BRAIN-CIMPUTER INTERFACES AND THEIR ENVIRONMENT

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Abstract: The work presented in this paper pretends to provide a general overview about the Brain-Computer Interface (BCI) systems used for partial recovery and social reintegration of persons with motor impairments using for this an intelligent environment.

1. INTRODUCTION

Millions of people worldwide suffer from motor disorders associated with neurological problems such as stroke, brain injuries, spinal cord injuries, multiple sclerosis, amyotrophic lateral sclerosis (ALS) also known as Charcot disease, Parkinson's disease and so on. Some of them are associated with motion disabilities thus being a handicap for the person in cause. For example in the case of multiple sclerosis (which has a prevalence that ranges between 2 and 150 per 100,000) the map of the disease distribution worldwide is presented in the figure below.

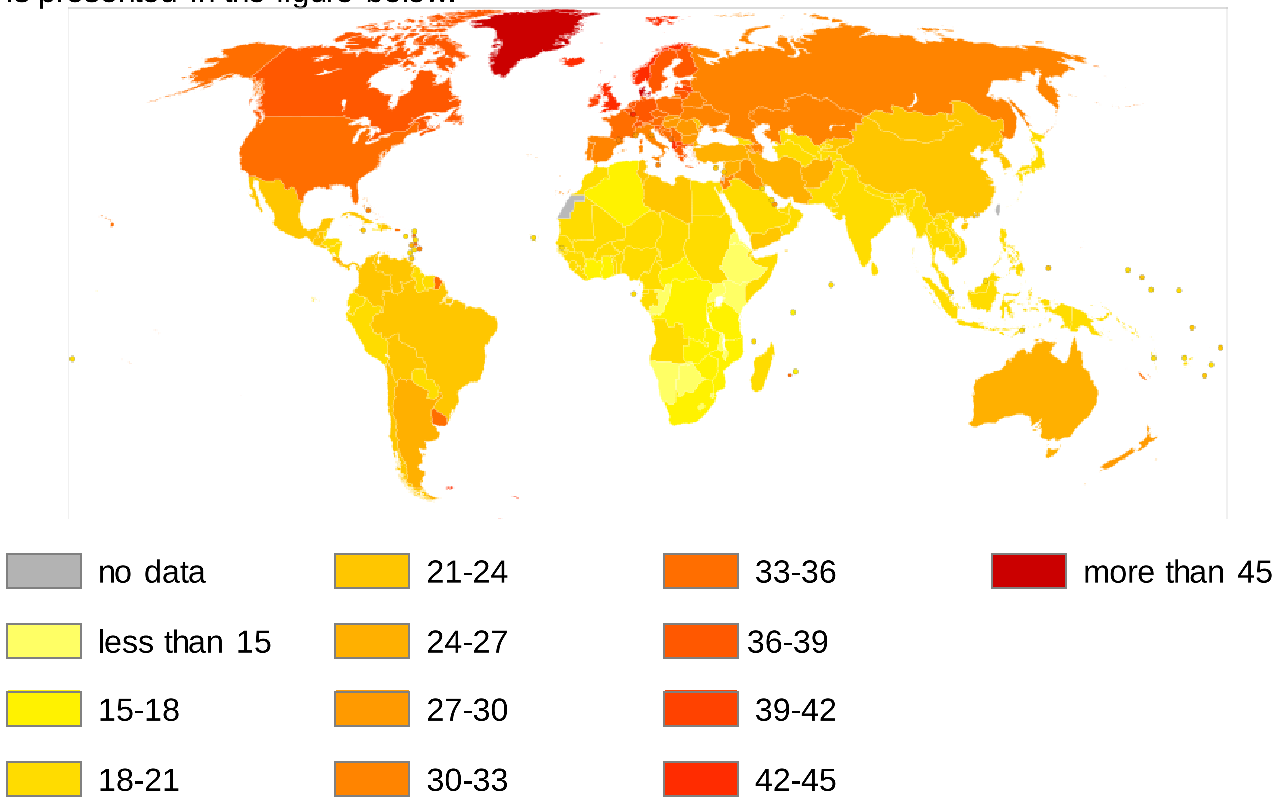

Fig.1 Age-standardised disability-adjusted life year (DALY) rates from multiple sclerosis by country (per 100,000 inhabitants) [http://en.wikipedia.org/wiki/File:Multiple_sclerosis_world_map_-_DALY_-_WHO2004.svg, dec.2012]

Also, stroke ranks as the third most common cause of death in industrialized countries. Despite dramatic advances in the management of acute stroke, patients may suffer motion disabilities which needs rehabilitation. Not always rehabilitation is complete and 15 to 30% of stroke patients remain with permanent motion disabilities.

