My-World-in-My-Tablet: An Architecture for People with Physical Impairment*

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Abstract. Mobile computing, coupled with advanced types of input interfaces, such as Brain Computer Interfaces (BCIs), and smart spaces can improve the quality of life of persons with disabilities. In this paper, we describe the architecture and the prototype of an assistive system, which allows users to express themselves and partially preserve their independence in controlling electrical devices at home. Even in absence of muscular functions, the proposed system would still allow the user some communication and control capabilities, by relying on non-invasive BCIs. Experiments show how the fully-software realization of the system guarantees effective use with BCIs.

Keywords: Brain Computer Interfaces (BCIs), tablet, home appliances, communication capabilities, software architecture.

1 Introduction

A cure for many neurodegenerative diseases is still unknown, yet advancements in life-supporting technologies and clinical practice allow a growing number of patients to survive longer. For instance, persons with Amyotrophic Lateral Sclerosis (ALS), undergo a degenerative process that lasts years, in which motor functions are progressively lost [7]; due to the heterogeneity of the disease (e.g., bulbar versus spinal forms), each patient experiences her own path of function deprivation; finally any chance of communication and action on the environment is lost; unless a fatal event occurs (e.g., a respiratory crisis) these individuals enter a locked-in state. While the advancement of life support technology and clinical practice can prolong the life of these subjects, it also extends the period in which her motor functions are very poor or even absent, leading to a state of

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complete dependence on the caregivers. As a consequence, social inclusion and quality of life of people with neurodegenerative diseases is decreasing, while the social cost for their assistance is increasing. Beside neurodegenerative diseases, other congenital or acquired deficits of the neuro-muscular system may lead to mild to severe limitations of mobility, motor skills, and speech.

In this paper we present the architecture and the prototype of an assistive system, referred to as My-World-in-My-Tablet (MWiMT for short in the following) suited for different inputs, fitting the residual abilities of the user, and aimed at preserving her communication ability at any stage of a progressing disease. The system allows the user to express herself and partially preserve her independence in controlling electrical devices at home. Even in absence of muscular functions, the proposed system still allows the user some communication and control capabilities, by relaying on non-invasive Brain-Computer Interfaces (BCIs) [15]. In fact, by relaying on modulation of brain activity voluntarily induced by the user, and detected by processing her electroencephalogram (EEG), BCI research has shown in the past decade the possibility of a communication even in absence of any muscular contraction.

MWiMT is based on a tablet device, and consists of two main software components: AuxiliHome, which provides basic communication tools and a flexible access to home automation appliances, and FlexyGlass, which allows operating different mainstream applications using a common interface supporting different kind of aids. Its design allows an early adoption of the aid, when the user can still operate it by means of conventional interfaces (e.g., a manual or automatic scan button), and can be re-configured whenever the user, due to her decay of motor abilities, feels no more able to operate it.

2 Preliminaries

The term *assistive technology* (AT) originally included all kinds of accessible, adaptive and rehabilitative devices addressed to people with disability, aimed at improving their activities and participation and thus their quality of life. Nowadays the term significantly changed its meaning, including, in addition, a wide variety of software solutions which replace, and in some case improve, the features originally provided by specific devices. *Augmented and alternative communication* (AAC) is a classical AT application aiming at compensating for severe speech-language impairments in the expression or comprehension of spoken or written language. Software packages for communication, supporting different inputs, running on a common personal computer are available; they can simulate communication boards (both alphabetical or symbolic), reproduce virtual keyboards, and can be equipped with word prediction systems and vocal output, optionally giving access to the internet. Home automation (*domotics*) represents another promising AT application area [12,8,3].

