, Schweitzer et al (1997) developed an active walker model, which responds to the environment as it moves around and also alters that same environment as it moves. The general rules used in these models are walking rules for interpersonal and obstacle avoidance and finding the shortest path to a predefined target. For another example, Helbing, Molnar et al (2001) used rules of shortest path, an individual desired speed, and keeping certain distance from other pedestrians and borders (Batty, 2001).

2.1.2 Crowd and fire egress simulation

Stahl (1982) and Ozel (1993) developed fire egress models, simulating the behaviour in emergency. Ozel's model uses actions (such as "go to exit") and goal modifier libraries (such as "alarm sounds") to define the behavioural rules. These libraries, in turn, use the fire event, the building configuration, and the characteristics of the people as the determinants of their rules.

2.2 Agents in games

Way-finding and fire egress simulations focus on a very narrow range of human behavioural needs, and an even narrower spectrum of environmental attributes. This is because these models are mainly used to test the *Level of Service* and only include the associated behavioural needs and environmental attributes. At the other extreme, human behaviour simulation models developed by the gaming industries neglect the environment and its relationship with the humans that use it. In game environments, players and NPCs usually have only limited interaction with the environment and other humans. Even there is player-NPC interaction; it is often represented by cut-scene videos. Player's and NPC's interaction with the environment is also not well-represented. In "first-person shooter" games, for instance, shooting a piece of wall will not leave permanent damage on it. The piece of wall would be fine again when it is revisited. Also, NPCs will disappear a little after they get killed. They would not affect the movement of other NPCs or players even when they are still lying on the ground.

Moreover, the level of interaction is always associated with the number of NPCs. The more the NPCs, the fewer the interactions. In some games, mass population without specific goals or roles, like spectators in car racing games, are often treated as background images or videos. That is, they are not things that could be interacted with.

On the other hand, NPCs in games are only autonomous in certain limited ways. Fully autonomous NPCs will limit the control of the game in terms of gaming experience and control of difficulty. In soccer games, game players can control team mates when they are close enough. In this sense, the NPCs cannot be fully autonomous. Even when the NPCs are *free,* they will follow certain movement patterns as defined in the game engine so that it is potential for the player to switch control. The game engine indeed acts as a coach to govern the movement of all NPCs in the game environment which individual NPC cannot make decision on its own motion.

2.3 Essentials for agents

The studies on virtual user simulation and games provide us some crucial considerations in the design of agents for our multi-user virtual environment. The central idea is to maintain the "naturalness" of the agents' behaviours while minimizing the computing resources. This is because when the decision making process is distributed to individual agents, the resources required to deal with one decision making is multiplied by the number of agents. If the agents' behaviour is linked to each other's actions, the required processing power increases exponentially with their number. That is, the more the number of agents, the more undesirable effects on the performance (e.g. Rendering speed, response rates and so on). Though computing power is becoming less critical with the advancement of technology, it is not practical to assume users have strong computing power in the designing stage especially when a real-time interactive performance is desired. For this reason, the model needs to have control of activity types and have an optimized mechanism for the decision making process.

Different activity types are essential for creating dynamics in the environment such that it appears as in real world situations. However, too many varieties might not be necessary in many cases. Also, fine detail activities, like facial expressions, and lip movements in talking, would be very resource intensive, yet not significantly useful for our purposes. Indeed, these fine detail activities would only be apparent when view in a very close distance. On the other hand, it is possible to combine a limited set of activities to generate a variety of different meanings. For example, two people waving hands and then moving in different directions can denote a parting event while two people waving hands and coming to a place can denote a meeting event. Therefore, the idea is to employ primary activities[1] to the agents. With careful selection and combination of primary activity types, we could effectively create the dynamics of the virtual environment while minimizing the computing resources. In fact, in way-finding and fire egress simulations, there is only a narrow range of human behavioural needs and thus potential activities, whereas in most game environments these needs are higher to accommodate a wider range of human social interactions.

Technically speaking, the model should have simple mechanisms for the agents to perceive and understand the environment, and to respond to it. There are several different entities in a multi-user virtual environment and each entity has its own properties. Agents have to understand the environment correctly so that it could react based on appropriate behavioural rules. Therefore, if the environment, perception mechanism and the behavioural rules are all too complicated, the efficiency of the decision making process will be negatively affected.

3. THE MULTI-USER VIRTUAL ENVIRONMENT (MUVE)

The multi-user virtual environment so described is a reconstruction of the 7th Street in West Oakland, California in the 1940s and 1950s.

