ISSN 1870-4069

Towards a Method for Biosignals Analysis as Support for the Design of Adaptive User-Interfaces

Heber Avalos-Viveros[1], Guillermo Molero-Castillo[1,2], Edgard Benitez-Guerrro[1], Everardo Bárcenas[1,2]

[1]Universidad Veracruzana, Xalapa, Veracruz, Mexico
heeber.av@gmail.com, edbenitez@uv.mx
[2]CONACYT−Universidad Veracruzana, Mexico
{ggmoleroca, iebarcenaspa}@conacyt.mx

Abstract. Biosignals are information sources obtained from the different biological and physiological structures of the human organism. This paper presents the advance of the proposal of a method for the biosignals analysis, which allows serving as support for the design of adaptive user-interfaces. This method includes four stages: biosignals collection, extraction and preparation, analysis, and getting patterns. This analysis and obtaining of user patterns through the biosignals could be especially useful because they represent valuable information related to events or actions of user behavior, which could be incorporated in the stage of requirements specification for the design of adaptive user-interfaces, and even serve for the refinement of these.

Keywords: Biosignals, Adaptive user-interfaces, Data mining, User requirements.

1 Introduction

In recent years, the technological development has allowed obtaining data sources through different devices, as brainwave diadems, smartwatches, smartphones and even by other body sensors. This in order to obtain biosignals generated by the human body [24]. These devices have processing capabilities, which make it possible the continuous collection of data flows about users and their environment, as interactions, locations, physiological states, contact with other users and other digital traces [27].

In this context, biosignals could be collected into different frequencies, with or without intervention human, and for prolonged periods [28]. Nevertheless, it requires a series of analytical considerations, beginning with careful experimentation to ensure the analysis and design of a case study, participant training, and data storage [27].

Therefore, through these biosignals, we try to know the human behavior related to events, that is, through the analysis of data we could discover certain events inherent in the user and their environment [8]. Through this type of analysis, data patterns related to the user could be obtained through the application of data mining techniques, as clustering, association rules, decision trees, Bayesian networks, among others.

For example, a case of special interest that is addressed in this research is to find a way to capture, process and analyze biosignals of the user in order to obtain information of interest, known as patterns, for the design of adaptive interfaces. These user data patterns can serve as support information for the design of adaptive user-interfaces of a particular system.

However, to have truly adaptive interfaces is necessary to acquire diverse information about the user, as your preferences, needs, features and software interests [14]. This represents a research challenge in human-computer interaction (HCI) for the detection and analysis of biosignals, reliably, related to human behavior events [15].

One of the current approaches to the capture of biosignals is through low-cost devices, as a) Emotiv Epoc, for the capture of brainwave signals through a multichannel electroencephalogram (EEG), b) smartwatches, to measure heart rates, and c) smartphones, for measure and control cardiac pulses through optical sensors, like the electrocardiogram. At present, these devices have a wide range of applications in HCI and interfaces customization [15]. Therefore, as part of this research, we have the intention to collect biosignals through this type of devices, which could be a complex task due to the noise of the signal [3].

This paper presents an advance of the proposal of a method for the biosignals analysis as support the design of adaptive user-interfaces. This method is divided into four phases: a) collection, b) extraction and preparation, c) analysis, d) getting patterns. It is sought that the information obtained from the user, through the biosignals analysis, could be useful as a support for the definition of requirements in the design of the adaptive interfaces. Since this is usually a complex task because it is needed translate the software needs of the users into a functions set and restrictions.

2 Background

2.1 Biosignals

A signal is a form of data transmission, the acquisition of which allows obtaining information about the source that generated it. In this sense, acquisition sources of biosignals are the different biological and physiological structures of the human body organism [13]. The representation of the biosignals facilitates the analysis and identification of the data. The main aim of the processing and analysis of these signals is the information acquisition, diagnosis, monitoring, therapy, control, and evaluation [22].

