Holographic Humans

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Abstract. Over the last few years, holographic technology has been made readily available. This modern technology may have various applications ranging from medical, cultural, educational and communication industries. Focusing on the three latter industries, the main aim of this project is to create virtual agents to behave in a believable manner and display them within a three dimensional model of local megalithic temple 'Hagar Qim' in a museum context. These holographic humans are not only visually appealing with clear animations but also behave in a psychologically sound and autonomous manner, matching our expectations of what life was like in those times. Believability is a cornerstone within Artificial Intelligence and consequently, in order to achieve such a high degree of autonomy and believability, the holographic humans developed in this work are self-determined with their own reactive plan of actions to organise their daily routines. In order to produce such believable behaviour, computational motivation models based on psychological theories from natural intelligence are explored. Furthermore, visitors are able to interact with the holographic humans in order to get a clearer picture of life in prehistoric times and witness the diverse personalities and interests of the humans. Finally, the system was tested empirically by a number of people and questionnaires were filled in order to test the subjective concept of believability of the system as a whole. Highly positive feedback was generated with a 96 % believability rate and an 80 % agreement that this platform would be suitable in a museum context. The designed system manifested believable daily routines which visitors were able to relate to as the humans planned their activities just like any ordinary person would having time to be productive and make the most of a day whilst also adhering to biological needs such as thirst and hunger as well as sleeping when dusk falls upon the virtual environment. Therefore, artificially intelligent holographic humans were created to serve as an interactive educational platform.

1 Introduction and Background

Museums are rich cultural hubs which serve the purpose of retaining and/or restoring various cultural aspects as well as educating citizens on the various cultural aspects pertaining to the specific display. Locally, museum experiences are presently static and non engaging. With the use of cutting edge technology

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and virtual agents enhancing the user experience of museum exhibits, museums may once again become a prime attraction [1].

The computing industry has an increasing concern when it comes to developing sophisticated virtual agents. Many commercial game developers implement traditional techniques such as finite state machines, rule-based systems and genetic algorithm to express intelligent behaviour. However, these approaches all depend on user interaction. Therefore if this interaction is not present, the agents will remain idle creating a non intelligent zombie effect [2]. Additionally, with today's highly detailed reconstructions of the real world in virtual worlds, having these agents rely on user interaction would not suffice to crate a believable platform. Therefore, virtual agents must be self-sustaining and able to follow their own agenda, living their own lives as their own human beings, altering their plans only when a user interacts with them [3].

Consequently, it may be noted that autonomy within the agents is a prerequisite and is sometimes seen as a trivial matter when it is confused with automation of an agent where goals are defined during the design phase [4].

Behaviour believability of virtual agents is argued to be a complex concept within the field of Artificial Intelligence. Multiple researchers all define the term "believable behaviour" in different ways, ranging from modelling different human psychological traits such as coping with emotions [5] or modelling anticipation [6] to having different simulation levels of detail defined in order to keep believable consistency within systems [7]. Others model different emotions and emotional models based on the changes in the environment in order to change the internal emotional state of the agent and consequently produce human-like behaviour [8].

Avradinis et al. argue that believability is not to be confused with realism even though the two are closely related. Realism, they argue has to do with the reconstruction and visual effects of the real world whilst believability is concerned with the actions of the virtual agent being consistent and sound with the environment the agent is in [3].

Therefore believability is concerned with the generation of behaviour that would be consistent to the agents' internal states and personality. This according to De Rosis et al. is how a believable agent should act in order to be consistent and coherent with the unwritten laws that govern the virtual world [9]. Furthermore, Ortony [10] and Dautenhahn [11] elaborate that believability does not necessarily imply complex behaviours but rather the agent's behaviour must match what would be expected of it from the user to allow users to easier relate to the agents.

This calls upon a motivational approach which mimics natural intelligence. Through different psychological models, it is noted that humans have basic biological needs that constantly need to be satisfied and they react according to the current situation of the world and their internal state as defined in Maslow's theory of Needs [12]. Many respected researchers base their work on this approach such as Avradinis et al. [3], Liu et al. [13], Krümpelmann et al. [14], and Chen et al. [15]. These develop motivational architectures where internal numerical scales are updated through the environment. Once these levels dip under a

certain threshold, the agent temporarily differs from their current agendas to satisfy their needs. This produces believable daily routines as it would result in the same daily patterns as those of natural humans, hence matching the expectations that the human users would have.

