Interactive Therapeutic Multi-Sensory Environment for Cerebral Palsy Users

Abstract. We present the foundations of the ITSE (Interactive Therapeutic Sensory Environment) research project that offers new opportunities on stimulation, interaction and interactive creation for people with moderate and severe mental and physical disabilities (e.g. people with cerebral palsy). Mainly based on computer vision techniques, the ITSE project allows the gathering of users' gestures and their transformation into images, sounds and vibrations. It can be used as a standalone application in individual sessions or, as an accessible musical instrument for music therapy sessions. The project was born in the Cerebral Palsy Centre of Tarragona (Spain) motivated by the low rate of users able to interact with computers. Although several assistive technology gadgets (e.g. key-guards, joysticks, switches, mouse emulators, etc.) and special software applications (e.g. cause-effect and educational activities, simple navigation environments, etc.) were used, most users "simply" didn't understand the interaction mechanisms. We believed that a high interactive activity (reinforced with sounds and images closely related with the gestures) would be more accessible to most users in spite of their sensory, motor and cognitive impairments. Currently we are working in a first prototype that is capable to generate sounds based on the user's motion and digitally process the user's vocal sound adding effects such as echo or reverberation. Tests with impaired users show that ITSE promotes participation, engagement and play. In this paper we explain the experimental methodology, the tools used and developed, the users' profiles and the first results and conclusions. Future goals include testing and developing the most appropriate machine vision interaction techniques, sound and image generation engines and, also to develop and apply an analysis methodology to show and improve the effectiveness of the system.

Keywords: Cerebral Palsy, Human-Computer Interaction, Elderly, Disabled People, Artificial Vision

1 Introduction

This article presents the Interactive Therapeutic Sensory Environment (ITSE) Project. Its main aim is to investigate, develop and apply a system that is able to analyze the movements and sounds of users (e.g. by means of artificial vision and microphones) and transform them into images, sounds and vibrations. By doing so, the system creates an adaptive sensitive space characterized by the absence of fixed constants and rules to be followed.

Our goal is to turn the system into a tool that allows users to explore, express, play and enjoy. Moreover, by means of these activities, users may develop capabilities – sometimes unconsciously– such as participation, communication or creativity and, thus, it will lead to an improvement of their quality of live.

The project focuses on people with cerebral palsy but we believe that it could also benefit other people with cognitive disabilities (e.g. autism, Down syndrome, mental retardation, elderly, and so on). In addition, the system can be used as a learning tool for people without special cognitive needs.

The rest of the article is organized as follows: In Section 2 we summarize some projects and articles related to the interaction with disabled people. Section 3 is devoted to the ITSE project and considers many of its aspects from the description of the system to the definition of user's profiles. Sections 4 and 5 provide some final conclusions and future research lines.

2 State of the art

In the following sections we summarize some relevant projects and systems that aim at improving the interaction of disabled people.

2.1 The Soundbeam system

In the early 90s, Phil Ellis started to use the so-called sound therapy with Soundbeam[1] on children with cerebral palsy, autism and profound and multiple learning disabilities (PMLD). Sound therapy combines the power of new technologies with an aesthetic response to sound. This can encourage the users interaction and the development of their communicative skills. Generally a non-interventionist (or minimally interventionist) approach is used [7].

Since 1998 Ellis has made the sound therapy to evolve to the so-called vibroacoustic sound therapy (VAST) and has experimented with elderly [8, 9]. VAST therapy includes using a microphone and vibratory devices. A vibroacoustic device is used to reinforce the sounds created by means of Soundbeam or a microphone. Also, VAST therapy improves users' relaxation at the end of the sessions, thus, promoting a general sense of mental and physical well-being. Since 2004 Ellis, from the iMUSE (interactive Multy-Sensory Environment) research centre in the Sunderland University (UK), focuses his work on the elderly and includes images in the feedback that users receive. By using multi-sensory integration they focus attention through immersion and unlock creativity through unusual yet intuitive perception-action couplings [10].

