INSIDE VIRTUAL: A NEW APP FOR INTERACTIVE AND INTELLIGENT CULTURAL HERITAGE FRUITION

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ABSTRACT
Technology is even more embedded into everyday life and its pervasiveness grows ceaselessly. People are becoming more and more addicted to technology that is seen a mean to improve life quality, extend human capabilities and enjoy free time. In this framework, the proposed research work seeks to combine information and communication technologies, web technologies, mobile technologies and serious games to create new models for cultural contents fruition and dissemination. The proposed approach results in a desktop and web application, INSIDE VIRTUAL, that can be installed on mobile devices. The user of INSIDE VIRTUAL, is involved in a learning path under the guise of a virtual museum (archaeological site) visitor that, in proximity of an artifact, receives information and cultural contents from dedicated avatars (driven by intelligent agents). Such avatars act as guides and are able to interact with the user avatar in several ways (even vocally through questions) and deliver custom contents based on the user preferences gathered at the game start and during the game evolution. In this paper, some aspects of the INSIDE VIRTUAL design and development process are covered and preliminary implementation activities are introduced.

Keywords: Cultural Heritage, Serious Games, Modeling.

1. INTRODUCTION

The proposed research is aimed at introducing some ongoing research activities belonging to a joint research project that involves CAL-TEK SRL and the MSC-LES Lab of the University of Calabria (The overall project presentation and architecture can be found in Longo et al. 2014). Being aware of the crucial role that cultural heritage has in education and tourism, the main idea behind this work is to promote new strategies for cultural contents dissemination and fruition. In more detail, the proposed solution combines cultural contents with digital, mobile and immersive technologies with the aim of making contents fruition a unique and engaging experience. One of the main outcomes of the aforementioned research project is INSIDE VIRTUAL, a Serious Game, delivered both in the form of mobile and desktop app, for virtual interactive visits in virtual museums/archaeological sites. INSIDE VIRTUAL is envisaged as an educational tool able to transfer contents in an effective manner and capture the interest of its users. Indeed, INSIDE VIRTUAL recreates not only a museum/archeological site and the artifacts in it but includes also advanced functionalities to let the player (that plays the role of a virtual visitor represented by an avatar) interact in a dynamic way with the virtual word as well as other avatars acting as guides. As a matter of facts, when the game starts, the player can choose to visit the museum by himself or rather to be supported by a virtual guide. In such a case the player has the opportunity to communicate and interact with the guide as it happens in the real word through questions and answers. To this end, guide avatars are driven by Intelligent Agents that are meant to provide the guide with a proactive behavior and to be responsive to any kind of user inputs (such as questions, preferences, etc.). This way, leveraging on visual aspects (3D reconstructions), on advanced interaction modes (vocal interaction between the player and the guide), and proactive functions (along the visit information on user preferences is gathered in order to drive the player toward artifacts he may be interested in) INSIDE VIRTUAL seeks to engage and involve the user making is attention and interest toward cultural heritage grow. To fulfill such a challenging research, the design and development process has been accurately and critically planned. At the early stage, conceptual modeling has been a crucial phase. Indeed, conceptual modeling has resulted in the identification and representation of all the entities and their mutual relationships setting a reference framework for the whole development process. In other words, conceptual modeling has enabled the identification and formalization of the logics that drive the game evolution based on the inputs provided by its users. It has been carried out with the purpose of:

- creating a common and shared knowledge base for the entire development team;
- documenting specifications, features and functionalities the app has been (will be) provided with;
- facilitating maintenance;
- promoting sustainability over time even if requirements may change.

