SENSORIAL VIRTUALIZATION: COUPLING GAMING AND VIRTUAL ENVIRONMENT

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Abstract: Virtual reality and virtualization are currently used to design complex systems and demonstrate that they represent the functionalities of real systems. However, the design refinement of the virtual environment (VE) and distributed virtual environment (DVE) are still time consuming and costly, as it is mainly based on running experiments and the analysis of data deriving from virtual task execution samples of users. Gaming provides the player with online feedback on his performance communicated to the user through different sensory channels: vision, spatialized audio and haptics. This paper presents a prospective vision and the potential of a novel approach that extends the concept of human-in-the-loop originated form the User-Centred Design to Game-Enhanced VE design. In this concept, the player performance scores are analysed online and used for the optimization of the VE. The dynamic interoperability between the user experience records and the VE properties could shorten the development cycle time and satisfy the requirements of the application domain.

Keywords: virtual environment; gaming; haptics; spatialized audio.

I. INTRODUCTION

Global competition and pressure is forcing system developers to reduce production cycles and enable product design agility. The use of Virtual Reality (VR) environments and games and edutainment are resulting in an innovative output that foreshadows a new Renaissance in learning – affording

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entirely new options for human creativity and global social interaction in science, business, and government (Psotka, 2013). The disruptive innovations and creative destruction that stem from these technologies are transforming the Human and Machine Interaction (HMI) paradigm completely and continuously. The need for simple, effective and efficient tools and systems is adamant in order to maximize potential in uptake and increase benefit for all users. Combining gaming and Computer-aided design (CAD) provide users with more enhanced sensory information and perform interactions that are readily (instant) visualized, in such that they can explore and manipulate a variety and diversity of virtual entities in the virtual realm.

Virtual Environments (VE) and virtualization attract a lot of attention because of the numerous applications and possibilities ranging from the educational and training area to entertainment and research. Virtualization could optimize for example the resource sharing among applications by collated cloud services. A current issue however is how to account for shared infrastructure usage? How to do chargeback of the costs running these services over existing physical infrastructures? Gmach et al. (2011) state, "… that when multiple virtual machines with different resource requirements are deployed to a resource pool and when the virtual machines may be frequently reassigned to different physical servers, the question becomes more complex: "who is responsible for the incurred costs?" and "how to attribute the cost recovery"?" So, the complexity and accounting increases exponentially when virtualization becomes part of shared resource pools that act and interact as private and public clouds and/or ecosystems. This is one of the major drawbacks and concerns in uptake of virtualization and widespread of integration of VE's.

Despite their popularity, the design and development of these environments are time consuming and require sophisticated tools which limits their widespread among a larger population of users. Most of the times, VEs are developed from scratch based on design needs. Oliveira et al. (2003) identified a number of reasons that lead to the high complexity of developing VE which include; non-extensibility, non-interoperability, VEs system latency, current high cost of VE systems, bandwidth, and poor scalability of existing systems. Another issue is that most of the efforts are dedicated to ensuring the visual quality and rendering efficiency against meeting user's needs and usability (Gabbard et al. 1999) compromising the user-system interaction. There is a general trend towards applying virtualization techniques to almost all ICT infrastructure machinery (Miller & Pegah, 2007), so we can expect more and more virtualization everywhere across all domains (education, business, industry, public space). Moreover, there is the current trend of blending technologies to gain value has opened new directions of research. This paper explores a mix of technologies that can enhance VEs. Since

haptic technologies have been proved to enhance learning experiences in terms (Hamza and Stanescu, 2010), haptics are the key player in this game-based approach. Measuring user performance, parameters such as movement times, error rate or throughput have recorded significant improvements, leading to the premises that haptic technologies are promoters of performance.

## II. GAME-ENHANCED VIRTUAL ENVIRONMENTS

In this section the authors present insights on the positive impacts game-driven approaches can have on VE.