1 The Soundbeam system uses an ultrasound sensor able to measure the distance to the closest obstacle.

2.2 Soundscapes

Soundscapes [2] refers to a body function capture library and also a collection of software able to generate a response from the gesture. One of the uses of Soundscapes is as an “expression amplifier” for people with disabilities. It allows users to generate images and sounds from body motion. The main idea is to create a virtual interactive space (VIS) in which users like to be and their motivation and creativity are promoted through play and fun. The therapeutically use of Soundscapes was exemplified in several European projects like Twi-aysi (*The world is - as you see it*) [14] and CAREHERE (*Creating Aesthetically Resonant Environments for the Handicapped, Elderly and REhabilitation*) [3, 13].

2.3 MEDIATE and other projects

The Mediate project [24] is a multi-sensory installation whose main goal is to let children with autism to have fun, play, explore and create in a controlled and secure environment. The Mediate project carried out psychological studies and provided parents with an environment where they could see their children playing. In the literature it can be found a number of similar systems like Intellivision [4] and others using machine vision techniques to create accessible musical instruments, for instance Virtual Music Instrument (VMI) [18, 17] or Adaptive Use Musical Instruments [23]. The ITSE project, like the projects described above, has their roots in the Interactive Music Systems (IMS). By definition, an IMS [16] satisfies that: it is computer based, it is interactive enough to affect and modify the performer(s) actions thus provoking an ongoing dialog between the performer(s) and the computer system and, generate a musical output at performance time.

3 The ITSE project

In the following sections, some aspects of the ITSE project are described. In Section 3.1 we define the goals of the project. Section 3.2 is a brief description of the technical aspects of the project. Section 3.3 explains how the users of the system are classified and why. Section 3.4 is devoted to the description of the project sessions. Section 3.5 comments on the methodology of analysis and Section 3.6 points out some preliminary results.

3.1 Goals

If we were able to foster the participation of people with severe mental disabilities – that normally remain passive– this would lead to a series of reactions that will favor their development. These people are usually withdrawn and their little communication abilities isolate them from their surroundings. Providing them with a channel that permits them to effectively communicate, express feelings, and even create will contribute to the improvement of their quality of life.

To cope with this task it is necessary to have the right tools providing this multimodal interaction in an efficient, simple, and economical way. Based on our experience [20, 19, 12, 11], we believe that artificial vision techniques using low cost devices (web cams) can play a very important role due to their versatility.

3.2 System description

The ITSE system consists of two modules of software: one captures the users' gesture while the other generates sounds and images.

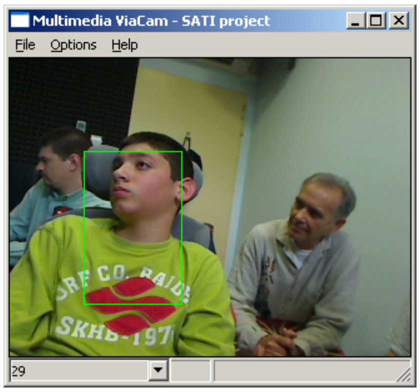

Figure 1: Screenshot of the motion capture system

Module 1 of gesture capture

- **Motions capture system.** It is an application that captures and processes in real time a video signal (see figure 1). From this signal a series of parameters can be extracted:
  - *Direction and quantity of movement in a specific area*: It allows selecting the area for the extraction of voluntary movement (e.g. the head, an arm, a foot, etc.) and, due to the high sensitivity of the procedure, it is especially indicated for people with very restricted movements.
  - *Position of a color marker*: A color mark - like a glove or a sticker- is placed on the participant (normally in an upper limb). It is indicated for rough movements.
  - *Index of global activity*: It allows extracting the amount of activity (movements) in the capture frame. It is useful to users that base their interaction on the movement of all their body.

- **Sounds capture system.** Is based on an application programmed with MAX/MSP that uses a microphone to obtain the signal coming from different sources, either voices or other sounds. The object "analyzer~" included in the patch (Figure 2) allows us to obtain a detailed description of the sound. We use this information to feed a controller that manages a set of engine parameters used to generate sound. From the analysis of the input signal a series of parameters can be extracted:
    - The waveform
    - Spectrogram and sonogram
    - Sound amplitude
    - Frequency and corresponding MIDI note
    - Brightness of the sound
    - Attacks

Figure 2: Patch MAX/MSP to analyze the input signal

Audiovisual generation module

The audiovisual generation module is based on an application programmed with MAX/MSP that processes the information of the capture system and generates images and sounds. The communication between the capture modules and the audiovisual generation module uses the MIDI protocol, which is frequently used by musicians and allows the communication between programs in a simple way.

