Spatial coverage vs. sensorial fidelity in VR

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ABSTRACT
With this paper we wish to promote a discussion about the different forms that an immersive VR system can take. This will be done by reflecting on a controversial concept: that of a totally immersive (understood as multimodal) but partial (understood as limited to a part of the body) virtual reality interface. The proposed concept of total/partial immersiveness may be seen as a new orthogonal dimension in the taxonomic classification of systems in the 'virtuality continuum' introduced in [2]. An interesting aspect of the proposed configuration is the possibility for it to be wearable. We will briefly describe the motivation for this new taxonomic dimension from a theoretical point of view, as well as explain the practical reasons that lead us to this concept. This will be done by discussing earlier work from one of the authors that illustrates the possibilities of a total immersive VR system but also pinpoints a number of inescapable limitations.

Author Keywords
virtual reality, immersive system, multi-modal, haptic

ACM Classification Keywords
H.5.1 Multimedia Information Systems — Artificial, augmented, and virtual realities,
H.5.2 User Interfaces — Haptic I/O

INTRODUCTION
Since the sixties and pioneered by the Sensorama simulator (a multimodal system created by Morton Heilig in 1962 [3]), lots of immersive systems were developed with different technologies and goals in mind. The main driving force was perhaps the entertainment industry with its clear goal of immersing the user as much as possible in a simulated environment governed by laws and rules of a specific gameplay. In this context, total immersion could be contemplated as the Holy Grail of Virtual Reality since it would afford the gamer to forget for a moment the (physical or social) constraints of the real world. However, researchers on the emerging field of Virtual Reality kept innovating with other goals in mind such as developing systems for training, learning, medical therapy and data visualization. Anticipating the development of highly immersion-capable technology, it appeared relevant to answer the question of how much immersion was going to be really necessary to succeed in each and all of these goals. Unsurprisingly, it turns out that the answer is extremely dependent on each particular goal. Moreover, it soon became clear that the sense of subjective *presence* in a virtual environment does not necessarily account for the level of objective sensorial *immersion* [4]. It may even be the case that immersion in an almost (but not completely) perfect simulation would provoke the user to distantiate himself from the rendered environment (there may be an 'uncanny valley' [1] for artificial *reality* as a whole, not just with respect to realistic humanoid robots). In an effort to clarify the relation between immersion and presence in the virtual environment, as well as related concepts such as coherent spatial perception and realistic interaction, some authors developed a taxonomy of virtual reality systems [2] which is useful as it introduces the concept of a 'virtual continuum' spanning the realm of the completely real to the completely virtual world, and qualifiy whatever is in between these extremes as 'mixed reality'.

Figure 1. photograph of the 'Time Machine'

We would like to discuss in this workshop the possibility of a total immersive interface (that is, reproducing with high fidelity most basic sensorial modalities and therefore belonging somehow to the totally virtual), whose action is restricted to a part of the body (and therefore making it impossible to classify it as an interface completely rendering a virtual environment). There has been a lot of research on enhancing a Head Mounted Display with binaural sound and other kinds of actuators; in a way, such a device would be the archetype of a total/partial immersive system, but we would like to discuss the possibility of deploying such configuration to other

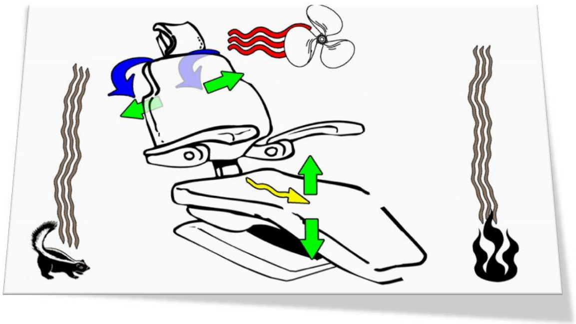

Figure 2. Schematic picture of the actuators

Figure 3. redering of the virtual environment

parts of the body (not necessarily encompassing all the sensorial organs). An example would be a box with an aperture for introducing a limb: when the user does so, he will experience as if his arm or leg is in another environment, say, a space filled with water and sea creatures he can touch and feel as real. Of course, one can argue that body propioception, vestibular sensation and visuospatial input are all basic senses that a 'total immersion interface' should be able to reproduce, and that this is in direct contradiction with the idea of a partial interaction with the body. However, in certain cases this is an apparent limitation: compelling presence within the simulated environment may be effective with this sort of interface - even though not all the sensorial apparatus is engaged, in particular thanks to task-oriented (bottom-down) perceptual blindness [5]. Of course, there has been some research on interfaces capitalizing on the limitations of human attentional span or the physical limitations inherent to the visual organs (the best known being the foveal displays [5]). We are however interested in another issue: that of an artificially generated *sense of presence of a part of the body* within a virtual environment. Evidence for compelling partial presence (i.e. partial body relocation) is described in [6]. Lastly, a practical motivation for the proposed concept is its compatibility with a wearable realization.

TOTAL IMMERSIVE SYSTEMS

A total immersive system needs to deal with at least two fundamental problems: the first is how to properly generate artificial sensory stimuli; the other is how to avoid the stimuli from the real world to interfere with the simulation (i.e. achieving sensory deprivation). Futuristic brain-computer interfaces may achieve both goals at once (c.f the 'neural plug' in the movie the Matrix, described earlier by pioneering writer William Gibson in his 1984 novel Neuromancer). Present day more or less invasive BCI enable elementary motor control [7] or generate sensations that would overlap with the external world stimuli if these are present [8], [9]. More conventional systems such as the CAVE [10] or HMD-based VR systems may instead capitalize on real world stimuli in order to enhance the realism of the immersiveness, but this is done at the expenses of the freedom of the simulation (i.e., one must constrain certain aspects of the simulated world such as the orientation on space, gravity and ground texture). With respect to the CAVE, the HMD-based configuration enables a limited form of body sensory deprivation - perhaps by immersing the rest of the body in a liquid or making the user relax on a bed or chair. The latter approach has been tried in an earlier experiment by one of the authors [11]. The intent of the experiment was to create a realistic sense of presence in the virtual world (a WWI battlefield), while at the same time cutting the subject from the real world sensory input. But can we imagine a system capable of totally immersing a part of his body in another world, while still capable of creating a (partial) sense of presence and sufficient emotional arousal?

