Integrating Agents and Virtual Institutions for Sharing Cultural Heritage on the Web

Anton Bogdanovych[1], Laura Papaleo[2], Massimo Ancona[2], Viviana Mascardi[2], Gianluca Quercini[2], Simeon Simoff[1], Alex Cohen[3], Antonella Traverso[4]

[1] School of Computing and Mathematics, University of Western Sydney, Australia
{a.bogdanovych, s.simoff}@uws.edu.au
[2] Department of Computer Science, University of Genova, Italy
{ancona, papaleo, mascardi, quercini}@disi.unige.it
[3] Federation of American Scientists, 1725 DeSales Street, Washington, DC, USA
acohen@fas.org
[4] DARFICLET Department, University of Genova, Italy
antonella.traverso@lettere.unige.it

Abstract. This work outlines the research activities carried out by our groups in the direction of the implementation of a tool for sharing natural and cultural heritage on the web. The tool will serve as a support to teachers and people involved in scientific and cultural activities (for example, archaeologists, historians, geologists, directors of museums and of exhibitions) for making historical, naturalistic, artistic content available in a game-like but scientifically well founded way based on Virtual Institutions and intelligent software agents. Our approach is illustrated on the example of the city of Uruk, which is believed to be the first city on Earth, where the culture of ancient Sumerians is preserved in terms of the natural environment, human behaviour and architecture.

1 Introduction

The safeguard of the world heritage is a very hot topic since 1972, when the general conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) adopted the convention concerning the protection of the world cultural and natural heritage. The motivating reasons behind the convention are that the cultural and natural heritage is increasingly threatened with destruction not only by the traditional causes of decay, but also by changing social and economic conditions. Each State agreeing to the convention is thus asked, among other duties, *(1)* to set up within its territories, where such services do not exist, one or more services for the protection, conservation and presentation of the cultural and natural heritage; *(2)* to foster the establishment or development of national or regional centers for training in the protection, conservation and presentation of the cultural and natural heritage and to encourage scientific research in this field [1].

The purpose of our research is twofold. On the one hand, we want to design a tool that supports domain experts and teachers (namely, the intermediate users

of the system) in describing past or present societal and environmental scenarios, characterised by norms that govern the society, agents that play roles in it, and an environment where interactions take place, in an easy-to-understand, but still scientifically sound way. This will help them to share and reason on the relationships among all of the factors characterising the society itself to explain why some event took place (or would take place), and to predict what could happen when some factors change. The tool will hence serve as a support for making plans for the protection and conservation of the natural and cultural heritage represented in the scenarios themselves. On the other hand, the same tool used by the domain experts might be exploited for presenting the cultural and natural heritage and for training persons in knowing, appreciating, respecting and, maybe, helping in safeguarding it. Thanks to a 3D interactive visualisation now widely available on the web, the final users (students, web surfers) will feel like playing a role game, but at the same time they will be learning the societal and environmental structure of the modelled scenario.

The primary concept that leads our research is that of institutions (more specifically electronic institutions, or *e-institutions* for short) as a mechanism for modelling and formalising (ancient) societies and historical social organisations, their relations with the environment, agriculture, natural events and other resources available at a considered time interval. It is now known that many of the past societies failed, and others succeeded for a long period of time. Following Jared Diamond, the past offers us a rich database from which we can learn, in order that we may keep on succeeding. Hence, we aim at exploiting *Virtual Institutions* (VIs, previously known as 3D Electronic Institutions [2]) to reproduce enhanced Virtual Worlds where the system's final users will move, interact, and learn history and ancient norms of behaviour through direct participation, in an immersive, amenable, and highly innovative way.

Such Virtual Worlds created by domain experts, using a *programming by demonstration approach* and made available via Web and with multilingual comments and explanations, could be used by two kinds of users: *(1)* by other *domain experts* for comparing, sharing and reusing their expertise and viewpoint, that are condensed within the Virtual World itself; *(2)* by *non-expert users*, that will enter the Virtual World playing a well defined role, and will experience the full immersion in the situation that the Virtual World models, thus having the possibility to learn which were the habits, behaviours and rules governing the modelled situation.