The capture of these biosignals allows us to extract information about the functioning of the different organs [13]. In the biosignals, amplitude and frequency ranges are considered as significant factors [10]. These ranges may vary depending on the method of acquisition, whether through brainwave diadems, smartwatches, smartphones, among other devices, and their values are approximate, whether they are normal or out of range. Figure 1 shows a conceptual representation of the extraction and analysis of biosignals in order to serve as support information in the definition of requirements for the design of adaptive user-interfaces.

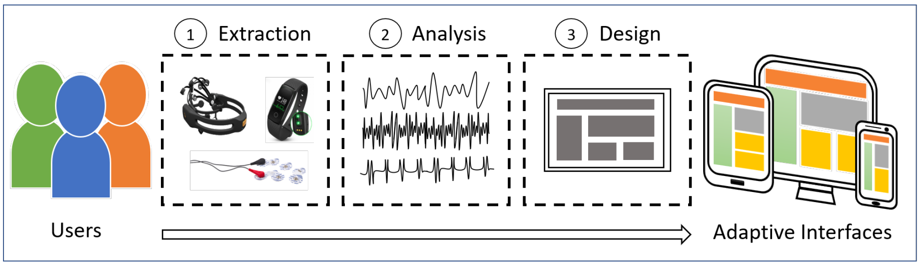

Fig. 1. Conceptual representation of acquisition and analysis of biosignals.

Given the variety of biosignals, nowadays, there are at least three ways to classify them [13]: by their existence, nature, and origin. By its existence: a) permanent, which exist without any artificial impact, or excitement; b) induced, which are triggered artificially, excited or induced. By its nature: a) quasi-static, that transports information in its stationary state that can exhibit relatively slow changes with time; b) dynamics, which produce large changes in the time domain. By its origin: a) electrical, such as the nervous system and muscle cells; b) magnetic, such as the heart, the brain, the lungs, among others; c) mechanical, such as movement, displacement, tension, force, pressure and flow; d) optic, which is generated from the optical attributes of biological systems; e) acoustic, blood flow, muscle noises; and f) chemical, which contain information about the levels and changes of chemical agents in the body.

2.2 Interfaces

Before 1960, the term user interfaces was practically non-existent. Later, in 1963 Ivan Sutherland published, in his PhD thesis, the creation of graphic images directly on a screen using an optical pencil. It was the appearance of the first graphical user interface [17]. Then, in the early 1960s, Douglas Engelbart and William English worked on a project on a new control device, which was the first mouse. Also, in 1968 Engelbart presented a system that was the first to incorporate hypertext, windows, document control and teleconferences.

On the other hand, in the 80s, the evolution of HCI became a field of user-centered research [12]. This field of knowledge studies the design, evaluation, and implementation of interactive technological devices, where technology happened to become a support tool [2].

Nowadays, user interfaces are the part of the system that is seen, heard and felt. They are the means by which the user can communicate with a device or computer. This way, HCI takes place through the user interface, which consists of interaction through a screen, keyboard, mouse, speaker, special buttons, lights, gloves that can feel the movements of the fingers, eye sensors, among others [11].

In this sense, adaptive interfaces are those that adapt automatically to the characteristics of the users, allowing the improvement in the satisfaction and permanence of the user interacting with the system [21]. Current trends are towards systems for the recovery and refinement of information [16], this depending on the interaction patterns that allow adapting the results through adaptive interfaces. However, at present it is sought interfaces that may be understandable, seeking greater effectiveness when performing certain tasks [21]. For this, we seek to define new support methods for the development of adaptive interfaces in terms of user-centered design.

2.3 Current Challenges

Nowadays, the biosignals analysis has an increase in the different fields and applications. The interest consists in analyzing physiological measurements [23]. Among the limitations are the problems of handling large amounts of data, noise and other factors that affect cognitive states [26].

This situation leads to various research challenges that are classified as technical and usability [1]. The technical challenges are related to the obstacles of the system, especially in the obtaining of signals, since the data obtained are not shown linearly, but dynamically with varied ranges and frequencies and with noise in the signals. Usability challenges describe the problems that affect the level of acceptance and express limitations that users face when using technology.

