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IMMERSIA, AN OPEN IMMERSIVE INFRASTRUCTURE: DOING ARCHAEOLOGY IN VIRTUAL REALITY

1. Introduction to virtual reality

Virtual reality is often considered solely as a field of computer science in relation to interactive digital 3D worlds. It actually holds a special position in the usual scientific scheme by coupling humanities sciences with engineering. According to Fuchs *et al.* 2011, 6: «The purpose of virtual reality is to make possible a sensorimotor and cognitive activity for a person (or persons) in a digitally created artificial world, which can be imaginary, symbolic or a simulation of certain aspects of the real world». This proposition positions the man and its activity in the centre of virtual reality.

A technical and literal definition of virtual reality attempts to characterise the domain in one compact and sufficiently consensual sentence so that the practitioners of the domain can relate to it: «Virtual reality is a scientific and technical domain that uses computer science and behavioural interfaces to simulate in a virtual world the behaviour of 3D entities, which interact in real time with each other and with one or more users in pseudo-natural immersion via sensorimotor channels» (Fuchs *et al.* 2011, 7).

1.1 *Virtual reality: historical overview*

Virtual reality is a relatively young domain. Ivan Sutherland is considered as a great precursor, through results published in his MIT PhD in 1963 (Sutherland 1963). He contributed shape editing and manipulation tasks with the SketchPad tool, which foreshadowed our current to industrial CAD tools. Shortly after, in 1965, Ivan Sutherland published *The Ultimate Display* (Sutherland 1965) where, in particular, he discussed the key elements related to immersion, interaction, capture of user activity and realism of 3D environments. This is to be considered and assessed in a context where the practical implementation of these concepts was impossible given the available technology.

Known as the "inventor" of the term *Virtual Reality*, Jaron Lanier founded in the 80s the company VPL Research, the first SME to industrialize software and hardware solutions for the production of virtual reality applications. In particular, among its solutions, this company integrated the first datagloves.

In any virtual reality application, the user is immersed and interacts with a virtual environment. Immersion is defined in Poupyrev *et al.* 1998 as a (perceptive, mental, emotional) state of a subject when one or several senses are isolated from outside and only stimulated with information from computers.

In the field of immersive visualization, the early 90s was marked by the development of immersive visualization systems with very wide screens, as the CAVE ™ in EVL (Electronic Visualization Laboratory: University of Illinois) (Drap *et al.* 2006*)*, by Fanti and Cruz-Neira. This concept was then extended to less cumbersome concepts of workbench.

In 1990, Poupirev proposed to categorize the interaction into two major families (Poupyrev *et al.* 1998):

– Exocentric interactions: the user is in an external position in relation to the virtual environment so that the environment can be seen as a whole. Among these techniques, we find in a way World-in-Miniature (Stoakley *et al.* 1995), Metaphor resizing (Mine 1997), and the technique of Voodoo-Dolls (Pierce *et al.* 1999), all providing a means to manipulate objects by miniature representations;
– Egocentric Interactions: the user is inside the virtual world. Among these techniques, we find the technique of virtual hand and its many variants (Mine 1999) linear extension of the arm when the virtual user's hand is close to his body, then exponential expansion from a given distance (Bowman, Hodges 1997).

Haptic perception when interacting (tactile feedback: Massimino, Sheridan 1993 or force feedback: Sreng *et al.* 2009) is a very strong trend in the scientific community, and it contributes to multimodal visual, auditory and haptic feedback (Zhang *et al. 2005*).

Concerning local or distant collaborative interaction (Fleury *et al.* 2010), the problem is essentially to permit several users to interact simultaneously on the same environment. Collaborative work in Virtual Reality addresses the problem of the perception of other users and their activities (Fraser *et al.* 1999). Several models of synchronization and communication architectures (client/server, P2P) can ensure the coherence of perceptual interactions and the validity of the collaborative interaction (Duval, Fleury 2011).

1.2 *Virtual reality and archaeology*

Introduced by Reilly in 1990 (Reilly 1990), virtual archaeology was initially presented for excavation recording and virtual re-excavation using multimedia technologies. In a similar way, Krasniewicz (Krasniewicz 2000) proposed a 360° visualization infrastructure to help archaeologists in their research work. In this case, virtual archaeology was not used to restore knowledge, but to acquire new knowledge.

