Virtual Agents and 3D Virtual Worlds for Preserving and Simulating Cultures

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Abstract. Many researchers associate a culture with some form of knowledge; other scholars stress the importance of the environment inhabited by the knowledge carriers; while archaeologists learn about cultures through the objects produced in the environment as a result of utilizing this knowledge. In our work we propose a model of virtual culture that preserves the environment, objects and knowledge associated with a certain culture in a 3D Virtual World. We highlight the significance of virtual agents in our model as, on the one hand, being the knowledge carriers and, on the other hand, being an important element establishing the connection between the environment, objects and knowledge. For testing the resulting model we have developed a research prototype simulating the culture of the ancient City of Uruk 3000 B. C. (one of the first human-built cities on Earth) within a Virtual World of Second Life.

1 Introduction

There is a disturbing lack of agreement amongst researchers as to what constitutes a culture. Most existing definitions of culture come from anthropologists, but even amongst them there is no solidarity. Stone axes and pottery bowls are culture to some, but no material object can be culture to others [1]. Some researchers claim that the environment itself constitutes an important part of the culture and strictly defines how the culture evolves [2], other researchers consider cultures being the knowledge transmitted by non-genetic means [3] and neither objects nor the environment are related to the culture in their view.

We do not take any side in this debate, but consider culture being tightly connected with both the environment and the material products created as the result of utilizing the cultural knowledge. This consideration is made based on the following observations. First of all, the majority of the existing methods of culture preservation and methods used for learning about extinct cultures are structured around discovering, preserving and learning from the objects produced by this culture. The environment also provides important clues that help to fill the gaps in the existing knowledge. Moreover, in some cultures, i.e. the culture of indigenous Australians, the environment is so tightly integrated with all human actions, beliefs and traditions that ruling it out as being irrelevant to the culture makes it impossible to understand most of the cultural knowledge.

The *aim* of our work is to discover the elements that are associated with learning and preserving cultures and to produce an integrated framework enabling culture preservation and learning that incorporates all those elements.

While studying the existing techniques for cultural preservation we have identified printed materials as the most popular way of preserving cultural knowledge and museums as the way of preserving a culture in terms of objects. The most popular techniques that link a culture to a particular environment are movies and 3D virtual environments. Through further analysis of these techniques we have selected 3D virtual environments (and their subclass 3D Virtual Worlds) as the most affordable, dynamic and interactive option for integrating the environment, objects and knowledge associated with a culture.

Using 3D virtual environments to reconstruct lost sites of high historical significance has become very popular during the last decade [4]. Initially, 3D heritage applications were only focused on reconstructing destroyed architecture (e.g. Roman Colosseum). While such an approach creates a unique possibility for general audiences to examine the architectural details of the heritage site it still does not help an observer to understand how this site has been enacted in the past. Therefore, at a later stage, some researchers started to populate these virtual sites with so-called virtual crowds [5]. Such crowds normally consist of a large number of avatars dressed as local citizens of the reconstructed site. The state of the art in combining crowd simulation and 3D heritage can be observed on the example outlined in [6] where a virtual City of Pompeii is populated with a large number of avatars that walk around the city avoiding collisions.

Introducing virtual humans into cultural heritage applications, in our view, is an important step towards integrating all the three key dimensions of a culture: knowledge, environment and objects. However, current approaches focused on crowd simulations are not normally concerned with having virtual agents as immersed knowledge carriers, but rather use them as moving decorations.

In this paper we analyze the mechanisms that are required for capturing and preserving cultural knowledge through virtual agents. To do so we suggest focusing on individual agents rather than crowds. In order to avoid the debate about the role of environment and objects in a culture we introduce the notion of *virtual culture*, which is a combination of cultural knowledge, environment and objects preserved in a 3D Virtual World. Further we investigate the phenomenon of virtual cultures. The key *contributions* of our work are as follows:

- Specifying the role of virtual agents as an important element in the preservation of virtual cultures.
- Producing a formal model of virtual culture enabling successful culture preservation, facilitating the learning of a particular culture by the visitors and providing the foundations for the computational enactment of a culture.
- Testing the developed model through a case study.

The remainder of the paper is structured as follows. In Section 2 we identify the key elements that constitute a culture by using existing definitions and mathematical models. As the result of it, Section 3 proposes a formal model of virtual culture. In Section 4 the resulting model is applied to the development of a prototype aiming at preserving the culture of the ancient city of Uruk, 3000 B.C. Finally, Section 5 presents concluding remarks and directions of future work.