In the case of biosignals processing, it requires at least three states [4]: a) measurement (biosignals acquisition), b) transformation (redundancy elimination and noise), and c) interpretation (logical base, heuristic reasoning, and statistical origin). To realize these stages requires effort, not only by the biosignals analyst but also by the users, since the changes in mood can trigger unreliable data records.

Another challenge is the selection of an adaptive channel for users, and thus have appropriate interfaces according to the needs for each of these [14]. Here, the environment has an important role when signals are captured to avoid noise and high ranges [3]. Unfortunately, there are noise problems at the time of signal acquisition.

On the other hand, in the context of user interfaces, the search for new interfaces is associated with technological advances. This is because of every day the number of users with different training, social level and abilities increases [19]. Therefore, there is a greater willingness to use new technologies. This situation represents a challenge for the HCI, which must keep pace with these advances and make the most of the technologies to be made available to users [2].

In this sense, the construction of user-interfaces that are easy to use, easy to memorize, efficient in terms of use and with a low error rate represents another important challenge [6]. Therefore, it is important to involve the user from the early stages of the construction process, considering aspects of interest, as the tasks, its interests, preferences, and even its physical limitations.

2.4 Related Work

At present, there are several works that seek to provide new mechanisms and applications that allow analyzing the behavior of users in certain contexts and thus develop new tools and interfaces in HCI.

In [7] the authors looked for a way to design adaptive interfaces through the biosignals analysis obtained from the human body. For this, they used functional near-infrared spectroscopy (FNIRS). This technology allowed recording changes in blood oxygenation in the brain is a non-invasive way and to obtain measurements in environments with lots of light and noise. By analyzing some interfaces, it was possible to measure the workload of the users when performing certain tasks. Two types of users were used, those who had knowledge about the operation of the interface and those who did not have prior information. The results determined that 90% of users with knowledge about the interface presented less workload compared to those who did not have knowledge. With this, the authors determined that the functioning of an interface could be measured through FNIRS.

Another approach to the design of adaptive user-interfaces was proposed by [15],where they developed a framework that allows acquiring related information about the interests and profiles of users. They place special emphasis on the design of adaptive user-interfaces for people with some type of limitation, that is, due to cerebrovascular accidents or aging, in order to improve accessibility problems in this type of users.

In [9] the biosignals collection was sought, but in a multimodal context, that is, acoustic signals (ACC), electromyography (EMG) and electroencephalogram (EGG) were used. The authors designed a framework for obtaining of signals through various devices at the same time. The objective was to create a tool for the collection, storage, and visualization of the signals obtained from the devices, this in order to analyze them based on possible relationships and dependencies between them. To later be used in the development of adaptive interfaces.

In [3] they used electroencephalography (EEG) signals from a point of view of experimental psychology and cognitive science. They focused on this type of signals because there are currently low-cost devices compared to traditional devices used in the field of Health. For this, they used Emotiv EPOC device, which allows obtaining information through brain waves. Two studies were done, one to determine the feasibility of using Emotiv EPOC to measure interhemispheric spectral differences, and another to analyze variations in cerebral activity. The results showed that, for the first case, the data obtained were sufficiently clean, which allowed revealing characteristics of interest through the EEG, while in the second case the variations in the signals were demonstrated by physical stimuli of the user.

In [20] the possibilities of using biosignals processing in real time were explored. This to improve the interaction with the user-interfaces. The analysis of an interface was made through an intelligent agent, who oversaw asking the user questions in order to know their reactions through eye signals and brain waves. The results obtained allowed to know the physical reactions generated by the user, this allowed to reflect and adapt their behavior according to the user's emotions.

