Eye Gaze Behavior of Virtual Agent in Gaming Environment by Using Artificial Intelligence

Avijeet Das[1] and Md Mahmudul Hasan[2,*]

[1] Department of Engineering and Information Technology, University of Technology Sydney, Australia

[2] Department of Computer Science and Engineering, Daffodil International University, Bangladesh

[*] E-mail: mhasan@daffodilvarsity.edu.bd

Abstract—**In the gaming environment, building natural looking avatar is a challenging task. An avatar represents a human character which includes speech, action, and eye movement in a virtual world. The movement and the expression of eye modeling is cognitive function. In order to assess virtual agent's eye gaze behavior on the basis of cognitive and emotional characteristics, this paper presents an experimental simulation to identify perfection of the eye gaze behavior. For this reason, this paper splits eye behavior into few levels by using CADIA Populus. But the goal of this research work is to focus on gaze behavior. In addition, it briefly describes the cognitive activities based on different cases. Furthermore this paper introduces an integrated framework for modeling the interaction of agent with the immersive environment. Finally, the gaze strategy and some simulation results from previous studies have been discussed to provide a concrete idea about gaze behavioral science in gaming environment using artificial intelligence.**

Keywords—Gaming environment, Eye gaze behaviour, Artificial intelligence, Virtual Agent, Non-player character

I. Introduction

The Virtual Agent community is closely associated to Virtual Assistants industry. It is a computer engendered, animated, artificial intelligent virtual character (virtual agent 2011). The agent takes an intelligent communication with users, performs suitable non-verbal behavior. In the gaming environment virtual agent have some capacity to improvise its actions. In gaming environment, the autonomous characters are called as non-player character *(NPC).* The next sub sections will discuss about the different aspects of virtual agents. Furthermore, additional concentration will be put into the activity of eye movement: steering and gaze behavior. The research work briefly discuss about the virtual agent and different features of the virtual agent. Furthermore it introduces an integrated framework for modeling the interaction of agent with the immersive environment. The framework also discuss on the decision making behavior and autonomous motion control of the avatar.

Finally, this paper also express various gaze strategies based on the framework. Furthermore, analysis of the simulation from previous studies also addressed.

A. Virtual Agent

Virtual agent or avatar in computer game is the graphical representation of human character. In the world of computer gaming it may represent as a three- dimensional form. There are a number of researches from the past for the improvement of avatar behavior and their physical appearance. According to Barbara Hays (1996), in the gaming environment we should concentrate three kinds of advanced skills exhibit by the virtual agent. First of all, agent should "exhibit life-like qualities". Secondly, agent are able to "follow the directions" which are taken from the external sources (Barbara 1996). Finally, agents are able to "improvise" many different aspects of behavior. Virtual agents are the economical and strongest link between human and service. According to Liu et al. (2010), a virtual agent is a computer generated 3D digital representation of human user. It sometimes refers as a computer program [1].

The term "virtual agent" consists of two parts: virtual and agent. The word virtual dates back to late 16th century as "inspired by physical capabilities". The Latin word virtus refer to excellence and efficiency. The word virtual first recorded in 1959 as: "capable of producing certain effect" (Virtual Agent 2011). The agent is a Latin word founded on back to 15th century which means "on who acts".

B. Different aspects of virtual agent behavior

It is expected that the virtual agents exhibit more realistic features. The features include communicative and expressive characteristics which is similar to the natural human. The features consist of speech, facial expression, gestures, eye movement (e.g. eye gaze, steering). For controlling the virtual human behavior the scientists are focused on autonomous behavior control ability. For designing the different behaviors of virtual agent physiological and physical behaviors are combined. This is very hard to put all the behavior and perform a decision by the agent. For the simplicity, this work specially focused on eye movement behavior of the controversial human agent.

C. Eye movement of virtual agent

In the realistic game environments, eye movement is a significant feature that virtual agent perform in a natural way. The eye movement is a cognitive function of an avatar [2]. Eye movement comprises steering behavior, gaze behavior, idle gaze, and locomotion. The quality of an avatar performance reflects on its eye. For an example, in a situation where an agent is perform fight with another agent. The user expects some realistic eye control behavior on the agent which makes the game more efficient.

D. Eye movements in natural behavior

In the natural behavior, eye movement is a cognitive function [3]. An experiment from "Yarbus" shows some positive findings in this field. They came up with three points about the understanding of the cognitive function of eye. The first is the demonstration of the pervasive role of the task in guiding where and when to fixate [4]. The second has been the recognition of the role of internal reward in guiding eye and body movements, revealed especially in neurophysiologic studies. The third important advance has been the theoretical developments in the fields of reinforcement learning and graphic simulation (Hayhoe & Ballard 2005, p. 188).