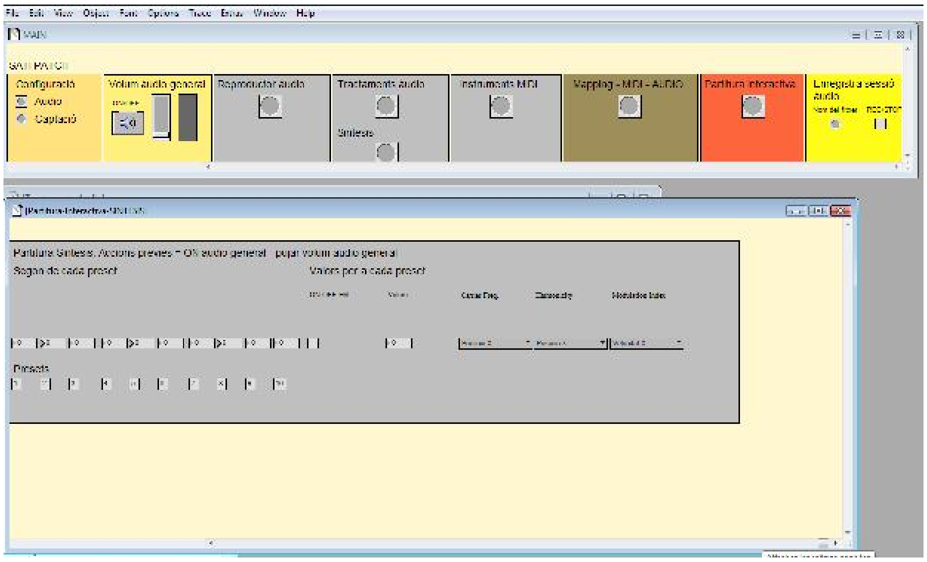

Figure 3: Patch MAX/MSP that analyzes the gestures and sound inputs of the user and transforms them into modified sounds

The audio engine is organized in several sub-modules:

- Loading sub-module. This module reads sound files (e.g. songs) and abstract textures files (e.g. random noise), and loads them into memory.
    - Mapping between gesture and generated sound
        - The position of the user in a virtual space controls the reading speed of a sound file.
        - User's voice pitch produces pitch changes and introduces echoes in the played sound.

- Real-time voice processing sub-module. This module distorts voices or other sounds. Several digital audio effects are used: reverberation, chorus and flanger, pitch shift, filter and echo

- Sound synthesis sub-module: Controls the timbers.

- Virtual instruments sub-module: it plays a virtual instrument from an existent score or generated with a MAX/MSP patch.
    - Virtual Instrument sub-module:
        - The position of the user in a virtual space executes the notes of the score and generates the transposition of the pitches.
        - The speed of movement controls the amplitude of the sound of the virtual instrument.
- Sound visualization sub-module. This module is still under construction. The tests that we have carried out consist on the visualization of textures and abstract

figures that move according to some sound parameters such as the amplitude. We use the R4 viewer (see Figure 4).

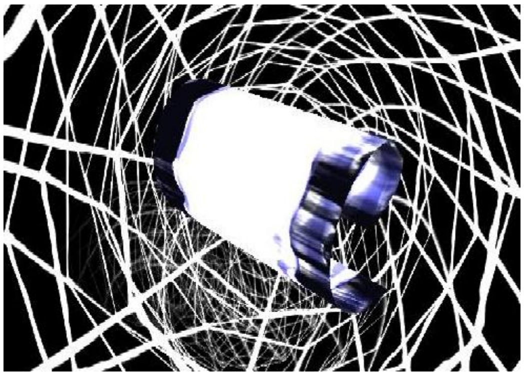

Figure 4: R4 viewer

3.3 User's profile

To be able to carry out this project, and due to our limited human resources and time, we are grouping the users into three blocks, and from each one we choose between three and four users to have the best representation of the collective and thus test the viability of the system in an efficient and real way. The groups are defined as follows:

- Group A. Users with sufficient intellectual capacity to understand the activity's mechanics, and that consciously and voluntarily respond to the orders given. The goal goes beyond the child just interacting, it is a question of obtaining a development in the artistic productions that they make with the system.
- Group B. Users with less intellectual capacity than the previous group, but good enough to observe and answer. These are the ones that probably do not comprehend, or the mechanics of the activity is very difficult or they forget its mechanics between sessions. The main goal is for them to begin to comprehend and enjoy their own productions like those in group A.
- Group C. Users with a low intellectual level and a relational capacity with a more limited environment than the previous groups, and whose answers to the system is observable with difficulty.