The reminder of this work is organized as follows. In Section 2 we briefly summarise related works and approaches on Virtual Heritage, outlining their main drawbacks. In Section 3 we describe our approach, while in Section 4 we show some initial results of our research. Finally, in Section 5 some concluding remarks are drawn.

2 State of the Art in Virtual Heritage

Virtual heritage is a term used to describe works dealing with information and communication technologies (ICT) and cultural heritage and it usually refers

to instances of properties and sites with archaeological, aesthetic, historical and cultural value within a technological domain.

The traditional way of capturing and preserving various attributes of a culture is outlined in Figure 1(a). In this case, the results of archaeological excavations in combination with written sources result in a set of functional descriptions and illustrations that describe a culture. The drawbacks of such approach include the lack of realism and engaging experience, the limited nature of this method for conveying knowledge about human interactions and styles of behaviour as well as very limited social learning possibilities offered to a user due to inadequate support of imitation learning.

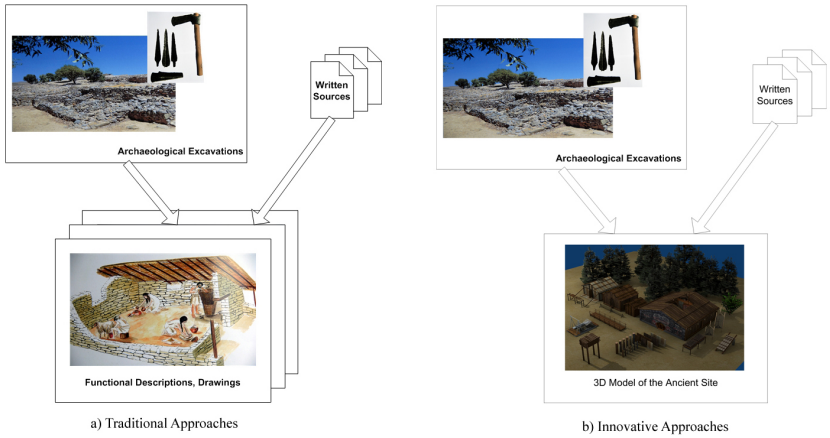

Fig. 1. Popular Existing Approaches to Cultural Heritage.

Innovative approaches to cultural heritage (Figure 1(b)) go beyond text descriptions and static images by visualising the heritage sites via interactive 3D graphics. The drawback in this case is the absence of people for interactions.

Recently, Virtual Institutions are emerging in the context of Virtual Heritage applications. Virtual Institutions [2] can be defined as 3D Virtual Worlds with normative regulation of participants interactions. They reduce the complexity of the virtual environment through formal specification of the norms of behaviour, interaction protocols and role flow of participants without distinguishing whether participants are humans or software agents. Such formalisation significantly simplifies the learning task of an agent. Every action performed by the human principle, that has institutional consequences, results in the change of the institutional state and the underlying Virtual Institutions technology informs the agent (imitating the human) about the details of this state change. In this way, an agent does not have to infer the goal of the principle (which is one of the biggest technical challenges in imitation learning [3]), but can treat reaching the new institutional state as the goal of the demonstrator.

We propose to use the combination of 3D Virtual Worlds, Artificial Intelligence and Virtual Institutions to support the preservation and simulation of ancient cultures not only in terms of architecture, but also human behaviour.

3 Our Approach via Virtual Institutions

The goal of our approach is to enable preserving ancient cultures within 3D Virtual Worlds, where a heritage site is reconstructed in its original form and populated with autonomous computational agents simulating the ancient inhabitants. In order to solve this task, we will employ the Virtual Institutions technology in combination with imitation learning (for teaching cultural characteristics to autonomous agents through embodied interactions with human experts).

