MOUSE CONTROL THROUGH ELECTROMYOGRAPHY
Using Biosignals Towards New User Interface Paradigms

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Abstract: Recent technologic breakthroughs have enabled the usage of minimal invasive biometric hardware devices that no longer interfere with the audience immersion feeling. The usage of EMG to extend traditional mouse-oriented user interfaces is a proof-of-concept prototype integrated in a wider horizon project. A subset of the main project's architecture was reused, specially the communication middleware, as a stable development platform. An originally intended EEG hardware was adapted to perform EMG and therefore detect muscular activity. It was chosen, as a practical proof-of-concept, that it was desired to detect winking as a triggering device to perform a given traditional user interface action. The described application achieved extremely positive records with hit rates of around 90%. The volume of false positives and undetected desired actions are considered negligible due to both system development stage and application contextualization - non critical systems. The success and acceptance levels of the project are really encouraging not only to the enhancement of the proposed application but also to the global system continuous development.

1 INTRODUCTION

In this global scenario, the authors have defined and already started a research project precisely with the intention of using biosignals to assess user emotions and use this information to enable subconscious interaction. The contextualization of this work has numerous points of interest both in the academic community and in commercial applications. The usage of new hardware solutions and biosignals to enhance traditional user interface paradigms or even to enable new ones has managed to bring together multidisciplinary private organizations and research communities. In spite of the main project being still in an initial stage, several high-level decisions have already been taken and a high percentage of them have been either implemented or designed.

Perfectly integrated in this scope, it was decided to produce a spin-off application capable of testing the global architecture and, simultaneously, generate experimental results capable of test initial hypothesis and therefore confirm them or generate new discussion paths. The mouse control tool enabled trough EMG is a proof-of-concept project with two distinct sets of objectives.

The first encloses the goals directly related to the experimentation and test of new interaction paradigms by using innovative hardware solutions. More specifically, it is intended to trigger regular mouse interaction like right click or drag operations by detecting user winking. Once again, these defined actions have merely conceptualization purposes and can be easily altered.

The second group of objectives regards the reuse and consequent validation of the main project architecture, namely communication protocol and multiple sensors data integration. With this option, the authors are able to validate the defined approach by early producing research results.

This document is organized as follows: in the next section the current state of the art is presented, in section 3 the mouse control project is described, specially the most significant decisions are detailed and justified. In section 4, experimental results are presented and related conclusions are extracted in section 5 as well as future work areas are identified.

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2 STATE OF THE ART

Regarding the main project nature, this section is structured in three wide components, namely, hardware solutions for emotion classification, biological data format standards and dynamic interaction paradigms.

2.1 Hardware Solutions

Since the beginning of the last century that there have been efforts to correlate biological signals to emotional states (Marston, 1917). The most traditional approaches are based on the standard polygraph where physiological variables such as blood pressure, pulse, respiration and skin conductivity are recorded in order to detect different levels of anxiety. Although the polygraph lie detection accuracy is arguable, the fact that it is an efficient tool to detect basic emotional states, especially individual related, anxiety levels, is not.

The human brain always performance an almost hypnotic attraction to several research fields, so in 1912, the Russian physiologist, Vladimir Vladimirovich Pravdich-Neminsky published the first EEG (Pravdich-Neminsky, 1913) and the evoked potential of the mammalian. This discover was only possible due to previous studies of Richard Caton that thirty years earlier presented his findings about electrical phenomena of the exposed cerebral hemispheres of rabbits and monkeys. In the 1950s, the English physician William Grey Walter developed an adjunct to EEG called EEG topography which allowed for the mapping of electrical activity across the surface of the brain. This enjoyed a brief period of popularity in the 1980s and seemed especially promising for psychiatry. It was never accepted by neurologists and remains primarily a research tool.