3.4 Session developments

The sessions last approximately between 15 and 30 minutes including preparation, participants entry and exit, note takings, and a final interview with the facilitator. Normally, they come together in a work block, using the module for sound treatment in real time and another block with the virtual instruments module except for special features that are stipulated before hand.

Thereafter, the facilitator is interviewed, where the first impressions are reflected after finishing the activity. This usually does not take more than 10 minutes. In all cases, intervening will be kept to a minimum, with the facilitator only helping the user when it is time to begin the activity.

3.5 Analysis methodology

The analysis of the sessions is mainly done through the records (videos, sound, etc.) obtained and with the help of video note taking tools[2]. To begin with, we are interested in studying the immediate effects that the use of the system produces, although it is important to confirm the long-term effects that are produced, even though it will not be possible to strictly attribute them to the use of the system.

The variables that are taken into account in the sessions are (among others): attention type (i.e. scattered, focused, etc.), attention duration (i.e. minutes, seconds, etc.), satisfaction, inhibition (voluntary or induced), connectivity with the task, etc.

The facilitator that knows and can better understand the user's answers performs the analysis of each video. To try to establish and to support, as far as possible, a common evaluation criterion, a consensus is established during the first sessions, and regular control meetings to support the above-mentioned consensus are scheduled.

3.6 Preliminary Results

After almost a year of experimentation and development of the ITSE project, we can state that it has shown itself as a very useful tool for most of the users who test it.

At a pedagogic level, it contributes to give continuity to the integral work that is carried out in the rest of the areas, like attention, perception, communicative intention or relaxation and muscular control.

From a therapeutic point of view, it helps the users to develop their expressiveness, their connexion with the most immediate environment, their imagination, the pleasure of realizing their own expressions and listening themselves. Furthermore, in some cases, it helps them to realize their own desires and fantasies related with playing an instrument (e.g. a guitar) which would have been impossible otherwise, due to their physical limitations.

Last but not least, at a playful level, it offers tools for the cerebral palsy affected people that let them learn, play and have fun at the same time.

---

2 We use Anvil in the SATI project, http://www.anvil-software.de

4 Conclusions

The research line presented in this article is a challenge. Working with people suffering from severe and multiple disabilities is not straightforward: we can rarely count on their cooperation; it is very complex to establish communication (if any) with them; due to their delicate state of health we have to pay a special attention to the appearance of crises and; generally, users cannot express their feelings clearly (e.g. by filling in a questionnaire). Moreover, results cannot always be generalized due to the reduced number and heterogeneity of these users.

Many different disciplines interweave: music, visual art, computer science, psychology, special education and physiotherapy. Due to this interdisciplinary environment a high degree of coordination is required amongst experts from very different areas that generally talk in different technical languages. Thus, there is a need for a tool that allows us to assess the results and obtain conclusions. Psychologists and users' relatives that help in confirming the hypothesis of the experts generally perform this assessment of the results.

Currently, we are testing a prototype of the system that generates sounds as a result of the images captured by a webcam. We have been working with this system for more than a year and we plan to add visual and tactile outputs to the system in the near future.

5 Future works

We plan to go ahead with a number of tasks in the near future.

- To elaborate tools or methodologies in order to improve the characterization of the participants. That way would be easier to link some observations with the particularities of a users group and to contribute, therefore, to the generalization of the results. Specifically, we will try to model the users profiles by means of the use of ontologies.
- To establish analysis methodologies of the system effects and to relate them to the profile of a concrete user. Also it would be interesting to involve other participants in the analysis process (for example, relatives or tutors) or to develop automatic technologies of analysis.
- To move towards more autonomous and usable systems for the professionals. It is necessary to derive computer applications from the developed prototypes that could be easily run by the people who will work with these systems (teachers, keepers, occupational therapists, musical therapists, parents, etc.) so that they could do an effective use of them. Actually, as our experience shows, there are several technological proposals for the special educative needs people, but most of them are not used "only" because they are not simple enough.