Taking into account all these aspects, conceptual modeling has been carried out through UML (Unified Modeling Language) whose characteristics in terms of expressiveness and simplicity proved extremely useful for the integration of the research team members and for setting up effective communication strategies with the museums that have been involved as end-users of the research outcomes namely the Museum of Operation Avalanche located at Eboli, and the Silk Museum of Mendicino, both located in Italy. After conceptual modeling, the issues of providing guide avatars with intelligent behaviors have been explored and the reference frameworks for Intelligent Agents implementation have been set out. After addressing these aspects, some preliminary implementation activities have been introduced. Thus the reminder of the paper is organized as follows: section 2 introduces and discusses the main INSIDE VIRTUAL conceptual models; section 3 is centered on the main reference approaches for Intelligent Agents implementation; lastly, section 4 introduces the development environment and the implementation of some basic features.

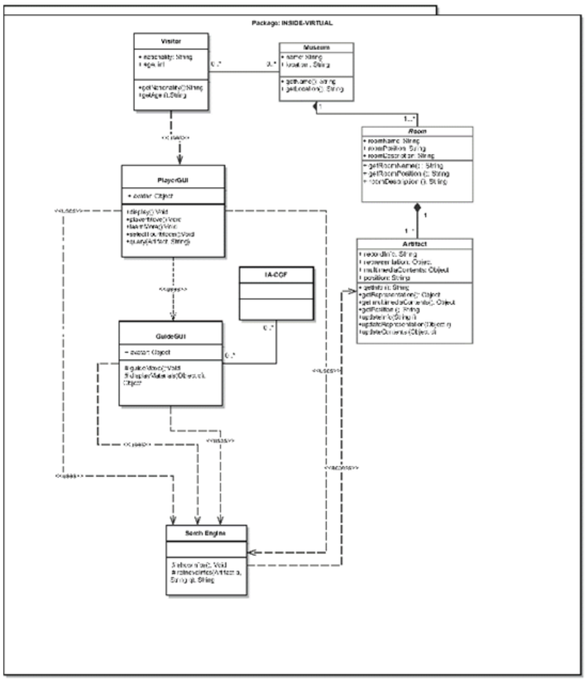

Figure 1 – Class Diagram

2. STATE OF THE ART

To date, digital technologies applied to cultural heritage have been mainly used for the reconstruction of the original appearance of artifacts as well as the storage and archiving of information in media format. Indeed, reviewing the state-of-the-art, it is possible to ascertain that, most of the time, researchers and research communities are mainly concerned with the preservation of cultural heritage through modeling techniques, graphics and virtual reality (Addison, 2000). As shown by Anderson et al. (2010), the use of Modeling, Simulation and Serious Games in the cultural heritage for teaching/learning historical contents has been little considered.

Anyway, talking about the digitization of cultural and historical heritage, it is worth considering virtual museums and information kiosks that are meant to make the contents more appealing. In addition, Sylaiou et al. (2009) point out that museums have different possibilities, in terms of tools and methodologies, to make contents fruition more engaging. Mostly, virtual reality and/or augmented reality technologies are deployed in museums/archeological sites to enhance visitor’s experience.

As for virtual reality, the most common solutions range from simple interactive screens to full-immersive systems that may include projection systems and 3D stereoscopic glasses. Augmented reality applications, instead, offer a greater variety of solutions. One of the very first solutions dates back to 1995 and was proposed by Bederson. This solution was based on the imposition of audio contents based on the user's location. Anyway, since 1995, many other applications were proposed such Mase et al. (1996), Brogni et al. (1999), White et al. (2004), Liarokapis et al. (2008), Sylaiou et al. (2009), and many others. It is worth mentioning also that remarkable research efforts have been oriented toward more advanced solutions based on the coexistence of real and virtual objects (Mixed Augmented Reality). Consider for instance Hall et al. (2001), Hughes et al. (2004) and many others.

