Interactive multi-sensory environment to control stereotypy behaviours

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Abstract. The paper presents an interactive multi-sensory stimulation environment based on computer vision techniques for users with profound cerebral palsy to work their education curricula. We developed a set of vision-based applications with a high component of interactivity to create a controlled and safe environment to treat the users' behaviours. We analyze the user's body movement captured by a standard webcam to trigger audible, visual and/or tactile effects to produce significant stimulus in the environment.

Keywords: vision based interfaces, human-computer interaction, interactive multi-sensory environments

1 Introduction

The environment is designed for users with profound cerebral palsy. Despite their limited cognitive and physical conditions, they show interest when there is a significant stimulus in the environment. Frequently, these users present self-stimulating behaviours, that is, "repetitive body movement which serves no apparent purpose in the external environment" [1], but that interferes with the daily routine. Furthermore, together with anxiety episodes, the self-stimulation can transform into self-injury. Self-injury is a destructive behaviour that implies social and personal consequences and risks the person's physical integrity like biting one's arm or banging one's head with the fist. These users also present other behavioural disorders such as screaming, banging the table and the floor or throwing objects.

Stereotypy, or self-stimulatory behaviour, can involve only one or all senses. Examples of these behaviour are: rocking, staring at lights, tapping ears, snapping fingers, making vocal sounds, rubbing the skin with one's hand or with other objects, scratching, placing body parts or objects in one's mouth, etc.

When these users receive a significant stimulus from the environment, the self-stimulating and self-injuring behaviours decrease [2, 3, 4, 5]. Users cannot access autonomously to interactive systems that could provide them with stimulus because of their capabilities. Caregivers in centres for disabled users cannot offer continuously significant stimuli to each individual. Therefore, we contribute with these interactive systems that give the control to the user in order to activate changes in the environment. Berkson and Mason [6] already related the increase of interactivity in an environment with a noticeable decrease in the self-stimulatory behaviours.

Furthermore, early stimulation is known to be a useful and necessary treatment aimed at developing as much as possible the social psychophysical potential of any person at high environmental and/or biological risk [7]. So, in the educational activities for users with this profile, we find all kind of tasks related to multisensory stimulation such as: coloured lights, tasting food, touching different textures, cold/hot sensations, etc.

This interactive environment offers caregivers and therapists alternative activities in their work for stimulation in an indirect attention mode, that is, when caregivers cannot pay total attention to one user as they have to supervise several users. Similar to other multi-sensory environments, our interactive system is a controlled and safe space with equipment designed to offer stimulation and calm. Moreover, we include interaction which can enrich the experience [8].

We present an interactive multi-sensory environment. The environment is divided in two modules. On the one hand, there is a computer with installed applications and on the other hand there is a multi-touch surface. The interaction is carried out by the movement of the user's body part. We detect and track the user's body part by means of a standard webcam and computer vision techniques. Due to the users' capabilities, they cannot access a computer; therefore, computer vision is our choice for interaction. Their movement causes a sensory stimulus change in the environment, as the computer offers auditory, visual and/or tactile stimuli adapted to each user.

The aim of the interactive multi-sensory environment is to improve the user's relationship with the environment in order to offer him or her significant stimuli and decrease the stereotypy behaviours.

The remainder of the paper is organized as follows. Section 2 describes the methodology of the design, development and evaluation process. Section 3 is the main contribution of the paper, as it explains the developed interactive multi-sensory environment. Finally, the last section concludes the paper.

2 Methodology

The methodology is a research-intervention model. The steps are:

- User selection: we selected six users to analyze the system's requirements. Users were five men and a woman with ages ranging from 23-28 years. They are individuals with hearing, sight and other sensory impairments, with motor impairments and with memory, learning and cognitive impairments. However, they show interest (to a greater or lesser extent) when stimuli are produced in the environment. They are regularly engaged in self-stimulating and self-injurious behaviours. We obtained informed consent from the parents prior to their participation.

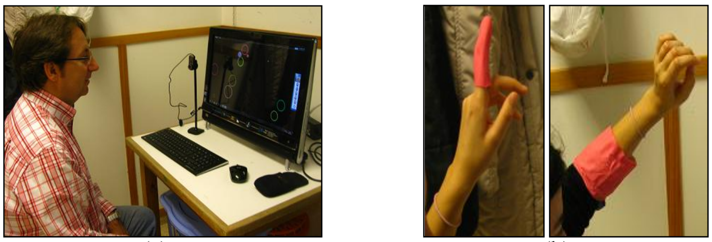
- Base line: users were recorded for two weeks in their daily routine in order to determine a base line for each of them. We registered the frequency, the duration and the type of self-stimulating and self-injuring behaviours as well as any disorderly conducts.
- Prototype design and development: considering users' capabilities and requirements, we designed and developed a prototype that will be described in the following section.
- Intervention: the system is already set up in a room and being tested. We will work with it during two months, 4 days per week, and sessions will be ten minutes long. Initially, sessions will be followed by a development member and a caregiver for helping the user, registering the user's feedback, the system's response and any other factor to take into account in the system's redesign or user's profile setting. Sessions are being recorded but just for the development group to analyze the system functioning.
- Evaluation: the users' psychologist work hypothesis is that users will decrease their self-stimulating and self-injuring behaviours. So, after working two months with the system, we will record users again for two weeks. Besides their daily work plan, the multi-sensory environment will be another activity included for indirect attention. In these two weeks, neither caregivers nor development members will help the user directly when working with the interactive multi-sensory system. Then the recordings will be analyzed and compared with the base line. We will consider the user's data when working with the interactive system and when working in other activities.