- To go towards adaptive systems so that they could be able to learn what kind of proposals are more attractive for the user in function of the produced interaction.
- To extend the offer of the audio-visual engine with such elements as graphical interactive scores, sound visualization, interactive painting application, etc.

References

[1] Francisco Alcantud, Gerardo Herrera, Gabriel Labajo, I. Dolz, C. Gaya, V. Avila, A. Blanquer, J. L. Cuesta, y J. Arnaiz. Assessing virtual reality as a tool for support imagination. En *Computers Helping People with Special Needs*, tomo 2398 de *Lecture Notes in Computer Science*, páginas 185–191. Springer, Berlin / Heidelberg, 2002.

[2] Anthony Brooks. Virtual interactive space(V.I.S.) as a movement capture interface tool giving multimedia feedback for treatment and analysis. En *Int Congr World Confed Phys Ther*, página 289, Japan, 1999.

[3] Anthony Brooks. CAREHERE: Creating aesthetically resonant environments for the handicapped, elderly and rehabilitation. En *Intl Conf. Disability, Virtual Reality & Assoc. Tech.*,, páginas 191–198, Oxford, England, 2004.

[4] Christine Brumback, Liubo Borrisov, Jeffrey Galusha, y Annette DiIorio. Intellivision. En *The Sixth International Conference Ubiquitous Computing*, Nottingham, UK, 2004. University of Nottingham.

[5] Antonio Camurri, Barbara Mazzarino, Gualtiero Volpe, Pietro Morasso, Federica Priano, y Cristina Re. Application of multimedia techniques in the physical rehabilitation of parkinson's patients. *The Journal of Visualization and Computer Animation*, 14:269–278, 2003.

[6] Sue Cobb y P.M. Sharkey. A decade of research and development in disability, virtual reality and associated technologies: review of ICDVRAT 1996-2006. *International Journal of Virtual Reality*, 6(2):51–68, 2007.

[7] Phil Ellis. Incidental music; a case study in the development of sound therapy. *The British Journal of Music Education*, 12:59–70, 1995.

[8] Phil Ellis. Improving quality of life and well-being for children and the elderly through vibroacoustic sound therapy. En *Computers Helping People with Special Needs*, tomo 3118 de *Lecture Notes in Computer Science*, páginas 416–422. Springer-Verlag, 2004.

[9] Phil Ellis. Vibroacoustic sound therapy: Case studies with children with profound and multiple learning difficulties and the elderly in long-term residential care. *Studies in Health Technology and Informatics*, 103:36–42, 2004.

[10] Phil Ellis. The development of interactive multisensory environments for expression, 1992 - 2007. Keynote, Luxembourg Society for Music Therapy, Noviembre 25 2006.

[11] Mabel Garcia y Cesar Mauri. Experiencia de interacción persona-ordenador a través de webcam con usuarios con discapacidad motriz grave y moderadamente afectados:. En *Tecnoneet*, Murcia, 2004.

[12] Mabel Garcia y Cesar Mauri. Parálisis cerebral y nuevas tecnologías: Ayudas técnicas basadas en visión artificial . En *IV Jornadas Onubenses Sobre Parálisis Cerebral*, 2005.

[13] i3net. CAREHERE. creating aesthetically resonant environments for the handicapped, elderly and rehabilitation. `http://www.bristol.ac.uk/carehere/`, Consultado por última vez: Julio 29 2008.

[14] i3net. Twi-aysi. The world is - as you see it. `http://www.bristol.ac.uk/Twi-aysi/`, Consultado por última vez: Julio 29 2008.

[15] Dean P. Inman y Ken Loge. Teaching motorized wheelchair operation in virtual reality. En *1995 CSUN Virtual Reality Conference*, Northridge, 1995. California State University.

[16] Sergi Jordà Puig. *Digital Lutherie: Crafting musical computers for new music's performance and improvisation*. PhD thesis, Universitat Pompeu Fabra, Barcelona, 2005.