This motivational model is implemented and extended through this work to include the social aspect of prehistoric virtual humans through an interface which allows the user to communicate with the humans that would be acting out their daily routine. Additionally, these believable virtual humans would be portrayed through a holographic device and set in a prehistoric world. This holographic platform is used to act as a museum exhibition in order to use the holographic humans as an informative and educational platform.

2 Aims and Objectives

The main research question this project seeks to achieve is whether holographic agents in a persistent holographic environment can be perceived as believable entities displaying routines, personalities and interests found in natural intelligence. Essentially, capturing the meaning of what it is to be human. Additionally, the project investigates the applicability of these holographic agents to museum exhibitions to educate visitors in a new interactive manner.

The project seeks to address the research question by achieving the following aims:

- Create a sufficient computational architecture for the virtual agents in order to be perceived as believable agents who perform natural daily routines and allow users to relate to the agents.
- Encompass the social aspect of the agents through the development of an interface for the viewer to communicate with the virtual humans. This further contributes to the believability aspect as it would generate more respect the visitors would have for the virtual agents.
- Create a sufficient virtual world to be projected as a holographic overlay on a physical model to mimic a museum exhibit and evaluate its educational aspect. This is achieved through the projection of a pre historic environment on a model, as well as through the creation of a virtual environment together with sophisticated human animations. This would serve as the virtual world for the virtual agents to live in.

3 Implementation

3.1 Motivational Architecture

The first step in implementing the system was to acquire a computational model of Hagar Qim's layout. Once this was modelled, it was three dimensionally printed to obtain the physical model. The same model was also imported into the Unity game engine to further develop the virtual world. The temple model

was coloured black so as to not show on the holographic display and allow the physical model to be seen. However it was still kept in the environment to block the lower parts of the humans when they are standing behind stones to improve realism of the overlay. It was also needed to create an appropriate navigational mesh for the humans to explore the world appropriately.

Next a terrain object was used to create the flooring and was painted in accordingly. Additionally a directional light was used to mimic the effect of the sun and provide light to the scene. Additionally, a layout of activities was decided upon as well as the different activities that each agent would perform.

With these in place, coding of the synthetic behaviour could begin. Since the humans were designed to select activities that were not being performed by anybody at that particular point in time, the first thing that was implemented is this social aspect in which the humans keep track of the current states of the other humans. Before the human would select an activity, an array list is updated to store the current states of all the different humans in the environment. The different humans are looked up and the current state class variable is copied into a local array list.

Once the human has an idea of what the other humans are doing, he or she may select a free activity. However, before the human is allowed to select a job, different checks are performed to check the well-being of the person. The different internal levels are checked and if these are below a certain threshold then the humans would be motivated to satisfy the specific need rather than select a job. However, if these internal levels are satisfied then the human moves on to select a prehistoric job from the assigned jobs. Therefore in order to take an informed decision, the array list of all the current states of the other humans is consulted for a particular state and if it is found it means someone is currently performing that action and therefore the job must be skipped for now. Another layer of checks also serves as a form of memory so that the human does not choose the same action twice in a row. This process is highlighted in Fig. 1.

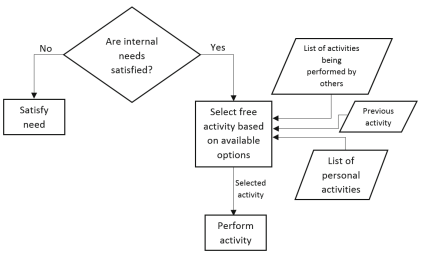

Fig. 1. Intelligent selection of activities. Source: [16]

Once a job is selected, the state of the human is set and the levels begin to decrease at the appropriate rate. At the same time, the human walks to the appropriate destination and upon arrival the animation of the activity is played. Upon arrival the boredom level begins to decrease.