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[1] Primary activities are activities which could be identified visually in a distance. Examples include walking, sitting, standing, and waving etc.

In the 1940s and 1950s, 7th Street in West Oakland was a bustling commercial district, anchored by dozens of jazz and blues clubs that earned it a reputation as a West Coast rival of the Harlem music scene. With its proximity to Oakland's waterfront, it hosted a large number of African Americans from the South who used to work in the naval shipyards during the war, and stationed at the military bases along the bay. The jazz and blues sounds from them blossomed the 7th Street. Most of the legendary blues and jazz singers and musicians, as well as soul and rhythm and blues artists, performed at the clubs, including Jimmie McCracklin, Sugar Pie DeSanto and Ivory Joe Hunter. In fact, many musicians got their start performing at the 7th Street clubs, defining a distinct Oakland blues sound and signing their first records with local music promoters like Bob Geddins and his Big Town recording studio and production company.

FIG. 1: Slim Jenkins bar/restaurant, West Oakland, c. 1950 (Photo courtesy of the African American Museum).

Complementing the clubs were numerous other business establishments up and down an eight-block stretch of 7th Street, all of which made it one of Oakland's major commercial and retail centers at the time. The street was home to colorful characters such as "The Reverend" who, along with his wife, preached from street corners, and Charles "Raincoat Jones"—a former bootlegger turned loan shark and dice game operator—who was known as the unofficial mayor of 7th Street and helped finance some of the jazz and blues clubs.

By the mid 1960s, there had been great changes in the area that a remarkable part of this Oakland's heritage was destroyed. In the 1950's, an elevated highway, the Cypress Freeway, was built. It sliced across the 7th Street and effectively isolated it from the city's downtown. In the 1960s, an elevated structure, the Bay Area Rapid Transit (BART) rail and subway system was constructed which created a huge eyesore and deafening noise from passing trains. In more or less the same time, a stretch of several blocks along one side of 7th Street was removed to host a 12-square-block U.S. Postal Service distribution facility. Later in 1989, the Cypress Freeway collapsed during the Loma Prieta earthquake. It was then torn down and the freeway was re-routed around 7th Street, the fruit of community pressure.

Today, the street is marked by boarded up buildings and empty lots and plagued by drug dealing and crime. Only a scattering of businesses now exist along 7th Street. The only remaining music club from the 1950s is Esther's Orbit Room. A walk down the 7th Street reveals almost no hint of the vitality of the area and the once thriving jazz and blues club scene.

From 2005, the Digital Design Research Group at the Department of Architecture of the University of California, Berkeley, has been reconstructing the 7th Street into a multi-user virtual environment (MUVE) (FIG. 2). In this environment, multiple players could participate in the jazz scene simultaneously through internet connections. They can explore, interact with the environment, characters and other fellow players. Players can then obtain information about the history of the environment through all these interactions. The aim is to provide an entertaining educational tool for young people to learn about the splendid history of West Oakland in its 1940s and 1950s. Although the environment we designed is technically speaking a Multi User Virtual Environment it also entails some aspects of a "3D adventure" game. This increases the engagement and appeal of the environment, hopefully to result in a better educational performance.

FIG. 2: Two views from the reconstructed 7th Street.

4. THE AGENTS

In this MUVE, we intended to automate the behaviours for all moving entities which include people and vehicles. However, it would not have been practical to employ a fully distributed autonomous behaviour algorithm, since this would have required a real-time computation of hundreds of bots simultaneously present in the game. Therefore, we developed an optimized model to simulate autonomous behaviour.

As the first line of our optimization efforts, we differentiated the bots from NPCs. Bots are the moving agents which have no direct interaction with the player, but just exist to populate the environment. NPCs, however, are special characters like "Raincoat Jones", with which the players need to interact. NPCs will need to follow a predefined interaction and conversation script so that they could react appropriately to the players.

In addition to the bots and NPC's, to enhance the dynamic feeling of this commercial district, we introduced running cars and trams in the environment. Since they will not interact with the players, they act as background props like the bots. Therefore it is suitable for them to be designed as autonomous objects. A note is that we also introduced parked cars on the sides of the streets. We treat parked cars as other street features like lamp posts and post boxes which are stationary and will not interact with other humans and vehicles in the environment, while the moving cars, trams and bots will be dynamic components of the environment which will be responsive to the players' actions and other environmental dynamics.