Besides, when dealing with digital technologies applied to cultural heritage, it is possible to notice that Serious Games are gaining increasing attention. According to the taxonomy adopted by Mortara et al. (2013), Serious Games can have various purposes including cultural awareness, historical reconstruction and can vary according to the learning objectives, genre (e.g. adventure, simulation) and application context. Representative examples in this regard have been proposed by Froschauer et al. (2010). Here, the INSIDE VIRTUAL contribution to the state of art relies not only on the innovation potential of Serious Gaming technologies deployed through mobile and desktop devices for cultural contents dissemination and promotion but also, and above all, on the combination of SG with Intelligent Agents able to drive the scenario evolution based on events sequences (actions and reactions) generated by the reciprocal and continuous interaction between real users and Intelligent Agents.

In this sector, the analysis of the state-of-the-art reveals that agents are a powerful metaphor for the modeling and analysis through simulation of complex systems in various application domains (Michel et al., 2009) and for the implementation of complex software systems (Jennings, 2000). According to this paradigm, a system is modeled as a set of entities (agents) capable of operating in a given environment with different degrees of autonomy and intelligence cooperating and/or competing to achieve their goals or those of the company/organization they belong to (Woolridge, 2002).

A relevant example on agent-based environments for cultural experience in museums can be found in Costantini et al. (2008) where the agent technology is used to offer suggestions in line with the profile and interests of visitors by monitoring (via satellite) the movements of visitors within an archaeological park.

At international level, many projects have been proposed and developed in the field of advanced fruition of cultural heritage. I.e. Anderson et al. (2010) explore some existing projects focused on ancient historical sites visualization and virtual reconstruction such as Nova Roma (Frischer, 2008), Ancient Pompeii (Maim et al., 2007), the Parthenon (Debevec, 2005). Nova Roma is a multi-year project on the 3D reconstruction of the Ancient Rome as it was in 320 AD and it has been integrated with a game engine in order to allow interaction between player and non-player avatars. Ancient Pompeii is a project based on the reconstruction of ancient Pompeii, through procedural modeling with real-time simulated entities. Analyzing in detail the technical specifications of both projects, it can be ascertained that: greater interactivity should be ensured as well as a more consistent web technology and the possibility of having apps for mobile devices.

There are numerous other projects such as the PEACH project (Stock and Zancanaro, 2010) and the MINERVA project (Amigoni e Schiaffonati, 2009). The PEACH project seeks to take advantage of synergies among different technologies (multi-agent architecture, audio-visual technologies, sensors for 3D visualization, etc..) in order to enhance the experience of cultural heritage fruition whereas MINERVA is a system that, in its latest release, supports the curators in the automatic creation of virtual museums. Many other projects, funded by the European Community under the Seventh Framework Programme, are also reported below.

The V.MUST.NET project aims to define a knowledge base, a common language, an ontology dedicated to the creation of virtual museums as well as to identify innovative visualization and interaction tools for virtual museums of the future. The 3D-COFORM project deals with all aspects of the 3D digitizing, the semantics of shapes and material properties of cultural heritage objects, with the aim of moving forward the 3D digitizing frontiers. A similar project (but smaller in size and partnership) is DASI that has the objective to digitalize the inscriptions found in the Arabian Peninsula before the Islamic period. Finally, the DECIPHER project promotes the development of new solutions that combine rules, engines, virtual environments and interfaces in order to support curators in the preparation and fruition of cultural goods which are as much as possible in line with the interests of the visitors.

This analysis of the state art allows ascertaining that INSIDE VIRTUAL contribution is the ability to combine, in a multidisciplinary approach, different methodologies (serious games, intelligent agents, virtual reality) and technologies (web technologies, mobile devices) resulting in a unique tool that can be used for cultural heritage contents and site promotion and dissemination. Indeed, INSIDE VIRTUAL will be deployed as an app for mobile and desktop devices and therefore with a great extent of accessibility even considering that it is meant to be used wherever and whenever the user wants. In addition, contents delivery entails greater interactivity (compared to the existing solutions mentioned above) from the users and offers advanced features in terms of visualization, contents customization, proactivity and responsiveness to users inputs. In addressing such requirements, the research and development team of the INSIDE VIRTUAL app takes advantage of many experiences gained along the years in the field of simulation (Longo 2012; Bruzzone and Longo, 2013; Bruzzone and Longo, 2014;), virtual environments (Longo et al. 2013) and agent-driven systems (Bruzzone et al. 2012; Bruzzone et al 2014).