2.1. Design Processing with VE

Generally, the design process of VR systems is divided into capturing the end-user requirements, the creation of the initial design of the VE, the verification of the functionalities and human related aspects through the process of incremental design: prototyping, evaluation and redesign and the final validation by the application domain expert (Figure 1, 2). This workflow is time consuming, requires significant budgets, involves multiple interactions, is prone to errors and does not allow proactive involvement of the end user.
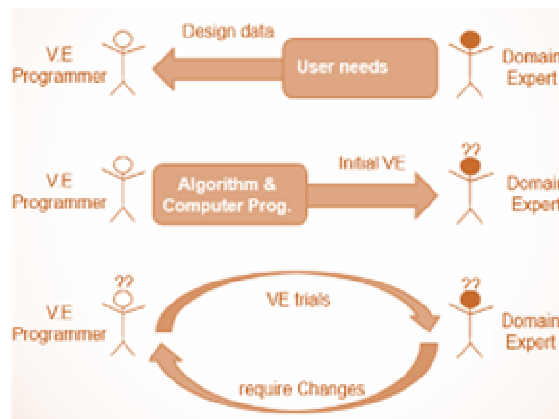
Figure 1. Exchange between the programmer and the domain expert for the VE design
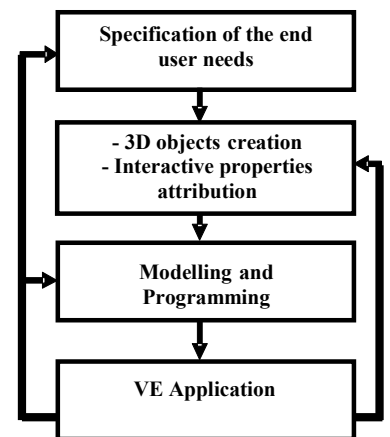
Figure 2. Traditional workflow for the design of VE

The attempts to accelerate the design process by using VR authoring tools have not, in general, been successful due to the required training and the initial cost of the software (Ramirez et al., 2013). Another reasons for this lack of success is that the user experience is not taken into account until achieving the final version

of the VE when a great deal of efforts was made in the cycle of trial and error. Some design parameters are dependent on a great deal of the domain expert knowledge, which has proved to be very difficult to formalize. Significant advances in gaming could be beneficial to the design of VE, notably by incorporating the game player into the design process.

Although there is research in creating VE environments from semantics representation as means of reducing the development phase and including novice user in the design phase (Pelens et al., 2005; Gutierrez et al., 2005), there is still a need to develop easy-to-use and efficient tools, taking into account the user experience and performance scores to create VE. Also a few approaches (Gaildrat, 2007; Trescak et al., 2010) were developed for automatic generation of VEs, they require extensive modelling and exclude the end-users from designing virtual worlds and applications.

The significant advancement of VR and gaming offers the potential to improve the quality of interaction. If they are coupled together they can produce more satisfying and enjoyable applications, therefore offering benefits at the design and usability levels since human perceptual capabilities and performance become considered as design criteria of the interactive environment.

The literature showed that most of the reported studies use data collected from experimental design such as the virtual task completion time and error rates as measures of human performance in VEs. This performance metrics is often used to refine of the VE in order to meet the requirement of the application. There is no work to suggest automatically integrating these data in the VE development cycle at early stages of the VE creation.

2.2. The role of the player and associated affects in digital gaming

When it comes to gaming, the way players play and their preferences in terms of game-play determine to a large extent game rules and game mechanics. Player motivations have been extensively studied in terms of commercial games over the last couple of decades.

Bartle's approach (Bartle R. (1996)) is a key reference in digital gaming research and was based on the identification of player types in MMORPG online video games (Massively Multiplayer Online Role-Playing Games). The model identifies four types of players (Achievers, Explorers, Socializers and Killers), each driven by their own distinctive motivations. The Achievers are basically players whose main objective is to beat the game and achieve the game's desired goals in order to advance in the game. The Explorers play so as to discover the surrounding environment and its components. They interact with the world from that perspective. Socializers use their communication skills in order to interact with other players in the game and focus on interaction rather than actual game play.