2 Background

When trying to replicate a culture inside a computer simulated environment it is important to have a formal model of the culture. The majority of research efforts focused on creating such artificial cultures originates in the field of artificial life [7]. To our knowledge, none of the existing works provide a comprehensive formal model of the culture that can be utilized for preserving a culture along its multiple dimensions. Therefore, in this section we will analyze the existing models and the available informal definitions of culture in order to understand which existing models to rely upon and how they should be extended.

2.1 Definitions

Most of the existing conceptualizations consider culture being some sort of knowledge. One of the first and most popular definitions of culture that is still accepted by the majority of modern researchers was produced by Edward Burnett Tylor. He defines culture as "that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society" [8].

The telling point of the definition proposed by [8] is that, although labelled a whole, culture is actually treated as a list of elements, which motivates us to look through other available definitions and identify those elements that can be included into the resulting formal model.

Through the analysis of the definitions linking culture to knowledge we identified the following elements that constitute such knowledge: Beliefs [8], Morals [8], Law [8], Customs [8], Habits [9], Techniques [9], Ideas [9], Values [9], Behavior Patterns [9], Standards of Behavior [2], and Rules of Behavior [2].

Culture is also believed to have a functional dimension, as suggested by [1]. It is not only considered as knowledge, but also as an evolving mechanism of utilizing this knowledge to better adapt to the environment and control it.

While not making a direct connection to physical objects in his definition, in his works Tylor also connects culture to human possessions. Specifically, he enumerates beliefs, customs, objects – "hatchet, adze, chisel," and so on – and techniques – "wood-chopping, fishing, fire-making," and so on [8]. The view that the concept of the culture is associated with certain objects created by its carriers is also shared by [9]. Herskovits in [2] takes an extreme materialistic view and considers culture being "the man-made part of the environment".

In [8] many of the attributes constituting a culture correspond to humans. In contrast to the majority of existing approaches to cultural heritage we are focused on including humans into both preservation and simulation of the culture and make them exhibit these attributes. So, in our model we will relate the knowledge aspect of a culture to humans and make humans the carriers of this knowledge. Additionally, the aforementioned definitions mention rules of behavior, techniques, standards and patterns of behavior and customs. While those elements are distributed amongst the culture carriers they have some kind of a unifying nature and can be preserved independently from their carriers. Therefore, we introduce the notion of institutions, which should be understood as the concept uniting all the aforementioned terms. While strongly associated with knowledge, the institutions are rather a global type of knowledge with individual agents having little impact on changing this knowledge. We find the notion of institutions being a central concept for culture preservation.

Generalizing the above considerations we can say that a culture is associated with institutions accepted by the virtual society, objects produced by culture carriers, culture carriers themselves together with their knowledge and behaviors.

2.2 Existing Models

Culture has been studied by social and computer scientists in the realm of the emergence of social consensus (e.g. [10, 11]), of which culture is a particular case. Here we examine these works as a basis for a general model of culture.

In [10] Axelrod observes that individuals can be characterised by their cultural features, such as language, religion, technology, style of dress, and so forth. Hence, the cultural traits of such features characterise each individual. Therefore, given a population of agents Ag, Axelrod characterises each agent $ag_i \in Ag$ by a vector of cultural features $\langle \sigma_i^1, \ldots, \sigma_i^m \rangle$, each one taking on a value to define an agent's cultural traits. Some of these traits change over time with the dissemination of culture, whereas other traits remain unchanged because an agent might be closed-minded or simply a given trait is not under its control (e.g. ethnicity). Similarly, in [11] Carley considers that culture is a distribution of facts among people, namely who knows what facts (e.g. a belief in God). Therefore, both Axelrod and Carley propose basic models to characterise *cultural knowledge*.

Despite the many definitions in the literature about culture, everyone agrees that people learn from each other. Hence, the dissemination of culture among people is based on the notion of social influence. In [10, 11], Axelrod and Carley incorporate a well-known regularity in the social world: "homophily" [12], or the tendency to interact with similar people. Thus, similarity among people's cultural features drives interactions. As a result of an interaction, two agents start sharing cultural features or knowledge that were different prior to their interaction.[1] Therefore, existing models of dissemination of culture agree on the need for a *local dissemination function* that each agent uses for changing her cultural knowledge or features based on her social influences (interactions).

Recent studies (mostly in the area of complex systems) on the emergence of social conventions agree on the importance of the structure (topology) of social relationships (e.g. the network of interactions among agents accounts for the local geography in Axelrod's model). Indeed, the work in [13] empirically shows that the network of interactions is important to reach consensus on either a

[1] Notice that considering homophily as part of a model of dissemination of culture assumes that social influences and interactions can only be positive.

single, global culture or on multiple cultures.[2] Hence, a model of culture must also take into account a model of social relationships.

