The Future of Cybertherapy: Ambient Intelligence and Immersive Virtual Telepresence

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Abstract: The convergence of biosensors, 4G mobile communication and multi channel multimedia technologies manifests itself as the next frontier of Information and Communication Technology. This convergence is stimulating a change in the way health care is carried out. In particular, the emerging result is shared e-therapy or telehealth, a globally distributed process, in which communication and collaboration of geographically dispersed users (patients and/or therapists) play a key role.

Within this process two trends are expected to shape the future of cybertherapy: Ambient Intelligence (AmI) and Immersive Virtual Telepresence (IVT). AmI is an emerging interface paradigm in which the computer intelligence is embedded in a digital environment that is aware of the presence of the users and is sensitive, adaptive, and responsive to their needs, habits, gestures and emotions.

IVT is a new hybrid platform including shared virtual reality environments, 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.

Here is outlined the possible role of IVT and AmI in health care by focusing on both their technological and relational nature. In particular, these tools differ from traditional therapy for their ability to provide the patient with a sense of presence or immersion. Moreover, it discusses the clinical rationale and the expected advantages associated with the use of these approaches in e-health.

INTRODUCTION

“Managed care” indicates a health care system that uses organizational and management controls to offer patients appropriate care in cost-effective treatment settings. Today, the managed care environment is beginning to focus its attention on new technologies especially in the areas of organization and clinical data management.

To date, some cybertherapy applications have improved the quality of managed care, and later they will lead to substantial cost savings. For instance, physicians can review radiological films and pathology slides in remote sites, or assist patients through e-mail.

However, most of the actual applications are used for discrete clinical activities, such as scripting, lab-testing, patient monitoring, and condition-specific diagnostics and treatment. As recently noted by Fifer & Thomas "the new question about E-medicine practice may be not "When will it happen?" but when will the fragmented E-health systems be connected?" (p.52).

The most recent research findings underline the possibility that cybertherapy, by blending with distributed communication media, could become a significant enabler of consumer health initiatives. In fact, in comparison with traditional communication technologies, this new form of cybertherapy offers greater interactivity and better tailoring of information to individual needs. In other words, distributed cybertherapy can be considered a process and not a technology, including different complementary areas: health care information provision, administrative and clinical data collection, therapy and assessment provision.

According to the recent “ISTAG SCENARIOS FOR AMBIENT INTELLIGENCE 2010” the
evolutionary cybertherapy scenarios 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.
- Increasingly relevant role of mobility, through the development of mobile communications, moving from the Universal Mobile Telecommunications System (UMTS) "Beyond 3rd Generation" (B3G);
- Increase of the range, accessibility and comprehensiveness of communications, through the development of multi-channel multimedia technologies.

The convergence of biosensors, 4G mobile communication 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 shared cybertherapy, a globally distributed process, in which communication and collaboration of geographically dispersed users (patients and/or therapists) play a key role. An important role will be played by intelligent environments for health care in which complex multimedia contents integrate and enrich the real space.

Within this process two trends are expected to shape the future of Cybertherapy: Ambient Intelligence (AmI) and Immersive Virtual Telepresence (IVT).

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Here is outlined the possible role of IVT and AmI in health care, by focusing on both their technological and relational nature. In particular, these tools differ from traditional therapy for their ability to provide the patient with a sense of presence or immersion. Moreover, it discusses the clinical rationale and the expected advantages associated with the use of these approaches in e-health.

AMBIENT INTELLIGENCE

Ambient Intelligence (AmI), is a new paradigm in information technology, in which people are empowered through a digital environment that is aware of their presence and context, and is sensitive, adaptive, and responsive to their needs, habits, gestures and emotions. As underlined by the AMBIENCE Project, AmI can be defined as the merger of two important visions and trends: "ubiquitous computing" and "social user interfaces":

"It builds on advanced networking technologies, which allow robust, ad-hoc networks to be formed by a broad range of mobile devices and other objects (ubiquitous- or pervasive computing). By adding adaptive user-system interaction methods, based on new insights in the way people like to interact with computing devices (social user interfaces), digital environments can be created which improve the quality of life of people by acting on their behalf. These context aware systems combine ubiquitous information, communication, and entertainment with enhanced personalization, natural interaction and intelligence".

(Online: http://www.itea-office.org/projects/facts_sheets/ambience_fact_sheet.htm).

According to the vision of AmI provided by the Information Society Technologies Advisory Group (ISTAG) to the European Commission, all the environment around us, homes and offices, cars and cities, through AmI will collectively develop a pervasive network of intelligent devices that will cooperatively gather, process and transport information. As noted by the ISTAG group:

"Such an environment is sensitive to the presence of living creatures (persons, groups of persons and maybe even animals) in it, and sup-
ports their activities. It 'remembers and anticipates' in its behavior. The humans and physical entities - or their cyber representatives - together with services share this new space, which encompasses the physical and virtual world' (p. 6).