Finally, the Killers play to maintain imposition upon other players. In other words, they play with the intention of dominating other players in the story. Similarly, Lazzaro (Lazzaro N. (2004)) proposed a player classification based on the perceived emotions experienced by players while playing. According to Lazzaro's experimental results, most people play to get immersed in the game experience rather than the game story and mental challenges are experiences considered independently from the story content. He identified several player categories. The internal experience category relates to players whose main concern is an experience based on emotion transformation. This is closely related to the movie spectator experience. Hard Fun is based on challenges and strategies. The player is expected to overcome obstacles and challenges so as to progress within the game. This category is similar to Bartle's achievers' type. Easy Fun is a category within which players enjoy the immersive aspect of exploring vast virtual environments. This is similar to Bartle's explorer type. In addition to these, Lazzaro, like Bartle, identified a socially oriented category of player where the main concern is to build up relationships with others through communication and observation. Finally, (Fullerton T. (2004)) identified 10 player types that reflected the wide variety of digital games available and shared similarities with the ones described by both Bartle and Lazzaro. Fullerton's model comprises: Competitor, Collector, Explorer, Achiever, Joker, Artist, Director, Craftsman, Performer and storyteller. Foo et al (Foo C. (2005)), concluded that while some categories are directly matched to each other, some are not related to any other types or motivations. It seems that classifying the players and building conclusion on what motivates them based on their type is not an altogether reliable approach.

Beyond the problem of structuring motivations in categories, players will exhibit a set of motivations for gaming activities and will probably cover several categories, making an accurate assessment of their motivations difficult. Yee (Yee, N. (2005)) argued that to define an efficient motivation model, proposed motivations should be tested rather than brainstormed to reveal contradictions between recorded data and the theoretical framework. Yee conducted a series of survey so as to formalize a motivation model for players. He first identified five categories based on behavioural observation of players: Achievement, Socialization, Immersion, Escapism and Competition. While most players would fall within these categories, the model needed to be refined and Yee identified additional components and subdivided his model. The achievement category integrated the sub-components of Advancement, Mechanics and Competition. The social category was extended so as to include Socializing, Relationships and Teamwork. Immersion was identified as the final category and was comprised of the Discovery, Role-Play, Customization and Escapism components. By scoring players interest for each sub-component, Yee (Yee, N. (2005)) was able to identify

their major preferences in terms of game play and interaction. For instance, a player with a low score in the socializing category was likely to avoid interacting with others and favouring on other aspects of the gaming spectrum. Ryan et al (Ryan, R. (2000)) took a different approach and based their motivation theory on the self-determination theory, and stated that one should investigate both the players' motivation to play a game but also the factors that may motivate the player to act within the game. The Self-Determination theory was based on the belief that the motivations to play video games is influenced by variables and factors associated with certain components in any game context, namely: Autonomy (Flexibility over movements and strategies, freedom in decision-making in choosing tasks and goals), Competence, Presence (Graphic environment, Compelling storyline) Intuitive controls and Relatedness (connecting with others).

Understanding the user's intention is crucial. Gamers make decisions in accordance to their acquired knowledge, affect and context. The identification and understanding of the player's strategies in problem solving are important for the game design and interactive virtual environment. The work carried out in the Digital Game domain has shown that context should not be underestimated and played a role in how receptive or reactive one is depending on the context in which a task is conducted. It is it important to not only monitor the player for cues and indication of affect but also the situational context in which interactions are taking place so as to maximizing the impact of interventions on users.