At this point we can compile the fundamental components identified in the literature to computationally model a culture. Thus, a culture can be characterised in terms of models of: (i) cultural knowdledge or features; (ii) dissemination of culture; and (iii) social relationships. And yet, we believe that there is something missing. In section 2.1 we have highlighted the role of institutions. Hence here we advocate that institutions shape social relationships with varying degrees of social influence. This is particularly true in ancient societies where institutions like the family, the law, religions, or tribes play a fundamental role in the dissemination of culture. For instance, consider the influence of the head of a tribe or the father in a family.

3 Formal Model of Virtual Culture

Based on the analysis of the definitions and existing formal models of culture presented in Section 2 we have produced a formalization of virtual culture. Our aim was to develop a model allowing for preserving a culture along as many of its attributes as possible. This aim is very different to the aims behind the models presented in Section 2.2, where the key motivation was to investigate a very particular aspect of cultures (dissemination) and the simplicity of the model was rather a positive than a negative factor. In our work we rely on those existing models, but extend them with additional elements identified in Section 2.1.

In our formalization a virtual culture develops in a virtual environment, mimicking the actual physical environment where a culture is *situated*, and populated by virtual agents whose interactions occur in the framwork of and are constrained by institutions (e.g. families, law, religion). The institutions are associated with a certain space within the virtual environment (e.g. temples, markets). Moreover, we consider that virtual agents employ virtual objects in their interactions, namely virtual replicas of artifacts that mimic the actual physical objects (e.g. spears, pottery) being used by the members of a culture. Therefore, we can regard virtual places along with artifacts as the objects produced by a culture. Wrapping all the above elements, we can characterise a virtual culture as a tuple:

$$VirtualCulture = \langle E, P, O, Ag, I, l \rangle \quad (1)$$

where E is the virtual environment; P stands for the set of virtual places occupied by a virtual culture; O stands for the objects produced by a virtual culture (buildings and artifacts); Ag stands for a set of virtual agents; I stands for a set of institutions constraining the interactions of virtual gents; and $l : I \rightarrow P$ is a function mapping each institution to a location, namely to some virtual place.

Institutions are used to regulate the interactions amongst the participating individuals by enforcing strict rules, norms and conventions on their behavior [14]. Researchers working in the field of Distributed Artificial Intelligence have been working on formalizing the concept of "institution" for over a decade. One

[2] Moreover, San Miguel et al. [13] also investigate cultural drift, namely the effects of spontaneous changes of cultural traits.

of the most successful institutional formalisms from this area is the concept of "Electronic Institutions" [15].

In our work we rely on the concept of Electronic Institution as a basis for producing the formal definition of a culture. Here an institution is treated as a composition of: roles and their properties and relationships, norms of behavior in respect to these roles, a common language (ontology) used by virtual agents for communications with each other (e.g. this ontology must allow virtual agents to refer to places and artifacts), acceptable interaction protocols representing the activites in an institution along with their relationships, and a role flow policy establishing how virtual agents can change their roles. As mentioned in Section 2.2 we take the stance that social relationships in the realm of an institution establish social influences of varying degrees that must be considered for culture dissemination. So, an institution in our model can be characterised as:

$$I = \langle R, ssd, sub, N, Ont, PS, \mathcal{I} \rangle \tag{2}$$

where R is a set of roles; $ssd \subseteq R \times R$ and $sub \subseteq R \times R$ stand for relationships among roles (incompatibility of roles and subsumption of roles respectively); N is a set of norms of behaviour; Ont is a common language (ontology); PS stands for a graph defining the relationships among interaction protocols and role flow of the agents; and $\mathcal{I} \subseteq R \times R$ stands for a set of directed arcs between roles, where $w : \mathcal{I} \rightarrow \mathcal{R}^+$ labels each arc with a degree of social influence.