Due to the medical community skepticism, EEG, in clinical use, it is considered a *gross correlate of brain activity* (Ebersole, 2002). In spite of this reality, recent medical research studies (Pascalis, 1998)(Aftanas, 1997) have been trying to revert this scenario by suggesting that increased cortical dynamics, up to a certain level, are probably necessary for emotion functioning and by relating EEG activity and heart rate during recall of emotional events. Similar efforts, but using invasive technology like ECoG[1], have enable complex BCI[2] like playing a videogame or operating a robot (Leuthardt, 2004).

Some more recent studies have successfully used just EEG information for emotion assessment (K. Ishino, 2003). These approaches have the great advantage of being based on non-invasive solutions, enabling its usage in general population in a non-medical environment. Encouraged by these results, the current research direction seems to be the addition of other inexpensive, non-invasive hardware to the equation. Practical examples of this are the introduction of GSR[3] and oximeters by Takahashi (Takahashi, 2004) and Chanel et al(G. Chanel, 2005). The sensorial fusion, enabled by the conjugation of different equipments, have made possible to achieve a 40% accuracy in detecting six distinct emotional states and levels of about 90% in distinguishing positive from negative feelings. *These results indicate that using multi-modal bio-potential signals is feasible in emotion recognition* (Takahashi, 2004).

There also have been recorded serious commercial initiatives regarding automatic minimal-invasive emotion assessment. One of the most promising ones is being developed by NeuroSky, a startup company headquarted in Silicon Valley, which has already granted five million dollars, from diverse *business angels*, to perform research activities (Rachel Konrad, 2007). There are two cornerstone modules, still in the prototyping phase, yet already in the market. The first is the *ThinkGear* module with *Dry-Active* sensor, that basically is the product hardware component. Its main particularity resides in the usage of dry active sensors that do not use contact gels. Despite the intrinsic value of this module, the most innovative distinct factor is the *eSense* Algorithm Library that is a powerful signal processing unit that runs proprietary interpretation software to translate biosignals into useful logic commands.

As previously referred it is still a cutting edge technology, still in a development stage, nevertheless it has proven its fundamental worth through participation in several game conferences(Authors, 2007c).

2.2 Data Formats

As an intermediate project subject, one must refer to biological data format definition. This topic is particularly important to this project due to the absolute necessity of accessing, recording and processing, eventually in a distributed system, data which origin may vary from multiple hardware solutions. The European Data Format – EDF – is a simple digital format sup-

[1]Electrocorticography (ECoG) is the practice of using an electrode placed directly on the brain to record electrical activity directly from the cerebral cortex

[2]Brain-computer interface (BCI), also called direct neural interface, is a direct communication between a brain (or cell culture) and an external device.

[3]Galvanic skin response (GSR) is a method of measuring the electrical resistance of the skin.

porting the technical aspects of exchange and storage of polygraphic signals. This format dates from 1992 and, nowadays, is a widely accepted standard for exchange of electroencephalogram and polysomnogram data between different equipment and laboratories (Kemp, 1992). This data format's implementation is simple and independent of hardware or software environments and has the peculiarity of enabling both XML and raw text definition. This duality is especially important if there is any computing power limitation and/or interoperability is a project requirement.

Although the unquestionable positive points of EDF, hardly accommodates other investigations topics. In order to overcome this critical hurdle, EDF+ is presented in 2003 as a more flexible but still simple format which is compatible to EDF that can not only store annotations but also electromyography, evoked potentials, electroneurography, electrocardiography and many more types of investigations. Its authors believe that EDF+ offers a format for a wide range of neurophysiological investigations which can become a standard within a few years (Kemp, 2003).

2.3 User Interaction Paradigms

On the pure interactive multimedia systems domain, one must refer to the growing immersion sensation provided to the audience by several factors in diverse fields. As examples of this statement one must consider the success of new generation videogame consoles that have boosted audiovisual quality and brought new interaction paradigms. Also worldwide multimedia players, like Microsoft with table computer and Apple with iPhone have invested hard in the so-called ”multi-touch” interfaces, which allow the user to move several fingers on a screen to manipulate data, rather than relying on a mouse and menus.