4.1 Mechanisms of the agents

Previous studies on agents typically include goals and behavioural rules for agents so that they could behave in a sensible way in the environment. In this MUVE, agents with autonomy are background objects that do not really need any specific goals. In terms of intelligence, we only expect them to possess the following behavioural capabilities:

- *Detour* or *stop and wait* when meet obstacles on path (for both bots and vehicles)
- *Turn left/ turn right / go forward* at street corners (for both bots and vehicles)
- *Find* seats available (for bots, inside bars)
- *Meet* with people (for bots, on street and inside bars)

As there is only very few intelligence for the dynamics to achieve, instead of behavioural rules and the demanding distributed real-time decision making systems, we introduced another concept for the autonomy of the agents, the *switch-nodes*. These nodes are points that give information to the background dynamics on available choices and the associated probabilities at that particular point of interest. FIG. 3 shows some nodes on street corners. The node on the lower left corner shows three options on the route from which the agents could choose. It is possible for us to define the probability distribution of bots crossing the road versus ones turning at the street corner.

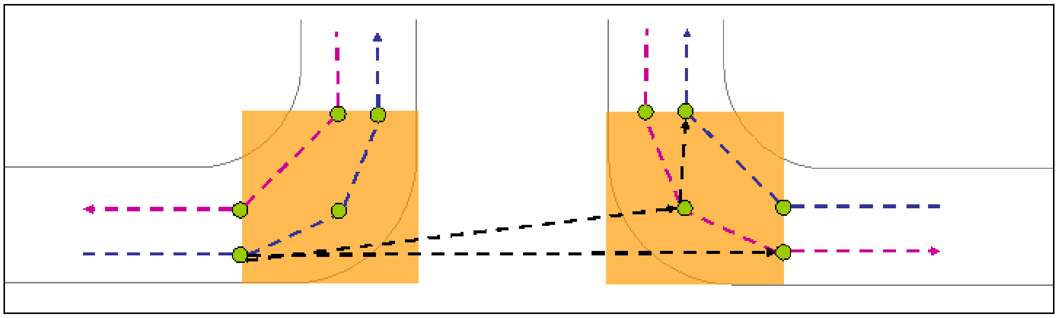

FIG. 3: Nodes on street corners.

As we are omitting the goals, there will be no endings for the lives of the agents. The agents will continue their actions until they arrive at the nodes. They will then make decisions at the nodes based on the available choices and the probabilities associated with each choice. With careful placement and arrangement of the nodes, we can make the agents move around in the environment and behave according to the storyboard in the scene. The decision making algorithm is located within the nodes. Instead of requiring every agent to make continuous context-aware decisions, this method efficiently distributes the responsibility of making decisions between the agent and the node.

4.2 The switch-nodes

In this MUVE, the switch-nodes are location-based triggers to possible behaviours of the agents. The nodes could trigger an action, a series of actions, an animation or a mixture of actions and animations. Decisions are made by the usage of a randomization function, where probability of each choice is weighted by distribution preferences. (FIG. 4) There are several advantages of using this system instead of, or even in conjunction with, an agent-based artificial intelligence function. The nodes provide 1)agent-independent behaviour patterns, shared by many agents, 2)a context-based behaviour palette. 3)parameterization of behaviour probabilities in response to environmental dynamics and agent-based preferences, 4)and the possibility of a branched organization, avoiding repetition and ensuring variability in actions.

Variability function	**Probability %**	**Action Trigger**
f (E,a)	*40%*	WALK TO *barnode1*
f (E,a)	*30%*	WALK TO *streetnode4*
fixed	*10%*	PAUSE for *30 seconds.*
f (a)	*10%*	ANIMATE *"WaveHand"*
f (a)	*10%*	ANIMATE *"LookAround"*

FIG. 4: Behaviour distribution table of a sample switch-node.

As shown by the table above, an action could be simply as "go to node *n*" or "pause 30 seconds". An animation could be "wave hand", "dance", or "play music". A combination of different actions and animations could create an endless variety of possibilities for the scene. There is also instruction in the nodes linking one node to the next, allowing for us to pre-design complex walk-paths. The agents could then go through series of actions and behave differently depending on the nodes and the choices they make. Moreover, the probability distributions of the variety of actions can be determined through parametric functions (*f*) that take environmental variables (E) or personal characteristics and preferences of an individual agent (a) into the equation. As an illustration, a node located at the entrance of a bar can direct more bots into the bar when it is night time, or when the band is playing inside, while the same node can direct more bots out when the show is over. Another node can direct female avatars into one action, while males into another, for example in a clothing store where sections are divided by gender.

FIG. 5 shows one circle of the live of a bot. In this circle, the bot goes through series of activities at each node, like going to a bar, taking a seat, drinking and dancing. At a certain node, he will go to another node which he would start another circle of life. In this sense, the nodes are intertwined in a loop that the life of the bot will go on and on until the end of the game.