From the agent perspective, we take the stance that virtual agents are culturally characterised by their appearance (e.g. dress, facial features, etc.) and their cultural knowledge, namely their beliefs. We also assume that virtual agents are endowed with patterns of behaviour[3], namely plans of actions, which allow them to act in different institutions. Based on its beliefs, a virtual agent selects a pattern of behaviour to perform in each institution. Moreover, the definition of culture presented in [3] suggests that culture is not transmitted by genetic means amongst agents and that culture can be transmitted from one agent to another via *social learning* mechanisms. Hence, a virtual agent requires a social learning function modelling the dissemination of culture, namely the way a virtual agent's knowledge changes after interacting with some other agent in the framework of an institution depending on the role each agent plays (since a role determines the degree of social influence). Following the above considerations, we can characterise the components of a virtual agent as a tuple:

$$Ag = \langle Ap, K, B, \pi, \delta \rangle \tag{3}$$

where Ap is the appearance of a virtual agent; K is the agent's knowledge; B is a set of patterns of behaviour the agent can perform; $\pi : K \times I \rightarrow B$ is a behaviour selection function that allows a virtual agent to choose a behaviour, a plan of actions; and $\delta : K \times R \times I \times Ag \times R \rightarrow K$ is a social learning function.

4 Case Study: The City of Uruk, 3000 B.C.

The case study aims at recreating the ancient city of Uruk from the period around 3000 B.C. in the Virtual World of Second Life letting the history students experience how it looked like and how its citizens behaved in the past (more

[3] Eventually these patterns are obtained either by cultural transmission or by learning.

about the Uruk Project as well as the prototype video can be found in [16]). The Virtual World of Second Life provides a unique collaborative environment for history experts, archaeologists, anthropologists, designers and programmers to meet, share their knowledge and work together on making the city and the behavior of its virtual population historically authentic.

Uruk was an ancient city located in present day Iraq. Many historians and archaeologists believe that Uruk was one of the first human built cities on Earth. Uruk played a major role in the invention of writing, emergence of urban life and development of many scientific disciplines including mathematics and astronomy.

4.1 Approach

Our approach to preserving and simulating the Uruk culture is shown in Figure 1.

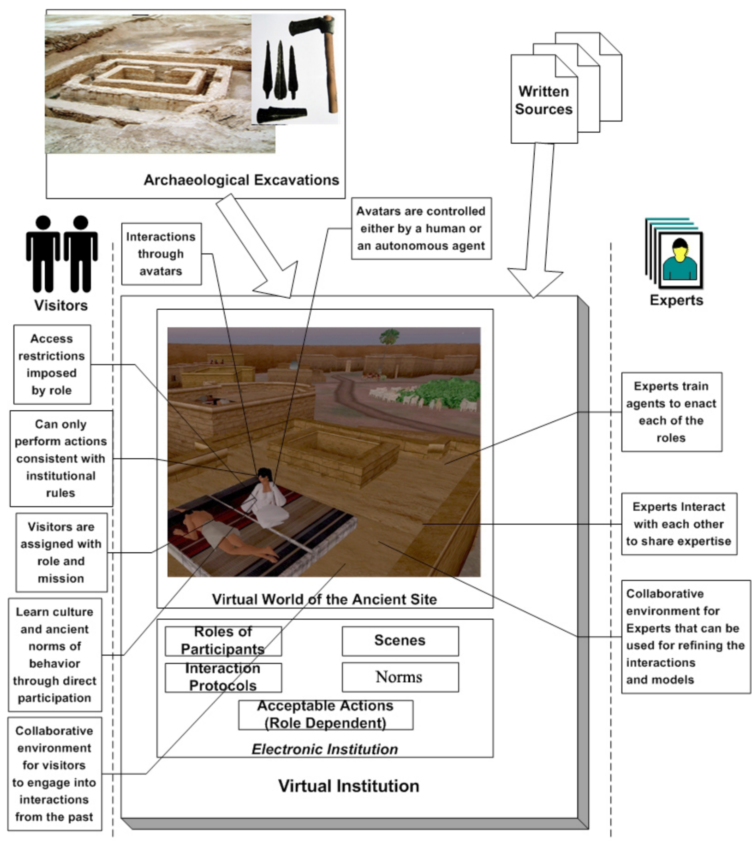

Fig. 1. Our Approach to Preserving and Simulating Cultures.

The 3D Virtual World is used for both preserving the culture and for teaching the resulting culture to the visitors. It is accessible by two types of participants: Visitors and Experts. Visitors are participating in the environment to learn about the given culture through exploration of the Virtual World and through embodied interactions with its virtual inhabitants. Experts are a key element in culture preservation. Through embodied interactions with other experts in the Virtual

World they share their knowledge and refine the appearance of the heritage environment, validate the correctness of the reconstructed buildings and artifacts, as well as help to refine the behavior of virtual agents. As the result of the joint work of historians, archaeologists, designers and programmers the resulting heritage site is recreated in the virtual world and populated with virtual agents that look and behave similar to the actual people that used to live in the given area. With the help of the Virtual Institutions technology [17] the agents are able to engage into complex interactions with other agents and humans, while following the social norms of the reconstructed ancient culture.