A schema presenting the approach is depicted in Figure 2. As shown in the Figure, our framework considers two classes of participants: *Visitors* and *Experts*.

Visitors explore the heritage site and learn about its culture through embodied interactions with virtual inhabitants. Experts, instead, share their knowledge and refine the appearance of the heritage site and the behaviour of its inhabitants. In particular, the domain experts will be able to populate the VI of avatars - controlled by autonomous agents - using a *programming by demonstration approach*. In this way, the experts will create avatars that enact the roles foreseen by the VI (as extracted by the digital content). This kind of interactive programming by training will result definitely easier to perform than a traditional implementation of the autonomous agents, based on explicit coding.

We also envisage the exploitation of intelligent text and image mining modules for extracting information on the society to model directly from existing textual and visual documents. Finally, a user-friendly GUI will allow the domain experts to give a realistic visual rendering to avatars's dresses and aspect, buildings, and surrounding environments that characterise the Virtual World.

Unlike other existing heritage applications that employ Virtual Worlds we plan not only to reconstruct the architectural objects, but also to populate heritage sites with autonomous computational agents that look and behave similar to the actual people that used to live there. With the help of the Virtual Institutions technology the agents will be able to engage into complex interactions with other agents and humans, while following the social norms of the reconstructed ancient culture.

4 Initial Results: Virtual Uruk

In order to highlight the potential of our approach, this section describes a prototype we developed. In particular, we present the work done in the recreation of the ancient city of Uruk in 3D, the formalisation of the Uruk Virtual Institution and the population of the city with interacting virtual agents.

4.1 The City of Uruk, 3000 B.C.: History and Significance

The city of *Uruk*, known in the Bible as *Erech*, was located in present day Iraq and situated roughly 250 km south of Baghdad on an ancient branch of the Euphrates River. Uruk was a major city in Sumer, built around 5000 B.C. It would be fair to say that Uruk was Mesopotamia's and the World's first city [4].

Sumerians, the inhabitants of Uruk, made an enormous contribution to the development of mathematics, astronomy, medicine, urban life and, most importantly, are believed to be the first to invent writing. It's due to Sumerians that

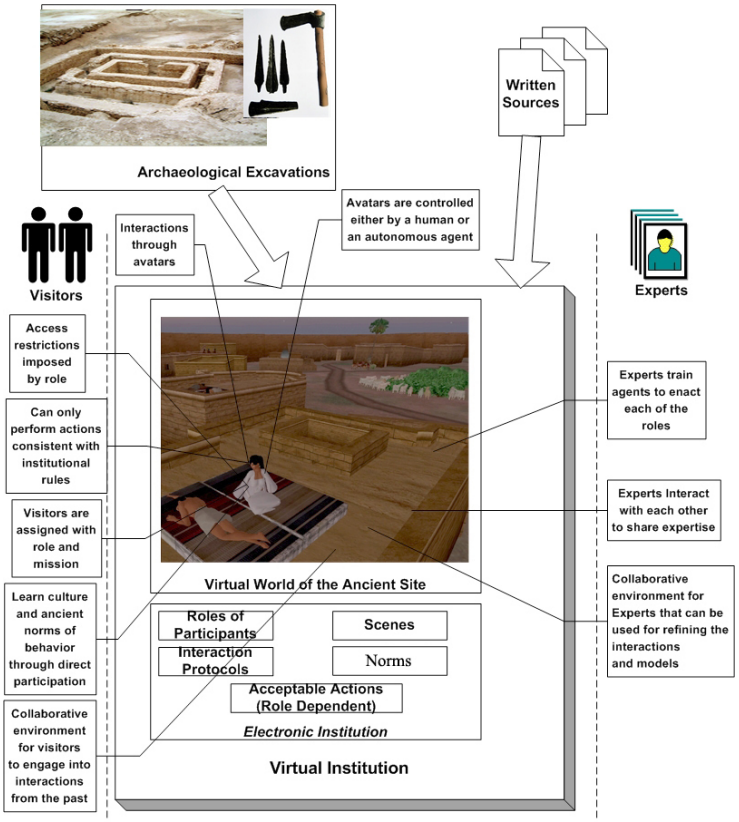

Fig. 2. Virtual Institutions in Cultural Heritage.

we divide a year into for seasons and twelve months as well as have twelve zodiac signs. Following their early measurement system we still count minutes and measure angles using the base of sixty. The majority of constellations are still referred to using the adapted translations of their early Sumerian names.