In spite of these advances, the mainstream entertainment industry has not changed the storyline linearity yet, but some promising research projects are trying to alter this reality. In this domain, one must refer to Glorianna Davenport's MIT Interactive Cinema Group (Authors, 2007b) that have been focusing its efforts on formal structures, construction methods, and social impact of highly distributed motion video stories.

Another recent interesting project is the apartment drama, 15-minute interactive story called *Faade* (Authors, 2007a), where two virtual characters powered by artificial intelligence techniques, allow them to change their emotional state in fairly complicated ways in response to the conversational english being typed in by the human player.

3 PROJECT DESCRIPTION

In this section both global and specific projects are described. With this intention, three subsections were designed: in the first global IT architecture is presented and depicted; afterwards the main decisions regarding the mouse control project are listed and detailed; and finally the key features of the action classifier are explained.

3.1 Global Architecture

In order to best understand the mouse control project, the main project IT design shall be considered and described as it is used and tested. The architecture's key concept regards the possibility to access biosig-

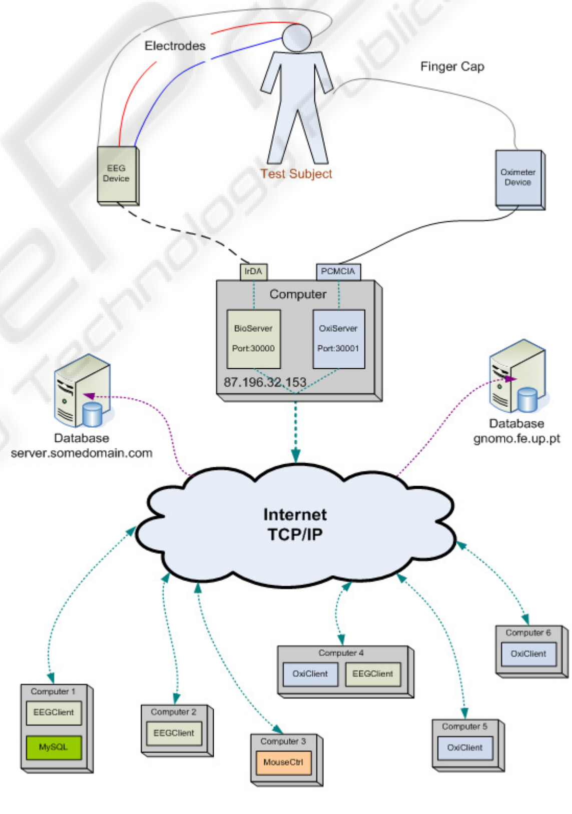

Figure 1: System Global Architecture.

nals independently of the resources physical location and nature. In other words, one must be able to read biosignals from a variety of equipments that might be connected to an arbitrary subject in a remote location without perceiving that other entities might be performing similar accesses, processing and actions.

With this concept in mind, Figure 1 is more understandable, as it shows the several project dimensions.

First, an arbitrary number and diversity of devices are connected to one or more subjects. Each device driver is encapsulated in a particular server software tool, responsible for signal diffusion, securing third-party code in a given logical compartment. These devices, as illustrated, might have distinct communication protocols but their are normalized to standard TCP/IP socket communication with a in-house developed logical protocol. Having this communication base established biosignal diffusion is possible to a wide kind of receivers that must explicitly connect to the broadcast server(s). These clients might have distinct objectives, namely signal visualization and/or processing; data storage; semantic extraction; etcetera.

3.2 Specific Decisions

Having the global system design being described in the previous subsection, the authors believed that a natural spin-off tool for proof of concept and test purposes would be materialized in a simple, yet effective, efficient and significant client application, capable of receiving realtime biosignals, process them and extract semantic information.

Two main specific decisions were taken. The first one resided in the choice of the base interaction mechanism. The decision fell to a traditional mouse hardware piece due to its simplicity and global usage. Two mouse functions/modes were selected for extension with the developed tool: right click and drag. Once the first is an operation less used than the left-click and some interaction paradigms do not contemplate it – original Macintosh machines – the second is a alternative mouse action with visual repercussions.