II. BEHAVIOURAL MODEL

A. Gaze Behavior

Gaze behavior is important in communication and social demonstration of a virtual agent. The action of an avatar represents by the movements of its eye. The structured action of gaze represents more realistic avatar. On the other hand, random or uncontrolled gaze behavior is both ambiguous and confusing (Badler, Chi & Chopra 1999, p.4) [4]. The agent has a large number of applications; such as in the interactive environment face to face communication is a vital role for agents. For such kind of situation gaze behavior plays an important role. Gaze model consists of many functions such as signaling, attention, adaptable turn-talking (Kipp & Gebhard 2008, p. 191). An avatar's personality and the current mode also reflect on its gaze behavior. A numerous number of scientists and researchers are working on the development of gaze behavior. They are trying to put the agent into a 3D social environment and investigate the social gaze of the agent [5].

B. Idle Gaze behavior

Idle gaze is a very important feature of human behavior, which shows the human interpersonal skills. In the virtual environment, it is expectable that the agent behaves naturally. Idle gaze is similar to gaze but the difference is that the gaze is in idle position. For example, if an agent is walking down the street or waiting for the bus the gaze behavior should be in idle place. In the later part of this report will show some statistical result related with idle gaze behavior of virtual agent [6, 7].

C. Steering Behavior

Steering behaviors consists of: seek, flee, pursuit, evasion, offset pursuit, arrival, obstacle avoidance, wander, path following, wall following, containment, flow field following, unaligned collision avoidance, separation, cohesion, alignment, flocking, and leader following (Reynolds 1999). In the steering behavior a vector is incorporated which is named as "steering vector". Consider an example agent is running behind a subject avoiding so many obstacles and the subject is fixed. So the agent is trying to run behind the subject and keep its eye on the subject. From figure 1; the agent flee as desired velocity for the target and the agent use seek steering. The gray line denoted as the steering vector. The length of desired velocity could be max_speed to the target which depends on the specific situation. From Reynolds (1999) the equation for steering from figure 1 is;

```
desired_velocity = normalize (position -
        target) * max_speed
  steering = desired_velocity- velocity
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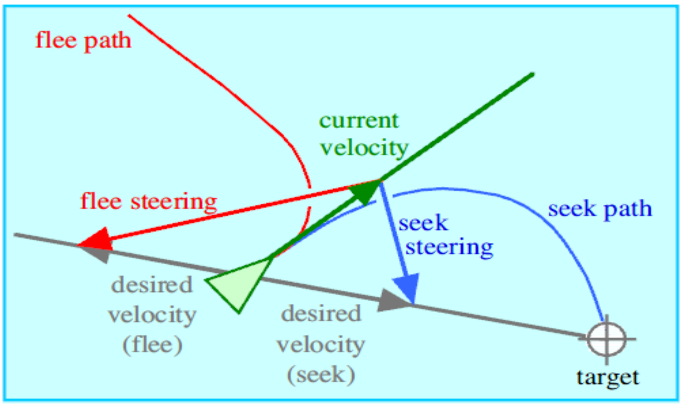

Figure 1. Steering behavior: seek and flee (Reynolds 1999)

Seek can be described as to steer the agent towards a specific location on the map. This behavior modifies the character ability which changes its velocity in the direction of the subject. This is not related to attractive force such as gravity which provides an orbital path around the subject (Reynolds 1999, p. 8).

Flee is opposite of seek which can be described as a steering character. The speed is "radially aligned" away from the target and the desired velocity works in the opposite direction [8].

Pursuit and seek is nearly similar but the main difference is: in seek behavior the subject is constant but in the pursuit behavior the subject is a moving subject. In the pursuit behavior an estimation of the next position is needed. The methodology is: first select a reference point and reexamine each point after a certain period of time. Another problem with the pursuit is if the agent and the subject move to each other from the opposite direction. It appears in a constant heading on the global space for the subjects.

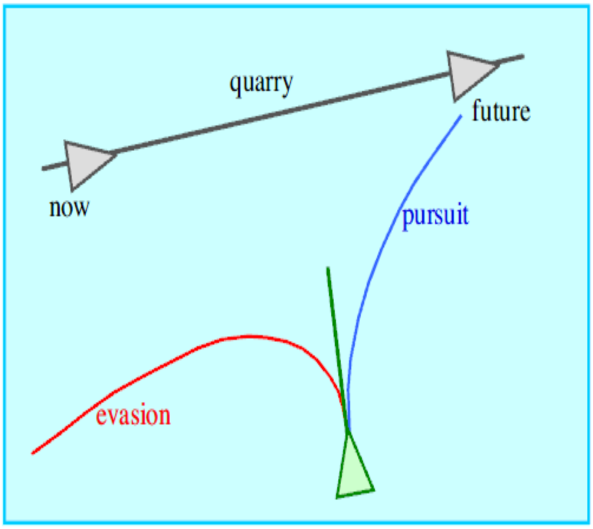

Figure 2. Steering Behavior: pursuit and evasion (Reynolds 1999)

Evasion is similar to pursuit, but the main difference is in fleeing. In the evasion the flee is used to steer away from the expected location of the subject. For controlling the movement optimal technique is applied on pursuit and evasion. But the natural system, the movement is unpredictable and non-optimal [9, 10].

In the arrival behavior, the position of the agent is far from the position of the target. But instead of the moving towards the subject at the full speed, the behavior enforces the character to slow down as it approaches the target which is shown in figure 3. Finally, slowing to a stop equivalent with the subject (Reynolds 1999, p.10).

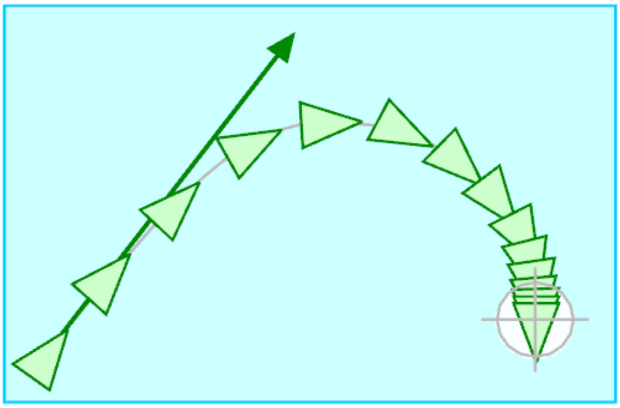

Figure 3. Steering behavior: arrival (Reynolds 1999)

The equation for the arrival behavior is:

