13 Immersive Virtual Telepresence: Virtual Reality meets eHealth

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Abstract Immersive Virtual Telepresence (IVT) tools are virtual reality environments combined with wireless multimedia facilities - real-time video and audio – and advanced input devices – tracking sensors, biosensors, brain-computer interfaces. For its features IVT can be considered an innovative communication interface based on interactive 3D visualization, able to collect and integrate different inputs and data sets in a single real-like experience.

In this paper we try to outline the current state of research and technology that is relevant to the development of IVT in medicine. Moreover, we discuss the clinical principles and possible advantages associated with the use of IVT in this field.

1. Introduction

According to the recent “ISTAG SCENARIOS FOR AMBIENT INTELLIGENCE 2010” [1] the evolutionary technology scenarios in support of the Knowledge Society of the 2000s will be rooted within three dominant trends:

- Pervasive diffusion of intelligence in the space around us, through the development of network technologies and intelligent sensors towards the objective of the so-called “Ambient Intelligence” (AmI) [2];
- increasingly relevant role of mobility, through the development of mobile communications, moving from the Universal Mobile Telecommunications System (UMTS) "Beyond 3rd Generation" (B3G) [3];
- Increase of the range, accessibility and comprehensiveness of communications, through the development of multi-channel multimedia technologies [4].

The convergence of AmI, 4G and multi-channel multimedia technologies manifests itself as the next frontier of ICT (Information and Communication Technology). This convergence stimulates a change in the way health care is carried out. In particular, the result is eHealth, a globally distributed process, in which communication and collaboration of geographically dispersed users (patients and/or therapists) play a key role [5, 6].
Within this process, an important role will be played by intelligent environments for health care in which complex multimedia contents integrate and enrich the real space [7]. In particular, we expect the emergence of "Immersive Virtual Telepresence" - IVT: in IVT tools, distributed virtual reality (VR) systems are combined with wireless multimedia facilities - real-time video – and innovative input devices – tracking sensors, biosensors, brain-computer interfaces.

The strength of the IVT approach is that IVT can be considered at the same time as a technology, a communicative interface and an experience. These characteristics better clarifies the possible role of IVT in medicine: a communication interface based on interactive 3D visualization, able to collect and integrate different inputs and data sets in a single real-like experience.

In this paper we try to outline the current state of research and technology that is relevant to the development of IVT in medicine. Moreover, we discuss the clinical principles and possible advantages associated with the use of IVT in this field.

2. Immersive Virtual Telepresence

2.1 The evolution of IVT

A typical first generation IVT system is virtual reality [8]. In VR, using visual and auditory output devices, the user can experience the environment as if it were a part of the world.

Further, because input devices sense the operator's reactions and motions, the operator can modify the synthetic environment, creating the illusion of interacting with and thus being immersed within the environment.

IVT, however, is not only a hardware system [9]. According to different authors the essence of IVT is the inclusive relationship between the participant and the synthetic environment, where direct experience of the immersive environment constitutes communication [10, 11]. In this sense, IVT can be considered as the leading edge of a general evolution of present communication interfaces like television, computer and telephone. Main characteristic of this evolution is the full immersion of the human sensorimotor channels into a vivid and global communication experience: IVT provides a new methodology for interacting with information [12].

For this reason, next generation IVT systems will have an improved focus on the communication capabilities. A possible future IVT application is Mobile Mixed Reality [13], the enhancement of information of a mobile user about a real scene through the embedding of one or more objects (3D, images, videos, text, computer graphics, sound, etc) within his/her sensorial field. These objects may be part of a wider virtual space whose contents can be accessed in different ways and using different media (cellular phones, tablet PCs, PDAs, Internet, etc.).

In general, the IVT perspective is reached through:

- the induction of a sense of “presence” or “telepresence” through multimodal human/machine communication in the dimensions of sound, vision, touch-and-feel (haptics).
- the widening of the input channel through the use of biosensors (brain-computer interface, psycho-physiological measurements, etc.) and advanced tracking systems (wide body tracking, gaze analysis, etc.).

Typically, the sense of presence is achieved through multisensorial stimula such that actual
reality is either hidden or substituted via a synthetic scenario, i.e. made virtual through audio and 3-D video analysis and modelling procedures.

