A Motion-based Interface to Control Environmental Stimulation for Children with Severe to Profound Disabilities

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Abstract
SINASense is a novel motion-based interface that serves as an educational application for children with severe or profound cognitive, sensory and physical impairments. The application makes use of computer vision to track the body movements of the user, which in turn trigger meaningful outcomes from the system. In this paper we describe the design principles of the interface, our experience during its evaluation, and finally we present ideas for future developments.

Author Keywords
Vision based interface; children with special needs; interactive environment; user interface; accessibility

ACM Classification Keywords
H.5.1 Multimedia Information Systems; H.5.2. User interfaces.

Introduction
People with severe to profound developmental disabilities present a poor interaction with the environment, which hinders their communicative, cognitive and personal development.

A description of the user's limitations leads to the development of a profile of needed supports, i.e. resources or strategies necessary to promote the development, education, interests and personal well being of a person with disabilities. Thus, appropriate individualized supports over a sustained period would bring improvements in the life functioning of these persons [1].

While it is recognized the important role technology can play either to increase the chances of relationship with the surrounding environment, or to develop independence, its access for impaired users is frequently restricted due to both the difficulties of use and accessibility. As a consequence, there is a lack of interactive applications for these users.

With this in mind, we have designed SINASense, a technological and educational support that allows users to acquire a level of autonomy in interacting with the immediate environment. In SINASense, this is achieved through the triggering of meaningful stimuli, that is, stimuli that are important or interesting for the user, such as the appearance of motivational images or playing preferred songs. Some examples of devices used to offer control over environmental stimulation with encouraging results are microswitches [1][5], lately tangible user interfaces (TUI) [11] and gesture based systems [8][9].

Technologically, SINASense is a simple and low-cost vision-based interface that detects the movement of the user's arm by tracking a coloured band. It has been thought to target children with severe to profound developmental disabilities who depend on others to interact with the environment.

Our aim with this paper is to introduce the initial prototype of SINASense. It has been intended to work with computer vision because we wanted a low-cost, flexible and highly responsive system to the users' movement, which would rapidly help them to reduce their isolation by interacting with the environment to obtain desired environmental stimuli.

In the following we present our proposal for the design of the system and the results of an initial evaluation.

Research Proposal and Methodology

Our previous experiences working in a cerebral palsy centre [6][7] allowed us to observe how a group of persons with profound disabilities lacked computer interaction opportunities. This motivated us in designing an interactive system for this population.

One of the main contributions of our work is the development of a system that provides an "invisible Human Computer Interaction" where users are not aware of the presence of a computer or input devices. To this end, the system has to be easy-to-use, totally automatic, and has to offer meaningful outputs. In order to achieve a continuous focus on the users from an early stage of the system design, we came up with a first prototype taking into account the users' needs and objectives compiled by the therapists and parents. We tested the prototype during three months with seven users, 5 boys and 2 girls, whose ages ranged from 4 to 12 years.

The selected users presented severe to profound cognitive disabilities and physical and/or sensory impairments in some cases. Several of them presented

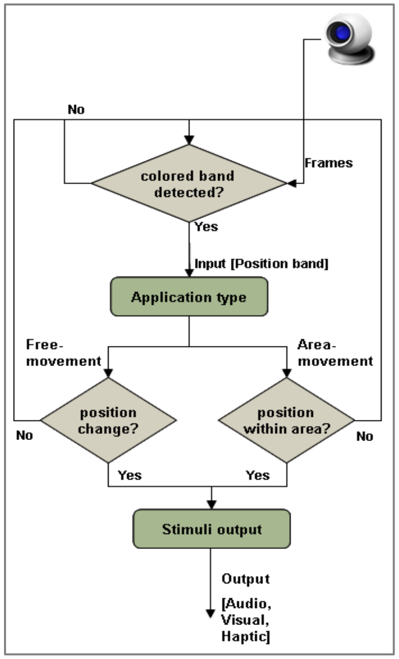

Figure 1. System operation

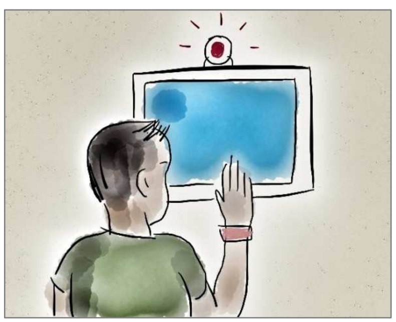

Figure 2. Example of user and devices placement.

self-stimulation behaviours and depended on a caregiver to interact with the environment.

