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SYSTEM SENSOR – A PRACTICAL HUMAN-COMPUTER INTERFACE FOR PEOPLE WITH DISABILITIES

Introduction

A human being is an entity that has an inborn, natural need of being with and among other people, and this requires approval of the society. Usually nothing stands in the way of such integration, as long as such a person is born and remains for life in a physical and mental condition not much varying from the average one accepted as a norm. However, disabled people need social acceptance as well. Though they are not always out in the open, they do exist among us (according to the National Census, in 1978 there had been 2 485 000 handicapped people living in Poland, ten years later − in 1988, this number had increased to 3 735 000, whereas in the year 1996 a number of 5 430 000 Polish citizens, that is 14.3% of the total population, was disabled; disability in any form touches more or less 10% of human population reaching around 37 million in Europe, of which roughly half is in the productive age) and they desire to be present in all spheres of public life [Ostro11]. Unfortunately, they do not always fully enjoy their rights and because of their disabilities are excluded from social life.

Economic, technical and many other barriers that the handicapped people have to face very often seem to be impossible to overcome. Of course it much depends on the form of the disability. It seems that one of the most troublesome forms of the physical disability is complete paralysis of the muscles that prevents the patient not only from moving, but also performing even the simplest life's activities, where practically the only way to communicate with the surroundings becomes the use of the sense of sight and hearing [Kane09]. Unfortunately, this is mostly one-sided contact, meaning that the patient can see and hear, but his changes in appearance or attitude, nor his needs can not be clearly interpreted.

Moreover, unstable relationships between people resulting from the lack of patience or being exhausted, constant life in a rush and pursuing money on the side of the healthy ones cause the disabled person left all alone without any possibility of wider communication with the outside world. Satisfying their basic needs, and above all, enabling the disabled people to participate in public life, is a key factor affecting their self-esteem making them no longer feel alienated, helping them begin to believe in their own abilities. Without such provision they see their life as meaningless. In civilized and developed societies, it is spoken nowadays about the widely understood rehabilitation, social integration and normalization of the disabled ones [Rimm99].

The purpose of this project, which is an example of putting efforts to improve the lives of people with disabilities, is to try to solve the basic problem of acceptance and participation in the public life of those in the fatal position, that is people almost completely paralyzed (physically disabled). In such cases contact with the surroundings could be possible through the combined use of seeing or thinking ability and the Internet, which would be mainly practical in social interactions with others outside of the disabled person's home [Leut04].

One of the indirect steps in the realization of this project is solving a problem of communication between the disabled and the machine, using only limited body movements, which are possible as some percentage of paralyzed people is able to move their thumb. That, in result, allows the synchronization of information signals transmitted from patient's sense of sight and movement, which consequently, can greatly improve the quality and speed of the communication [Trew06].

At the end of the research project a hypothesis regarding the type and the kind of the used sensor-transducer (or possibly their greater number and various types) should be stated. An isolated group of measured signals will be a foundation on which a computer program based largely on signal compression algorithms will be build, thereby increasing the speed of information transmission, and, in an ideal situation, ensuring the working speed equal to a perfectly healthy person typing on a computer keyboard.

After obtaining satisfactory results of the first and the second stage, a complete system allowing meeting the stated conditions has to be constructed. Complementing the project should be an analysis of a study relating to human – machine communication using the power of thought.

Related work

Nowadays, solutions to the problem of communicating with people completely paralyzed can be found when basing on the observation of two states of one's eyelid: an eyelid open and an eyelid closed, and the transition from one state to another, that is, a blink. Observing the state of the eyelids, mainly the transition state, seems to be the simplest method, like binary number system. In practice, however, having a relatively large numbers of "communication" dictionaries, the time of the mutual exchange of a low information entropy between the disabled and the computer is very long. Existing computer programs (such as The Blink program developed by Krolak and Strumiłło [KrSt08, KrSt09] at the Technical University of Lodz just within two years), intended mostly to change a blink into a letter of an alphabet, the designation of the correct letter requires a large number of blinks, which makes the communication process tiresome and tedious, and, above all, challenging to develop a fairly complex programs. Focusing only on the observation of the alteration moment of the eye requires using fairly precise equipment – mainly vision camera (photoelectric infrared light sensors, which are illuminating eyelids, are commonly used, too), as well as more complex programs analyzing changes of the observed image. Neither good equipment nor a good program give satisfactory results in this case. The alteration moment of the eye is not always interpreted accurately. Moreover, a hard work is often required of the paralyzed person to learn cooperation with the system, especially if the paralyzed must blink at the exact moment when the sliding illuminated point is positioned over the desired character in the chart displayed on the monitor screen. It is important here to maintain a constant position of the head, so as not to interrupt the communication process. It is, however, very often a huge obstacle to a bedridden or a wheelchair-bound person.