According to the Eurostat statistics, 25.3% of the European Union (15 countries) population are “severely hampered” (9.3%) or “hampered to some extent” (16.0%). More specifically, these figures refer to “hampered in daily activities by any physical or mental health problem, illness or disability” [11]. Their quality of life would improve substantially if they could participate more actively in the society, while society itself could benefit from this contribution. [17]. Considering these information, researches were conducted in the last years towards the improving of the quality of life for people suffering motion disabilities.

2. BRAIN-COMPUTER INTERFACES

Devices that are using brain (cortical or scalp) electric or magnetic potentials, or other techniques (NIRs), which allow brain function signals to control machines (or computers) are called brain-computer interfaces BCI.

Application areas of BCI technologies for disabled individuals: motor recovery, motor substitution, communication and control;mental state monitoring; entertainment&gaming.

The use of the electrical activity of the brain for communication and control has gained significant interest in recent years. The so-called BCI (brain-computer interface) is constructed by recording, processing and classifying the brain signals which are induced by mental task. Since these tasks are executed without the need of any muscular act, the related activity has great potential as a new mechanism for handicapped people to interact with their environment.

An electroencephalogram (EEG) based Brain-Computer Interface (BCI) is a communication system and represents a direct connection between the human brain and the computer. Mental activities or “thoughts” result in changes of electro-physiological brain signals. A BCI is able to detect and translate these changes into operative control signals. Imagination of movement effects similar neural networks in the brain as real execution of the same movement [6]. Therefore motor imagery is one important control strategy in BCI applications [10], and used to operate e.g. computer-controlled spelling devices (virtual keyboard) in patients with locked-in-syndrome [7] or neuroprosthesis in patients with spinal cord injury. Patients suffering from amyotrophic lateral sclerosis (ALS) could re-establish a communication channel to their surrounding environment by controlling electric spelling devices [1]. In general the electroencephalogram (EEG) is used in BCI systems due to its ease of recording and low cost. 1-D or 2-D BCI feedbacks are usually used. The graphical possibilities of virtual reality (VR) should help to improve BCI - feedback presentations and create new paradigms, with the intention to obtain a better control of the BCI.

3. BCI-VR SYSTEM

Results from experiments in which EEG based BCI was combined with virtual reality as feedback medium were presented in [5]. Virtual-reality can provide dynamic and controllable experimental environments and is optimally suited technology to create and design different types of realistic 3-D feedback. The combination between VR and BCI offer new possibilities for diagnostic and therapeutic arrangements. The authors used subjects which navigated in the virtual environment by the mean of the control signal achieved from the BCI; left and right rotation was piloted by the imagination of left or right hand movement. In the experiment the EEG was recorded over the sensoriomotor cortex during the imagination of different types of movements, processed online, classified and transformed into a control signal. The event related desynchronization (ERD) was used to convert brain states into control signals. Characteristic spatial patterns were found in the ERD depending on the preparation of the type of movement.

The diagram of the BCI-VR system used is presented in the figure 2.