Input devices for AT systems can be classified into two main categories, namely *pointing devices* (e.g. trackballs, joysticks, touch screens, trackers) and *switches* (or more generally binary input devices, used in combination with automatic scan or step scan systems). Beside these classical input methods, last years have seen a growing interest in *brain computer interfaces* (BCIs) and more generally in biosignal based interfaces. BCI is intended as a mean for providing severely physically impaired people (locked-in subjects) a direct communication channel between the brain and an external electronic device. In particular, many studies have been conducted with so called non-invasive BCIs in order to translate electroencephalographic (EEG) activity or other electrophysiological measures of brain function into commands [2]. A set of different EEG features which can be translated into control signals together with the needed processing steps are described in [15]. A BCI translates these features into control signals either continuous or discrete in time.

While BCI performance improved over the years, required hardware and software became cheaper and simpler to use giving the chance of bringing BCI directly at home without the continuous support of a specialized technician. Nowadays, portable EEG amplifiers can be accessed by a computer using standard interfaces (e.g. RS232, USB, Bluetooth). Additionally, a set of established software BCI platforms is freely available for real-time EEG signal processing (e.g., BCI2000, OpenVibe). However, currently, a few demonstrations of BCI as possible assistive product have been given and few cases are reported in the literature of motor disabled users that can access to communication and environmental control through a BCI [14,2].

3 The System

The goal of our work is the definition of a modular user-centric platform, depicted in Figure 1, in which an off-the-shelf tablet is used as a generic and extensible integration container for a set of different technologies.

Input methods are split into *hardware-based* and *biosignal-based* ones. Different input methods allow for different information transfer rates from the user to the controlled devices. A user usually chooses the input method which, by taking into account her abilities, degree of impairment and required effort, offers the higher information transfer rate. A key advantage of such an architecture is the transparency of the input method with respect to the controlled application.

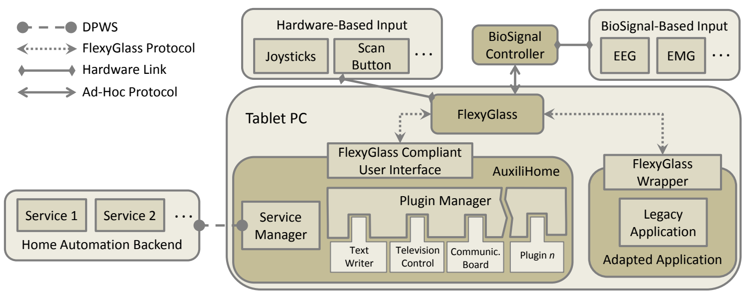

Fig. 1. My-World-in-My-Tablet architecture

Using a biosignal as input method is only possible using a biosignal controller, which is the component (hardware or software) devoted to the translation of the biosignal into a *control signal*. This work focuses on BCI as biosignal-based input method so, in the following, we will refer to this component as the BCI controller. This component may run directly on the tablet as well as on a different computer connected to the acquisition hardware. Its output may provide either a discrete control signal or a continuous one. At the actual stage of development, our prototype relies on BCI2000 as a BCI controller providing a discrete control signal based on P300 feature (see Section 3.2) of EEG.

The employed *home automation back-end* [3] hides all the home automation functionalities behind well-defined software services; it has been designed to be enough versatile to be application agnostic, allowing to detect, use and compose every kind of device on a *semantic* base.

The tablet represents the way a user with impairments is able to communicate her needs and ideas and to control the domestic environment using the available input methods. This mobile device runs several different applications, most of which have not been designed to interact with special input aids. The most innovative component of our architecture, namely FlexyGlass, has been devised as a way to provide a standard interaction method with installed software, despite the variety of available input methods for the user. An example of such a software is given by the AuxiliHome component, which gives access to a set of application plugins and to the services provided by the home through an adaptive and extensible GUI.

Personalized dynamic accessibility [6,4] aims at achieving a more effective user interaction by making the software adaptive with respect to user's needs and abilities changing over time. This is obtained through the *customizability* and the *dynamic adaptivity* of the user interface. Our work pursues the same purposes providing respectively *(i)* the possibility to configure and personalize the applications composing AuxiliHome (see Section 3.1) and *(ii)* the possibility of using several different input devices and modalities thanks to the novel FlexyGlass subsystem (see Section 3.2).