EARLIER WORK

'Time Machine: VERDUN 1916' [11] is an immersive system build by one of the authors that 'sends' users back in time at the site of Verdun (a battlefield during World War I). The system achieves a high level of immersion thanks to a HMD and number of different actuators described in the following (figure 2).

A commercial stereoscopic HMD (the Z800 3DVisor from eMagin with a diagonal FOV of approx. 40 deg) and inertial head tracking was used to render the simulated environment (figure 3). Thanks to the information provided by the inertial sensors, the user was able to look around while tied on a modified dentist chair. The chair could tilt and vibrate as a whole (to simulate explosions) then providing some form of vestibular stimulation, and was also covered with dozens of tactile actuators to simulate the ground texture (as the wounded avatar was being dragged on the floor). A belt covering the torso was fit with sixteen vibrators and was used to render the footsteps of a rat walking over the lying body (figure 4).

The HMD is fitted with noise cancelling ear bud speakers, but a pair of large isolating headphones seemed more efficient in reducing interferences from the real environment. Additional speakers and a subwoofer were used to render low frequency sounds produced by the shock waves of virtual explosions. Since air flow can greatly enhance the feeling of presence on an open (virtual) space, a fan was installed to simulate wind as well as heat waves. Finally, an air-pump connected to a box containing chemicals (figure 5) would bring the smell of powder and dead corpses.

Figure 4. photograph of the vibrators inside the chair and the belt

The Time Machine was exhibited at the 2007 Laval Virtual international conference on VR. During a five day long exhibition, more than 300 people tried this immersive experience. Nobody was indifferent and some people were disoriented for a couple of minutes when 'coming back to the reality'. Also, two individuals asked to stop the 'Time Machine' because they grew scared. But of course, the machine was not conceived to function as a ghost train in a fun fair: there was no gratuitous surprise, nor rendering of blood or explicit scenes of fighting. One can wonder what aspect of the experience was more scary for these people: the emotionnaly charged context (i.e. the simulated battlefield), or the fact that they were immersed in a realistic, multimodal VR environment for the first time in their lives. From the technical point of view, this experiment demonstrates that low-cost immersive systems are not dreams anymore; also, it shows that the combination of a relatively low number of discrete multi-modal actuators is enough to create a completely immersive experience and make forget the low view angle of the HMD for example.

The team received two Awards at Laval Virtual; the best prize of the Student competition and the best prize of the IVRC Jury with an invitation to participate to the final step of the International Virtual Reality Contest in Japan.

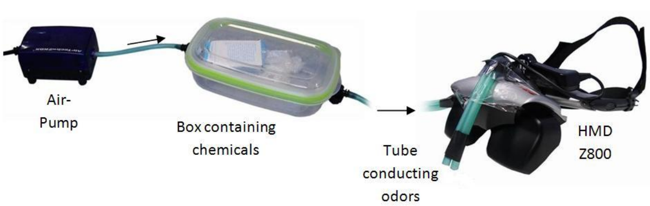

Figure 5. photograph of the odor system and the HMD

DISCUSSION

A subject having tried the system says: "I've never been immersed in such a way. I've never been emotionally immersed, and that's really an incredible experience. That's exactly the kind of immersion I was waiting for in a virtual world. There was no interactivity apart from the head movement, but maybe thats the reason why it worked" [12].

This comment is enlightening: the experience is believable precisely because the story being simulated matches the limitations of the interface: the subject is a wounded soldier, and as such *cannot move*. There may be many cases when a proper design can get around the limitations of the interface (in this case, it's inability to arbitrarily generate artificial propioceptive stimulation); however, one problem faced with the Verdun simulator was its bulkiness, immobility as well as the necessity of one or more technical operators for a unique subject in the machine.

CONCLUSION

There is some evidence that realistic auditory and haptic stimuli might be more important than realistic visuals when treating some types of phobia using VR systems [13]. This means that a total/partial immersive system not involving the sense of vision may be able to accommodate this type of simulation. An example would be for instance a wearable globe extending on the forearm that would create the impression of walking spiders and/or the temperature of virtual bodies. An early prototype of such a device is described in figure 6 [14]. From the point of view of the taxonomy described in [2], the total/partial immersive system can be seen as the counterpart of the 'window-on-the-world' mixed reality systems (these are monitor based, non-immersive video displays showing real scenes upon which computer generated imagery is electronically overlaid). Indeed, the proposed configuration can be seen as a window on the *virtual* world, not necessarily encompassing the visual senses, but instead the rest of the perceptual modalities. Perhaps a better analogy would be that of a spatio-temporal wormhole or a portal to another world. It is partial in the sense of it being a window located at a specific place in (real) space where the user can introduce a part of the body. As said before, this makes compatible the

Figure 6. photograph of the 'Ants glove' [14]

notion of partial/total immersion with that of a wearable interface, as opposed with total immersive systems where the user is completely immersed in the virtual world. An second potential advantage of such system could be that if there is an uncanny valley for artificial environments, as suggested in the introduction, then it may constitute an advantage that these systems secure a cognitive distance between the rendered environment and the user's 'reality'.

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