3. INSIDE VIRTUAL CONCEPTUAL MODELS

As mentioned before, conceptual modeling has been carried out through UML diagrams. To have a clear operational picture of how the game works, of the functionalities it has to provide, of the logics that rule its evolution over time as well as of the basic components and entities involved, the following diagrams have been drawn up: the class diagram, the use case diagram, the state machine diagram, the sequence diagram and the activity diagrams have been drawn. The class diagram is shown in Fig. 1 and highlights the main entities and interactions that occur within the scope of INSIDE VIRTUAL.

Therefore it is a very useful mean to represent in a rather direct and immediate way the application domain and its key elements such as the visitor, the museum environment, the halls, the exhibits and the Graphic User Interface (GUI). In particular, the GUI makes specific functions available to the users such as the request for additional information, the option to choose between guided and free tours inside the virtual site, the possibility to select how the user and the guide avatars look, etc. Furthermore, other basic components include intelligent agents, computer generated actions and a search engine. Such components allow defining the logic that drives the game evolution as time goes by as well as the guide behavior and its interaction with the user when guided tours are activated. On the other hand, the search engine role is to allow the user to ask for further information when visiting the virtual museum/archeological site both in the guided tour and in the free tour mode.

As well-known, the class diagram provides a static representation and as a consequence does not show the game evolution over time based on user interaction patterns. To overcome this limitation, the use case diagram has been drawn in Fig. 2, where the app functional requirements are depicted.

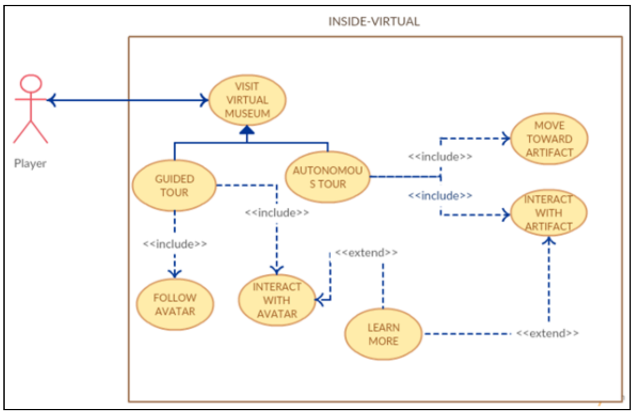

Figure 2 – Use case diagram

As shown in the figure, the virtual tour in a museum can be driven by a guide or by the player. In the first case, the guide leads the player through a virtual tour in which the user can interact with the guide to acquire information and eventually ask questions on specific aspects and curiosities that arise while visiting a particular artifact. On the other hand, the player has also the possibility to move freely in the museum as an independent visitor and when an artifact is reached he may decide to interact with the object through dialogue and / or information boxes. Moreover, he may seek additional information and / or ask specific questions.

System states and transitions are, represented in the State Machine diagram shown in Fig 3. This chart is useful for understanding the serious game dynamics and evolution patterns based on the actions taken by the user/player. In fact, the picture highlights that the transitions between states are purely determined by the choices and actions of the user (e.g. The selection of initial parameters, of the visit type, the transition from one object to another, the passage from one level to the next, etc.) putting in evidence the "event-driven" nature of INSIDE VIRTUAL.