Regarding action classification, the authors chose *wink* detection, mainly, for three reasons: it is an action that most people are able to perform – at least with the non-dominant eye; it has a clear signal signature; and it stills remains as an unused potential interaction mechanism.

3.3 Action Classifier

The action classifier module resides its success in the correct detection of user *winking*. In order to achieve realtime high classification hit rates – and once again having in mind the concept decisions referred in the previous subsection – this module had to keep low levels of complexity without loosing its efficiency.

A signal study showed that muscular activity regarding quick *winks* had a very recognizable pattern with two consecutive signal peeks, having the second a lower strength. Figure 2 illustrates the shape of two possible consecutive *winks* delimited by the two vertical segments.

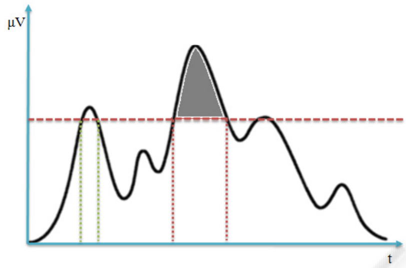

Figure 2: Classifier Parameters Appliance.

Once again keeping the approach simple enough to be enable realtime computation even in mobile devices, two distinct parameters where defined to, through signal monitoring, enable reliable action classification. These parameters were designated *peek value* and *time span* and are also visible in the referred illustration. The *peek value* can be understood as a threshold and is illustrated as the dotted horizontal line. Only signal values above this threshold are considered for further analysis. Again in Figure 2 it is visible that only to signal intervals respect this primary condition. The *time span* parameter is designed to prevent extemporary phenomenons like jitters and represent the minimum temporal interval that the signal must consistently be above the *peek value*. If a closer look is given to the reference illustration, one is able to perceive that the first *wink candidate* is discarded because its signal is too brief and only the second is valid. One important note is that either of these parameters is configurable to best fit the user natural abilities. More on this feature is elaborated in sections 4 and 5.

4 RESULTS

In this section experimental results are objectively presented. In the first subsection, experimental conditions are detailed and in the second, collected data is depicted and treated for analysis purposes.

4.1 Experimental Conditions

In order to perceive the accuracy and adequacy of the developed software tool, there were conducted several experiments. There were formed two distinct groups of subjects: one where users attended a fifteen minute theoretical formation, where the authors explained the tool's basics and how actions were detected. After these sessions, subjects had another ten minutes to free practice and to get in touch with the application. The second group of users did not have any kind of training specific regarding the presented software. Experimental subjects were randomly selected among laboratory researchers and college students, constituting two groups os user with fifteen elements.

Test sessions were similar both to trained and untrained user groups. Each session was supervised by one of the authors and each subject was asked to close his non-dominant eye ten times, as winking, whenever the subjected wanted to perform a mouse action – either it was a right-click or activate drag mode operation. Environment conditions were similar to both groups either in terms of noise, illumination and time of day.

As sessions were defined in performing a given action ten times, or equal number of actions were detected – false positives – accuracy rates have been fractioned in steps of five percent.

4.2 Collected Data

As described in the previous subsection, experiments were conducted considering two sets of fifteen subjects, one with trained elements and the other with untrained ones. The thirty sessions have been completed in on week and the collected data distribution is illustrated in Figure 3. One must clearly refer that

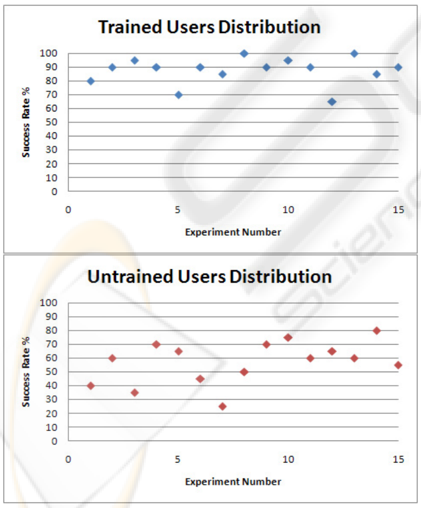

Figure 3: Experiment Result Distributions.

the trained users group has a greater performance with an average success rate of around ninety percent, minimum values of sixty-five and registry error free sessions. If we consider the untrained set, the average rate drops to less than sixty percent with lower bounds of twenty-five and maximum values of eighty percent.