The city of Uruk saw the emergence of urban life in Mesopotamia and led to the full civilisation of the Early Dynastic period. Education, craftsmanship, law and even the invention of the first wheel are believed to be tightly connected with the city of Uruk. Having two major temples on its territory Uruk also played an important role in the religious development and mythology of the Mesopotamian civilisation. The city remained important throughout the 3rd millennium B.C., but declined in importance during the later part of that period. It remained in occupation throughout the following 2 millennia, down to the Parthian period, but only as a minor center [4].

4.2 Recreating the City in 3D

The 3D model of the city was produced based on the results of archaeological excavations and available written sources. The development of the 3D models

was supervised and evaluated by the subject matter experts. The actual city was very large, so the reconstruction features an approximation of the actual city and includes the buildings only: ziggurat of Uruk, Inanna temple, a number of private residences, school, local market and the city well. Similar to the actual city, virtual Uruk lies on the bank of a river and is surrounded by a large wall. Figure 3 shows virtual Uruk recreated in the Virtual World of Second Life[5].

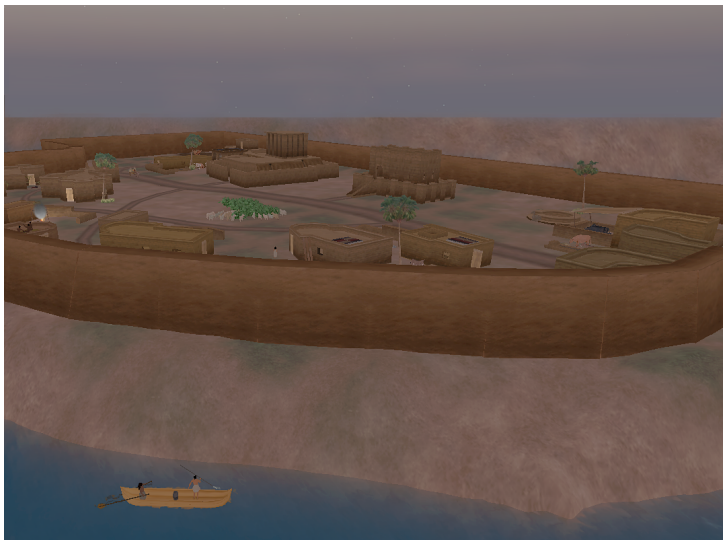

Fig. 3. The City of Uruk in the Virtual Worlds of Second Life.

4.3 Formalising the Uruk Institution

The norms of behaviour of the ancient Sumerians, scenes and common interaction protocols, the role hierarchy and the role flow policy are formalised using the Electronic Institutions technique [5] - a widely acceptable method within the area of Multiagent Systems. The extended description of the process and the methodology used for formalising the Uruk institution are presented in [6]. For the purpose of this presentation we only focus on the key components present in the resulting Uruk institution.

Figure 4 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 initialising the scene, so that no other participants can enter it before the initialisation occurs.