```
target_offset = target - position
distance = length (target_offset)
ramped_speed = max_speed * (distance /
slowing_distance)
clipped_speed = minimum (ramped_speed,
max_speed)
desired_velocity = (clipped_speed /
distance) * target_offset
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steering = desired_velocity - velocity
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Obstacle avoidance behavior is a complex behavior, which is comprises seek and flee. This behavior provides the ability to movement in a tangled map by dodging around obstacles (Reynolds 1999, p.11).

Path following behavior allows an agent to follow a preset path like terrain, roadway or path on the space. This is widely used in those virtual environments where paths are predefined. For an example, in the car race the paths are preset and the cars are moving along the track which is shown in figure 4.

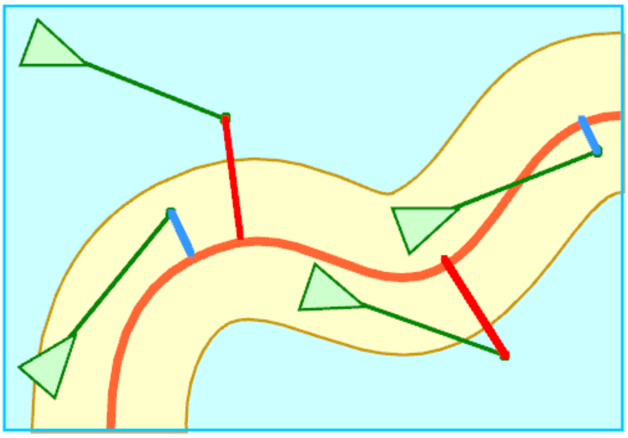


Figure 4. Steering behavior: Path following (Reynolds 1999)

Path following sometimes characterized by flow following and wall following. The goal of the path following is to move a character alongside the path while staying within the specific radius and spine (Reynolds 1999, p .13).

