ASPICE: an interface system for independent life

F. Aloise[a], F. Cincotti[a,1], F. Babiloni[a,c], M. G. Marciani[a,d], D. Morelli[a], S. Paolucci[a], G. Oriolo[e], A. Cherubini[e], F. Sciarra[f], F. Mangiola[f], A. Melpignano[g], F. Davide[g], D. Mattia[a].

[a]Fondazione Santa Lucia IRCCS, Roma, Italy; [c]Dip. di Fisiologia Umana, Univ. "La Sapienza", Roma, Italy; [d]Dip. di Neuroscienze, Univ. "Tor Vergata", Roma, Italy; [e]Dip. di Informatica e Sistemistica, Univ. "La Sapienza", Roma, Italy; [f]Unione Italiana Lotta alla Distrofia Muscolare, Sezione del Lazio, Roma, Italy; [g]Telecom Italia Learning Services, Roma, Italy

Abstract. In the framework of the ASPICE project, a hardware/software system has been developed, which allows the neuromotor disabled persons to improve or recover their mobility (directly or by emulation) and communication within the surrounding environment. The system pivots around a software controller running on a personal computer, which offers to the user a proper interface to communicate through input interfaces matched with the individual's residual abilities. The system uses the user's input to control domotic devices - such as remotely controlled lights, TV sets, etc. - and a Sony AIBO robot. Preliminary results of a clinical validation are reported.

Keywords. Technologies for Independent Life, Brain-Computer Interfaces, Robotic Navigation, Ambient Intelligence, Severe Motor Impairment.

Introduction

In the field of rehabilitation, the main goal is to reduce disability consequent to any pathological condition, by means of orthesis, and the management of the disability related to the social disadvantage, by means of different types of aids.

The project described in this paper offers the opportunity to integrate into a prototype the core technologies (Brain Computer Interface, Domotics, Robotics), in order to prove that an application in every day's life is possible, with particular attention to people who suffer from diseases that affect their mobility (e.g. Spinal Muscular Atrophy, Duchenne Dystrophy, Amyotrophic Lateral Sclerosis). The residual muscular strength, if present, cannot be adequate for the utilization of conventional aids and in those conditions in which practical obstacles or security concerns could prevent a displacement from bed.

[1] Corresponding author: Febo Cincotti, Fondazione Santa Lucia IRCCS, via Ardeatina 306, I-00179 Roma, Italy. Tel +39 06 5150 1466. Fax +39 06 5150 1465. email febo.cincotti@uniroma1.it. This work is partially supported by the Italian Telethon Foundation Grant GUP03562

1. Overview of the Aspice project

The ASPICE project (Assistive System for Patient's Increase of Communication, ambient control and mobility in absence of muscular Effort) fosters its aims through the integration of disciplines brought from the partners of the development consortium.

The key elements of the system are:

a) interfaces for easy access to computer: mouse, joystick, eye tracker, voice recognition, up to utilization of signals collected directly but non-invasevely from Central Nervous System (BCI);
b) controllers of intelligent motion devices which can follow complex paths, based on a small set of commands (Robotics);
c) information transmission and domotics, establishing an information flow between patient and controlled appliances (Domotics).

The ASPICE architecture, with its input and output devices, is outlined in Figure 1.

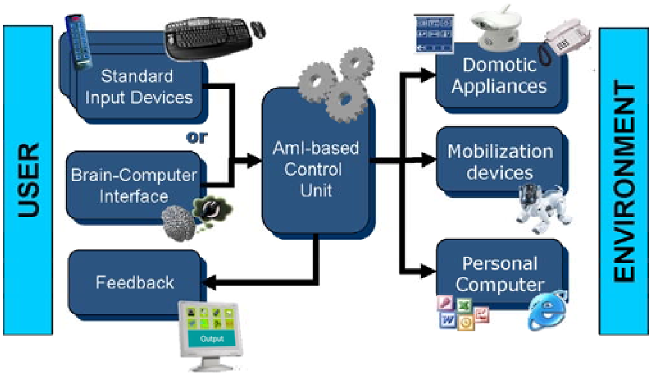

Figure 1. Outline of the architecture of the ASPICE project. The figure shows that the system interfaces the user to the surrounding environment. The modularity is assured by the use of a core unit that takes inputs by one of the possible input devices and sends commands to one or more of the possible actuators. A feedback is provided to keep the user informed about the status of the system.