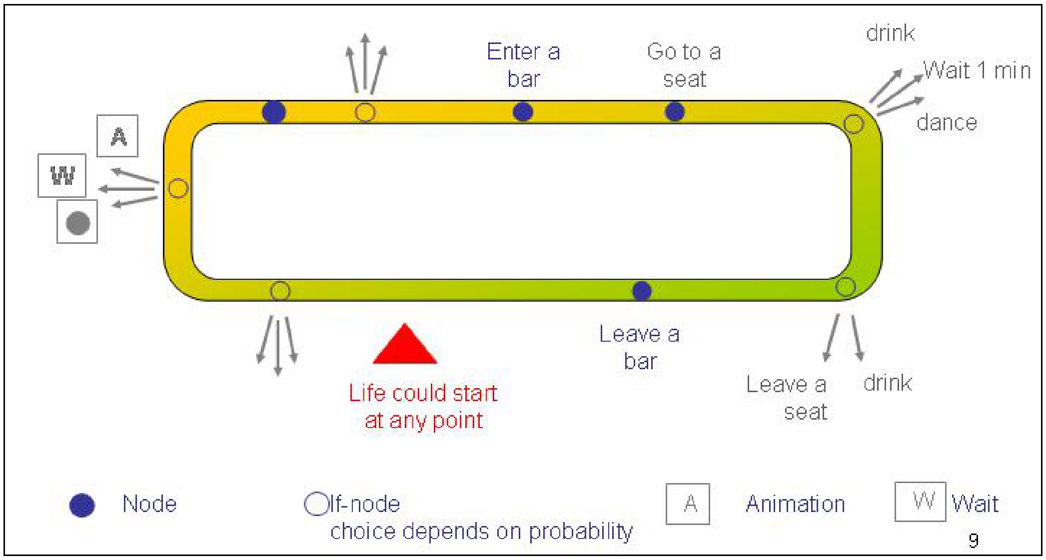

FIG. 4: The life-cycle of a sample bot.

5. CHALLENGES OF THE DESIGN

In this MUVE, we only use switch-nodes to govern the behaviour of the agents. The agents do not have individual goals or a concrete set of behavioural rules to prevent the possibility of conflicts or unreasonable behaviour in the environment. As a result, we came up with some challenges which we need to deal with very carefully.

5.1 Conflicts of basic interactions

There are buildings, street features, people and vehicles in the scene. When the agents move around, there is a chance that they might collide with the fixtures or other moving objects on the way. Meanwhile, connections between nodes are in straight lines which the agents will not detour when there is an obstacle on the way. A reasonable method to detect obstacles and trigger appropriate actions to avoid collisions may be needed. A careful planning of the nodes and actions might prevent or minimize collisions, but it might become problematic when the number of objects in the scene is increased.

5.1.1 Moving vs. static entities

Collisions with static objects only happen when the object is accidentally placed on the bot's path. Although this should be avoided by design, the agents can also incorporate an algorithm to detour when they encounter a stationary object, like a wall or a light post on the way.

5.1.2 Bots vs. running vehicles

There are also chances that avatars or bots would cross the road while there are vehicles running. In this case, the nodes on each side of the street can act like traffic lights, stopping the vehicle traffic while there are pedestrians crossing the road or directing bots to cross the road while there are no vehicles coming.

5.1.3 Bots vs. bots

Crossing interactions between bots are trickier. As mentioned, the bots will not detour when there is an obstacle on their path. Therefore, it is inevitable for bots to cross through each other when the population increases. The same principles for the running vehicles, employing intelligent “traffic light” nodes, do not work in this case. Therefore, we disabled collisions between bots so that they will *cross* through each other like ghosts in the chance that they share intersecting paths. As the duration is very short, and the likelihood of such collisions was minimized by design, this solution did not impose any awkward feeling. In a way, it looks pretty “natural” to the players.

5.2 “Naturalness” behavioural pattern

A big challenge of using agents without goals and rules is to create varieties in the scene so that it does not look like having zombies running around in the environment. To achieve variation, one method is to include options as specified within the nodes that agents would not behave the same way even they reach the same node. At a macro scale, the routes taken by all the agents will not be identical, so as the experience throughout the trip will never be the same.

Another way is to vary the speed of the agents. With different speeds, two agents walking in the same direction would not appear as robots with synchronized motions.