D. Locomotion

Locomotion is a kind of activity which collects the information from steering behavior and converts into motion of the character's body [11, 12]. This motion is subject to constraints imposed by the body's physically-based model, such as the interaction of momentum and limitation of forces applied by the body (Reynolds 1999). There are different types of locomotion: an avatar could have a locomotion characterized by physically-based dynamically stabled movement which gives us both genuine animation and behavioral locomotion. On the other hand an agent could have a simple locomotion model which is attached by pre-animated model. An adaptive locomotion is the avatar shall have the ability to learn from the environment. The best approach is to represent hybrid model approach which is to use simple model and adaptive model both. In the locomotion behavior the steering behavior remains same but the movement of the body is shifted. For example, someone wants to ride on the bicycle. So he walks to his cycle, ride onto it and start cycling. In the whole process the agent might steer on its cycle, but the movement to the cycle and riding on it in a physical balanced manner. At the end locomotion can be controlled to the motion with the mixer of some predefined movement like walking, running and so on [13].

III. FRAMEWORK FOR MODELING EYE BEHAVIOR OF AVATAR

Liu et al. (2010) proposed a framework for virtual agent behavior modeling [3]. The model helps the user to interact with the virtual environment through the agent. The framework divided into different layers. There are basically three layers, which are: i) Information perception, ii) Behavior decision making, iii) Autonomous motion control

A. Information Perception

This part of the framework handles all the cognitive behaviors which are shown in figure 5. Perception and cognition comprises four phases: synthetic vision, audition simulation, intention and attention, and memory. Synthetic vision helps an agent to collect the information in its eye sight. In the complex scenario, the visibility can be accomplished by testing against the virtual human's view frustum (Liu et al. 2010, p. 2) [3]. Audition simulation can be achieved by the cross-examination of system messages. A vocal message passes to the agent and agent check in the system. After perform the examination on system message agent check the scalar distance between the position from the origin of the message to its own position. After acquiring vision information and audition information, the agent performs action to limit its focus to confine the object. Using perceptual attention, the scale is balanced between the perception processing output and decision making behavior. Intention helps the agent to pick the object it focused on. Memory model helps the agent to remember the perceived objects through sensitivity [14].

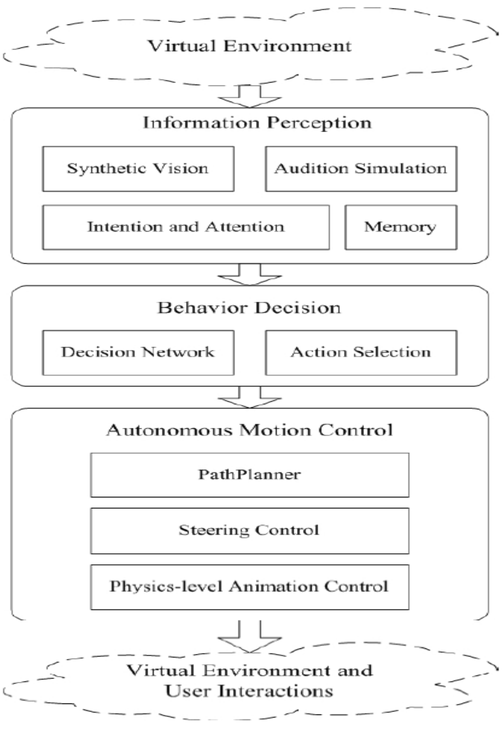


Figure 5. Framework for modeling avatar eye behavior

B. Behavior decision making

The decision making behavior consists of two modules, which are: i) decision network and ii) action selection. Decision network is used to perform agent decision making process. It solves the problem of complexity and uncertainty (Liu et al. 2010, p. 2) [2]. Decision making networks works in a hierarchical manner: the top level response network, the acquaintance behavior network, the attack-response behavior network and energy-restore behavior network. The top level behavior network applied to choose the remaining three networks. After that the chosen network is used to handle the analogous behavior network. The decision network decides to choose the corresponding action for that particular scene.

C. Autonomous motion control

Movement animation control has three phases: path planner, steering control and physics level control. Path planner is responsible for defining where the agent planned to move and engendered a target. For path finding the A* search algorithm is used. The algorithm provides to find optimal path from the source to endpoint. But the A* algorithm cannot deal with the dynamic object in gaming environment. So that, steering control behavior is implemented. Steering control behavior helps the agent to deal with the dynamic objects. A "sidestep repulsion vector" is used to determine the steering path. The steering control is fastest solution to avoid obstacle but the physical action is performed by the physical control behavior. Here in the physical level controlling collision detection mechanism is used. This method help to avoid stuck on any obstacle [15].

D. Different Gaze Strategies

According to Kipp & Gebhard (2008), the three gaze strategies are used for the framework discussed earlier. Three gaze strategies are: i) The Mona Lisa Strategy, ii) Dominant Strategy (Dom), and iii) Submissive Strategy (Sub). The diagrams for three strategies were modeled using "timed finite state automata".