2.3. Coupling Gaming and VE

Different approaches for the design of games and virtual environment were developed, however, despite the acquired advancement in knowledge and technologies virtual environment and gaming were not coupled. Taking advantage of the aspects specific to gaming such as the user experience, motivation, self-determination, online feedback on performance would have a great positive impact on the design of virtual environment and at the same time would be beneficial to the design of enriched gaming with multisensory feedbacks such as immersion, haptic sensation and spatialized audio. Kousmadoudi et al. (2013) state that Computer-Aided Design (CAD) applications often promote memorable experiences for the wrong reasons. Coupled with complex functionality and poor user experience the learning curve is often steep and overwhelming. Invoking design creativity remains limited to conveying established geometry. Gameplay conversely excels in memorable and formative experiences and could spur intuition and natural creativity. If games are profoundly imbued for purposeful play, thriving on tacit and explicit user knowledge, a CAD system carefully stylized with ludic mechanisms could potentially be highly productive. Furthermore, when a CAD system is designed to accept input with the user defining the rules in comparison

with the game system, is it possible for the game UX to be transferred to fit a CAD system? If so, could gaming make the user design process in CAD more interactive and meaningful?
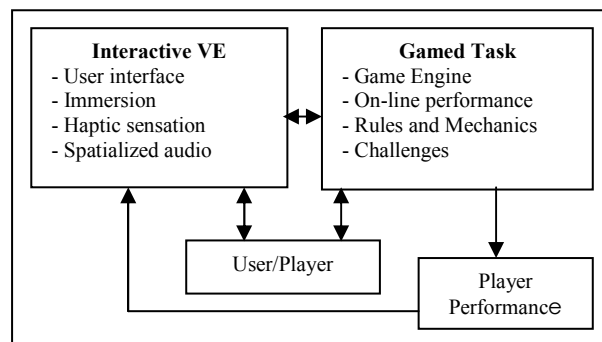
Figure 3. Coupled Gaming and Virtual Environment

Many studies providing a useful list of game-relevant issues and cognitive models that aid the understanding of the outcome of the experience (Wendrich et al., 2009, Jennett et al., 2008) yet none has been able to evaluate which game mechanics or set of game mechanics cause engagement with a system. There is lack of statistical models to evaluate whether engaging and enjoyable interactions have taken place and under which specific game mechanics (Kousmadoudi, 2013).

This prospective approach aims at shortening the development cycle of the VE and extending the concept of the game design currently restricted to linear approach. Moreover, coupling VE with gaming would improve the presence of the user interacting with the virtual environment, hence the learning effect in gaming context.

2.4. Audio-Visuo-Haptic interaction for navigation game

The integration of different sensory feedbacks in the interaction with VE or in game design provides the user/player with natural sensations as in the real world. The integration of senses such as vision, audio and haptics improves the user engagement, his learning capabilities and his performance (Ermi, L.2005).

The virtual environment for multisensory interactive game was developed at the ENSAM-Image Institute (Figure 4). The initial setup was developed using OPENHAPTICS software for haptics rendering, FMOD sound library for spatialized audio feedback and OPEGL library for 3D object creation and graphics rendering. The virtual environment is made of a labyrinth with a network of paths, an entrance and a way out, displayed on a 21,5" PC screen with a resolution of

1920 x 1080 and in another setup the scene is displayed in a VR4 Head Mounted Display. The interactive mode consists of following the optimal path leading to the way out with the minimum deviations and in the shorter possible time. In the future setup the interactive mode will be designed as a game with a complex maze for which the player will have to find the path leading to the way out with the minimum flaws. In order to evaluate the contribution of the different sensory feedbacks to the player performance the following interaction conditions were designed: audio-visuo-haptic, audio-haptic, audio-visuo and visuo-haptic interaction.
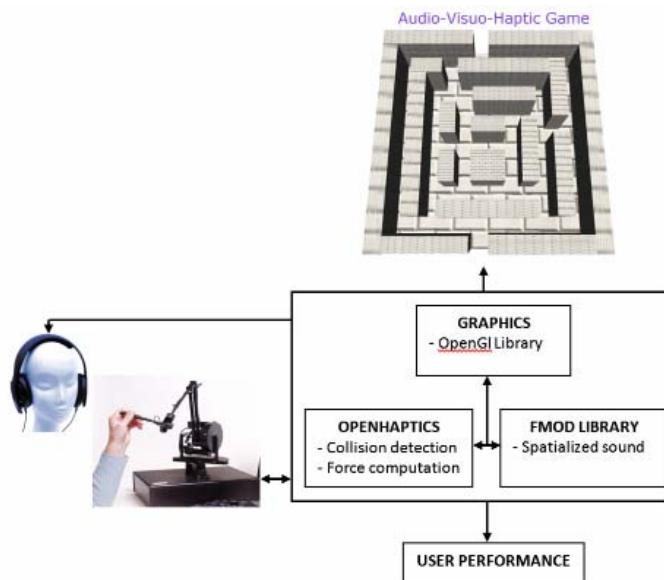