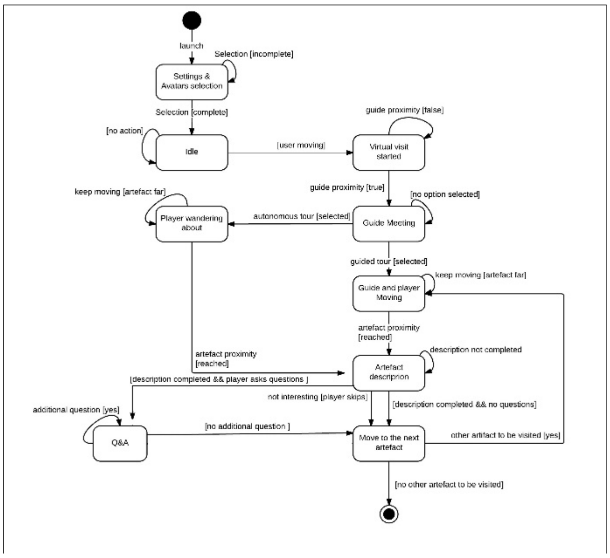

Figure 3 – State machine diagram from the player perspective

A relevant aspect when dealing with the evolution of the game is represented by the intelligent logics that govern the guide's behavior. For this reason, a State Machine Diagram, intended to represent what happens from the guide point of view, has been drawn up (Figure 4). In particular, this diagram is meant to show the states that characterize the guide such as: the movement from one artifact to another, the waiting for the player arrival before information delivery, the resumption of the tour when the user ceases to ask questions, the reaction to user inputs, etc.

Another crucial aspect is the need to identify and model the interactions between objects, actors and entities in the system with a particular focus on information exchanges. To this end, temporal and casual links are displayed within the sequence diagram in Figure 5.