The Mona Lisa Strategy(ML+, ML-) comprises of continuous following of user's position at all times which makes 3D effect on agent eyes. When the 3D effect switched on that means ML+, agent looks at the position of virtual camera. When the effect is switched off (ML-) that means avatar looks at the virtual gaming environment which is basically not the camera (Kipp & Gebhard 2008, p. 193).The Mona Lisa is widely used for request for attention, stare, look straight into other agent eyes, shows the anger of the avatar even cold anger.

Dominant Strategy (Dom): Dominant strategy involves the eye contact when avatar communicates with another avatar. The strategy consists of speaking and listening with another avatar. It was observed that, the advanced status agent gazes spend less time than the lower status agent. The activities are related to the amount of time for listening and speaking and calculated by Visual Dominance ratio (VDR). According to Kipp & Gebhard (2008, p.138), dominant strategy comprises eye contact while conversation between two agent and arbitrarily changes of gaze behavior while listening. The agent usually holds eye contact while speaking and listening.

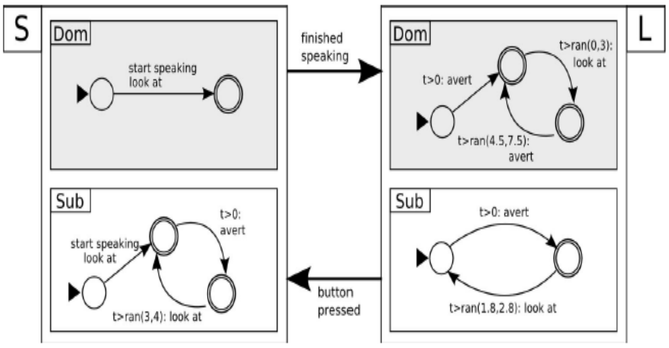


Figure 6. A simulation used to model the gaze behaviors of dominant (upper states) and submissive (lower). S/L refer to speaking/listening modes (Kipp & Gebhard 2008, p. 194)

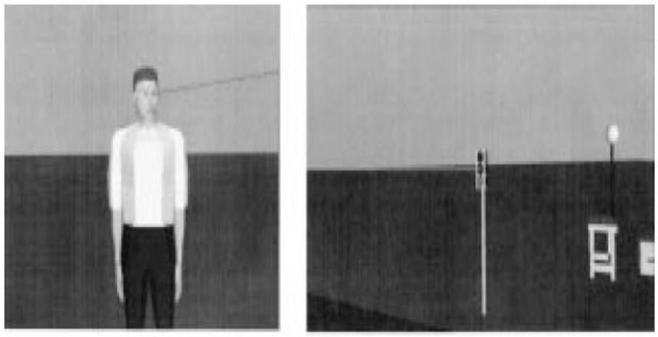
Submissive Strategy (Sub): This strategy is related to dominant strategy. If the agent breaks the eye contact and looks back, that agent is lower status. This strategy helps the agent look briefly every from time to time and changes the gaze. The agent maintains while talking but avoids its gaze instantaneously (Kipp & Gebhard 2008, p. 194). The gaze remains avert for 3-4 sec. After that the agent starts eye contact again and looks back instantaneously. In terms of listening, the only difference is time which is 1.8-2.8 sec.

IV. Simulation of Eye Gaze Behavior

The following simulation is based on gaze behavior, steering and locomotion. Two researchers named S. Chopra and N.I. Badler from "University of Pennsylvania" accomplished the simulation [4]. The result was very impressive than the previous simulation on eye gaze based on cognitive modeling. The problem was to generate a visual attending behavior in controversial virtual humanoid. The behavior comprises some cognitive behavior such as eye control and head motion with the other actions like gaze, locomotion. Their goal was, when an agent moves toward the target, or looks for someone in the social situation; the behavior should appear as actual eye behavior (Chopra & Badler 2001, p.2) [4].

For the simulation the taken scenario was, an agent asked to walk to one point from another. So that to achieve the goal: he has to cross the road, look for oncoming traffic and wait for the suitable traffic signal. A social scenario was animated to investigate the simulation.

A virtual human model was taken to investigate all the tasks. A walking eye behavior produced adds appropriate sites to IntentionList. The IntentionList consists of the destination and the ground in front of agent's feet. The corresponding eye behavior remains active while walking along the road. The simulation showed, when the agent walks along the street more items added into IntentionList. The agent uses its monitoring eye gaze behavior. The line in the second part of the figure 7 indicating agent's LoS (Line of sight).