On one side this approach enables knowledge, content organization and processing. On the other side, it also enables the direct natural and intuitive interaction of the user with applications and services spanning collections of environments - including the cyberspace level. In this sense the AmI paradigm can be seen as the direct extension of today's concept of ubiquitous computing: the integration of microprocessors into everyday objects. However, AmI will also be more than this: a pervasive and unobtrusive intelligence in the surrounding environment supporting the activities and interactions of the users.

In the near future, even simple objects like a pen or a box, will be able to sense the presence of a user and calculate his/her current situation. Throughout the environment, bio-sensing will be used to enhance person-to-person and person-to-device communications. Biometrics technology will be used to enhance security by combining static (facial recognition) and dynamic information (voice and lip movement, uncontrolled user gestures), as well as user's habits, which the network will be able to acquire and maintain.

The interaction process will be enabled by the AmI Space: networked (using a changing collection of heterogeneous network) embedded systems hosting services which are dynamically configured distributed components (see Figure 2). The AmI Space can be seen as the integration of functions at the local level across the various environments and enables the direct natural and intuitive dialogue of the user with applications and services spanning collections of environments - as well as at the cyberspace level - allowing knowledge and content organization and processing.

In particular the AmI Space should offer capabilities to:

* **Model the environment and sensors available to perceive it**, to take care of the world model. This deals with the list of authorized users, available devices, active devices, state of the system, and so on.

* **Model the user behavior** to keep track of all the relevant information concerning a user. Also, it automatically builds the user preferences from its past interactions and eventually, abstracts the user profile to more general community profiles.

* **Interact with the user** by taking into account the user preferences. Natural interaction with the user replaces the keyboard and

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**Figure 1.** The AmI Space (adapted from ISTAG, 2002).
windows interface with a more natural interface like speech, touch or gestures. **Control security aspects** to ensure the privacy and security of the transferred personal data and deal with authorization, key and rights management. **Ensure the quality of services** as perceived by the user.

The most ambitious expression of the AMI is **Intelligent Mixed Reality (IMR)**. Using IMR it is possible to seamlessly integrate computer interfaces into the real environment, so that the user can interact with other individuals and with the environment itself in the most natural and intuitive way. Within IMR, a key role will be played by **Immersive Virtual Telepresence**, the enhancement of information of a mobile user about a real scene through the embedding of any objects (3D, images, videos, text, computer graphics, sound, etc) within his/her sensorial information. In this scenario, the embedded information is based on factors like location and direction of view, user situation/context aware (day of the time, holidays of business related, etc), user preferences (i.e. preference in terms of content and interests), terminal capabilities and network capabilities.

**IMMERSIVE VIRTUAL TELEPRESENCE**

A typical first generation IVT system is virtual reality (VR). 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. The critical advantage offered by VR to cybertherapy is 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 virtual world. In the virtual environment (VE) the patient has the possibility of learning to manage a problematic situation related to his/her disturbance in a functionally relevant, ecologically valid experience.

IVT, however, is not only a hardware system. 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. 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.

This is possible because the key characteristic of IVT, differentiating it from other media or communication systems, is the sense of **presence**, usually defined as the "sense of being there" or the "feeling of being in a world that exists outside the self". In particular, a growing group of researchers considers presence as a neuropsychological phenomenon, evolved from the interplay of our biological and cultural inheritance, whose goal is the control of agency.

The link between communication, action and presence is theorized to contribute to the efficacy of VR as rehabilitation tool: the successful use of VR exposure therapy for phobias, posttraumatic stress disorders, and the pain reduction obtained in burn patients during a VR session underline the possible role that an high level of presence, elicited by the VR experience, may have in the rehabilitation process.

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 (MMR)**, the enhancement of information of a mobile user about a real scene through the embedding of one or more information objects within his/her sensorial field. These objects may be part of a wider virtual space – the AMI Space - whose contents can be accessed in different ways and using different media (cellular phones, tablet PCs, PDAs, Internet, etc.).

The possibilities offered by MMR are huge. By integrating within a common interface a wireless network connection, wearable computer and head mounted display, MMR virtually enhances users’ experience by providing information for any object surrounding them. They can
manipulate and examine real objects and simultaneously receive additional information about them or the task at hand.

Moreover, using Augmented or Mixed Reality technologies, the information is presented three-dimensionally and is integrated into the real world. Recently, Christopoulos identified the following applications of MMR:

- **Smart signs added to the real world**: Smart signs overlaid on user real world may provide information assistance and advertisement based on user preferences.