In [5], the evaluation of adaptive user-interfaces was sought, taking into account the emotional state and workload of the user when interacting with these. For this, monitoring devices were used that allowed to capture physiological signals of the human body, such as eye-tracking and brain waves through Emotiv EPOC. The study focused on measuring the time it took the user to use an interface with certain tasks, as well as measuring the number of errors that arose at the time of their interaction. These tasks were carried out through three interaction mechanisms: a) toolbar, b) menus, and c) interactive bar, named Boulevard. The results determined that the user had a good acceptance and little workload when using the proposed interaction style (Boulevard). Therefore, they demonstrated that the use of physiological signals measuring devices could be of great help to know the behavior of the user with certain user interfaces.

Finally, in [29], the authors sought to provide a graphical user-interface as an expressive channel to represent the artistic qualities of several users with a disability. They presented special attention in the design of the interface, whose input data were biosignals type electromyography (EMG), electrooculography (EOG) and electroencephalography (EEG). For this, they used a mechanism through which the biosignals were acquired, then the data processing was done, where to mitigate low signals and with noise, was used the mathematical method called Lorenz System. Thus, through the results obtained from various tests with users, with and without disabilities, they were able to determine that, through biosignals as data entry in the interfaces, it was possible to execute actions in the application; in this case they used predefined data to model a vase, and then design one freely.

3 Method

In order to obtain reliable biosignals data sources, as support for the design of adaptive interfaces, four work stages were defined, shown in Figure 2. These stages are exploratory and applied type since it is an emerging issue that seeks to solve the problem through a theoretical-practical exploration.

In the first stage, the beginning of the research is proposed, which is fundamental to obtain reliable data sources that support the analysis of biosignals obtained from physical and logical sensors, with the purpose of measuring physiological signals of the users. The second stage focuses on the analysis and conceptual design of the solution proposal for obtaining and analyzing biosignals. The third stage is the development of the analysis method associated with the study case. The fourth stage focuses on the evaluation of the biosignals analysis

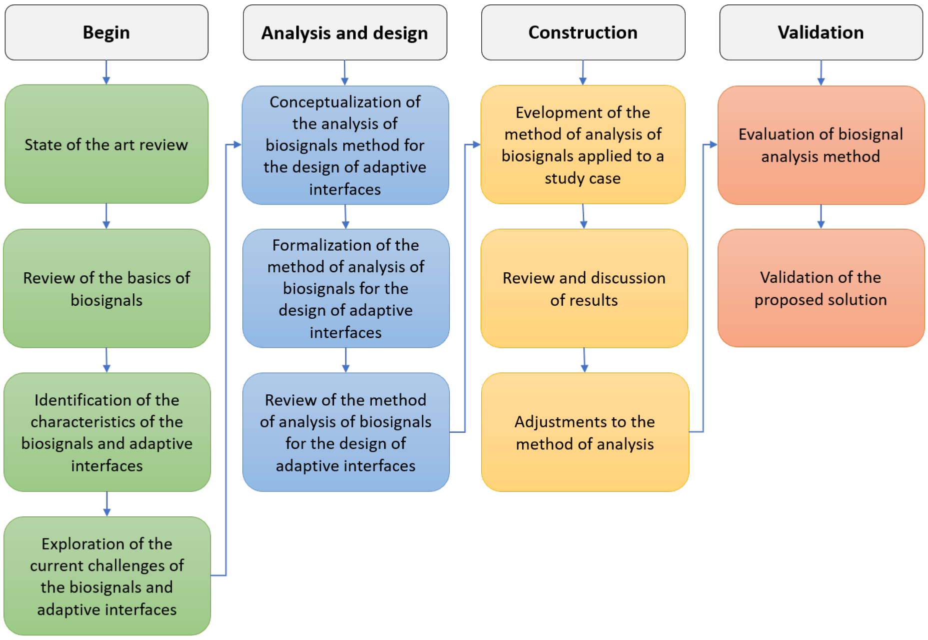

Fig. 2. Method of work for the development of the research proposal.

method, from the point of view of performance and compliance with the initial requirements and objectives.