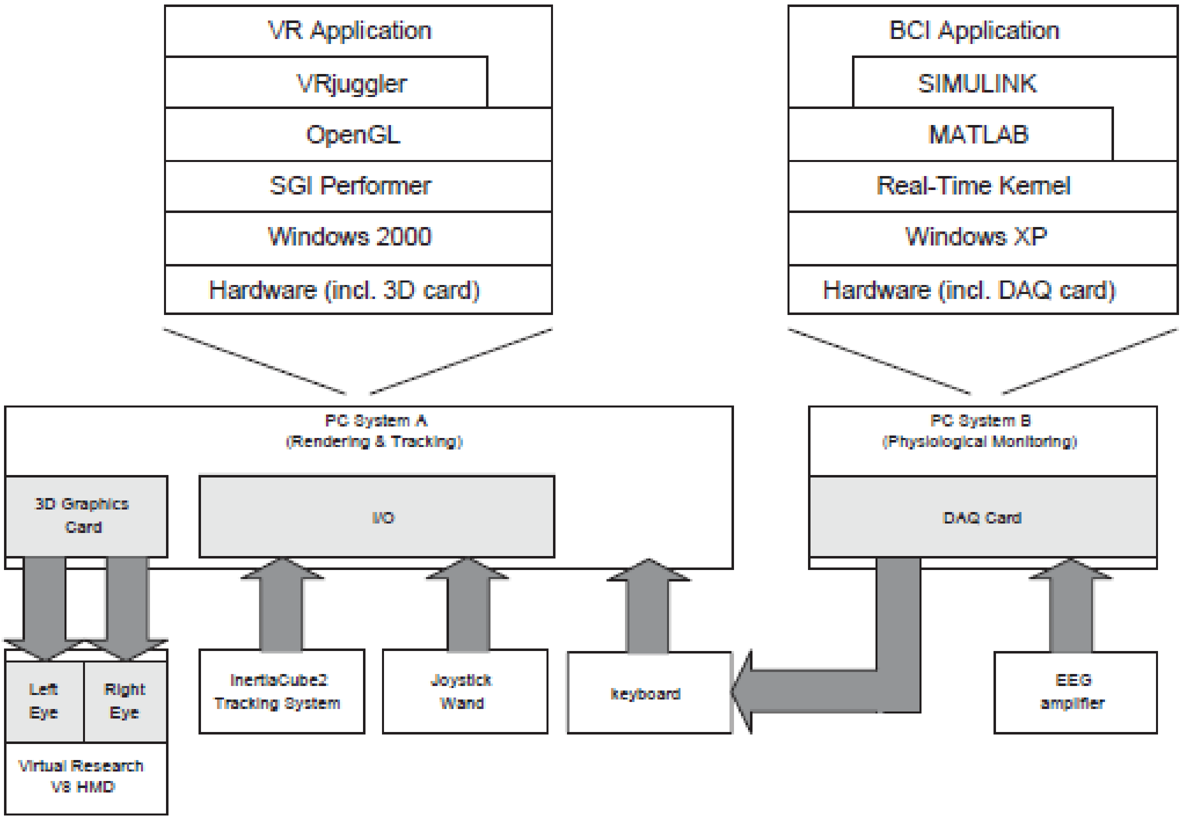

Fig.2 Block diagram of the BCI-VR system.

The VR system on the left of the diagram gets input information from the tracking system, from a joystick and from a keyboard. Two stereoscopic images are calculated and sent to the HMD (head mounted display). The BCI system (right side) has the EEG as inputs and calculates a control signal. On top of the diagram the software layers of both systems are displayed. The VR application layer has access to both the VR Juggler and Performer. The real-time BCI application is running simultaneously on Simulink and MATLAB.

In figure 3 the schematic model of the combined framework the BCI system on the left and the VR system on the right side is presented. According to authors' conclusions, the combination of the BCI with VR as feedback medium is possible. No technical or systematic interferences or disturbances of this combination could be found. Also it was shown that the subjects were able to navigate the virtual environment by using motor imagery. Another conclusion was that feedback behaving in an unknown or unpredicted way, not as it is expected in the real world, may cause problems.

The evolution of EEG evolved towards simpler devices such as EPOC from Emotiv, Australia, and iBrain from NeuroVigil in the USA, with applications in computer gaming. The last one, as its inventor says, is the first single channel EEG device. It appears that EEG devices are going to be much comfortable and lightweight for the users in the next future.

The BCI-PC sends extracted and classified EEG parameter is to the VR-PC and controls there with the visual feedback ("navigation by thoughts"). The visual representation, BCI and the VR represents a closed loop system.