- **Information assistant (or “virtual guide”)**: The virtual guide knows where the user is, his/her heading, as well as the properties of the surrounding environment; interaction can be through voice or gestures, and the virtual guide can be an animated guide and provides assistance in different scenarios based on location and context information.

- **Augmented Reality or Virtual Reality combined with conversational multimedia (or “virtual immersive cooperative environments”)**: Conversational multimedia can be also added to a VR or an augmented reality scenario, where a user can see the avatar of another user coming into the scene and a 3D video conference is carried on. If we use VR, given the position and orientation information of the first user in the world, the second user can put the first one (or his/her avatar) in a 3D synthetic world.

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 stimuli 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. Following these premises, a general system functional architecture for a high-end 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 **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.

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. This model requires unique XML messaging services that make the IVT database accessible to external authenticated users. Moreover, IVT standards are needed in both client and server configurations making a whole range of medical data available for export and import over clinical connections.

**CONCLUSIONS**

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

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

For these reasons, IVT and Ambient Intelligence offer a blend of attractive attributes for therapists. In particular, these tools differ from traditional therapy for their ability to provide the patient with a sense of presence or immersion.

More in detail, AmI and 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 real or augmented world. Moreover, these tools offer a high level of control of the experience without the constraints usually found in computer systems. They 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.

Finally, these tools 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.

AmI and IVT also offer 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.

Figure 4. IVT in the patient-therapist relationship.
improved motivation, increased hope for recovery, and an internal locus of control.

In order to transform this vision in reality, below we tried to outline a real health care scenario including all the innovations described before:

Luigi, a 35-year obese subject was directed by his general practitioner to start a self management education program. Before beginning the programme Luigi is asked to provide for information that enables the clinician to target the educational contents for his age, lifestyle, risk factors and medical history. When Luigi goes to the hospital to book for the class and for the visit the unique ID code of his Personal Area Network is recorded into the Information System and tracked in the Local Area Network of the hospital. Moreover, a micro-payment system will automatically transfer the amount into the e-purse of the hospital when he gets out of it.

When a week later Luigi comes back to the hospital; his Personal Area Network is immediately recognized. In a couple of seconds a young nurse appears on the UMTS phone and describes the diagnostic tests and the location of all the different professionals. In the mean time, each professional can track the position of both Luigi and any other patient on his office monitor. In case of delays or problems the visit schedule is modified to reduce the waiting time. In this way, all testing is done in one morning in one place. Through the use of GRID technologies, the collected data are stored and compared with millions of images and files of relevant medical information held on distributed computer. All the analyses are normal.

In the afternoon, Luigi can choose lifestyle consultations customized to meet his health needs. The hospital endocrinologist, clinical psychologist, exercise physiologist and registered dietitian give to Luigi specific indications that are recorded on the PDAs of the professionals. Should Luigi come back later to the office of the specialist, his Personal Area Network is tracked by the Local Area Network and through the GRID system all the info about any previous visit and any assessment result will be immediately available on the specialist’s monitor.

After the visits, the primary examining physician explains Luigi test results and provides a personal health action plan. Through the UMTS phone, a detailed written report and individualized directions are provided to Luigi at weekly intervals. In this way Luigi can follow the plan independently from his physical location.

In his home, a couple of days after, Luigi wears its IVT system and starts his learning programme. In a few seconds the headset switches on and appears a wide shared 3D environment: a room looking much like a hotel foyer with comfortable furniture pleasantly arranged. As Luigi enters the room and finds himself a place to work, he hears a voice asking “Hello Luigi, here is the program of the courses: are you ready?” The electronic tutoring system goes briefly through its understanding of Luigi’s availability and preferences for the day’s work. Luigi is an active and advanced student so the electronic tutoring system says it might be useful if Luigi spends some time today trying to pin down the problem using enhanced interactive simulation and projection facilities. It then asks whether Luigi would give a brief presentation to the group. Finally, Luigi agrees on her work programme for the day. During the connection individuals and sub-groups locate in appropriate spaces in the ambient to pursue appropriate learning experiences at a pace that suits them. The electronic tutoring system negotiates its degree of participation in these experiences with the aid of the mentor. Time spent in the 3D environment ends by negotiating a homework assignment with each individual.

Transforming this vision in reality is not an easy task: the most a technology is complex and costly, the less the user is prone to accept it. Significant efforts are still required to move AmI and 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 AmI 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
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ANNUAL REVIEW OF CYBERTHERAPY AND TELEMEDICINE


Submitted: January 21, 2004
Accepted: May 28, 2004
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