Figure 4. Virtual environment for multisensory interactive game

2.5. Haptic feedback and 3D sound

The haptic sensation is provided by a Phantom Premium device (Figure 5) rendering a 3D force upon the collisions of the device pointer with the walls of the labyrinth. The collisions are accompanied with the display of a non-speech spatialized sound emerging from the end effector of the haptic system. Additionally, speech sounds are included to display alerts and cues for the player through a pair of headphones.

Figure 5. Experimental setup with different interaction modes

2.6. Evaluation of the multisensoriality of the interaction
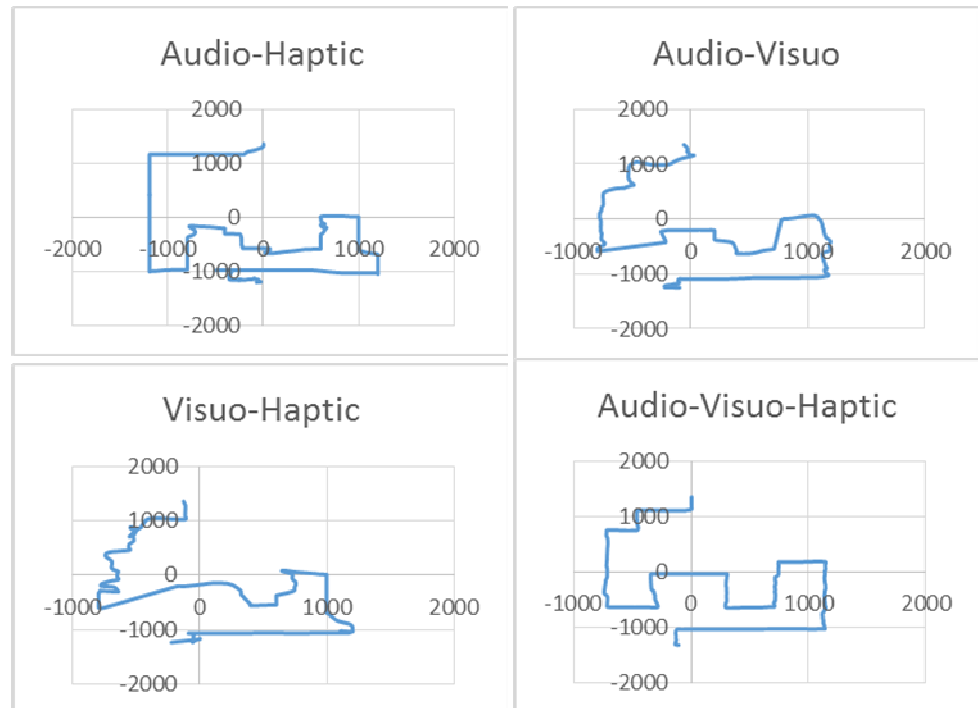
Figure 6. Trajectories recorded during the experiments

In order to obtain a quantitative evaluation of the affects of the sensory feedbacks on the user performance an experiment was conducted for each of the interactive conditions. The followed trajectory was recorded and used for the performance metrics. The rendered force was also recorded for further analysis of the quality of the interaction.