In high end IVT systems, multimedia data-streams, such as live stereo-video and audio, are transmitted and integrated into the virtual space of another participant at a remote system, allowing geographically separated groups to meet in a common virtual space, while maintaining eye-contact, gaze awareness and body language. Presence with other people who may be at distant sites is achieved through avatar representations with data about body movement streamed over a high-speed network.

Since e-health is principally involved with the handling and transmission of medical information, IVT has the potential to enhance the e-health experience through the expansion of human input and output channels. The two principle ways in which IVT can be applied are:

a) as an interface, which enables a more intuitive manner of interacting with information, and
b) as an extended communicative environment that enhances the feeling of presence during the interaction.

These approaches will be strengthened by the development of 3RD generation IVT systems including biosensors, mobile communication and mixed reality.

2.2 IVT System functional architecture

Following these premises, a general system functional architecture for a eHealth IVT systems should includes three main modules:

- The Visualization Module will use virtual environments and augmented reality to provide totally new clinical services and interfaces to patients. The research will focus on the characteristics and components of wearable personal virtual reality systems with augmented reality display systems, tracking systems, wireless communications and wearable computing. An essential requirement of IVT personal interface is that it should work wireless, otherwise the patient is tied with
cables and the freedom of movement is lost. Wireless communication is needed between components of the system and also between personal augmented reality system and networks services, such as world models and other users or avatars.

- The **Core Module** within the system manages the information flows both internally within the software and externally within the clinical environment to allow remote access and interrogation. The project will develop unique XML messaging services that make the IVT database accessible to external authenticated users. Moreover, the project will develop IVT standards in both client and server configurations making a whole range of medical data available for export and import over clinical
connections. To ensure that the system remains compatible with the latest systems, the latest messaging standards such as HL7\(^1\) will be tracked and monitored.

- **The Biomonitoring Module** will give therapists access to a wide range of physiological data to support highly individual and focused clinical interventions. Biosensors are a neural interface technology that detect nerve and muscle activity. Currently, biosensors exist that measure physiological activity, muscle electrical activity, brain electrical activity, and eye movement. Extracting accurate physiological data from biosensors is often a complex task. In particular, extracting data from different typologies of biosensors will require architecture of great flexibility and the possibility to connected them to different external monitoring devices.

### 2.3 IVT research

As recently noted by Satava [14], former US Army colonel and head of the DARPA research in this area, the advantages of IVT tools for health care can be summarized in a single word: revolutionary.

However, the research on IVT technologies in the health care sector is moving fast. In 2002 different US government institutions (i.e. Office of Naval Research, National Science Foundation, and Defence Advanced Research Projects Agency) funded research in this area to the amount of 26 million US$ (Source: DARPA bulletin, 2003). In the same year the European institutions funded research in this field with less that 4 million Euros (estimated from CORDIS database, 2003): less than 1/10 of the US effort.

Up to now, Europe has matched the reduced funds with the creativity of its researchers. In fact, the main applications of virtual reality (1\(^{st}\) generation IVT system) in psychological assessment and rehabilitation come from Italian, Spanish, and English institutions.

According to the leading scientific databases the European researchers have the highest number of published papers in this area on peer-reviewed journals (Sources: MedLine, Science Citation Index, PsycLit; Keyword “Virtual Reality”; Accessed: 19 August 2003).

However, the EU research advantage is tightening. In 1997, European researchers authored 72% of all the published papers in this area on peer-reviewed journals. This percentage slipped to 53% in 2002 (Sources: MedLine, Science Citation Index, PsycLit; Keyword “Virtual Reality”; Accessed: 19 August 2003).

Moreover, no European institutions are now exploring the possible use of 2\(^{nd}\) generation and 3\(^{rd}\) generation IVT tools, exploiting the potential of remote consultations, mobile communication and the use of biosensors. In this specific field no significant effort is made at European level. In US, instead, different companies (Microsoft, Intel) and research institution (MIT, Darpa, USC) are working on the development of prototypes and proofs of concept.

The actual European situation can be explained by the scarce national funding, as well as on the absence of an organization to direct the research with authority. Researchers belonging to the EU run the serious risk of being unprepared, both at a cultural level and at an industrial level, to face the growth that foreign countries are likely to achieve in the vast ICT sector. In this situation, the exigency of a European coordination is of paramount

\(^1\) The Health Level Seven (HL7) Messaging Standard is recognized as the current core message format standard for the electronic exchange of Patient Medical Record Information (PMRI).
importance, one that is able to promote and lead the development of the research in the application of IVT technologies to health care.