3.1 AuxiliHome

The graphical interface of AuxiliHome consists of several screens, each of them based on a grid layout into which graphical components can be placed. The number of rows and columns of the grid can be configured and determines the minimum size of a graphical component. Such a grid layout is easily described in a declarative manner, through a specific XML document, to be offered by services and external applications.

Grid positions are occupied by buttons (see Figure 2) which, assuming different sizes, allow to strengthen the visibility of specific objects according to specific user's needs. A minimalistic interface has been targeted thus avoiding irrelevant or rarely needed information. The default look of the graphical user interface was designed aiming at complying with usability and accessibility guidelines [9]. Buttons come with a matte black background and white icons and labels. Only

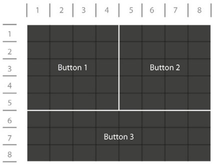

Fig. 2. UI elements

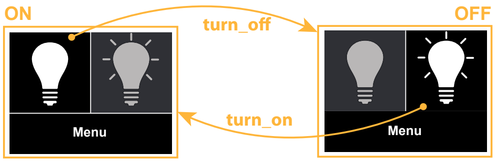

Fig. 3. Light service model

these two colors were used to code information in the whole interface and they maximize contrast ratio. The big contrast and the uniform background improve to screen clarity and readability.

AuxiliHome is a collection of applications that implement functionalities needed by users with disability; such applications are accessible through the graphical interface. The level and type of disability vary from user to user and may evolve over time, thus, the organization of applications should be as dynamic and flexible as possible. Applications can be added or removed easily from the system whenever necessary, must be configurable and, in order to provide maximum expandability of the system, can be developed and deployed by third parties. Applications can be either *tightly* or *loosely* coupled to the graphical interface and to the tablet.

Generally speaking, we can say that all the home automation applications can be considered loosely coupled to the tablet, i.e., they run outside the tablet since they belong to a specific home environment and installation. Both sensors and actuators in the home make their functionalities available according to a *service oriented architecture* (SOA) approach [3], which employees Web services as a way to face the heterogeneity of device's specific protocols. According to a rich service model, a Web service consists not only of the service interface specification, but also of its conversational description and of the graphical widgets (i.e., icons) needed when presenting the operations in the user interface. *Light control* for example (see Figure 3) allows the user to turn on or off a light. In this case the behavior of the application and of the UI can be easily modeled with a descriptive approach. Similar services related to armchairs, beds, alarm bell and doors have been employed during validation.

Among the currently available technologies for implementing Web Services, we chose Devices Profile for Web services – DPWS. By relying on DPWS, devices are discovered as soon as they join the local area network and the appropriate application is dynamically loaded on the tablet whilst, on the other hand, the asynchronous *event driven architecture* allows the graphical user interface to immediately reflect changes in the state of each device.

Tightly coupled applications are implemented as *plugins*. From this point of view, AuxiliHome behaves as a host application, which provides common functionalities that a plugin can use (e.g., the speech-engine). Plugins must implement a simple interface consisting of some methods that are executed during their life-cycle. This solution grants maximum expandability to the system, allowing third party applications to be easily developed and deployed only focusing on the core functionalities, without worrying about the graphical interface or the input mechanism that are under the responsibility of the AuxiliHome container.

Two applications/plugins for communication purpose are already available. The first one is a speech synthesizer for frequently used sentences. The list of sentences is fully customizable by the user or by the caregiver. The second one consists of a virtual keyboard provided with a word completion system and a speech synthesizer; it additionally shows a flipped copy of the inserted text at the top of the screen to make possible face-to-face conversations. Moreover plugins for infrared controlled devices such as TVs and DVD players are provided.

3.2 FlexyGlass and Adapters

The FlexyGlass component is an independent software module which makes the employed input method totally transparent to the controlled application. The basic idea (see Figure 4) behind FlexyGlass, is to over impose a transparent pane to the controlled application UI (using a topmost window with a transparent background); such a transparent pane contains a set of virtual controls which inherit size and position from the controlled application real controls (buttons, links or focusable objects) and which act in principle as proxies: if a virtual control is selected using the input method chosen by the user, the corresponding real control is triggered.