The realization of the project requires at first analyzing the mechanisms of moving the eyelids, and in particular the rules of operating of the orbicularis oculi muscle, which works as follows: contraction of the orbital part of the orbicularis oculi causes tightening the eyelids, contraction of the tarsal plates causes closing the eye softly, a muscle called the levator palpebrae opens the eye, while a muscle called procerus is responsible for frowning (that is visible as a vertical fold of skin between the eyebrows). The next step is analyzing the performance of the six muscles that move the eyeball.

Any other solutions are based on the facial movements recognition. The movement dictionary contains of the eyelids and jaw movements. Different combinations of the eyelids and jaw positions are translated into movement of the cursor on a computer screen [Barr00]. This real-time system design utilizes electromyographic biosignals from cranial muscles and electroencephalographic (EEG) biosignals from the cerebrum's occipital lobe, which are transformed into controls for two-dimensional cursor movement, the left-click command, and an ON/OFF switch for the cursor-control functions.

Another study from Chen [Chen01] describes the purposes and the design considerations of an economical head-operated computer mouse. It focuses on the invention of a head-operated computer mouse that employs two tilt sensors placed in the headset to determine head position and to function as simple head-operated computer mouse. One tilt sensor detects the lateral head-motion to drive the left/right movement of the mouse. The other one detects the head's vertical movements up and down and transfers them to operate the mouse. A touch switch device has been designed to gently touch operator's cheek. Operator may puff up his cheeks to trigger the device to perform single click, double click, and to drag commands.

System Sensor

System Sensor allows to control one's computer, TV and a television set-top box or an intercom. It can be operated by the disabled ones suffering from partial or total paralysis of the upper extremities (quadriplegia), and in a case of a loss of voice – being able to contact the outer world. In order to improve the typing speed, the system has been equipped with its own vocabulary hints dictionary, which suggests default words matching the first letters put.

The very first user of System Sensor was an immobilized person with a severe nervous system illness. Due to the rapid progress of the disease he lost any contact with the outer world, except for the four walls of the room in which his bed stood. Roman Biadała, System Sensor's main designer, built it having in mind his disabled friend. After a couple of initial tests a system was created that, for the first time in a long time, enabled the bedridden person to turn on the computer and use its features without any help. Using System Sensor a person can run any program that is already installed on one's computer. The only limitation is the inability to install the operating system. A disabled may also signal his needs to his friends or family.

Fig. 1. An example of installing sensor type “A” at a distance of 7 cm from the operating person’s face

The device is directly connected to the USB port, whole system is powered through the USB port of a computer or an additional USB-DC 5V power supply. The device works with two types of sensors that are installed depending on the degree of one’s disability. Sensor “A” must be placed at a distance of about 7 cm from the body part that the disabled will use to operate the system. The system automatically calibrates itself and determines the relative position between the sensor and the object. The second sensor which can be used, sensor “B”, should be fixed at a distance of about 1 cm from the muscle, through which one will control the system. Just like in the case of the first sensor, the second one can be placed anywhere on the body of a disabled person.

The device has two already built-in universal remotes that allow programming two tools: a remote control to operate the TV and another one to operate the decoder. A side panel of the device is equipped with a socket used to connect external accessories such as doorbells, intercoms or any other systems. The device works in two modes. The first mode is to control the computer using a designed program operating it. The second mode does not operate the computer, as it runs all the external devices: the remote control, the intercom and the doorbell.