The institution can be accessed by the agents playing the following four roles: *SpearOwner*, *BoatOwner*, *WaterSupplier* and *FireKeeper*. The Performative Structure also includes the roles *Fire, Boat, House1, House2, Well* which

[5] http://www.secondlife.com

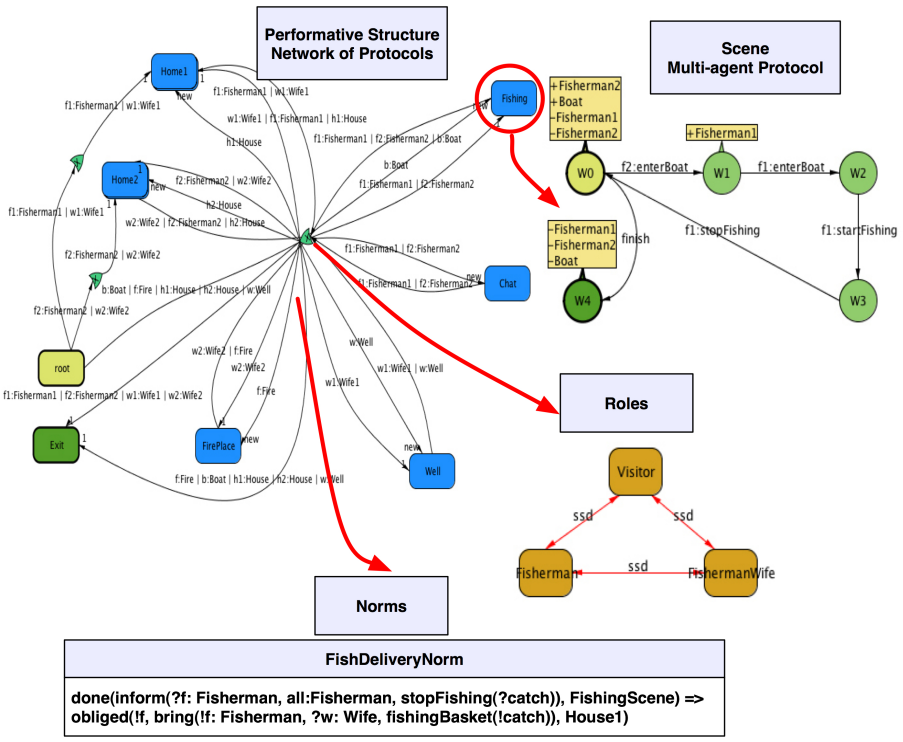

Fig. 4. Some Components of the Uruk Institution.

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 formalised appropriately in the specification of the institution to ensure correct behaviour. The *root* and *exit* scenes are not associated with any patterns of behaviour and simply define the state of entrance and exit of participants into the 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.

4.4 Populating the City with Virtual Agents

The agents re-enacting the life of the ancient Sumerians in our prototype are developed using the architecture outlined in Figure 5.

The agents are capable of sensing the changes of the environment state, as well as to react on the institutional illocutions and environmental actions. The

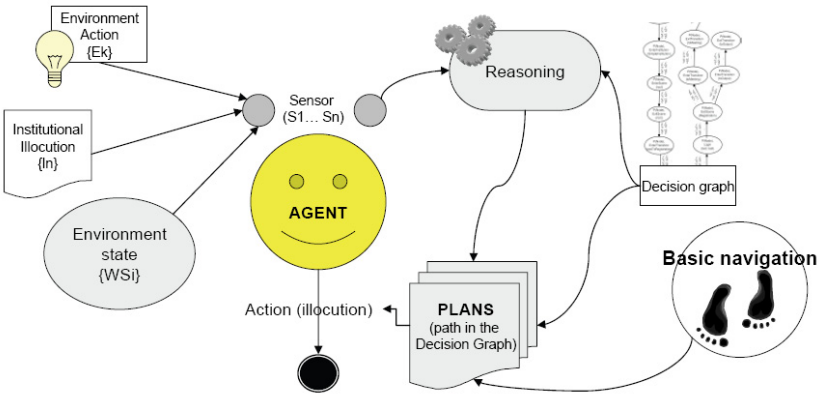

Fig. 5. Agent Architecture.