4.2 The Prototype

The prototype aims at showing how to enhance the educational process of history students by immersing them into daily life of the ancient city of Uruk, so that they gain a quick understanding of the advance of technological and cultural development of ancient Sumerians. The prototype was built following the formal model outlined in Section 3. It does not currently feature culture dissemination and agent actions are limited to non-verbal behaviors.

4.3 Uruk Environment

Based on the available data we have recreated the environment of the city of Uruk in the Virtual World of Second Life. The environment features a flat desert-like area with very little vegetation. It contains animals: donkeys, sheep, eagles and fish. These animals are known to be living in the city of Uruk in 3000 B.C.

4.4 Uruk Objects

Based on the results of archaeological excavations and the available written sources we have recreated the buildings and artifacts that were available in Uruk. Both modeling of the city and programming of the virtual humans populating it were conducted under the supervision of subject matter experts. The object designers used input from our subject matter experts, who provided them with sketches, measurements and positions of the objects. Many of the artifacts were replicated from the artifacts available in museums.

4.5 Uruk Agents

Our model presented in Section 3 identifies some functionalities a virtual agent must implement to successfully operate within a virtual culture. In particular, each virtual agent must incoroporate a machinery to "decide" how to behave within institutions (through patterns of behaviour) and how to handle the social influences. To make this possible the agent must have access to the institutional formalization. Such access is provided by the virtual institutions technology [17].

For the purpose of this study we have selected fishermen daily life of ancient Uruk in order to illustrate our model of virtual culture. We created four agents that represent members of two fishermen families. Each family consists of a husband and a wife. Every agent has a unique historically authentic appearance and is dressed appropriately for the period around 3000 B.C.

The agents literally "live" in the virtual world of Second Life. Their day is approximately 15 minutes long and starts with waking up on the roof of the house (where they slept to avoid high temperatures). The wives would wake up first to collect some water from the well and prepare breakfast for their husbands. The husbands normally start their day by having a morning chat while waiting for the breakfast to be prepared (eating and cooking are not currently implemented).

After breakfast the fishermen would collect their fishing gear and walk towards the city gates – Figure 3 a). Outside the gates on the river bank they would find their boat which they will both board and start fishing. One of the agents would be standing in the boat with a spear trying to catch the fish and the other agent would be rowing. Figure 3 b) illustrates the fishing process.

a) b)

Fig. 2. The City of Uruk Prototype.

After fishing, the men exit the boat, collect the fishing basket and spear and bring them back to their homes. This daily cycle is then continuously repeated with slight variations in agent behavior.

Each of the agents enacts one of the four social roles. Agent Fisherman1 plays the "SpearOwner" role. He is the young male fisherman. He possesses the fishing spear and is capable of catching the fish with it. He and his brother also jointly own a fishing boat. His daily routine consists of waking up on the roof, having a morning chat with fisherman 2, fishing, bringing the fishing gear back home and climbing back on the roof to sleep.

Fig. 3. Fisherman Family 1: Fisherman1 Andel and Wife1 Andel.

Wife1 Andel enacts the "WaterSupplier" role. She is the young wife of Fisherman1, who is responsible for collecting water from the well. Her daily routine consists of waking up on the roof, collecting the water from the well, doing house work and climbing back on the roof to sleep there. As any other typical fisherman wife in Uruk she does not have any recreation time and is constantly working.

Agent Fisherman2 is the older brother of Fisherman1 playing the social role "BoatOwner". He lives with his wife in the separate house next to his brother. Both families are very close and spend most of their day together. Fisherman2 possesses a fishing basket and paddles for rowing the fishing boat. His daily routine consists of waking up on the roof, having a morning chat with Fisherman1, fishing, bringing the fishing gear back home and climbing on the roof to sleep.

Fig. 4. Fisherman Family 2: Wife2 Jigsaw and Fisherman2 Jigsaw.

Wife2 Jigsaw, the wife of Fisherman2, plays the "FireKeeper" role. She is older than Wife1 and, therefore, is the key decision maker for controlling the integrity of both households. She makes fishing baskets and trades them for other household items. Starting the fire and preparing food are her direct responsibilities. Her daily routine consists of waking up on the roof, starting a fire for cooking, routine house work and climbing back on the roof to sleep there.

In the current prototype we employ an incomplete model of an agent as compared with the model described in Section 3. Each agent has an appearance, a number of behavior patterns and a behaviour selection function, but has a very limited knowledge about the culture and no social learning function to realise the dissemination of culture. These features are left for the future work.