More recently, Pujol Tost (Pujol Tost, Sureda Jubrany 2007) contributed to the interaction, perception and simulation in VR for archaeology, and not only for the visualization of 3D models.

Le Cloirec (Le Cloirec 2009) focused on 3D models, and further extended their use in immersive structures as a perception tool to evaluate the functional or symbolical role of some architectural elements and spaces.

Vergnieux (Vergnieux 2011) considered the simulation for the movement and gesture validation, the physical coherency and the technical feasibility of constructions.

According to new trends in the domain, Forte (Forte 2011), one of the mainstays of virtual archaeology, suggests to replace the terminology related to a "reconstitution of the past", by the expression "Cyber-Archaeology" relying on a "simulation of the past".

Christou *et al.* (Christou *et al.* 2006) used an immersive CAVE-like structure combined with haptic devices and 3D sound for pedagogic purposes in a museum exhibition, but also as a tool for research. The Archave project (Vote *et al.* 2002) integrated also a CAVE-like structure and proposed tools for archaeologists to study historical sites. Another interesting work (Forte, Kurillo 2010) presents a tool where archaeologists collaborate remotely on shared virtual objects through realistic avatars reconstructed from 3D cameras. Their virtual reality framework proposed a rich toolkit of interaction features, including navigation, measurement, lighting and dragging. However, due to real-time 3D capture and rendering of users, the visualisation was restricted to small image resolution (320×240 pixels) to ensure fluid rendering (25 FPS).

All of these contributions were based on models of sites manually built in 3D modelling tools. Another trend, when dealing with existing buildings or sites, is to consider photomodelling tools. This technique allows to automatically build textured 3D models from sets of photos of a site or object. An interesting example is presented in Drap *et al.* 2006 with the provision of an immersive virtual reality interface for Shawback Castle. The immersive environment consists of a large stereoscopic projected wall, with infrared tracking. The work focuses on semantic annotations of blocks to ensure consistency with a knowledge database associated to the model.

In parallel, during the last decade, many contributions in the domain focussed on 3D restitution of past structures or environments visualization. In particular, there has been a great deal of effort to communicate archaeological and historical heritage to a large public through various media such as web (Pescarin *et al.* 2008), second life environments (Morgan 2009), or museum exhibitions (Bale 2011).

2. Going further

We believe that fields of virtual reality and archaeology may enjoy mutual benefits triggered by questions such as:

1) How can virtual reality, considered in its whole scope from science and technology to human sciences and natural sciences, benefit to archaeology? 2) What are the specific challenges brought by archaeology to virtual reality?

2.1 *Virtual reality for archaeology*

Immersion, and particularly immersion in scale-one environments, should allow archaeologists to access to the evaluation of symbolical or cultural roles of architectural buildings. Moreover, archaeologists can be placed in situations to validate specific activities, ranging from displacements within environments to more complex interactions by using haptic devices to evaluate the physical feasibility or the coherency of a task. This aspect is strongly pertained to ergonomics and musculo-skeletal activity (Pontonnier *et al.* 2012). Fig. 1 illustrates an experiment performed in our virtual reality platform. In order to evaluate ergonomics, the user was immersed in a virtual environment mimicking the real environment. Motion capture, electromyographic (EMG) electrodes, force sensors and subjective questionnaires were used to evaluate sensory-motor aspects.

Collaborative virtual reality can be of a great help to build or modify shared 3D environments through the collaboration of multiple users. In such a context, we proposed the Collaviz open source software platform (Dupont 2010) dedicated to real-time remote collaboration for the design and visualization of scientific simulation-based applications. We connected two immersive infrastructures, Immersia and UCL VR platform, enabling two distant users to collaborate on the same digital world, a 3D model of the underground propagation of a seismic wave, using shared tools (Fleury *et al.* 2012) (Fig. 2).

It is worth noting that a lot of work is produced on integrating digital 3D models of large landscapes such as countries (http://www.territoire3D.com/) in virtual reality. In a similar way, reconstitutions of archaeological sites in their real geographical context are certainly a great challenge.