4 Proposal

The analysis and design of user-interfaces is a complex process since the requirements and needs of the users must be known, to whom the interface is addressed [7, 15]. Currently, to identify these requirements and needs of the users, conventional techniques are used [18], as documentation analysis, observations, interviews, quizzes, mind maps, brainstorming, sketches, prototypes and other instruments of interest.

However, the previous techniques may not be enough, due to poorly used the development tools and methods by software developers [25]. Therefore, an adequate understanding of the user's requirements is of great importance, in this way, it is fundamental to consider other aspects of the users, such as: their interests, preferences and even affective states, as well as the development environment and the available technologies.

Based on the above, this research project seeks to design a method to extract and analyze biosignals data obtained from users, with the purpose of using this information as support in the design of adaptive user-interfaces. The reason for obtaining and analyzing biosignals is that they represent valuable information related to events or actions of user behavior. For this, as a method four stages of work are proposed (see Figure 3) a) biosignals collection, b) extraction and preparation, c) analysis, and d) getting patterns.

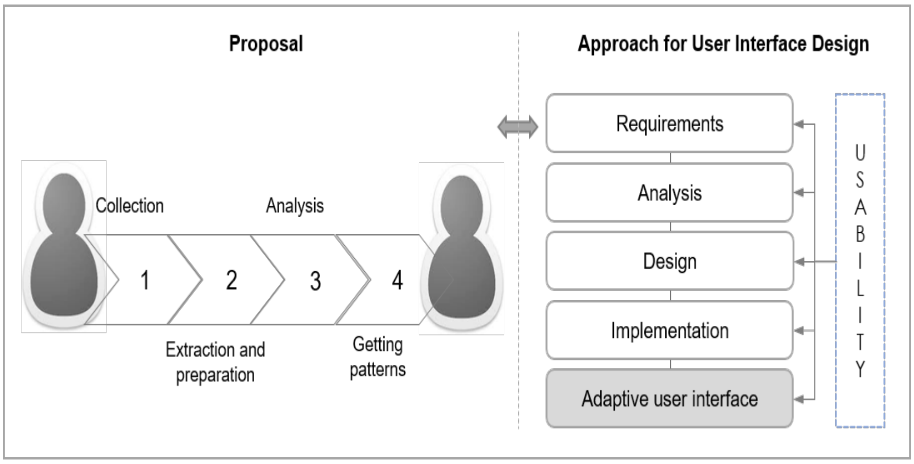

Fig. 3. Conceptual design of the biosignals analysis method.

The collection (phase 1) involves the use of devices to capture the EEG type biosignals and cardiac pulses, either through brainwave tunes, smartwatches and even by body sensors. Once the acquisition devices have been defined, it must be defined a data capture strategy, for this, it is suggested to deliver to the users a letter of consent and a fact sheet with the activities that must perform on a specific user-interface. For the execution of activities, it is recommended to use the guided tasks method, that is, the participants will be dictated aloud to tasks they must perform. As part of the strategy, it is also suggested recording the tests in order to monitor the interaction of users with the application. This with the purpose of finding usability problems in the user interface.

In the extraction and preparation (phase 2) a selection of data is made to obtain a base source of biosignals on which subsequent analyzes will be made. This selection and preparation are made because a large amount of data is commonly collected, whose measurements contain noise and atypical values, which need to be filtered, deleted and even transformed for the application of a particular technique. In addition, this type of biosignals are registered in small timestamps as seconds and milliseconds, and even in nanoseconds. Subsequently, to eliminate redundancies and possible high dimensionalities it is advisable to do an analysis of correlations and dispersion of the data.

Biosignals analysis (phase 3), apart from statistical measurements as mean, standard deviation, variance, covariance and other interest estimates, seeks to identify patterns in the data, which were previously extracted and prepared. This patterns identification is done through the use of one or more data mining techniques, as clustering (hierarchical and partitional), association rules, correlations, regressions, decision trees, and artificial neural networks. These patterns represent a set of interest characteristics about the users evaluated, as tastes certain colors, sizes, format styles, presentation and other aspects of interest.