These result distributions were translated into histograms, for analysis purposes, as visible through Figure 4. If a deeper study is conducted, one must refer that eighty percent of the trained subjects registered three or less errors. On the other hand, the untrained user group results are more distributed, although they are slightly concentrated in success rates between fifty-five and seventy percent.

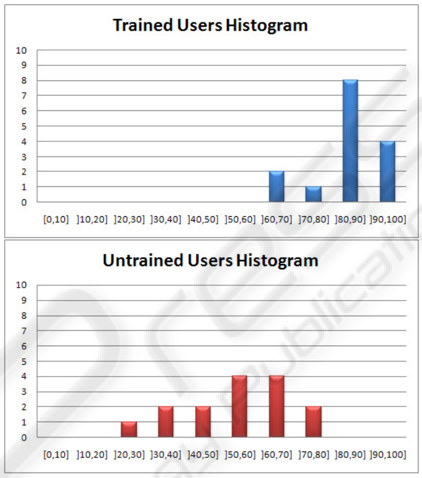

Figure 4: Experiment Result Histograms.

5 CONCLUSIONS

In this section, extracted conclusions are presented and future work topics are identified. Regarding the first theme, one must state that the objectives depicted at the beginning were completed achieved. In what concerns to the main project goals, the communication protocol was successfully tested, the IT architecture was used and validated and it was proved the versatile equipment usage, once again, sustaining the defined structural design. The specific project goals were also accomplished as it was proved the concept of utilizing biosignals to control interaction facets, even when this case study is merely a proof of concept.

Another important conclusion is the need of distinguish trained users from untrained ones, when considering the tool's usability values. One ought to refer that previous contact with the concept allied with a few minutes of practice enhances the software utilization success rates. However, even the untrained group of users has registered fair results. These can be rated as more than acceptable if one considers the whole project's intention.

Considering only the classification engine, a registered positive key point is the system ability to distinguish user winking from user blinking, especially if user specific parameterization is considered. However, even if this last feature is discarded, the default parameter values are sufficient to discard weaker signals that, with high probability, refer to blinking.

Despite the enunciated positive features and conclusions, there were identified some issues, namely the existence of false-positive results that refer to other user muscular activity. These faults are included in the numbers presented in section 4 and are, in most cases, related to sudden and wide head movements. On the other hand, some *winks* are not detected as it is necessary some *vigor*. However, this issue, as referred, can be suppressed by tuning classification parameters. At last, some minor occasional, application stability issues were detected, especially in what concerns the mapping between *wink* detection and action triggering, mainly due to the tool's lack of maturity. This last issue is development-oriented and does not have a negative impact in what concerns the main project's concept.

5.1 Future Work

The main future work topics are not related to this particular tool, once it is a proof of concept one, but rather with the main global project. With this in mind, there were identified the following areas:

- Reading Hardware Diversity Reinforcement: It is intended to handle a greater number and diversity of devices capable of acquiring biosignals so that information fusion, conjugation and complementary is possible;
- Semantic Leap: It is intended to use syntactic information – biological signal – to extract more complex information like emotions and simple commands;
- Software Control: The accomplishment of the previous item would enable both conscious and subconscious control of several tools and/or multimedia contents;
- IT Architecture and Network Reinforcement: Full-duplex data transfer would enhance user training and system adaptation levels.

Considering the main project's intentions and the future work topics referred, diverse practical applications come into sight. Some of them might be the videogame and virtual entertainment industry, multimedia contents adaptability, user interfaces enhancement, direct advertising, medical applications, namely in phobia treatments and psychological evaluations.

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