(a)

Figure 7. Agent look for the traffic using monitoring eye gaze (Chopra & Badler 2001) [4]

A monitoring eye behavior also produced to check oncoming traffic on the road. This behavior remains until the agent crosses the road.

V. Analyzing the Model of Idle Gaze Behavior

Idle gaze is an important aspect of human behavior. In the gaming environment it is necessary to look avatar more realistic. The simulation was made on CADIA Populus. For analyzing the model, two situations were chosen: i) waiting for the bus and ii) walking down the street. The simulation was done on social situation. It is essential to know how an agent reacts in social gaming environment. The avatar was modeled using CADIA Populus.

Three researchers Cafaro1, Gaito1&Vilhjalmsson (2009) took the video for analyzing the model. The video studies were performed in different situations [8]. The two cases are:

Case 1: The waiting behavior was observed and the camera was placed 30m away from the bus station. The people were waiting for the bus and the eye behavior of that time was taken.

Case 2: The walking behavior was observed, and the camera was placed in a shopping center. While the people were walking they change their gaze depending on the gender.

After analyzing these two cases, some results can be produced. From the case 1 we found:

i. The observed person fabricates a glance and maintains his glance for a short period of time. The shorter glances were used to look at the other person near him.

ii. The longer gazes used to look at the target away from him. Such as oncoming bus.

And from the case 2, we found:

i) The person looks at the ground frequently while walking.

ii) The person closes his eyelids just before moving his head.

iii) Most of the time the person never looks up, up-left or up-right.

Now while observing the case 1 we can produces a table. The table shows the time relationship gaze targets and proxemics where the subject is waiting for a bus. All the time durations are in seconds.

TABLE I. THE RELATIONSHIP BETWEEN GAZE TARGETS AND PROXEMICS FROM CASE 1

	Objects			Persons		
Proxemics Area	Time on Target	%	Avg. Dur.	Time on Target	%	Avg. Dur.
Intimate	84.11 out of 84.11	100%	6	0 out of 6.43	0%	-
Personal	10.26 out of 10.26	100%	5.13	7.3 out of 61.16	12%	2.43
Social	14.36 out of 22.56	64%	4.80	45.17 out of 96.68	47%	22.60
Public	1.33 out of 1.33	100%	1.33	6.90 out of 29.46	23%	2.30
Extra	5.90 out of 8.66	68%	5.90	9.00 out of 35.56	25%	3.00

The following table shows the observation where person look while walking down the shopping street. How their gaze reacts with the same gander and the opposite gender.

After putting all together in the CADIA Populus, there was an improvement for the avatar was observed. The idle gaze required lower update in the case of waiting for the bus, but the gaze required higher update in the case of walking down the street. The goal was to produce autonomous agent for the social environment. The social situation needs steering behavior of the agent to make it more realistic. In the public space the blind cone for the agent is 90 to 150 degree.

TABLE II. OBSERVATION OF CASE 2 WHERE PEOPLE LOOK WHILE WALKING DOWN IN THE SHOPPING STREET

Targets			Durations		
Target Type	%	Time on Target	Avg.	Min.	Max.
Same Gender	3%	7.75	0.64	0.24	1.24
Opposite Gender	5%	12.92	0.72	0.29	1.15
Shops	13%	33.58	0.74	0.14	1.34
Cars	9%	23.25	0.93	0.1	1.8
Ground	25%	64.58	1.5	0.5	2.5
Camera	7%	18.08	-	-	-
Other Side	16%	41.33	-	-	-
Unknown	22%	56.83	-	-	-
Total	100%	258.32			

Visual perception is divided into central view and peripheral view. The main focus is to make the gaze behavior more dynamic. To make it more dynamic the avatar has the intention to change the gaze for the surrounding area. So the gaze shifts during to choose a target.

VI. CONCLUSION

This paper provides an overview of a virtual agent in semi-immersive environment. The simulating model shows the implementation of the gaze strategies using timed automata. Gaze is a dominant interaction modality with many functions like signaling attention, regulating turn-taking or deictic reference (Kipp & Gebhard 2008, p. 191).

From the above studies, it proves that steering behavior and gaze is important aspects of avatar. Improvement of cognitive behavior makes avatar more efficient and realistic. Moreover, the simulation from different cases shows the results to make the avatar more dynamic. To construct realistic reactive systems, we have to develop tools and systems to model where the human agent can freely reactive with the environment in future.

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