Subsequently, through the getting of patterns (phase 4), it is sought to interpret the patterns of users previously identified. The preferences of the users about a certain type of interface are described, as colors, text size, size of the icons, the position of the elements and other characteristics of interest. This information from users could be especially useful as part of the definition of requirements in the analysis and design of adaptive interfaces. Since the definition of these requirements is usually a complex task because it is necessary to translate the software needs of users into a set of functions and restrictions.

In this sense, considering the approach of developing adaptive user-interfaces (requirements specification, analysis, design and implementation), the analysis of biosignals is intended to support the first stages of development, such as requirements specification, analysis, and design. In addition, these could be refined by the biosignals. Consequently, biosignals could be useful not only for the development team but also for the user for whom the interface is intended. Therefore, it is sought through the biosignals analysis to serve as a support mechanism for the design of adaptive user-interfaces.

5 Conclusions

Technological advances in recent years have allowed the implementation of new mechanisms for the design of adaptive user-interfaces, which seek to cover a greater degree of satisfaction of users when interacting with them. Currently, various techniques are used for the analysis and definition of requirements, which allow the construction of prototypes that could be evaluated and determine changes or improvements to the system, which is a practical method that results in an executable software model.

Another practical way to include valuable information in the specification of requirements is through the analysis and understanding of biosignals obtained from users. For its capture, diverse devices exist that allow monitoring their behavior related to the events. For this reason, it is important to consider new mechanisms to find useful information to support the design of adaptive interfaces.

As part of the research, this document showed the advance of the design of a method for the analysis of biosignals as support for the design of adaptive user interfaces. This method consists of four stages: a) biosignals collection, b) extraction and preparation, c) analysis, d) getting patterns. This proposal could be especially useful because the information obtained from users could be incorporated into the requirements specification phase of adaptive user-interface design.

As future work of this proposal, it is contemplated to make a practical experimentation on the biosignals analysis to a group of users. The objective is to make an incremental and systematic development of the proposal of extraction and analysis of biosignals as support for the design of adaptive user-interfaces.

Acknowledgments. This work was partially supported by the National Council of Science and Technology (CONACYT) of Mexico, as part of the project Cátedras CONACYT "Infraestructura para agilizar el desarrollo de sistemas centrados en el usuario" Ref. 3053. The first author was also supported by CONACYT through a MSc. scholarship, Ref. 629916.

References

1. Abdulkader, S.N., Atia, A., Mostafa, M.S.M.: Brain computer interfacing: Applications and challenges. Egyptian Informatics Journal 16(2), 223–226 (2015)
2. Acosta, A., Zambrano, N.: Importancia, problemas y soluciones en el diseño de la Interfaz de Usuario. Universidad de Oriente (2006)
3. Burnet, D.H., Turner, M.D.: Expanding EEG research into the clinic and classroom with consumer EEG Systems. Georgia state university (2017)
4. Cuenca, J.N.: Informática médica: Análisis de bioseñales (2008), `http://slideplayer.es/slide/4617122/`
5. Eichler, Z.: Towards Multimodal Adaptive User Interfaces. Ph.D. thesis, Masarykova univerzita, Fakulta informatiky (2014)
6. Fernández, M.J., Ullate, J.M.A., Salvador, J.A.: Interfaces de usuario: diseño de la visualización de la información como medio de mejorar la gestión del conocimiento y los resultados obtenidos por el usuario. In: Actas del V Congreso ISKO-España. pp. 42–54 (2001)
7. Girouard, A., Solovey, E.T., Hirshfield, L.M., Peck, E.M., Chauncey, K., Sassaroli, A., Fantini, S., Jacob, R.J.: From brain signals to adaptive interfaces: using fnirs in hci. In: Brain-Computer Interfaces, pp. 221–237. Springer (2010)
8. Hayes, G.R.: Knowing by doing: action research as an approach to hci. In: Ways of Knowing in HCI, pp. 49–68. Springer (2014)
9. Heger, D., Putze, F., Amma, C., Wand, M., Plotkin, I., Wielatt, T., Schultz, T.: Biosignalsstudio: a flexible framework for biosignal capturing and processing. In: Annual Conference on Artificial Intelligence. pp. 33–39. Springer (2010)
10. Kaniusas, E.: Fundamentals of biosignals. In: Biomedical Signals and Sensors I, pp. 1–26. Springer (2012)
11. Lauesen, S.: User Interface Design: A Software Engineering Perspective. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA (2005)
12. Marcos, M.C.: Hci (human computer interaction): concepto y desarrollo. El profesional de la información 10(6), 4–16 (2001)
13. Martínez, J.G.: Ingeniería biomédica. Universidad de Valencia (2004)
14. Moro, R., Berger, P., Bielikova, M.: Towards adaptive brain-computer interfaces: Improving accuracy of detection of event-related potentials. In: Semantic and Social Media Adaptation and Personalization (SMAP). pp. 34–39. IEEE (2017)
15. MyUI: Basic concepts relevant for creating an adaptative myui application (2017), `http://myuidocumentation.clevercherry.com/overview/basic-concepts`
16. Narayanan, S., Koppaka, L., Edala, N., Loritz, D., Daley, R.: Adaptive interface for personalizing information seeking. CyberPsychology & Behavior 7(6), 683–688 (2004)