4.6 Uruk Institution

The extended description of the process and the methodology used for formalizing the Uruk institution are presented in [18]. For the purpose of this presentation we only focus on the key components present in the resulting Uruk institution.

Figure 5 outlines the Performative Structure, Roles of participants and gives an example of a Norm and an interaction protocol (Scene). The Performative Structure is a graph defining the role flow of participants among various activities. The nodes of this graph feature the identified scenes and the arcs define the permission of participants playing the given role to access certain scenes. Arcs labelled with "new" define which participants are initializing the scene, so that no other participants can enter it before the initialization occurs.

The institution can be accessed by the agents playing the following four roles: SpearOwner, BoatOwner, WaterSupplier and FireKeeper. Here SpearOwner and BoatOwner are two subroles of the role Fisherman and WaterSupplier and FireKeeper are the subroles of role wife. The Performative Structure also includes the following roles (Fire, Boat, House1, House2, Well). These roles correspond to dynamic objects that change the state of the environment by performing some actions in it. The interaction of the agents with such objects must be formalized appropriately in the specification of the institution to ensure correct behavior.

The "root" and "exit" scenes are not associated with any patterns of behavior and simply define the state of entrance and exit of participants into the

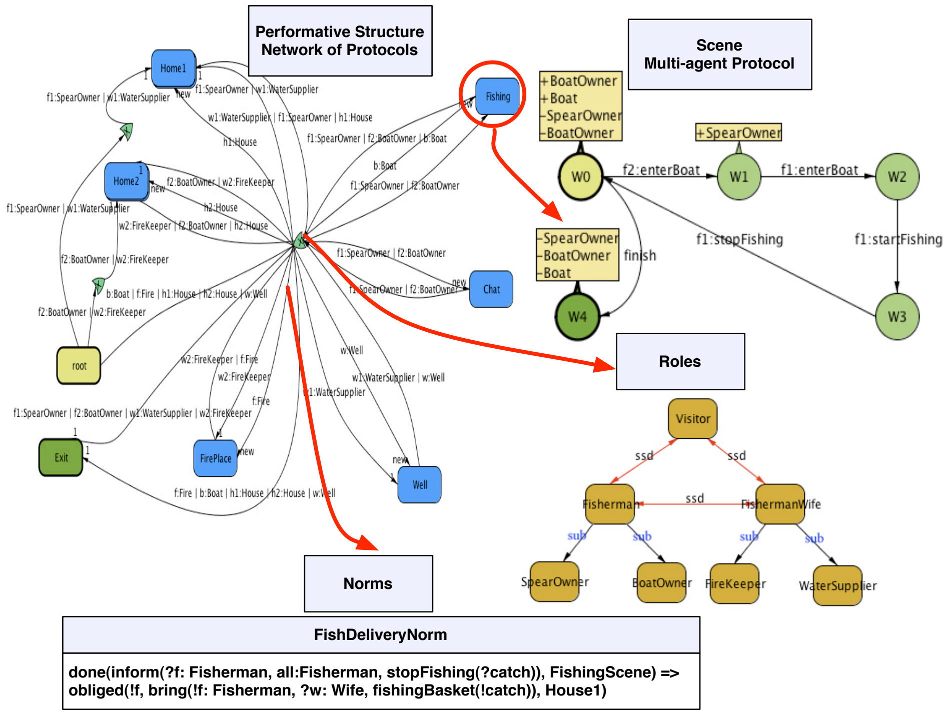

Fig. 5. Some Components of the Uruk Institution.

institution. Apart from them each of the scenes in the Performative Structure is associated with a Finite State Machine defining the interaction protocol for the participants that are accepted into the scene. To change the scene state a participant has to perform an action accepted by the institutional infrastructure.

The scene protocol here defines in which sequence agents must perform the actions, at which point they can join and leave the scene and what they should do to change the scene state. In Virtual Institutions we consider every action that changes the state of the institution being a speech act (text message). Every action (i.e. grabbing an object or clicking on it) a participant performs in a Virtual World is captured by the institutional infrastructure.