The described approach requires a direct connection between a controlled application and the FlexyGlass, and a communication protocol allowing FlexyGlass to *(i)* request the list of currently available controls to the controlled application in order to update virtual controls, and *(ii)* to communicate the last selection triggering the execution of a real command (the controlled application will acknowledge the completed execution of the command).

The FlexyGlass component is intended to support different kinds of input methods, each one requiring a different kind of interaction. A scan button, for example, can be used for either *(i) manual scan*, which uses short pressures to move the focus between controls and longer ones to trigger a command, or *(ii) automatic scan*, which automatically move the focus and interprets each pressure

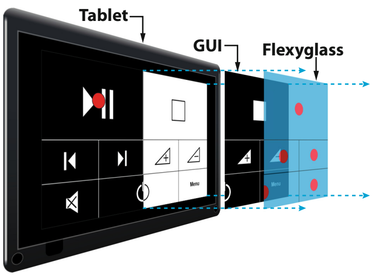

Fig. 4. A layered perspective of FlexyGlass

as a trigger. User who are able to move a mouse, but not to click, may use a *dwell mouse*, which automatically click after a predefined dwell time.

Currently, FlexyGlass supports P300 as the BCI-based input method. The P300 potential is a large and positive deflection of the EEG activity which reaches a maximum of amplitude over the centro-parietal scalp areas between 250 and 400 ms after a relevant stimulus (*target* stimulus), presented within a sequence of frequent irrelevant stimuli (*non-target* stimuli), is recognized [10]. The *speller* paradigm [5] is based on a n by m selection matrix divided into stimulation classes, one for each row and column composed by a set of symbols stimulated together. A *trial* is a stimulation sequence made up by a fixed number of consecutive shuffling of the whole set of stimulation classes. A specific symbol lays at the intersection between a row and a column , thus, if we suppose to have k repetitions, a user concentrating on a symbol will see it flashing $2k$ times (each followed by a P300 potential) within a train of $2k(n+m)$ stimuli. At the end of a trial, a score is assigned to each stimulation class; the system then selects the row and column with the highest score and returns the correspondent symbol.

The usage of P300 as an overlaid stimulation interface was first introduced in [11]. Here a P300 overlaid interface was used to control the commercial assistive technology application suite QualiWorld. FlexyGlass makes that idea more general, by allowing to use coherent graphics to control generic applications with different kinds of inputs ranging from BCIs to hardware switches. Using a BCI input requires a BCI controller (BCI2000 in our case) which has to be connected using an ad-hoc protocol. Creating an overlaid interface raises the problem of how the classical matrix layout of the P300 speller may be adapted to a more general layout. Before a trial begins, FlexyGlass analyses the controls available on the controlled application, chooses the minimum matrix size with enough space to define a one-to-one association between controls and matrix positions.

Controlling an application using P300 requires a continuous attention to the stimulation in order to avoid incorrect selection bringing the controlled application into an unwanted state. A user might desire to pause the system because she is either tired or occupied in some other tasks. FlexyGlass proposes a mechanism consisting in stimulating over the window shown in Figure 5.

Controls has to be highlighted in all previous input methods. By knowing the position of the available controls of the controlled applications, FlexyGlass is able to move the focus over a control by drawing over the layered window.

FlexyGlass have been designed to be easily extensible with different highlight graphics. Figure 6 shows the currently available stimulations, the *dot* [11]

Fig. 5. Pause for P300 input

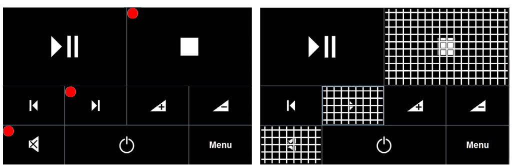

Fig. 6. Stimulation over the DVD remote control

and the *grid* [13] ones, which have been proved to be very effective with P300-based BCIs. The FlexyGlass graphical configuration utility allows for customizing each aspect of the available stimulations (colors, sizes, etc.).