The experiment was conducted with subjects who were all familiar with 3D interaction systems and gaming. The initial results showed the potential added value of the audio-visuo-haptic condition, nevertheless the visuo-haptic, the audio-haptic and the audio-visuo also indicated relatively good performance (Fig. 6).

2.7. Low Cost Strategies for Virtualization

VR is considered as a way to improve upon limitations of ordinary human computer interfaces. Thereby this technology cumulates the use of complex and highly integrated interfaces to yield solutions to new applications (Mathew, 2014). VR had its breakthrough with innovative applications like its high technology system which correlates with the display technology, simulation technology, network technology, sensor technology artificial functions as well as computer graphic technologies (Saldana, 2011).

Virtualization technologies promise great opportunities for reducing energy and hardware costs through server consolidation. Moreover, virtualization can optimize resource sharing among applications hosted in different virtual machines to better meet their resource needs. Virtualization offers the potential for cost-effective service provisioning (Gmach et al., 2011). The use of low cost products, COTS components and developing affordable services are key for the promotion and uptake of virtualization and VE's. According to Klasing Chen (2013), there are two main low cost models that can be distinguished; 'low cost adaptation' and 'smart low cost design' (SLCD). The former is the restructuring of products towards its basic core-functionality to reduce costs, the latter is frugal product development in the early stages of design processing. Both strategies have similar effects, although SLCD is considered richer (Klasing Chen, 2013) Affordability and low-cost (i.e. products, services, devices) and addressing emerging markets and the bottom of the pyramid (BOTP) have been discussed in literature extensively (e.g. Prahalad and Allen, 2002; London et al., 2010; de Wit and Zuidberg, 2012; Basker, 2005; Gmach et al, 2011; Klasing Chen, 2013). In gaming and edutainment (e.g. World of Warcraft; Final Fantasy; Sims; Angry Birds; MInecraft) we witness the application of the same low-cost strategies and models whereby players and/or users play affordable games and use low-cost services for entertainment or edutainment. The impact and effect of low-cost strategies on emerging markets and BOTP are highly disruptive and bring about massive changes in society around the globe. Likewise in gaming where hundreds

of thousands or millions of participants are supported in Massively Multiplayer Online Games (MMOGs). This virtualization created the emergence of high-bandwidth and low-latency network infrastructures and the development of large-scale DVE applications (Liu and Theodoropoulos, 2014). In the design and engineering domain the uptake, distribution, and emergence of DVE's is generally restricted to large multi-national companies, military, or global OEM partnerships that have extensive budgets to invest in such VE systems and infrastructures. However, more than 90% of the world population makes a living working in SME's, is self-employed or runs brick-and-mortar stores Accessibility, low cost strategies, and virtualization for the masses would democratize the uptake and popularity of not only gaming but also in combination with CAD (DVE's) could lead to disruptions in the current industrial production, manufacturing and processing paradigms. Therefore it is imperative that adaptation, implementation, and transformation of game-mechanics and gamification techniques should be applied towards design, engineering and production domains to distribute, expand, and share knowledge, resources and communications on a grand-scale to reach society at large. Playing and gaming in combination with sensorial VE's (DVE's) are a possible combinatorial solution towards improved products and enhanced user experiences, at lower costs and with reduced time budgets.

III. CONCLUSIONS AND PERSPECIVES

Coupling human sensory feedbacks allows representing natural interaction in real world. The improvement of the user performance is an indicator for the quality of the interaction. This finding is useful for the development of virtual environment and gaming. If the virtual task is designed as a game and the player's scores are used as feedback loop to the process of VE design, the development cycle time will be reduced and the user preferences will be addressed proactively. This approach will create a pleasurable and joyful gamed virtual environment that could enhance learning.

In future research the full coupling and the interoperability of VE and gaming will be carried out and investigations will be conducted on the impact of this approach on the process of designing gamified virtual environment.

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