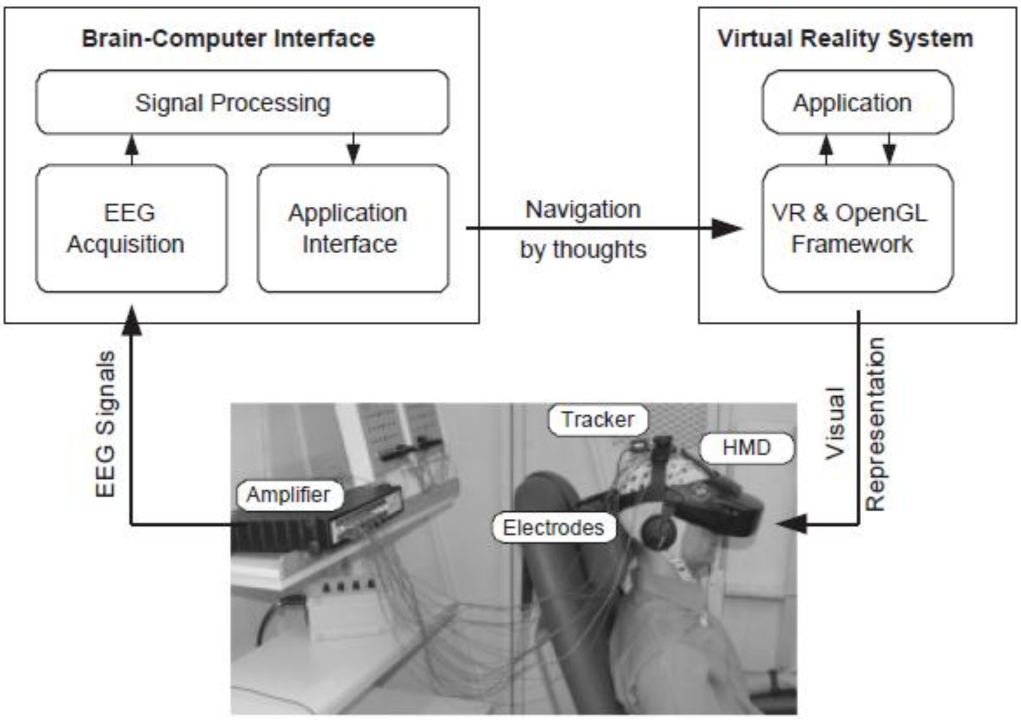

Fig.3 BCI-VR system

4. THE INTELLIGENT ENVIRONMENT

An intelligent environment can be defined as a context in which people interact each other and with the environment and are assisted in their tasks in a certain smart way [9].

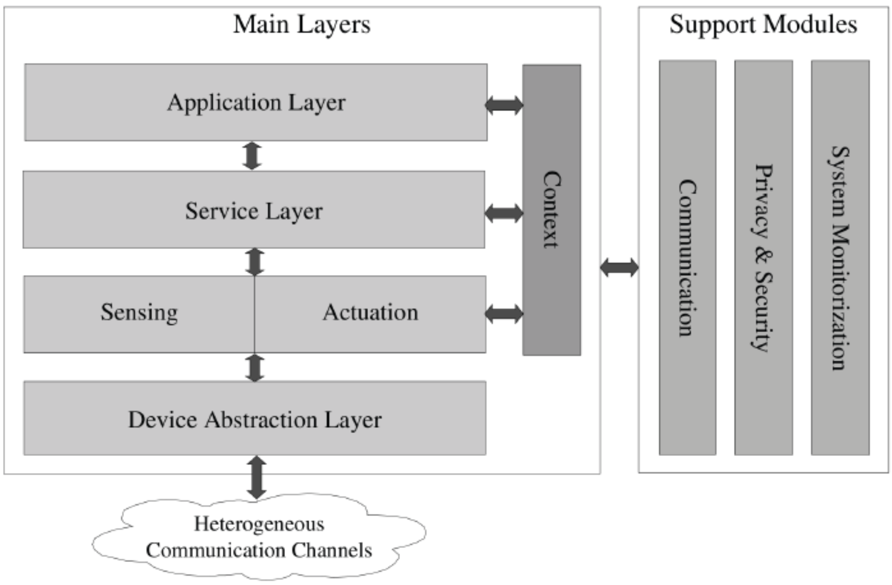

Fig.4 Intelligent environment, conceptual model

The term intelligence concerns the response that users expect from the system in terms of what artificial intelligence stands for, that is, proactivity, predictability and adaptability in its behaviour. Such a system is made up of many different elements: sensors, actuators, applications providing functionalities to users, intermediate services that provide common functionalities to applications, system-level utilities for system control and logging, etc.

Such a system considering the conceptual model is presented in figure 4. System is composed of separate layers interacting one to another and with the context and also it contains support modules such as communication, privacy and security, system monitoring.