The third method is to start the lives of the agents at different positions in the scene. At time 0, the agents are distributed all around the environment, some on the 7th Streets and some on the minor streets. There will be some other bots distributed in the bars and other buildings. All the agents face different directions and start to move forward when the game starts and their activities will be changed upon arrival at the next node.

5.3 Social components

7th Street was famous for its richness in cultural and commercial activities. People would go to the bars and clubs in groups. They will also meet on the street and may even talk for a while on the street. Therefore, it would be sensible to include some social characteristics on the street. At the beginning, we placed continuous social activities on the street which are not really autonomous. An example is that we put a group of kids jumping around on a street corner to create the scene of a group of children playing on the street.

On the other hand, we would also like to include meeting and parting events. For this reason, we specified some nodes on the street where bots could gather in groups and part. To simplify the process, the bots would *not* know who they are meeting. They will just choose to meet with others at the nodes. In fact, it is not necessary to decide in advance on which bots will meet each other since it is never apparent on the street that *Bot A* might know *Bot B*.

To characterize the meeting and parting behaviour, we intended to use a combination of simple activities in the representation. For meeting, the bots will wave to each other and stop for a while. At this point, the bots will be gathered next to each other to denote a meeting acquaintance. The same principle is applied to parting events. The group would stop for a while, engage in idle conversation, wave to each other and move in a different direction.

5.4 Computing resources

In this MUVE, all of the background objects are situated in the environment since the beginning of the game. They do not appear as players are nearby. Also, we have carefully designed the mechanism so that the autonomous background objects would not use a large amount of resources in order not to affect the performance of the game. Therefore, apart from the nodes mechanism, we have few other means to control the consumption of computing resources.

- Various levels-of-detail for objects in the scene. The detail levels of the objects would increase as they become closer in the view.
- Careful planning of nodes. In the environment, the players mainly move along the 7th Street. Therefore, the nodes are carefully planned such that the agents would stay in *viewable* areas in the environment. This could greatly reduce the number of agents to be located in the environment.

- Create complex behaviour by combination of simple activities. Instead of creating a big pool of activities to accommodate all possible behaviours, we intended to use combinations of simple activities to represent different human behaviours in the scene. These activities are clustered around nodes according to the specifics of the contexts that the nodes are placed in. Currently, we only include mutually exclusive motions like sitting, standing, walking and dancing for bots. Combining with other, but not mutually exclusive, motions like waving, getting and drinking, we have created many behavioural varieties in the scene.

6. CONCLUSION

In the process of reconstructing the bustling commercial district of 7th Street in West Oakland, California, in its 1940s and 1950s, we attempted to employ autonomy for background objects which include bots and running vehicles. Instead of using goals and behavioural rules which are traditionally used in virtual user simulation, we used another mechanism, the switch-nodes, to govern the behaviours of the agents in the environment. The nodes system differs from goals and behavioural rules in this sense that it does not fully distribute the autonomy to the agents. In our case, this is advantageous as we do not want the background dynamics to impose too much computation load for the system.

Though so, we also experienced some challenges as the node system does not prevent conflicts or unreasonable behaviour in the environment even for a narrow range of behavioural needs. Nevertheless, with some adjustments, careful planning and some creativity, we were able to achieve "naturally appealing" behavioural patterns without receiving a significant penalty on the overall gaming performance.

7. FUTURE PLANS

Currently, the game is still under development and we are introducing more stories, quests and activities in the MUVE. At the same time, we are introducing more nodes to enrich the environment. The behaviour directed by the nodes can change according to the changes in the environment or individual characteristics of the agents. However, we did not have the chance to utilize this functionality to the fullest extent yet. In the coming future, we hope to increase the dynamics in the environment by employing more variables in the nodes that change according to the changes in the environment. In this case, we would be able to introduce "peak hours" for the street, along with having other possibilities for the dynamic manipulation of the social scene of the environment. This would provide a greater flexibility in the game development and different gaming experiences for the users.

At the same time, more research will be done on the social behaviour of the pedestrians. The first objective is to include more varieties of social activities on the 7th Street which used to be a very popular urban environment. The second objective is to fine tune the behaviours of the bots to make them more "human like". For example, introducing more body movements for bots talking to each other.

8. ACKNOWLEDGMENTS

The project is the production of a collaboration between the Architecture Department's Digital Design Research Group and the Graduate School of Journalism. The study has been awarded the Knight News Challenge Grant. We particularly need to thank Prof. Yehuda Kalay and Prof. Grabowicz for their lead of the project. We also thank for those who worked in avatar design, modelling and animation, especially Ahmed El Antably and Mao Ye.

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