As an example, Figure 5 outlines the institutional formalization of the Fishing Scene (associated with the area around the boat). Once a scene is initialized its initial state becomes "W0". While the scene is in this state Fisherman2 and Boat can join the scene and both Fisherman1 and Fisherman2 can leave the scene (the "Boat" is part of the scene when this is activated). Fisherman1 can only enter the scene after Fisherman2 successfully enters the boat. This occurs when the avatar of Fisherman2 boards the boat by performing the action "f2:enterboat" (labelling the transition from "W0" to "W1"), making the scene evolve from state "W0" to state "W1" (BoatOwner on board). After Fisherman1 enters the boat, by performing the "f1:enterBoat" action, the institutional infrastructure makes the scene evolve to state "W2" (SpearOnwer on board) and notifies all participants about the state change. Then Fisherman1 may request to start the fishing, by performing action "f1:startFishing", which would bring the scene into “W3” (Fishing). The result of this is the change of the boat state from “standing” to “afloat”, Fisherman2 will start rowing and the boat object will move. In state “W3” the only action that can be performed is informing all the participants by Fisherman1 that fishing is finished. When the fishing is finished Fisherman2 must return the boat to the initial position, park it there, drop the paddles, take the fishing basket and exit the boat. Fisherman1 will also have to exit the boat. No participants can leave the scene in this state and must wait until the scene evolves to “W0”. While the scene is in “W0” again, the Boat object will change its state to “docks”, this being captured as a “finish” action by the institutional infrastructure that makes the scene evolve to its final state “W4”. This deactivates the scene and makes it impossible for the participants to join it and act on it (no participant will be able to sit inside the boat).

Similar to the Fishing scene the interaction protocols have to be specified for other scenes present in the Performative Structure. We would like to point out that the scene protocol does not define how the actual fishing should take place, but simply provides the key states within the scene so that the agents can have a formal understanding of the performed actions.

4.7 Validation

Our approach to modeling cultures is based on the 3D Virtual Worlds technology. The importance of this technology for transmitting knowledge was highlighted by the outcomes of the research summit on the role of computer games in the future of education [19]. The outcomes suggest that 3D Virtual Worlds is an important technology for teaching higher-order thinking skills such as strategic thinking, interpretative analysis, problem solving, plan formulation and execution, and adaptation to rapid change. Based on the opinions of over 100 experts in education the summit concludes that virtual experience is beneficial for learning as it helps the students to maintain a high level of motivation and goal orientation (even after failure); enables personalized learning and, under certain conditions, is associated with unlimited patience. The key identified benefits of using Virtual Worlds for learning are: personalization, active learning, experiential learning, learner-centered learning and immediate feedback [19].

In order to test the validity of our particular approach to modeling the selected culture in a Virtual World we conducted additional validation from two different perspectives. The first perspective is *Expert Validation*. To verify our simulation of the culture of the city of Uruk, 3000 B.C. we have collaborated with 2 subject matter experts. The experts helped us in revising the scenarios and 3D models of the objects. Once the prototype was completed, the experts confirmed that the created prototype indeed reflects the way of life of ancient Sumerians from the city of Uruk and confirmed its historical authenticity.

The second perspective of validation is *Learners Feedback*. In order to conduct this validation, we have selected 10 people (students and staff members) from two Australian universities. The key selection criteria for our *sample* was that those people are supposed to have very little [next to nothing] previous knowledge about ancient Mesopotamia and the city of Uruk. To ensure this, before conducting the study all participants were asked about their previous knowledge in this respect. We aimed at analyzing the impact of our simulation on people from different genders and different age groups. To ensure this, another level of candidate screening was associated with their age and gender. As the result we have selected 10 people (5 males and 5 females) with their age evenly distributed between 23 to 63 years old. All the participants claimed to have no previous knowledge about ancient Mesopotamia and the city of Uruk.

During the *study* each test subject was asked to sit in front of the computer screen and was given a very brief introduction. The introduction mentioned that what is shown on the screen is the 3D reconstruction of the city of Uruk in 3000 B.C. After this the participant was given instructions on how to navigate in the Virtual World and was asked to follow each of the 4 virtual agents present in our prototype. The interviewee was giving commands as to which direction to go and which avatar to follow. Once the participant successfully observed the key activities in the life cycle of the selected agent he/she was asked to follow another avatar. For the purpose of this study we kept the duration of this experience under 20 minutes for each participant.

At the end of this experiment the Virtual World browser was closed and the participant was interviewed about the Virtual World experience. The aim of these interviews was to verify whether the users of our simulation are able to learn about the culture of ancient Mesopotamia along all the dimensions we have identified. Each *interview* consisted of 18 questions. The first 16 questions aimed to test what was learned by the participant about the Uruk culture along each of the 4 dimensions covered by our model. For example, some of the questions focused on the environment, asking the test subject to describe the climate, vegetation and weather. Other questions targeted the institutional structure, i.e. social relationship between the observed virtual agents as well as information about their social roles and interaction protocols. Another two groups of questions focused on agent behavior and on objects in Uruk city. Finally, the last two questions aimed at evaluating the overall experience, asking the test subjects to briefly summarize what they have learned about the culture, identify any of their concerns and list the key highlights of the virtual experience.