3 The interactive multi-sensory environment

In this section, we will describe the vision-based interactive multi-sensory system. As commented before, there are two modules: a set of applications and a multiuser multi-touch surface.

3.1 Interactive multi-sensory applications

In the first module, we work with a computer that counts with a webcam, loudspeakers and a radiofrequency (RF) remote plug. All applications are vision based interfaces and the caregiver can select to motivate or inhibit the body part movement depending on the user's aims.



(a) (b)

Figure 1. (a) Hardware configuration. The user interacts with head movements, although s/he is not aware of the computer's presence (b) Different body parts to place the coloured band

As users move or stop a selected body part, the computer will offer feedback in form of auditory, visual and/or tactile effects which search to produce a change in the environment. In order to detect the movement, we can use different input systems.

On the one hand, an input is the head movement. By using the SINA interface [9,10], the user does not need to wear any sensor on the body. The system detects and tracks automatically the user's nose and this information is converted in mouse positions, which inform us on the head's movement to inhibit for example user's rocking front to back or moving the head from side-to-side. See Figure 1 (a).

On the other hand, we can detect and track any body part by means of a coloured band using the Camshift probabilistic algorithm [11]. The band is placed over the body part to motivate or to inhibit. In the case of motivation, the aim would be to increase the user's relationship with the environment. An example of inhibition would be to avoid the user snapping fingers. See Figure 1 (b).

The presence or absence of motion (depending on the therapist's aim) triggers or stops the system's output. This output is in the form of audible, visual and/or tactile effect. The outcome can be configured with the user's preferences in music, sounds and images. See Figure 2. This is very important to motivate the user. For example, we are using the parents' voices. Specifically, the computer's feedback is:

- Striking images shown on the screen
- Sounds, music or voices.
- We can switch on or off any plugged device that works in binary mode, that is, it is on or off. For example an electric mirror ball turner or a vibrator to give tactile feedback to the user. By means of the RF plug, the activation can be controlled by the computer.
- The system allows capturing the screen position of the play/pause button in any program; therefore, the user can start or stop any media (films or music files) by moving a body part. Viewing a presentation can be done as well.

Figure 2: Example of outputs: music is playing and circles with different radius and widths go appearing. Music played with Windows Media

3.2 Multiuser multi-touch surface

We have also designed and built an autonomous interactive multi-touch table that allows the installation of action/reaction applications that provide visual and/or auditory responses to the tactile stimuli. The table uses a DLP projector to output visual feedback on the surface and a webcam to capture the user-device interaction. We use frontal diffuse illumination (DI) from the environment, so no additional lighting is required. Stimuli can be generated according to the contact detected, so a smooth and long contact will trigger visually striking images while fast and disordered contacts, common in uncontrolled and abrupt movements, are ignored and won't produce any response.

Being multi-touch, the table allows either multiple effectors (fingers, hands, ...) or multiuser interactions. Although such devices are currently commercially available, two reasons justify the need for an adapted device. First, medium-size multi-touch devices still require a high-cost investment and second, as they are based on traditional output devices such LCD displays; they are too fragile to be used in environments where users have little control on the motion and pressure of their gestures. This could lead to dangerous situations and compromise the security of the users.

We use optical technologies because of its low cost, setup and scalability. Optical technologies require a source of light, an optical sensor and an output device. The output device is built from a projector. It displays a feedback image on the screen through a mirror. The screen is a one-centimetre-thick acrylic panel that ensures resistance to break and, thus, increases user security. A diffuser distributes light homogeneously. We have to avoid the interference of the image produced by the projector with the objects being tracked. This is accomplished using infrared light to discern the visual image displayed by the projector on the touch surface and the fingers or hands being tracked. The webcam is modified to capture only infrared light. We replace the built-in infrared filter of the webcam with a filter that removes the visible light of the electromagnetic spectrum. See Figure 3 and 4.

Figure 3. Interior of the multi-touch table

Figure 4 Multiuser multi-touch table

4 Conclusions

In this paper we have presented an interactive multi-sensory stimulation environment based on computer vision techniques for users with profound cerebral palsy. It is composed of a multimedia environment and a multi-touch table. The environment offers caregivers and therapists alternative activities in their work for indirect attention, allowing for controlled autonomous stimulation.

The system is currently being tested and some feedback has already been received from therapists. Accessibility problems to the multi-touch table have been reported for wheelchairs and a redesign in on the way. The main question to answer is whether the users realize that their motion or steadiness cause a change in their environment. In some cases, it seems that the user connects with the environment, in others this feedback has still not appeared. We don’t know if in these lasts cases the experience will teach them. It is very difficult to work with profound CP users as they cannot express themselves.

Nowadays we are carefully observing their responses: if they smile, if they stop their stereotypy behaviours, if they pay attention to the stimulus, if they make sounds, if they change their body posture or any other symptom of being engaged with the environment.

In the near future, we will be able to compare the evaluation recorded data with the base line to analyze the evolution of the users.

Acknowledgments

This research was partially supported by:

- FRIVIG. D/031964/10. Formación de Recursos Humanos e Investigación en el Área de Visión por Computador e Informática Gráfica, granted by MAE-AECID (Programa de Cooperación Interuniversitaria e Investigación Científica e/ España e Iberoamérica.
- TIN2010-16576. Modelos de Interacción basada en Visión en Interfaces Gestuales , granted by Ministerio de Ciencia e Innovación, Gobierno de España (Programa Nacional de Investigación Fundamental No Orientada)

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