Using the users' archival records, and the professionals' observations and expertise, we collected information on the motor and psychological states, communication skills and visual perception of the participants. Our intention was to come up with a system that would make the users:

- Increase the intentional movements of their upper body limbs.
- Reduce their isolation.
- Control the interaction with the surrounding world.
- Achieve their active participation in the task.
- Suppress the self-stimulation by offering them external senses stimulation.

SINASense

As a response to the former requirements we developed SINASense, a system that offers sensory stimulation based on the user's movement. This is performed by detecting and tracking a coloured band placed on the user's hand using a standard webcam (See Fig. 1 and Fig. 2). We used the OpenCV library for real time computer vision [9] and the IrrKlang as the audio library [2]. Consequently, two types of applications were designed: a free-movement application and an area-movement application. A standard webcam was used, as tests with a Microsoft Kinect™ to obtain depth information were ineffective. This was due to difficulties in depth computation because of the wheelchair, the chair or the pram of the user.

Free-movement

This application was designed following the kind of tasks users carry out in the classroom. One of these activities was of the type Action/reaction, which allows the user to learn and to be aware that when s/he moves, the computer offers an immediate feedback. This relationship is very important to help them to establish a causal mapping between past and future events. Therefore, this group of applications responded to any kind of movement of the coloured band, so when the user stopped moving the upper limb with the coloured strip, the system's feedback stopped too. Different feedbacks could be selected and configured to be interesting for the user:

- A black screen where moving colourful geometries and any image file selected by the therapist are shown, while music sounds in the background.
- A slideshow created by the therapists with presentations including family and friends photographs, parents' voices, pets' sounds and preferred songs.
- A video or audio file played/paused in the presence or not of user's movement.
- The switch on/off of any device (vibrator, light, radio, electric mirror ball) which works in binary mode and is connected to a radiofrequency (RF) remote plug or to the USB connector.

Area-movement

This type of application controls whether the user's hand is within a particular region, giving audio as a feedback. This application is more relaxed as the user does not have to move continuously the arm, but rather in a more controlled manner. This was demanded by the therapists because some users just

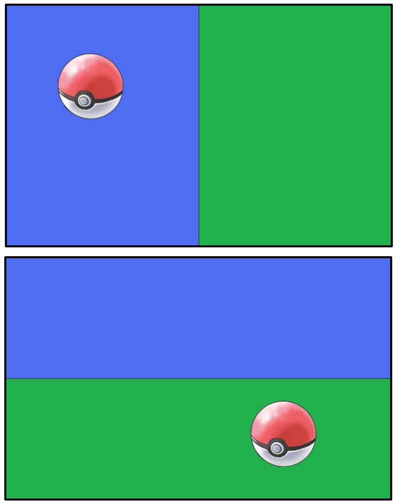

Figure 3. Area-movement application screenshots. Top: to train horizontal arm motion. Bottom: to train vertical arm motion

dropped their arms in an uncontrolled way, or the continuous movement of the hand required in the free-movement applications caused them fatigue.

For the area-movement application, the screen can be divided into two vertical or horizontal regions (See Fig. 3). The region that offers the feedback is configured depending on the work to be carried out with the user and the kind of intentional movement to motivate: lifting the arm, extending it towards the screen or moving it towards the body.

The hand position is represented in the application by a ball which offers feedback to the therapists, helping them to place correctly both the webcam and user depending on the arm movement range, the hand with the coloured band, the user's height and the proximity of the user to the table, sometimes limited by the kind of wheelchair or pram the user has. In order to trigger the outcomes, the user has to move the ball within the active region. When the ball is not placed in that area, the stimuli stop.

Experience

The experience was carried out in ASPACE Pinyol Vermell, a school for students with special needs, especially for children with cerebral palsy. The therapists of the centre contributed to our work by selecting the users to participate in the experience based on their conditions, and gathering the users' requirements to be taken into consideration in the design and development of the system. Additionally, they collected, together with the parents of the users, motivational material to include in the system.