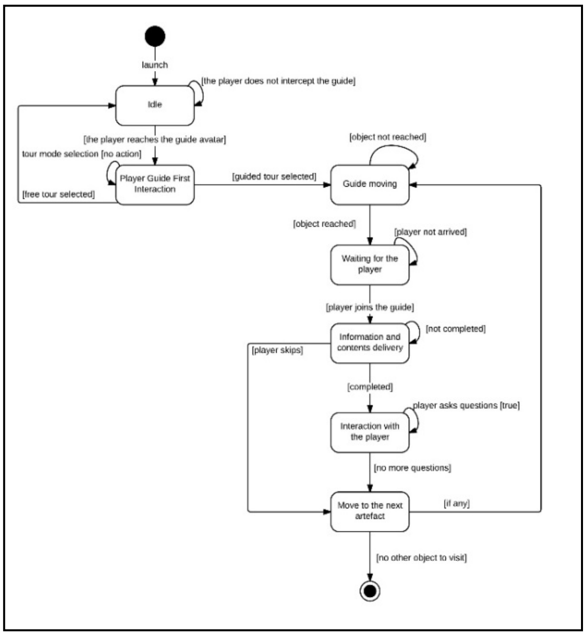

Figure 4: State machine diagram for the guide perspective

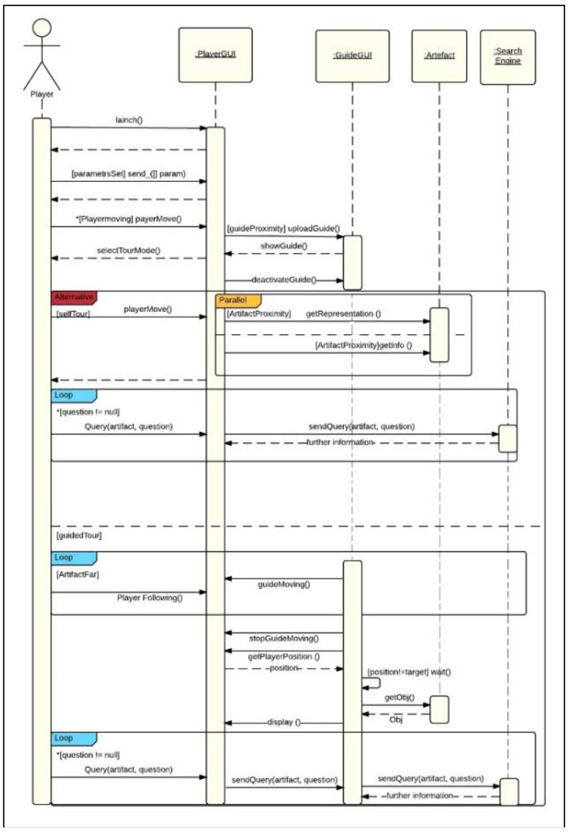

Figure 5 – Sequence diagram

Thus the INSIDE VIRTUAL design has acquired a greater level of detail as the analysis of interactions and their timeline clarifies the nature and the way communications occur establishing which communications are synchronous and which asynchronous. On the other hand, a relevant achievement of the sequence diagram is to have methods and classes mapped in order to give evidence of the pieces of code required to make the game evolve properly over time. In other words, the sequence diagram, has had a critical role to characterize and express all the INSIDE VIRTUAL scenarios. Finally, the Activity Diagram shown in Fig. 6 describes the INSIDE VIRTUAL workflow completing the overall representation of INSIDE VIRTUAL conceptual models.

4. INTELLIGENT AGENTS AND COMPUTER GENERATED FORCES IN INSIDE VIRTUAL

As shown in Section 2, great attention has been paid on Conceptual Modeling that has ended up with the UML diagrams reported so far. Such diagrams provide a detailed and intuitive description of INSIDE VIRTUAL in terms of components, features, requirements and dynamics but not only. As a matter of facts, this phase has been crucial to establish the requirements as well as the behavioral patterns of the virtual guide (that is driven by Intelligent Agents) along the interaction process with the virtual visitor. In other words, UML diagrams and the underpinning modeling effort have highly contributed to clarify the structural and behavioral models that Intelligent Agents (IA) have to embody.

Recalling the definition of Goi and Torre (2009) an agent is a computational system that:

- interacts with and is responsive to its surroundings;
- is able to take decisions and to act, in an autonomous way, to achieve a goal (which may be predefined or negotiated). Therefore it is proactive.
- is able to communicate (coordinate, cooperate, negotiate) with other agents (and / or with human beings). Therefore it is capable of social interaction.