The *results* of the study confirm that participants were able to acquire new knowledge about the Uruk culture along every dimension we have identified. None of the participants gave 100% correct answers, but all of them provided at least 70% of correct information. The incorrect responses were not biased along any of the dimensions and seemed to be highly individual. Some of the wrong answers had clear correlation with the lack of skills in controlling the interface.

5 Conclusion and Future Work

We have presented a formal model of a virtual culture that is suitable for preserving a variety of cultural attributes and for simulating a giving culture to the public. Our model is based on the Virtual Institutions technology [17] with Virtual Agents being the carriers of the cultural knowledge, while the 3D Virtual World provides a necessary environment for visualizing a culture. The resulting model was used for creating the research prototype of the city of Uruk 3000 B.C. The prototype aims at simulating the culture of two fishermen families in ancient

Mesopotamia. The validation of the developed prototype ensures the feasibility of the selected approach and suggests that it is possible to preserve the cultural knowledge along all the dimensions we have identified trough our research.

Future work includes extending the scenarios with more agents, improving the agent architecture, introducing more variety in agent behavior and further formalization of the Uruk institution. In the future we will support the dissemination of culture, namely how culture spreads and evolves. We will also work on gathering more scientific evidence in favor of our approach to modeling cultures by comparing it with traditional approaches. In particular, we will investigate whether the users of our simulation are able to learn more about a particular culture than those accessing the same information through printed materials.

References

1. White, L.: The Concept of Culture. American Anthropological Association (1959)
2. Herskovits, M., Jean, M.: Cultural anthropology. Knopf New York (1955)
3. Dictionary.Com: Definition of Culture. Published Online: http://dictionary.reference.com/browse/culture, (Accessed: 15 February 2009)
4. Addison, A.C.: Emerging trends in virtual heritage. IEEE MultiMedia **7**(2) (2000) 22–25
5. Gutierrez, D., Frischer, B., Cerezo, E., Gomez, A., Seron, F.: AI and virtual crowds: Populating the Colosseum. Journal of Cultural Heritage **8**(2) (2007) 176–185
6. Mam, J., Haegler, S., Yersin, B., Mller, P., Thalmann, Daniel,, Van Gool, L.: Populating Ancient Pompeii with Crowds of Virtual Romans. In: 8th International Symposium on Virtual Reality, Archeology and Cultural Heritage - VAST. (2007)
7. Upal, M.A.: From Artificial Intelligence to Artificial Culture. In: Papers from the AAAI-06 Workshop, Menlo Park, CA, USA, AAAI Press (2006) 1–5
8. Tylor, E.B.: Primitive Culture. J.P. Putnams Sons, New York, USA (1871)
9. Kroeber, A., Kluckhohn, C.: Culture: A critical review of concepts and definitions. New York: Random House (1952)
10. Axelrod, R.: The dissemination of culture: A model with local convergence and global polarization. Journal of Conflict Resolution **41**(2) (April 1997) 203–226
11. Carley, K.M.: A theory of group stability. American Sociological Review 56, S.331-354 (1991)
12. Cohen, J.M.: Sources of peer homogeneity. Sociology of Education **50**(4) (1977) 227–41
13. Miguel, M.S., Eguiluz, V.M., Toral, R., Klemm, K.: Binary and multivariate stochastic models of consensus formation. Computing in Science and Engineering **7** (2005) 67–73
14. Schotter, A.: The Economic Theory of Social Institutions. Cambridge University Press, Cambridge, USA (1981)
15. Esteva, M.: Electronic Institutions: From Specification to Development. PhD thesis, Institut d'Investigació en Intelligència Artificial (IIIA), Spain (2003)
16. Uruk Project: http://www-staff.it.uts.edu.au/∼anton/Research/Uruk_Project
17. Bogdanovych, A.: Virtual Institutions. PhD thesis, UTS, Australia (2007)
18. Bogdanovych, A., Rodriguez, J., Simoff, S., Cohen, A., Sierra, C.: Developing Virtual Heritage Applications as Normative Multiagent Systems. In: Proceedings of the AOSE '09 Workshop, Springer (2009)
19. Summit on Educational Games: Harnessing the Power of Video Games for Learning. Public report, Federation of American Scientists (October 2006)