17. Patrick, E.: Intelligent User Interfaces: Introduction and Survey. Delft University of Technology (2003)
18. PMOinformatica: Tecnicas de levantamiento de requerimientos software (2016), http://www.pmoinformatica.com/2016/08/tecnicas-levantamiento-requerimientos.html
19. Porta, M.: Human–computer input and output techniques: an analysis of current research and promising applications. Artificial Intelligence Review 28(3), 197–226 (2007)
20. Prendinger, H., Mori, J., Mayer, S., Ishizuka, M.: Character-based interfaces adapting to users' autonomic nervous system activity. IEICE Transactions on Information and Systems E0-D, 1–6 (2003)
21. Salazar-Ospina, O.M., Rodríguez-Marín, P.A., Ovalle-Carranza, D.A., Duque-Méndez, N.D.: Interfaces adaptativas personalizadas para brindar recomendaciones en repositorios de objetos de aprendizaje. Tecnura 21(53), 107–118 (2017)
22. Sánchez-Morillo, D.: Procesado y transmisión de señales biomédicas para el diagnóstico de trastornos y enfermedades del sueño. Ph.D. thesis, Universidad de Cádiz (2008)
23. Schmidt, A.: Biosignals in human-computer interaction. interactions 23(1), 76–79 (2015)
24. Shahmohammadi, F., Hosseini, A., King, C.E., Sarrafzadeh, M.: Smartwatch based activity recognition using active learning. In: Connected Health: Applications, Systems and Engineering Technologies (CHASE). pp. 321–329. IEEE (2017)
25. Sitou, W., Spanfelner, B.: Towards requirements engineering for context adaptive systems. In: Computer Software and Applications Conference. 31st Annual International. vol. 2, pp. 593–600. IEEE (2007)
26. Vartak, A.: Biosignal Processing Challenges In Emotion Recognitionfor Adaptive Learning. Ph.D. thesis, University of Central Florida (2010)
27. Voida, S., Patterson, D.J., Patel, S.N.: Sensor data streams. In: Ways of Knowing in HCI, pp. 291–321. Springer (2014)
28. White, F.: Data fusion lexicon. In: data fusion subpanel of the joint directors of laboratories technical panel for C3. pp. 1–13 (1991)
29. Wu, L., Akgunduz, A.: User interface design for artistic expression based on biosignals: An eeg feature extraction method based on weak periodic signal detection. In: Innovative Design and Manufacturing (ICIDM), Proceedings of the International Conference on. pp. 5–10. IEEE (2014)