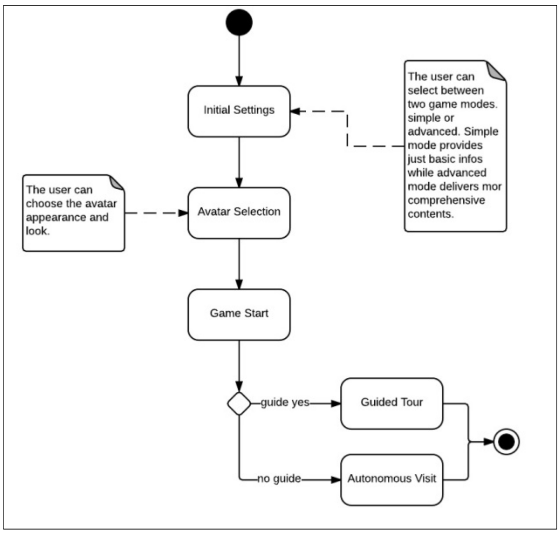

Figure 6 – Activity diagram

This definition fits very well the role and the features of the guide within INSIDE VIRTUAL. In fact, the guide interacts with the museum environment and the objects in it, communicates with the player and acts autonomously choosing how to design the guided tour based on the inputs it gains from the user and the user profile. Needless to say that the guide can attain the user interest to the extent that it is able to deliver custom contents that fall under the user's preferences. Thus Intelligent agents driving the guide behavior are developed through a symbolic deliberative approach that provides the agent with both declarative (or domain) and prescriptive knowledge. Here prescriptive knowledge consists of a set of rules that allow identifying a proper sequence of artifacts and information to be delivered. As a consequence, building agents with this approach requires a formal description of the domain specific knowledge (i.e. the museum and the artifacts in it), of the objectives to achieve and of the actions (along with related preconditions and effects) that can contribute to reach such objectives. In greater detail and from a methodological point of view, the reference framework is that of practical agents that are agents governed by cognitive processes in two steps: the goal selection (which depends on the input provided by the user when the game starts for instance the age) and the planning phase where the agent establishes which actions have to be implemented to achieve the goal. For planning purposes the agent uses a dedicated algorithm that allows selecting the most suitable plan from a selection of possible plans. In addition, considering that an intelligent behavior is, by its nature, related to user interactions, such an approach has been integrated in order to make the agent responsive to the user inputs. For example, if the user chooses to skip an object the agent has to revise its action plan passing over similar objects. Conversely, if the user asks a lot of questions about a particular object, it is likely that objects of the same type /period are of interest to the user. Thus the agent has to be able to infer user preferences collecting as many inputs as possible and changing the plan or selecting a new one accordingly. Implementing such capabilities requires a great effort to organize and structure the plans as well as to manage metadata properly so as to ensure an effective and dynamic rescheduling during guided tours.

4. INSIDE VIRTUAL DEVELOPMENT ENVIRONMENT AND DEVELOPMENT ACTIVITIES

As discussed so far, in order to encode the conceptual models previously introduced, an extremely flexible development environment is required. It should be a cross-platform environment able to support the development of interactive Serious Games with advanced functionalities and properties. To this end, after a thoroughly evaluation of both open and owner systems, UNITY3D platform has been selected. UNITY3D has a number of extremely important features such as a visual editor with advanced features for display and live previews, extensibility, ability to create optimized contents ensuring excellent performances and high-quality graphics. Thus UNITY 3D is currently used to recreate a virtual museum that will implement all the INSIDE-VIRTUAL functionalities. The virtual museum will be based on a real museum: to this end, the museum involved in the project is the Museum of Operation Avalanche (MOA), located in Eboli, Italy. This museum was founded in 2012 to remember some historical events of the World War II. In September 1943, during the

Second World War, Salerno Coast (in South Italy) was a war theatre for one of the most relevant landings in the history, called Operation Avalanche by Allied Forces (a similar landing was the Normandy landing, in 1944). “Operation Avalanche” was characterized by 1000 ships (400 Army ships and 600 merchant ships adapted for military operations) and 170.000 soldiers (100.000 English Soldiers and 70.000 Americans). The MOA is a place where visitors can relive some events of World War II. Figures 7 shows some military helmets used by soldiers during the Operation Avalanche landing; figures 8 and 9 respectively show a German Machine Gun and an American Ammunition Box.

Figure 7 – Military Helmets at MOA

Figure 8 – German Machine Gun at MOA

Figure 9 – Ammunition Box at MOA

Realistic 3D models are currently under development and will be imported in the virtual environment to give the sensation to experience a real museum visit. Figures 10 and 11 respectively show the 3D model of a military helmet and an ammunition box; both models will be successively imported within the 3D virtual environment of the INSIDE-VIRTUAL app.

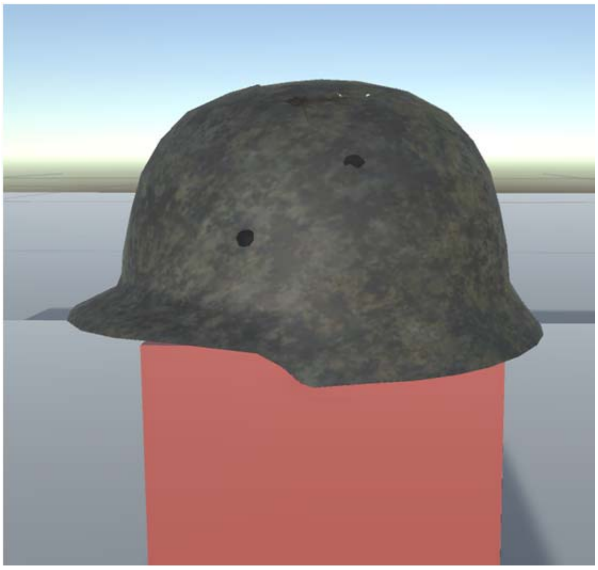

Figure 10 – An example of 3D models (a military helmet) that will be used within the INSIDE-VIRTUAL app