2.2 *From archaeology to virtual reality*

Until now, virtual reality has been essentially focussed on industrial applications. In this context, the user interacts with recent, smooth and clean manufactured objects modelled by well-known CAD tools. In the context of archaeology, manipulated objects may be closer from nature, less steady, thus represented by more complex geometric models. The management of this new kind of data requires the study of new methodologies.

Since reconstitution of historical sites is an empirical activity, subject to assumptions, approximations and modifications, virtual reality should propose methods to handle this uncertainty and enable dynamic modification

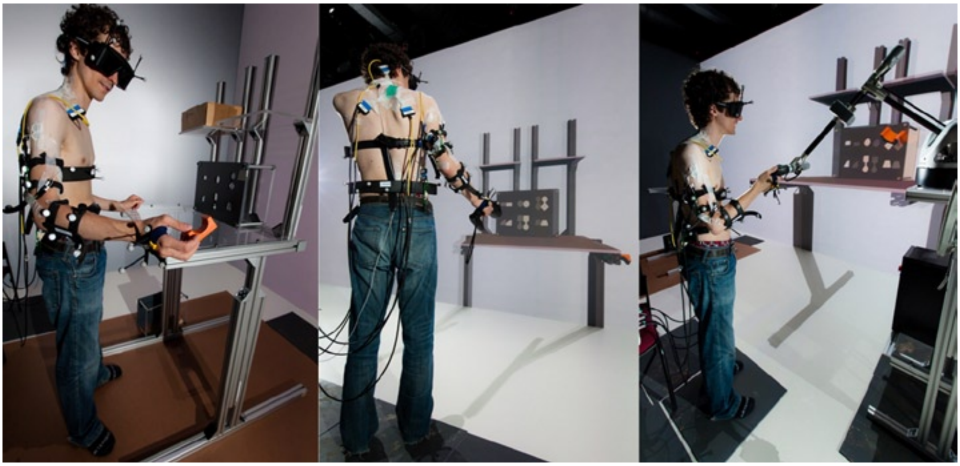

Fig. 1 – A manipulation task in real (left), virtual (centre), virtual with haptic (right).

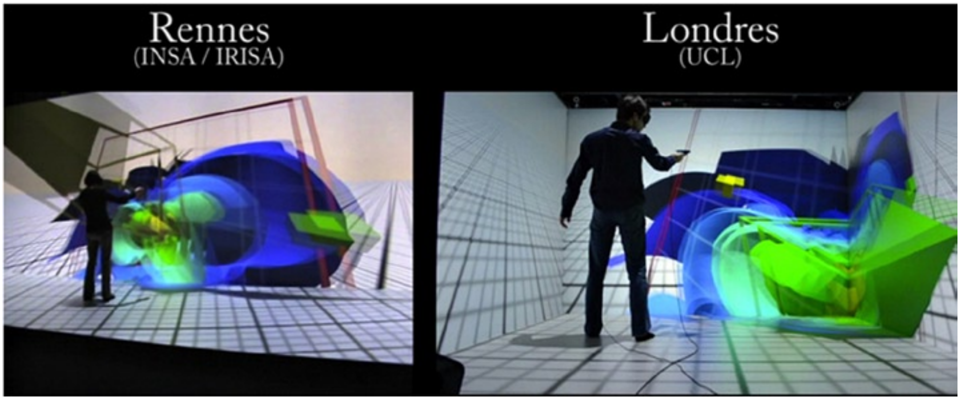

Fig. 2 – Collaborative work between Immersia and UCL VR platform.

of the digital universe. Realism and objective credibility of the rendering are diametrically opposed issues. Objective credibility is an intrinsic quality of the model depending of the archaeologist's perception. As an X-ray picture has a functional credibility for a medical practitioner, virtual archaeological models and universes must be designed to ensure this credibility. This will lead to the development of generic methods that should push the boundaries of virtual reality.

Scale-one immersion is a key characteristic proposed by virtual reality to archaeology; it is also a real issue in virtual reality while dealing with the concept of immersion within an environment at human size.

3. Immersive virtual reality in Immersia

We present the immersive platform Immersia, its role in the European project Visionair, and two projects related to archaeology that illustrate the possibilities of such an environment.

3.1 *Immersia platform*

The immersive platform of the Irisa/Inria computer science laboratory is a large virtual-reality room dedicated to real-time, multimodal (vision, sound, haptic, BCI) and immersive interaction. It hosts experiments using interactive and collaborative virtual-reality applications that have multiple local or remote users.