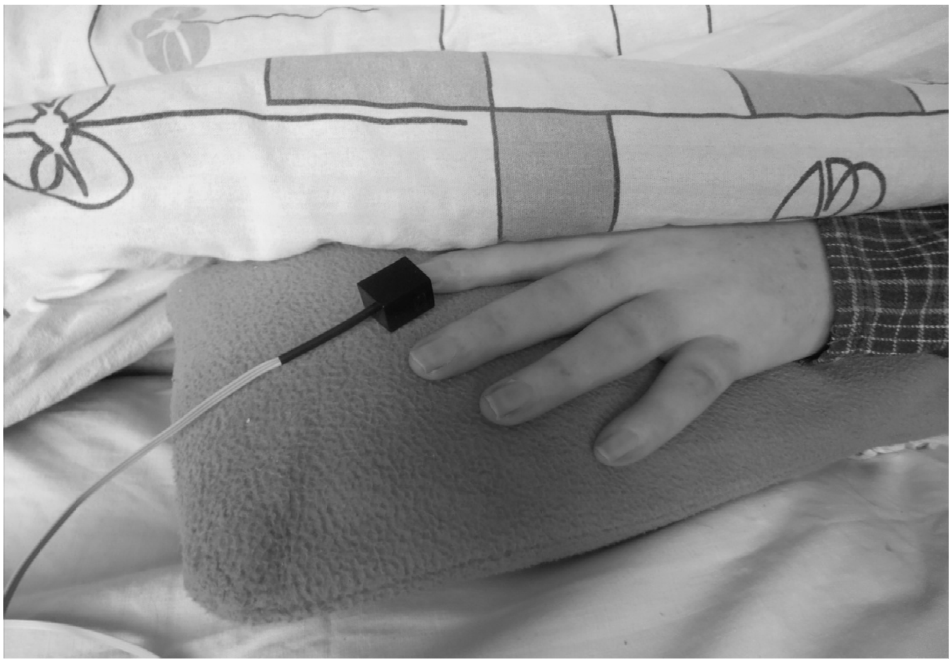

Fig. 2. An example of sensor type “B” connection at a distance of 1 cm on the user’s index finger

System Sensor – Galvanic Skin Response

Another version of the system, presented by its designer in 2013, is called System Sensor GSR. This time, the device is operated by emotions received and processed by a special sensor connected to the computer. Using the phenomenon of changes in human skin resistance (galvanic skin response), users can now communicate with the world using a computer which does not require any muscle activity [Moor04]. The previous version of the system, System Sensor, was dedicated to those patients who are able to at least slightly move some parts of the body. System Sensor GSR is designed for people deprived even of this ability.

In such case, in communication with the computer a phenomenon called the “biofeedback” is applied. It is known and used in disciplines like psychology, medicine, sports, and even forensics in the so-called lie detector. When absorbing any information with one’s eyes, an information about an obstacle for instance, a person instantly knows how to avoid it. This information is processed by the brain into an appropriate physiological reaction. Similar situation happens with the emotions – they cause changes in polarization of human’s skin. The phenomenon of “biofeedback” was used in the next version of System Sensor GSR, which monitors human’s emotions and changes in skin’s polarization caused by them.

Even if somebody is unable to perform any movement, his mind generates different kinds of emotions that are translated into changes in his skin resistance recorded by a special Sensor GSR's detector, and then transmitted to the computer as "a click". This sensor, looking like a computer mouse with fixed electrodes instead of keys, emits a sound signal that's intensity varies with a change of emotions. For example, when deepening concentration lower tones are heard, in the moments of distraction, however, the tones are getting higher. This allows the disabled to learn to consciously modify body functions that normally are not controlled, such as muscle tension or electrical resistance of the skin (GSR).

System Sensor GSR users are made out of people moving on a wheelchair because of muscular atrophy. They point out that communication is not that easy at the beginning. First, emotions have to be controlled, just as during relaxation. Support is provided by the System Sensor's sound, which changes as the person is gradually relaxing or full of emotion. Mastering the communication with the device means controlling the emotions to such extent, that the sensor starts to "listen" and stops the cursor at the right time.