Applications which are compliant with FlexyGlass are automatically discovered through a `hello` protocol. There exist two kinds of application: those which are natively built to be controlled via FlexyGlass (it is the case of AuxiliHome) and those (the vast majority), which we refer to as *legacy* applications, which require the development of a *wrapper* in order to be controlled. In the case of a browser like Firefox or Chrome, a wrapper may be easily implemented as an extension.

4 Validation and Experiments

Usability, reliability and learnability of MWiMT have been specifically assessed in an experimental protocol, which includes: *(i)* communication task: users were requested to spell predefined sentences; *(ii)* environmental control: users were requested to perform some actions on the smart home. In order to provide a reference level to estimate accuracy and reliability, users were also involved in a BCI session with a widely validated P300-based Brain Computer Interface (the BCI2000 built-in speller). User satisfaction was measured with a visual analogue scale (VAS) at the end of each condition. Users were asked to rate their "overall satisfaction", drawing a vertical bar on a line where number 0 indicated that they were "not satisfied at all", whereas number 10 meant that they were "absolutely satisfied". At the end of each session, users were also administered with the System Usability Scale (SUS), assessing the perceived satisfaction and usability with a score ranging between 0 and 100.

Table 1 reports the results of the experimentation over three end-users. The Amyotrophic Lateral Sclerosis Functional Rating Scale - revised (ALSFRS-r) [1] is an instrument for evaluating the functional status of patients with ALS. It can be used to monitor functional change in a patient over time. Score ranges from 0 to 48 and the higher the score the more function is retained. All users were able to complete the proposed tasks; they reached on average the 95% classification accuracy with MWiMT, conversely, the accuracy achieved with the classical

Table 1. Results of the experimentation

<table>
<tr><th>User</th><th>ALSfrs-r</th><th>Device</th><th>Task</th><th>Accuracy</th><th>Satisfaction</th><th>SUS</th></tr>
<tr><td rowspan="4">User1
(F)
Age 75</td><td rowspan="3">38</td><td>P300 Speller</td><td>Communication</td><td>100%</td><td>9.7</td><td>42.5</td></tr>
<tr><td rowspan="2">Prototype</td><td>Communication</td><td>100%</td><td rowspan="2">10</td><td rowspan="2">70</td></tr>
<tr><td>Environment Control</td><td>89%</td></tr>
<tr><td colspan="6">Strong dysarthria, no experience with ATs</td></tr>
<tr><td rowspan="4">User2
(M)
Age 56</td><td rowspan="3">37</td><td>P300 Speller</td><td>Communication</td><td>100%</td><td>10</td><td>82.5</td></tr>
<tr><td rowspan="2">Prototype</td><td>Communication</td><td>100%</td><td rowspan="2">8.3</td><td rowspan="2">60</td></tr>
<tr><td>Environment Control</td><td>100%</td></tr>
<tr><td colspan="6">Slight dysarthria, motor impairment upper limbs, no experience with ATs</td></tr>
<tr><td rowspan="4">User3
(M)
Age 59</td><td rowspan="3">9</td><td>P300 Speller</td><td>Communication</td><td>95%</td><td>9.8</td><td>77.5</td></tr>
<tr><td rowspan="2">Prototype</td><td>Communication</td><td>89%</td><td rowspan="2">10</td><td rowspan="2">95</td></tr>
<tr><td>Environment Control</td><td>90%</td></tr>
<tr><td colspan="6">Severe motor disability. Residual movements: head, eyes, one finger of both the hands (very weak movements). Experience with ATs: communicator (used slowly with the finger)</td></tr>
</table>

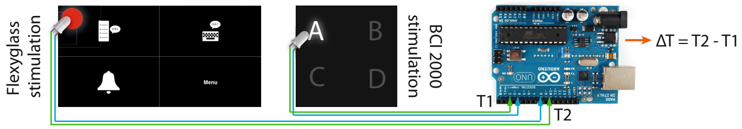

Fig. 7. The hardware platform employed for the feasibility test

P300 Speller ranged from 95% to 100% . Users expressed an high satisfaction with both the P300 Speller (values ranging between 9.7 and 10) and MWiMT (values between 8.3 and 10). The perceived usability, measured by means of the SUS, was on average 67.5 for the P300 Speller and 75 for MWiMT.