In parallel to all these computations, the humans' internal levels are constantly being updated. The levels are updated through a function which is fired at every frame of the game. Each job affects the internal scales at different rates as manual labour is more tiring than arts and crafts. Therefore, by checking the current job of the human, the internal scales would be decremented appropriately. The reactive motivational architecture methods that command the logic of when the internal needs have to be satisfied, follow the same reasoning of the other jobs. They update the current state of the human and they start a path to the locations of where food and drink are found. However, once the human arrives at the destination, in addition to decrementing the boredom level, the energy, thirst and hunger levels are incremented (depending on the need that is being satisfied at that time). The internal levels are constantly monitored. This is due to the fact that the level of a need may hit zero whilst an action is being performed. Consequently, it would need immediate attention and not wait until the human gets bored of the current job. Therefore, as soon as the scale reaches zero, indicating the human's deficiency from a basic biological need, it would be picked up by the framework, interrupt the current activity and fire the method to satisfy the need instead.

3.2 Interface

The mobile interface was created using the Brass Monkey software development kit [17]. The dynamic controller in the framework allowed for the creation of the interface the way it was designed. That is, having a main menu screen to select the different humans, which once selected, a textual paragraph explaining what they are doing in the environment, as well as buttons at the bottom of the screen to allow the user to select different activities are displayed.

The interface is not a sequence of different screens, but rather one static screen that has changes in a texture field which shows the different textual paragraphs and buttons that are displayed and hidden at the appropriate times. Therefore each button on the interface, besides manipulating the behaviour of the humans, also updates the interface accordingly.

When a human is selected through the interface, the current state is checked and the appropriate texture is selected. It also checks the state of the world and whether the two previously interacted before.

The interface also calls upon methods from the motivational architecture through the activity buttons as once these are pressed the appropriate methods are fired so that the agent moves to the location and the levels are updated accordingly. Additionally, it not only manipulates the agent it is currently communicating with, but when the buttons are pressed, it also searches for any agents that are performing the current activity and forces it to select a new activity, repeating the whole intelligent activity selection defined in the previous subsection.

Finally, if the human is in a state where he or she is satisfying a need, then the interface does not display the default text and buttons, but rather a simple line excusing the agent and removes the buttons. This disables the choice of forcing

the agents to perform different activities, which in turn, increases believability as the interface respects the fact that the agents are their own human beings with their own needs.

3.3 Animations

The animations were all created in the images of prehistoric men and women. Each agent was fitted with a boolean modifiers. When these boolean values are set to true, the animation plays. Therefore an invisible box was placed at each location of each activity. Once the agent comes into contact with this box, the appropriate boolean is modified and the animation is played. It is played in a continuous manner whilst the human is in that area. As soon as the human leaves the area, the boolean is set to false and walking animations are played instead.

The walking animations do not make use of these boxes but rather take into consideration the direction the agent is moving in to play the appropriate animation.

4 Evaluation

Due to the subjective nature of believability that this project seeks to aim, evaluation could not be done through any computational means. Consequently, the involvement of empirical testing through a questionnaire is essential. Various users had to use and interact with the system themselves, after which they were requested to fill in a questionnaire. This method of evaluation is suggested and carried out by other researches such as Martinho et al. [6] and Alfonso [18] whose work also involved the creation of a believable agent. To truly test if their system achieved their aims, they too had a number of different users from all walks of life use their system and after respond to a questionnaire.

Following the footsteps of these respected researchers, thirty test subjects viewed and interacted with the system for around ten minutes, after which a questionnaire was filled in. These encompassed varying ages, the youngest being ten years old whilst the eldest was sixty six.

The designed questionnaire focused on five main topics; the believability of the behaviour the humans displayed, the usefulness and value of the created interface, the realism of the world and animations, the effect of the holographic overlay and lastly, the educational aspect and the system's applicability for a museum. By testing for these, the three main aims of the project may be determined whether they were achieved or not. The tabulated results could be found in Table 1.

Starting off with the believability of the system, most identified that the agents within the system behaved in a believable manner as they all performed different typical activities essential for their survival but also had their own needs and emotions. They added that the needs is what completed the system as without them the humans would have autonomously and repetitively done

Table 1. Intelligent selection of activities. Source: [16]