Images are rendered on four glass screens: a front one, two sides and a ground. Dimensions are 9.6 m wide, 2.9 m deep and 3.1 m high. Over 15 millions pixels are displayed. The visual reproduction system combines thirteen HD projectors. A tracking system, composed of 16 infrared cameras, enables real objects to be tracked within the scene. Images are recomputed as the user moves to fit his point of view, together with high-resolution rendering, active stereoscopy and homogeneous colouring, thereby delivering a visually realistic experience. Spatial sound is rendered by speakers with 10.2 format or by headsets with virtual 5.1, controlled by the user's position.

3.2 *Visionair project*

Immersia is a key node of the FP7 European Project Visionair (Kopecki *et al.* 2011) which goal is to create a European infrastructure that should be a unique, visible and attractive entry towards high-level visualisation facilities for Virtual Reality, Scientific Visualisation, Ultra High Definition, Augmented Reality and Virtual Services. These facilities, distributed across about twenty countries in Europe, are open and easily accessible to a wide set of research communities. Both physical access and virtual services are provided by the infrastructure. Full access to visualization-dedicated software is offered through call for projects, while physical access to high level platforms will be partially accessible to other scientists, free of charge, based on the excellence of the project submitted.

3.3 *Archaeology research projects in Immersia*

Two projects started in Immersia, in collaboration with two different archaeology research laboratories. The first one, with the Creaah, a laboratory of archaeology, archeoscience and history, relies on immersive reconstitutions of several paleolythical existing buildings. Associated with interactive tools, the project enables archaeologists to extract new knowledge *ex situ*. The second one, with the French preventive archaeology research institute Inrap,

Fig. 3 – Immersive work in the virtual chamber of Carn.

Fig. 4 – Exploring the Bais Gallo-Roman *villa*.

focuses on the immersive reconstitution of a Gallo-Roman ruined site, the Bais domain.

3.3.1 The Carn monument

This project has three main objectives: (i) propose a common workflow to reconstruct archaeological sites as 3D models in fully immersive systems, (ii) provide archaeologists with tools and interaction metaphors to exploit immersive reconstitutions, and (iii) develop the use and access of immersive systems to archaeologists.

In a first contribution (Gaugne *et al.* 2012), we proposed a procedure to model the central chamber of the Carn monument, and compare several softwares to deploy it in an immersive structure (Fig. 3). We then proposed two immersive implementations of the central chamber, with simple interaction tools, and evaluated them with the help of archaeologists. The results obtained in this work validated the possibility and relevance of working in an immersive virtual reality structure.

3.3.2 The Gallo-Roman Bais site

Following a different approach, we started from a 3D model proposed by an archeologist of Inrap based on the excavation of a Gallo-Roman *villa* in Bais, France (Le Cloirec 2011). We then built an immersive application from this model, focusing on the navigation inside the site (Fig. 4).

The goals of this work, still under progress, are (i) to validate at scale-one different assumptions made by the archaeologists during the modelling step, (ii) to study the possible human displacements in the site, (iii) to better understand the life of the people with the immersive perception of the place.

Virtual reality provides in this case tools for argumentation, reasoning and understanding to the archaeologists, by placing them at the centre of the simulation.

4. Conclusion

This paper focussed on cross-domain mutual enrichment between archaeology and virtual reality. On the one hand, virtual reality could be a real improvement for archaeological field by ensuring the ability to propose collaborative modelling and analysis of archaeological objects in their real geographical context. On the second hand, the application field of archaeology could provide complex models that will lead to propose new generic methods for complexity management and interaction in an immersive context for large environments.

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ABSTRACT

This paper contributes to the cross-domain mutual enrichment between archaeology and virtual reality. We are presenting here Immersia, an open high-end platform dedicated to research on immersive virtual reality and its usages. Immersia is part of the European project Visionair that offers an infrastructure for high level visualisation facilities open to research communities across Europe. In Immersia, two projects are currently active on archaeological themes. One is relative to the study of the Cairn of Carn, with the Creaah, a multidisciplinary research laboratory of archeology and archeosciences, and the other concerns the reconstitution of the Gallo-Roman *villa* of Bais, with the French institute Inrap.