Besides the validation with the users, we performed some tests in order to analyze the visualization delay of the stimuli over the FlexyGlass layered window. The BCI2000 built-in speller is directly connected to the sequence generation allowing for the best delay between the visualization request and the effective onset of the stimulus on the screen. In our case, the stimulation sequence is transmitted using an interprocess communication channel introducing an unpredictable transmission delays. This delay is the time difference between the instant a stimulus is shown on the BCI2000 interface (taken as a "gold standard"), and that one the correspondent stimulus is shown over the FlexyGlass. A hardware test bed (Figure 7), consisting of 2 photo-transistors connected to the analog inputs of an Arduino One board, has been designed at this aim. The two photo-transitors are placed directly over the monitor screen; one over an element of the BCI2000 speller and the other one over the corresponding control of the FlexyGlass transparent window. The board is in charge of detecting light flashes onsets on both transistors and calculating the time difference.

Two experiments have been performed and results are shown in Figure 8. In both cases a sequence of 20 trials has been performed with 10 repetition of stimulus classes. During the first experiment, the BCI2000 ran directly on the tablet together with FlexyGlass and AuxiliHome. We can see how the third quartile of delay measurements are below 8.2 ms while the half of the measurements are comprised between 4.9 (first quartile) ms and 8.2 ms. During the second experiment, BCI2000 ran on a separate machine (an off-the-shelf laptop) connected via wired network to the tablet. The third quartile is now significantly higher then before (about 16 ms) while the maximum is of 51 ms.

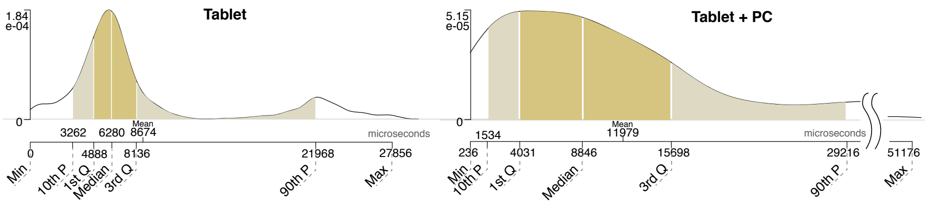

Fig. 8. Density function of measured delays (P - Percentile, Q - Quartile)

Despite the fact that our tests showed a measurable delay in the FlexyGlass stimulation, this does not impact on the P300 BCI performances. The P300 waveform shows 1 or 2 order of magnitude slower time constants, so recognition will note be affected by such a small relative time shift of the waveform.

5 Concluding Remarks

This work presented a general architecture, and the related prototype, based on a tablet device, for allowing physically impaired people to interact with the surrounding in a fully automated home environment. The proposed approach offers extensibility in terms of provided applications and input methods, and adaptivity in terms of automatic adaptation to the home automation system.

This is possible trough a specific software architecture, whose pillars are the wrapping of home appliances as Web services, a plugin approach for incorporating specifically designed applications, and the FlexyGlass component for incorporating legacy applications and allowing specific input methods requiring stimulation (such as BCIs). The FlexyGlass may be used, in principle, in combination with every kind of application (provided with a specific adapter).

We have validated our approach with real users and demonstrated, through some tests, that introducing FlexyGlass as overlay over existing applications does not degrade performances of the input methods, even in the case of BCIs.