System Sensor – Mouse

System Sensor Mouse is another device, differing from System Sensor which is used to control the computer. System Sensor Mouse is dedicated to children and people suffering from cerebral palsy and designed for exercising and rehabilitation. System Sensor Mouse is a device that has a high value for rehabilitation and therapy.

As a therapeutic method, this device supports children with very specific learning difficulties, especially with such problems with movement programming as dyspraxia, dysgraphia and dyslexia. Also, as a method of rehabilitation, it improves the quality of life of people with all kinds of problems in movement development. When speaking about children with spinal muscular atrophy, SMA-1, which becomes evident in the very first year of life, the device gives them an opportunity to develop communication with their environment. In other forms of muscle atrophy usually revealing themselves in older age, system enables maintaining communication with the outer world. It also allows further development of communication with children with cerebral palsy.

Fig. 3. System Sensor Mouse

Thanks to the system, a person with any developmental disorder can make new friends, exchange ideas, share experience, definitely is not doomed to isolation or loneliness. The system affects social, emotional and cognitive sphere of ill person's life, as well as helps in creating self-image and the image of the surrounding world. It opens the world up, broadens the horizons, gives the opportunity to make decisions, allows to make choices, promotes active participation in various forms of social life. It allows usage of such devices as smartphones or mobile phones. It allows the child to have its own space, develop it, improve its sense of direction, helps in reconstructing spatial systems. Because of its appealing form, the device encourages activity, gives an opportunity to choose, indicates mistakes if any occur at the same time giving the possibility to correct them. It improves many forms of coordination: visual − motor, auditory − motor, visual − auditory − motor, enhances the attention span.

System Sensor Mouse also allows people who have difficulties in using a traditional mouse, to write on the computer. Using the onscreen keyboard of the System Sensor Mouse it is possible to write on and use a computer. Onscreen keyboard displays a virtual keyboard with all the standard keys. Keys can be selected using a mouse or other pointing device. A single key as well as a group of keys can be used to navigate between each key on the screen.

The device was especially designed for disabled children and people with cerebral palsy with the purpose to help in rehabilitation and communication with the environment. Such persons can not use neither the first version of System Sensor, because of not knowing the letters, nor System Sensor GSR, because of not being able to focus attention. Additionally, they are mentally and manually disabled therefore not able to use neither the traditional keyboard nor joystick.

System Sensor Mouse serves as a pointing device and is based on carefully planned use of large buttons performing the functions of traditional keyboard and computer mouse (hence the name given). With the help of these characteristics, special international graphic computer programs, which has already been used in children with cerebral palsy therapy, can be operated. Handling such programs by the people with combined mental-physical disorders is possible.

System Sensor Mouse does not require any additional drivers or software, and works well with the following operating systems: Windows, MAC OS, Linux, Android. After connecting System Sensor Mouse to a computer or a tablet, the device is detected by the operating system and is ready to work. The huge advantage of the device is its easy to use form, that is especially important for people with reduced motor or intellectual abilities, and the ones caring for them. It enables previously mentioned ones to use a computer, tablet or even smartphone with installed software to an alternative communication applications, like the Polish prosthesis speech device "MÓWik" and "The Grid 2" which allows communication by means of symbols, images, or one's own photos. These programs are useful tools in alternative communication.

In a situation when the strength and precision of pressing a key, for instance, is rather small, the user's communication possibility with the use of communication devices previously available is greatly hindered. System Sensor Mouse is a device that supports communication. It provides a possibility to hover on the message box and approve of the selected message by clicking joystick button, as well as hand, or foot, depending on the user's preferences or capabilities.

Independent joystick and keyboard working modes make it possible to make full sentences, consisting of single short messages, and activate them using an innovative text-to-speech solution. System Sensor Mouse works well with Android, making it able to handle the Polish speech prosthesis called "MÓWik", that is dedicated to, among others, people with cerebral palsy. The speech prosthesis works on tablets and smartphones, some users, however, due to the lack of motor abilities is not able to push boxes with prompts and thus does not have the possibility to communicate with the outer world. First experience with System

Sensor Mouse shows its significant relevance in the process of rehabilitation and education of the disabled children, as well as its impact on the increase of their motivation to act and learn. For these reasons, it is a complementary support for people with cerebral palsy or combined mental-physical disorders in the course of their learning and, what is more, adjusting educational requirements and communicating with the society.