An educational psychologist was hired specifically to conduct the sessions with SINASense. The initial sessions were also supervised by the user's therapist to help the educational psychologist learn about the user's preferences, skills, communication and behaviour.

In the case of action/reaction activities, the educational psychologist assisted children physically and orally to help them to be aware of the reaction in the environment that their body motion was causing.

Depending on the user, lights were switched off to allow him or her to concentrate and focus on the stimuli provided by the system. A pink strip was put as a bracelet on the user's hand to perform the movements. Therapists selected the most functional arm/hand for each user to train it and aiming at producing an impact in their daily lives.

The 15-minutes sessions were carried out in a private room set aside in the school and monitored by the educational psychologist. A minimum of 9 sessions per user and a maximum of 23 were performed during three months. The user who completed only 9 sessions temporally did not participate in the evaluation due to a physical decay. Sessions were video recorded and the educational therapist took notes along the session of important events. The area-movement application was used in most sessions, as it caused less fatigue. However, initially all participants used the free-movement applications to work with action-reaction activities.

Results and Discussion

At first, children were not aware that their arm movement was the one causing the feedback. With the

Figure 4. Users working with the system. Top: lifting the arm. Bottom: moving it horizontally towards the body.

aid of the educational therapist, they were able to build the relationship between their actions and the reactions. During the interaction, the users seemed to enjoy the stimuli as several of them smiled when listening to the music and one even started laughing and tapping the table when he heard his mom's voice.

After three months of work, the educational therapist reported an increase in the intentional movement of all users, especially in the duration of the movement, see Table 1.

User	**Hand/ App.**	**Frequency of intentional movement**	**Duration**
1	RH, VAM	Very low increase	Very high increase
2	LH, VAM	High increase	Low increase
3	LH, VAM	Low increase	High increase
4	RH, HAM	High increase	High increase
5	RH, HAM	Low increase	Low increase
6	RH, VAM	Very low increase	Very high increase
7	RH, VAM	Very low increase	Very high increase

Table1. LH: left hand, RH: right hand, HAM: horizontal arm motion, VAM: vertical arm motion

From this evaluation we also obtained important insights that should be considered in the development of an interface for users with this profile. The insights were:

- The positive feedback has to be very clear, motivational and especially promptly [3]. The feedback has to make the user aware of the relationship action/reaction, but also provide him or her with entertainment and recreation to increase the engagement with the stimuli. Immediate outcomes such as audio or video greatly improved the interaction of the user with the system. On the contrary, the use of slideshows during the interaction with the free-movement application did not convey the expected results. Despite being very motivational, the fact that each slide was presented for few seconds on the screen, made it difficult for the user to relate his or her motion with the output of the system.
- The tracking of the coloured band has to be very robust to not confuse the user with feedback not triggered by his or her movement. Difficulties appeared when the user's dressing had similar colours, which were solved by using other clothing.
- The system has to be highly-configurable, the setting it up has to be fast and profiles have to be able to be saved. In this way, therapists could better focus on the user and not on the system.
- Area-movement applications are more recommendable once the user has learnt his or her movement causes the stimuli.
- It would be interesting to define more regions in the area-movements applications to offer different stimuli, e.g. to turn up the volume when the user lifts the arm higher.

Conclusions and Future Work

In this paper we have presented SINASense, a motion-based interface that offers new and engaging ways of interaction to users with severe to profound disabilities, who have never accessed a computer. SINASense provides them control over environmental stimulation in a recreational and pleasant fashion.

A preliminary evaluation of three months with a system prototype was performed with impaired kids between 4 and 12 years old. The results show that our proposal promotes their active participation and engagement with what is happening around them and increases their respond.

At this stage, after having analyzed the results we achieved, we are encouraged to continue working along this line, improving the applications with different active-regions, including more settings and combining different stimuli such as haptic, auditive and visual as feedback.

Future work will include more usability tests to validate our system. In the current version of SINASense, all sessions were accompanied by a therapist who supported and guided the user during the interaction. Therefore, it would be interesting to see in future experiments how the user, once is trained, works alone with the system without any external help.

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