Figure 11 – An example of 3D model (an ammunition box) that will be used within the INSIDE-VIRTUAL app

Besides, the avatars movement management system (for the player and for the guide) was set up along with the animation system, ad hoc search functions and dialog windows etc. Some of these features are shown in Fig. 7. The avatars shown in Figure 12 are those currently used for tests and ongoing research activities; however, from a graphic point of view, these avatars will be later replaced with more realistic ones.

Figure 12 – INSIDE VIRTUAL Preliminary implementation

As far as the animations are concerned, scripts for movement have been developed using C#. Such scripts include interpolation functions that offer many possibilities in terms of directions and movement types for both the user and the guide avatar. Some of the main motion parameters are reported on Figure 13. Furthermore, some default paths have been identified and implemented: these are some of the paths that will be used when the game evolves according to the "guided tour" mode. Lastly, collisions between avatars and objects have been implemented.

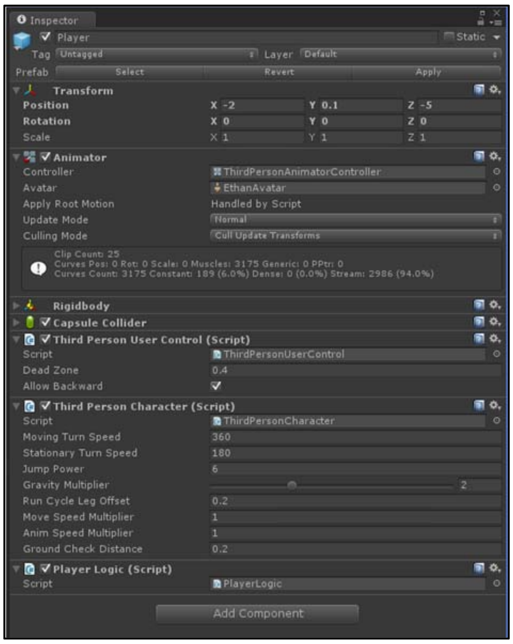

Figure 13 – Motion parameters for avatars

5. CONCLUSIONS

The proposed research introduces the design and implementation process of an advanced Serious Game and app, INSIDE VIRTUAL, for cultural heritage promotion and fruition. The game logic and functionalities have been carefully designed and as a result conceptual models have been drawn up. This phase has been documented through UML diagrams that have allowed expressing in a rather immediate and intuitive way all the game functional requirements and properties. Such diagrams have been a fundamental premise for evaluating and detecting suitable development frameworks. It applies to the intelligent logics that drive the game evolution, to the development environment selection and to the basic building blocks of the INSIDE VIRTUAL app.

In particular, a symbolic deliberative approach is adopted for implementing the intelligent logics that drive the guide behavior along the game while, considering the game functionalities and properties, UNITY3D has been chosen as authoring tool. Here, the virtual environment is currently under development as well as artifact reconstructions. Some functionality such as animations, collisions, search functions, dialog and information windows and the movement management system have been already shaped up.

The INSIDE VIRTUAL app is part of a two years research project financed by the Italian Ministry of Education, University and Research. As shown, INSIDE VIRTUAL app is provided with advanced functionalities that require a considerable effort both in terms of research, modeling and coding. However preliminary results look promising and the whole research team, that involves both industry and academia, is confident that the final project outcomes will be in line with the expectations.

ACKNOWLEDGMENTS

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