Conclusions

The practical Human-Computer Interaction system thoroughly explained above, represents a potential alternative for the communication of individuals with severe motor disabilities using their computers. Because of the fact that the system gives commands to the cursor movements on the basis of detection and classification of GSR signals, its operation is relatively simple for the user. Usage of the interface requires only a voluntary contraction of a set of chosen muscles, requiring little training on the part of the user.

The interface of System Sensor is fully operational. It allows people with disabilities to move computer cursor through galvanic skin sensor, by using their thoughts. Second interface helps people with disabilities, especially children with cerebral palsy or spinal muscular atrophy, to move computer cursor and use virtual keyboard.

In comparison with other unassisted interfaces dedicated to users with disabilities, the GSR interface described above has the potential to be more affordable and portable than others, such as eye-gaze tracking devices.

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References

[Barr00] Barreto A.B., Scargle S.D., Adjouadi M.: A Practical EMG-based Human-computer Interface for Users with Motor Disabilities. „Journal of Rehabilitation Research and Development" 2000, Vol. 37, No. 1, January/February, pp. 53-64.

[Chen11] Chen Y.: Application of Tilt Sensors in Human-computer Mouse Interface for People with Disabilities. „IEEE Transactions on Neural Systems and Rehabilitation Engineering" 2001, Vol. 9, Iss. 3, pp. 289-294.

[Leut04] Leuthardt E.C., Schalk G., Wolpaw J.R., Ojemann J.G., Moran D.W.: A Brain-computer Interface Using Electrocorticographic Signals in Humans. „Journal of Neural Engineering" 2004, 1(2), pp. 63-71.

[Kane09] Kane S.K., Jayant C., Wobbrock J.O., Ladner R.E.: Freedom to Roam: A Study of Mobile Device Adoption and Accessibility for People with Visual and Motor Disabilities. Proceedings of the 11th International ACM SIGACCESS Conference on Computers and Accessibility ACM 2009, pp. 115-122.

[KrSt09] Królak A., Strumiło P., Eye-Blink Controlled Human-Computer Interface for the Disabled in Human-Computer Systems Interaction. In: Advances in Intelligent and Soft Computing Vol. 60, 2009, pp. 123-133.

[KrSt08] Królak A., Strumiło P.: Vision-based Eye Blink Monitoring System for Human-computer Interfacing. Conference on Human System Interactions, Kraków 2008, pp. 994-998.

[Moor04] Moore M.M., Dua U.: A Galvanic Skin Response Interface for People with Severe Motor Disabilities. ACM SIGACCESS Accessibility and Computing ACM 2004, No. 77-78, pp. 48-54.

[Ostro11] Ostrowska A., Sikorska J., Gąciarz B.: Osoby niepełnosprawne w Polsce w latach dziewięćdziesiątych. Instytut Spraw Publicznych, 2001.

[Rimm99] Rimmer J.H.: Health Promotion for People with Disabilities: The Emerging Paradigm Shift from Disability Prevention to Prevention of Secondary Conditions. „Physical Therapy" 1999, 79(5), pp. 495-502.

[Trew06] Trewin S., Keates S., Moffatt K.: Developing Steady Clicks: A Method of Cursor Assistance for People with Motor Impairments. Proceedings of the 8th international ACM SIGACCESS Conference on Computers and Accessibility ACM 2006, pp. 26-33.

SENSOR SYSTEMU – PRAKTYCZNY INTERFEJS CZŁOWIEK-KOMPUTER DLA NIEPEŁNOSPRAWNYCH

Streszczenie

W artykule zaprezentowano interfejs stosowanych dla detekcji biosygnałów i dla interpretacji wzorców biosygnałów dla komunikacji człowieka z maszyną. System sensorowy i jego zastosowanie zostały wyjaśnione na przykładach. Ponadto przedstawiono rozwiązanie zwane System Mouse Sensor zaprojektowane dla osób chorych na porażenie mózgowe oraz niepełnosprawnych fizycznie.