3. Immersive Virtual Telepresence in health care

As we have seen before, IVT is at the same time a technology, a communication interface and an experience: a communication interface based on interactive 3D visualization, able to collect and integrate different inputs and data sets in a single real-like experience.

In this sense, the use of Immersive Virtual Telepresence offers many new possibilities to therapists.

Applications of virtual reality – a first generation IVT environment - have been developed in many clinical areas ranging from surgical procedures to the visualization of medical databases. If we check the two leading clinical databases – MEDLINE and PSYCINFO – using the “virtual reality” keyword we can find 829 papers listed in MEDLINE and 693 in PSYCINFO (accessed 17 August, 2003).

However, there is a growing recognition that 2nd and 3rd generation IVT environments will play a broader role in neuro-psychology, clinical psychology and health care education. IVT offers a blend of attractive attributes for therapists. The most basic of these is its ability to create a 3D simulation of reality that can be explored by patients. In many virtual environments, the graphic renderings of people and objects are quite simple, but they are still able to give the visitor a strong sense of presence. In other words, their responses to events and situations within an IVT environment are similar enough to what they would have been in a real environment, thus establishing the possibility of effective treatment and patient support.

The IVT-based treatment differs from traditional therapy in that computer graphics and various display and input/output technologies are integrated to provide the patient with a sense of presence or immersion. More in detail, IVT provide a new human-computer
interaction paradigm in which users are no longer simply external observers of images on a computer screen but are active participants within a computer-generated three-dimensional synthetic world [15]. In this world the patient has the possibility of learning to manage a problematic situation. Moreover, IVT offers a high level of control of the experience without the constraints usually found in computer systems. IVT environments are highly flexible and programmable. They enable the therapist to present a wide variety of controlled stimuli, such as a fearful situation, and to measure and monitor a wide variety of responses made by the user. This flexibility can be used to provide systematic restorative training that optimize the degree of transfer of training or generalization of learning to the person's real world environment [16].

Finally, IVT systems open the input channel to the full range of human expressions: in rehabilitation it is possible to monitor movements or actions from any body part or many body parts at the same time. On the other side, with disabled patients feedbacks and prompts can be translated into alternate and/or multiple senses [17].

IVT also offers a strong support to patient mobility. It will enhance patient’s compliance by introducing home-based therapeutic exercises and treatment. IVT, provides the patient access to an augmented interface that will take advantage of state-of-the-art biosensors mobile or pervasive computer technology. The immersive nature of IVT and its ubiquity may also provide numerous psychological benefits, such as mood elevation, improved motivation, increased hope for recovery, and an internal locus of control.

4. Conclusions

The use of virtual reality – a first generation IVT environment - supports the possible efficacy of IVT as eHealth platform. In summary the advantages expected by this approach are:

- **Effective Therapy**: as indicated above, IVT offers better significant advantages to the selected diseases that can complement and/or improve existing approaches.
- **Patient Acceptance**: As reported by previous researchers a consistent theme amongst people who suffer from neuropsychological disturbances has been that they would be much more willing to undergo assessment and rehabilitation in a 3D synthetic environment than in a real physical environment.
- **Cost Effectiveness**: Many stimuli for exposure are difficult to arrange or control, and when exposure is conducted outside of the therapist's office, it becomes more expensive in terms of time and money. The ability to conduct exposures of war situations PTSD patients, for example, without leaving the therapist's office would make better treatment available to more sufferers at a lower cost.

Unfortunately, there is still a limited of controlled clinical studies showing significant advantage of IVT over traditional methods. Moreover the lack of coordinated efforts makes most applications just advanced prototypes that have a limited impact on real world health care provision.

Significant efforts are still required to move IVT into commercial success and therefore routine clinical use. Possible future scenarios will involve multi-disciplinary teams of engineers, computer programmers, and therapists working in concert to treat specific clinical problems. It is hoped that by bringing together this community of experts, further stimulation of interest from granting agencies will be accelerated. Information on advances in IVT and eHealth technology must be made available to the health care
community in a format that is easy-to-understand and invites participation. Future potential applications of IVT are really only limited by the imaginations of talented individuals.

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