[17] Roger Knox, Andrea Lamont, Tom Chau, Yani Hamdani, Heidi Schwellnus, Ceilidh Eaton, Cynthia Tam, y Patricia Johnson. Movement-to-music: Designing and implementing a virtual music instrument for young people with physical disabilities, Mayo/Mayo 2003.

[18] Andrea Lamont, Roger Knox, Tom Chau, Yani Hamdani, Heidi Schwellnus, Cynthia Tam, y Patricia Johnson. Converting movements to music new musical exploration opportunities for children in rehabilitation. En *Canadian Association for Music Therapy 29 th Annual Conference*, páginas 26–30, Regina, Saskatchewan, Canada, 2002.

[19] Cesar Mauri. Interacción persona-ordenador mediante cámaras webcam. En Jesus Lores y Raquel Navarro Prieto, editores, *Interacción 2004*, páginas 366–367, Lleida, Mayo3–7 2004. Universitat de Lleida.

[20] Cesar Mauri, Toni Granollers, Jesus Lores, y Mabel García. Computer vision interaction for people with severe movement restrictions. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, 2(1):38–54, Abril 2006.

[21] Max M. North, Sarah M. North, y Joseph R. Coble. Virtual environment psychotherapy: A case study of fear of flying disorder. *Presence: Teleoperators and Virtual Environments*, 6(1):127–132, Febrero/Febrero 1997.

[22] Max M. North, Sarah M. North, y Joseph R. Coble. Virtual reality therapy: An effective treatment for psychological disorders. En *Handbook of Virtual Environments: Design, Implementation, and Applications*, páginas 1065–1078. Lawrence Erlbaum Associates. Mahwah, NJ, 2002.

[23] Pauline Oliveros, Leaf Miller, Zevin Polzin, y Zane Van Dusen. Adaptive use musical instruments: Software musical instrument. http://bsjeon.net/thisAbility/en/pauline.html, Consultado por última vez: Septiembre 30 2008.

[24] Narcis Pares, Anna Carreras, Jaume Durany, Jaume Ferrer, Pere Freixa, David Gomez, Orit Kruglanski, Roc Pares, Ignasi J. Ribas, Miquel Soler, y Alex Sanjurjo. Promotion of creative activity in children with severe autism through visuals in an interactive multisensory environment. En *IDC '05: Proceedings of the 2005 conference on Interaction design and children*, páginas 110–116, Boulder, Colorado, 2005. ACM.

[25] David-Paul Pertaub, Mel Slater, y Chris Barker. An experiment on public speaking anxiety in response to three different types of virtual audience. *Presence: Teleoperators and Virtual Environments*, 11(1):68–78, 2002.

[26] Albert Rizzo, Jarrell Pair, Peter J. McNerney, Ernie Eastlund, Brian Manson, Jon Gratch, Randy Hill, y Bill Swartout. Development of a VR therapy application for Iraq war military personnel with PTSD. En *Medicine Meets Virtual Reality 13: The Magical Next Becomes the Medical Now*, tomo 111 de *Studies in Health Technology and Informatics*, páginas 407–413. IOS Press, 2005.

[27] Cecilia Sik-Lanyi, V. Simon, L. Simon, y V. Laky. Using virtual public transport for treating phobias. En *The Fifth International Conference on Disability, Virtual Reality and Associated Technologies*, UK, 2004. University of Reading.

[28] P.J. Standen y J. J. Cromby. Can students with developmental disability use virtual reality to learn skills which will transfer to the real world? En *1995 CSUN Virtual Reality Conference*, Northridge, 1995. California State University.

[29] Dorothy Strickland. A virtual reality application with autistic children. *Presence: Teleoperators and Virtual Environments*, 5(3):319–329, 1996.

[30] Dorothy Strickland. Virtual reality for the treatment of autism. En *Virtual Reality in Neuro-Psycho-Physiology*, páginas 81–86. IOS Press, Amsterdam, 1997.

[31] Patrice L. Weiss, Yuval Naveh, y Noomi Katz. Design and testing of a virtual environment to train CVA patients with unilateral spatial neglect to cross a street safely. *Occupational Therapy International*, 10:39–55, 2003.

[32] Patrice L. Weiss, Debbie Rand, Noomi Katz, y Rachel Kizony. Video capture virtual reality as a flexible and effective rehabilitation tool. *Journal of NeuroEngineering and Rehabilitation*, 1, 2004.