2. Achievements of the project

At this stage of the project, a prototype of the system has been implemented and is available at the Fondazione Santa Lucia for the validation with patients.

2.1. Input Devices

The system input devices are customized on the users'residual motor abilities: users can access the system through the aids they are already familiar with, and that have been interfaced to provide a low level input to a more sophisticated assistive device. On the other hand, the variety of input devices provides robustness against worsening of patients' abilities, which is a typical consequence of degenerative diseases.

The software implementation of this modular attitude benefited from the use of the ICon package [1]

An extreme instance of input devices that can be interfaced to the system are Brain–computer interfaces (BCI's). A BCI allow an individual to interact with the environment through communication and control channels that do not depend on the brain's natural output channels (nerves and muscles) [2]. In practice, a BCI detects voluntarily induced changes of brain activity (by measuring the electrophysiological signals) and transforms them into a control signal that are downstreamed to other units. [3-6]

2.2. Core Operation

The system core receives the logical signals from the input devices and converts them into commands that can be used to drive the output devices.

Its operation is organized as a hierarchical structure of possible actions, whose relationship can be static or dynamic. In the static configuration, it behaves as a "cascaded menu" choice system. It will be duty of the Feedback module to choose the most appropriate representation of the available choices (i.e. a text menu, a set of icons, etc). In the dynamic configuration, an intelligent agent tries to learn from use which is the most probable choice that the user will make.

Whenever the user select an action that, rather than changing the internal context of the core (i.e. selects a non-leaf item of the cascaded menu), it instructs the system to undertake a physical action, the Control Unit fulfils the user's demands by sending the appropriate control signals to the output appliances. Drivers are used to offer a homogeneous interface from the Control Unit's point of view.

2.3. Feedback

The user can select the commands and monitor the system's behaviour through a Graphic Interface. Like all other modules, inter-module communication is transported via TCP/IP socket; among others, this allows each module to be run on a different computer. The Feedback can significantly benefit from this, since a lighter an low power computer such as a palmtop PC or even a smart phone can be used to give the subject the feedback he/she needs, while being of minimum burden for the user.

Figure 2 shows a possible appearance of the feedback screen. In this case, choices are pictured as button-shaped icons. This is possibly the most simple interface, and for sure the most practical to be operate with a reduced set of available input signals.

Figure 2. Appearance of the feedback screen. The Feedback application has been instructed to divide the window into three panels. In the top panel, the available selections (commands) appear as icons. In the bottom right panel, a feedback stimulus by the BCI (matching the one the subject has been training with) is provided; the user uses his learnt modulation of brain activity to move the cursor at the center to hit either the left or the right bars – in order to focus the previous or following icon in the top panel – or to hit the top bar – to select the current icon. In the bottom left panel, the Feedback module displays the video stream.

2.4. Actuators

The Aspice system allows the user to operate remotely electric devices (e.g. TV, fan, lights) as well as monitoring the environment with remotely controlled videocameras. Moreover, A robot navigation system has been developed, based on a small set of commands, which has been interfaced with the Aspice system.[7]

3. Clinical validation

Clinical validation of the prototype has been carried out with the voluntary collaboration of 20 adult subjects affected by motor disability of variable degree due to neuromuscular diseases. These subjects were asked to interact with the prototype and to provide information about how it was perceived in terms of augmented independence in daily life activity. The results indicated that the individual's needs and interest must be analyzed and reinforced. Environmental control is a strong positive reinforcement even if the subject partially regains some independency in operating domotic devices. It remains to be tested how positive reinforces could be integrated into a general training framework.

4. Conclusions

The quality of life of an individual suffering from severe motor impairments is importantly affected by its complete dependence upon the caregivers. An assistive device, even the most advanced, cannot substitute – at the state of the art – the assistance provided by a human. Nevertheless, it can contribute to relief the caregiver from a continuous presence in the room of the patient. Most importantly, the perception of the patient is that he has no more to rely on the caregiver for each and every action. On one side this increases the sense of independence of the patient, on the other side this grants a sense of privacy, that is almost absent in the case another human has to take care. For both reasons, the quality of life of the patient is sensibly improved.

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