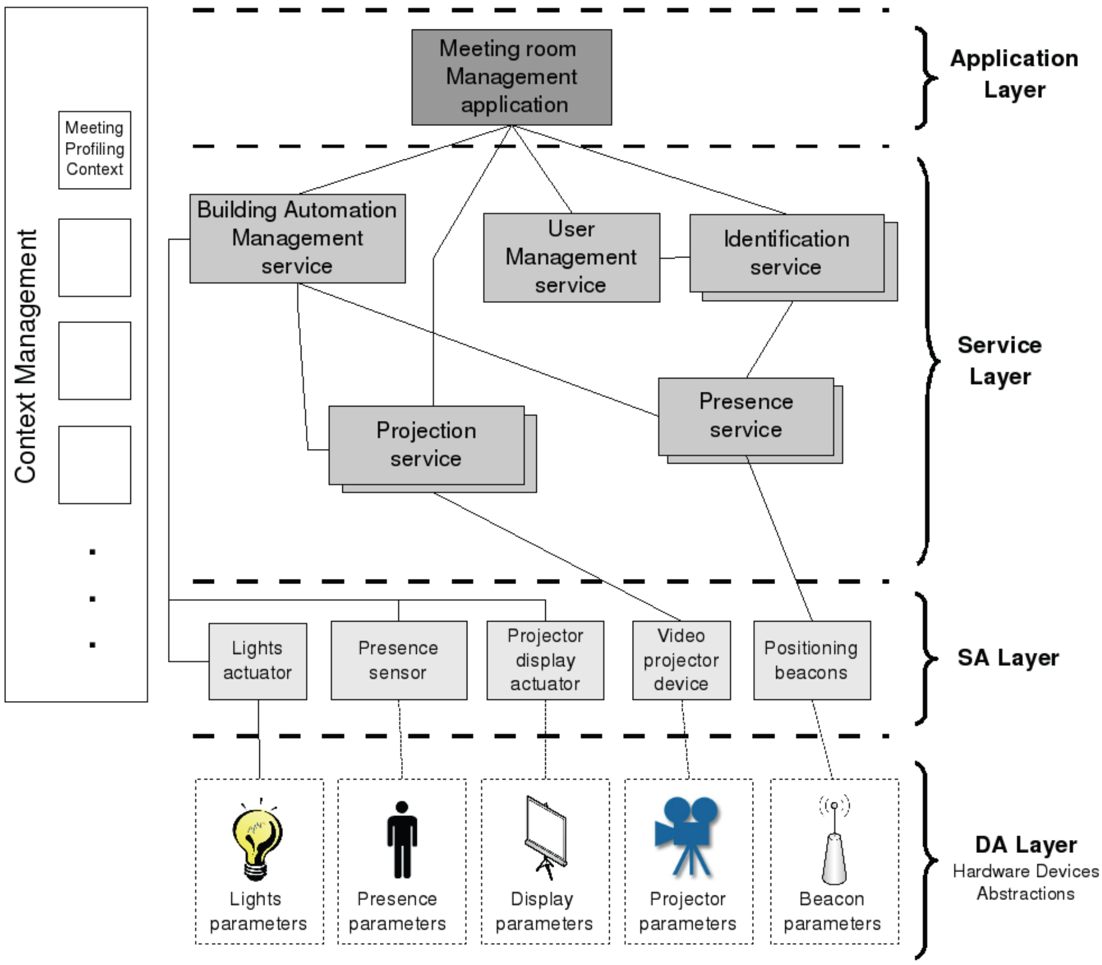

Fig.5 Intelligent environment, component diagram (example)

The main layers defined for such a model are:

- **Device Access Layer**: It includes elements that encapsulate concrete logic to access physical devices. It is divided into two sub-layers: device drivers and device access API..
- **Sensing and Actuation layer**: There are two types of elements in this layer: sensing elements and actuation elements. Sensing elements provide access to sensor type devices (using the device access API). Similarly, actuation elements must provide the required functionality to command actuator type devices. The elements of this layer are proxies of the physical devices.

- **Service layer**: A service is an element designed to solve a high level task that does not provide a complete solution for a system use case. Services are managed through a repository that enables the discovery of services required by others to perform their task.
- **Application layer**: This layer hosts the elements representing and implementing particular functionalities that a user expects from the system. These components make use of services registered in the system to carry out their tasks.

Furthermore, there is a component that is shared by the three higher level layers, the context. Its main goal is to define and manage the elements that must be observed in order to model the current state of the environment.

5. RESEARCH AT UNIVERSITY OF ORADEA

In what concerns the research team from the University of Oradea researches regarding signal acquisition from the brain were conducted in the last period of time, using EEG devices combined with National Instruments data acquisition devices and software.

There are several human activities where the awareness and conscious control is a very important factor: vehicle driving, heavy equipment operation, hazardous materials manipulation. In these cases drowsiness can be the cause of injury or even death. For example car driver drowsiness is one of the causes of serious traffic accidents, which makes this an area of a significant importance. So, in [2] is presented our research based on the study of EEG and EMG signals and aims to develop algorithms capable to detect features specific to the drowsiness state and decide the moment in which the driver or operator should be alerted.

In [3] was described our experiments and the development of data processing for EEG signals, focusing on identification of ERD characteristics which can be used in brain – computer interfaces. The experiments showed that EEG signals had to be carefully acquired and processed in order to identify ERD components. Data acquisition equipment quality, careful selection of subjects and subject focus capacity are of major importance in achieving successful results. Data preparation had been done considering simple and time effective algorithms which can be used for real time processing of EEG signals.

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