A note should be reported about the possibility of using whichever application in conjunction with FlexyGlass. This is not completely true if the selected input method is P300 BCI. In fact P300 classification is very influenced by stimulus distribution over the screen, suffering in particular of stimulation very close one to each other. A possible way of addressing this issue could be the possibility for the FlexyGlass to automatically analysing the set of provided controls and reorganizing it using call out and subsets definition. Additionally while FlexyGlass is able to automatically detect compliant application (native or legacy), no accessible interface is currently provided to select among these applications or switch from an application to another one. A future enhancement is about the menu structure of AuxiliHome, which is currently fixed. Unfortunately, some aids provide a low information transfer rate which can potentially make a single selection expensive. Future version of AuxiliHome could provide a menu structure which dynamically evolve following user favourite selections (learnt over past executions).

References

1. Cedarbaum, J., Stambler, N., Malta, E., Fuller, C., Hilt, D., Thurmond, B., Nakanishi, A.: The alsfrs-r: a revised als functional rating scale that incorporates assessments of respiratory function. Journal of the Neurological Sciences 169(1), 13–21 (1999)
2. Cincotti, F., Mattia, D., Aloise, F., Bufalari, S., Schalk, G., Oriolo, G., Cherubini, A., Marciani, M., Babiloni, F.: Non-invasive brain–computer interface system: towards its application as assistive technology. Brain Research Bull 75(6), 796 (2008)

3. Di Ciccio, C., Mecella, M., Caruso, M., Forte, V., Iacomussi, E., Rasch, K., Querzoni, L., Santucci, G., Tino, G.: The homes of tomorrow: service composition and advanced user interfaces. ICST Trans. Ambient Systems 11(10-12) (2011)
4. Edwards, W.K., Bellotti, V., Dey, A.K., Newman, M.W.: The challenges of user-centered design and evaluation for infrastructure. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 297–304 (2003)
5. Farwell, L., Donchin, E.: Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials. Electroencephalography and Clinical Neurophysiology 70(6), 510–523 (1988)
6. Gajos, K.Z., Hurst, A., Findlater, L.: Personalized dynamic accessibility. Interactions 19(2), 69–73 (2012)
7. Hardiman, O., van den Berg, L.H., Kiernan, M.C.: Clinical diagnosis and management of amyotrophic lateral sclerosis. Nature Reviews Neurology 7(11), 639–649 (2011)
8. Helal, S., Mann, W.C., El-Zabadani, H., King, J., Kaddoura, Y., Jansen, E.: The Gator Tech smart house: a programmable pervasive space. IEEE Computer 38(3), 50–60 (2005)
9. Nielsen, J.: Ten usability heuristics (2002), http://www.useit.com/papers/heuristic/heuristic_list.html
10. Polich, J., Kok, A.: Cognitive and biological determinants of p300: an integrative review. Biological Psychology 41(2), 103–146 (1995)
11. Riccio, A., Leotta, F., Bianchi, L., Aloise, F., Zickler, C., Hoogerwerf, E.-J., Kuebler, A., Mattia, D., Cincotti, F.: Workload measurement in a communication application operated through a P300-based Brain-Computer Interface. Journal of Neural Engineering 8(2) (2011)
12. Roberts, J.: Pervasive health management and health management utilizing pervasive technologies: Synergy and issues. Univ. Computer Science 12(1), 6–14 (2006)
13. Tangermann, M., Schreuder, M., Dahne, S., Hohne, J., Regler, S., Ramsay, A., Quek, M., Williamson, J., Murray-Smith, R.: Optimized Stimulation Events for a Visual ERP BCI. Int'l. Journal of Bioelectromagnetism 13(3), 119–120 (2011)
14. Vaughan, T., McFarland, D., Schalk, G., Sarnacki, W., Krusienski, D., Sellers, E., Wolpaw, J.: The wadsworth bci research and development program: at home with bci. IEEE Transactions on Neural Systems and Rehab. Eng. 14(2), 229–233 (2006)
15. Wolpaw, J.R., Birbaumer, N., McFarland, D.J., Pfurtscheller, G., Vaughan, T.M.: Brain-Computer Interfaces for communication and control. Clinical Neurophysiology 113(6), 767–791 (2002)