state of the environment represents the time of the day and positions of the objects and agents in the virtual world. The institutional state corresponds to the set of currently active scenes and the state of each scene. The reasoning of the agents is based on the concept of *decision graphs*. Depending on the current goal of the agent and the state of the world, the agent selects the path in this graph that has the highest probability of achieving the given goal. A detailed explanation of a particular case of decision graphs used by our agents is given in [7]. The agents are capable of simulating a human-like conversation with human visitors through the chat mechanism provided by Second Life. In order to participate in a conversation the agent employs ALICE chat engine based on the AIML language [8]. Each agent uses a number of AIML files that represent what can be seen as a common sense database. Additionally to this database every agent is supplied by personalised AIML files that reflect on its personality and the data relevant for its role within the Uruk society. Each agent can extend its knowledge (update the corresponding AIML files) through interactions with subject matter experts. The actions of the agents are limited to chat messages that they can exchange with human users, illocutions that they send to the institutional infrastructure, locomotion, playing an animation or performing operations with objects. The locomotion of the agents is based on artificial potential fields [9]. The agent behaviour is restricted to those actions permitted by the institution. The agents must comply with the social norms and interaction protocols, and are only permitted to participate in those activities that their social role grants them the access to. Having an institution also allows us not to differentiate between agents and humans. For an agent it potentially does not matter whether it interacts with the agent or a human, as long as the human follows the interaction protocol specified for the given scene.

4.5 Interacting with the Environment and Virtual Agents

The Virtual World simulating the city of Uruk is created with the Second Life platform. This platform enables the users to explore the environment using key-

board and mouse, provides collaborative building facilities and maintains the persistency of the environment.

As it is explained in Figure 2 there are two types of users: visitors and experts. Visitors learn the history and culture of the heritage site through exploration of the Virtual World and embodied interactions with its virtual inhabitants. Experts engage into discussions, collaborative design and training of the agents.

Figure 6 illustrates two types of interactions with the agents the users can be involved into. In Figure 6 a) the user is playing the visitor role. Having this role the user is not restricted to choosing a specific appearance or to behave in a certain way. The visitor can communicate with agents using the chat facility provided by Second Life and will otherwise not be able to engage into any other forms of interaction. Another form of interaction is through choosing a certain role in the Uruk society. Each role is associated with a specific appearance and the user playing this role is not allowed to change it. Another restriction associated with the role is that every participant is forced by the institution to strictly adhere to the specified institutional norms and interaction protocols. Figure 6 b) illustrates the interaction between a user and an agent both playing the *Fisherman* role.

Fig. 6. Two types of interaction between users and agents.

5 Concluding Remarks

In this work, we presented a novel approach that, with the combination of 3D Virtual Worlds and Artificial Intelligence, can support the preservation and simulation of ancient cultures. The goal is to obtain a 3D Virtual World that reproduces, in a very realistic way, the situation described in the digital content used as source for the process. For accomplishing the goal, we designed a tool which uses a semi-automatic extraction of information from textual and visual documents, creates layouts, norms and rules governing a Virtual Institution, defines and creates software agents populating the Institution and performs a realistic visual rendering. The Virtual Worlds created are modelled relying on the domain experts knowledge and they are made available via Web and with multilingual comments and explanations.

The proposed approach is modular and general. The system architecture is well defined, as are the techniques and algorithms that we would like to employ. Many bricks of the application have already been developed as the result of research activities carried out by the authors and their groups. In particular, in this work, we illustrated initial results by presenting the prototype featuring the 3D recreation of the city of Uruk, 3000 B.C.

On the basis of the initial results, our approach seems very promising. Our future activities will be devoted to the actual implementation of the overall system and of the functionalities identified which will include features for text mining [10] and semantic annotation and matching. We will also use our experience on Cultural Heritage and mobile applications [11] to verify the feasibility of the approach using mobile devices, as we did in [12]. Also, to test the validity of the approach we will compare the resulting virtual culture with an actual ancient culture. One of the few ancient cultures that still exist today is the culture of indigenous Australians. Through the above-described techniques we plan to capture and recreate non-verbal cultural attributes of aboriginal Australians in the Virtual World of Second Life.

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