	Statements	No. of Agreements	%	No. of Disagreements	%
Believability	Agents behaved in a believable	29	96	1	4
	Agents were social beings	30	100	0	0
	Agents walked along believable paths	25	83	5	17
	Internal levels contributed to believability	30	100	0	0
	Agents were reactive	30	100	0	0
	Agents had believable daily routines	30	100	0	0
Clarity	System was clear and easy to follow	30	100	0	0
Interface	Interface was user-friendly	30	100	0	0
	Interface enhanced experience	30	100	0	0
	Agents displayed different personalities	24	80	6	20
Holographic Display	Physical model came to life	30	100	0	0
	Coherent system was created	30	100	0	0
Realism	Environment hacks improved system	22	73	8	27
	Animations were realistic enough	15	50	15	50
	Animations were necessary to consider the agents as humans	21	70	9	30
Museum	System applicable for museums	24	80	6	20
	System has an educational value	30	100	0	0

jobs without achieving any visible aims. One criticism was faced in this aspect in the fact that it did not totally encompass all the aspects of pre historic life as the humans did not age, reproduce or adhere to nature's callings such as voiding the bladder which are also natural human behaviours. The finished product matched the expectations the users had on prehistoric life and therefore was considered to be believable with a high percentage.

The interface was well received across all the ages and added value to the system as all enjoyed communicating with the sophisticated holographic humans. However, some had problems identifying the different personalities of the humans. This is not vital for the system however it is an additional design factor that would add to the whole experience. The personalities presented through the interface may not have been adequate enough for some people to relate to them completely or they felt that the natural language was too scripted and had a negative impact on the believability of the personalities. Better sophistication on the model that drives the text produced could have been implemented to enhance the variations in the text produced.

The holographic display received positive feedback when asked if the overlay added value and life to the static three dimensional model of the temple. The exact mapping of the overlay with the physical model created one whole coherent system as the activity of the stone work seemed to directly interact with the stones of the actual physical model whilst the walking animations would also be blocked by the physical stones in the model.

However, some heavy criticism was directed towards the realism of the world created and the animations of the humans. Some of the animations, while managing to capture the image of prehistoric men, were not realistic enough as they were either not very detailed or were lacking in variety. Additionally, many agreed that the environmental effects such as the lighting of the torches and the dimming of the light at night time were not all that noticeable. Moreover, most testers felt that the animations were necessary in order for the humans to actually be identified as humans. Although there was a mixed feeling, the majority stated that it was not enough that they only behave like humans, they must also look like them in order to relate to the humans and perceive them as believable humans.

Lastly, from the statistical data gathered users would appreciate the system in a museum setting. They were also able to get a better understanding of how life in those days actually was thereby verifying the educational aspect of the project.

5 Conclusion and Future Work

In conclusion, the main aim of creating a sophisticated computational model to manifest believable behaviour was achieved with satisfactory results. The reactive motivational architecture developed manifested behavioural patterns that were perceived as believable and relatable by 96 % of the thirty people who used the system. The agents matched the expectations of the users and they were able to relate to and interact with the holographic humans on an intellectual level.

Additionally, the second aim of this project was achieved through the development of the mobile interface. This provided a basis to develop the social aspect of the agents as different personalities with their interests are shown through it. This further improved the narrative concept of the system to help educate viewers and provide a better insight on the daily routine of prehistoric men and the hardships tribes in those times had to face without the luxury of contemporary technologies. Again this interface achieved satisfactory results as there was a 100 % agreement that the interface added value to the project and allowed the humans to be interpreted as more social. However, a lower percentage, 80 %, perceived this interface as a platform to manifest agent personalities. It may be concluded that although it was beneficial to the system, further research should be put into developing better sophisticated interfaces to bring out the personalities of the humans more efficiently.

Although the visual appeal of the system faced some criticism, study was, for the most part, successful as the main aims this work sought to achieve had a lowest scoring of 80 %. The graphical world only served as a base to manifest believable behaviour on and the aims and objectives focused mainly on the generation of believable social agents rather than creating detailed reconstructions of the world. Therefore, it may be concluded that by achieving the aims presented in this work, virtual agents may be perceived as believable humans and may serve as a platform to educate people in a new innovative way. The agents' daily patterns matched the expectations of the viewers and even surpassed them by educating every visitor and giving them a better understanding of what life was like in those days simply by observing and interacting with these intelligent agents.

However, besides extending the framework to include more activities, there is still room for further research into how virtual agent behaviour could be improved to encompass complex long term aspects of natural intelligence and catering for higher levels of Maslow's theory. Moreover, the literature covered in this project together with the results achieved, indicate that further research needs to be put into the generation of interfaces to develop sophisticated enough interfaces to reflect the intelligence and personalities of the agents.

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