E-LEARNING MULTIMODAL SYSTEM FOR TEACHING AND LEARNING PROGRAMMING

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ABSTRACT

The high failure rates and abandonment are common in introductory programming courses in many higher education institutions worldwide. Different solutions have been proposed in literature trying to solve the problem but the situation remains virtually unchanged. Some members of this group also contributed with computer-based tools and different studies to understand and reduce this problem. Among the works carried out, the importance of investing in motivational aspects and the ability to solve problems is highlighted. This paper describes a new approach in order to contribute in solving this problem. The idea is to investigate the psychophysiological response of individuals during testing. The goal is to measure aspects of interest like the ability of abstraction, emotions, concentration, frustration, immersion, load/stress and cognitive level, in complex scenarios such as the resolution of programming problems. Thus, we intend to use new forms of interaction as Brain Computer Interfaces (BCI), eyetracking and other low-cost instruments (e.g.: BITalino) using body signals to extract information of interest. This information will be included in an e-learning system adapting its interface according to the users actions.

KEYWORDS

Brain Computer Interfaces; Human Computer Interaction; Neuropsychological Assessment; Cognitive abilities; Programming Learning; Adaptive systems.

1. INTRODUCTION

High failure and dropout rates are common in introductory programming courses in many high education institutions worldwide [2, 3, 6, 7, 8]. This is a situation that affects mostly freshmen as those courses are usually placed at the beginning of the curricula [3]. Many causes for the learning difficulties have already been identified. [2, 7, 8]. Different solutions have been proposed in literature, but the situation remains mostly unchanged, as many students continue to struggle with basic programming. Our research group started its work in Computer Science Education Research with the development of some visualization tools intended to help students in their early programming stages [9]. Research in this field includes efforts in several areas, from psychological studies to computer-based tools. Our current research focuses on student understanding mainly the mental and conceptual models that students have about a particular subject matter and their conceptions and misconceptions about it.

The first phase of this work intends to acquire measurements on aspects of interest (emotions, concentration, frustration, load/stress, cognitive level) in complex scenarios such as solving programming problems. To this end we intend to use new forms of interaction such as Brain-Computer Interface (BCI) and other low-cost instruments (e. g.: BITalino) using body signals to extract information of interest. BCI research seeks to develop an alternative communication channel between humans and machines, which implies no muscular intervention in the communication process. These devices determine the intent of the user from scalp-recorded electrical brain signals (EEG - Electroencephalogram) or from electrodes surgically implanted on the cortical surface (ECoG- ElectroCorticoGraphy) or within the brain (neuronal action potentials or local field potentials) [1]. These signals are translated into commands that operate a computerized application. Despite advances in this research field the BCI systems are still presenting several challenges that can be resumed in: Usability, Accuracy and Speed. Many factors determine the performance of a BCI system, among them is the quality of the brain signals, the methods used to extract signal information and the output applications. A BCI device must take into account all of these factors to provide a reliable performance [5]. The traditional BCI system has two distinct stages. The first one is the training stage, where mutual adaptation of the BCI system and the user is performed. During this stage, the BCI parameters are tuned based on specific training scenarios. The second stage corresponds to the normal functioning of the BCI, termed as the on-line stage, where the BCI parameters are fixed. However the EEG signals are non-stationary, their statistics can suffer significant changes over time, and periodic calibration of the system may improve its reliability. In order to address these issues, the key characteristic of the BCI is its adaptability. The BCI system must be able to identify malfunctioning events (for example accumulation of errors in interpreting the user intentions) and provide a way to correct them [5]. A new adaptive BCI architecture is used which can switch back to the training stage in order to adapt the BCI parameters in malfunctioning situations. We intend to use this kind of BCI systems to build an adaptive e-learning system modifying its contents, navigation and interface according to the user needs. This project includes a body of research, development, implementation and testing translated into a set of steps described below.

2.1 PHASE1 - EXPERIMENTAL PROTOCOL ELABORATION AND SETUP ASSEMBLY

Previous studies show that engineering students have great difficulties in solving problems. Mainly the difficulty in abstract thinking, necessary for learning programming. The Neuropsychological Assessment plays an important role in the diagnosis of problems at the level of development and learning. One of its prominent areas is the study of executive functions. The problem being investigated is the study of brain and body functions that may provide useful indicators (of cognitive, mental, emotional and other states). These could be used for the implementation of new strategies in order to minimize the difficulties presented by the students while programming. Thus, we intend to measure what is happening with the user and determine how specific parts of the brain or other body elements can measure different functions [1, 10]. This study involves the testing and studying of intended functions, in order to find patterns that measure the ability of individuals to formulate abstract principles, emotional states or other cognitive elements of interest based on the feedback received after each test. Another problem identified in previous studies is the lack of motivation that students show when having to learn to program. This phase includes the creation of a set of experimental protocols that will allow us to verify the learning performance and motivation of the users for programming learning. In a first approach we will consider several types of signal acquisition devices, with different types of nature, in order to acquire the maximum cognitive features possible. The signal acquisition devices used are: EEG signal acquisition devices, Video signal acquisition devices and software to obtain keyboard and mouse input data. EEG signal acquisition devices will allow extracting very important parameters such as excitement or frustration levels, attention, sleepy or stress conditions. Video information will allow us to detect facial expressions and eye tracking information useful to infer the level of attention and focus of the user. Keyboard and mouse input information give us details of the users input patterns.

2.2 PHASE 2 - SIGNAL ACQUISITION AND DATA BASE CREATION

In this phase, we aim to develop a number of individual tasks that involve cognitive abilities; which underlie the complex task of general computer programming. Programming involves attention, abstract reasoning, problem solving, decision making, and error monitoring, among others. Our aim is to make EEG recordings while participants are performing these tasks. The EEG will then be processed offline with various advanced signal-processing techniques in order to identify the psychophysiological signatures of these processes. These electrophysiological features of the EEG can be later used in a BCI to help monitor brain processes involved in computer programming. All tasks will be programmed using the experiment generator software E-Prime. We will use standard psychological tasks, which are known to involve the aforementioned cognitive abilities and to elicit specific event related potentials (ERPs), which, among other EEG features, can also be used to identify certain brain processes. At the end of this phase we intended to have a Database with the synchronization of the following signals: an EEG signal, a video signal and a Keyboard/mouse input data.

2.3 PHASE 3 - SIGNAL ANALYSIS AND FEATURE EXTRACTION

The main goal of this phase is to develop techniques and methods of signal processing analysis. The implementation of a filtering routine for removing artifacts based on a signal processing methods in order to clear any previously collected EEG will be done. A standard technique based on Singular Spectrum Analysis (SSA) with zero delay will be used. The study of signal processing methodologies for the analysis of ERP signals in order to characterize them quantitatively and qualitatively will be done. Induced potentials represent transient components in the electroencephalogram generated by responses to a sensory stimulus. To make the evoked potential signal visible, a large number of single trial responses are needed to carry out an average of the set to obtain the activity associated with a given condition. Therefore, for the study of evoked potentials it is necessary to consider signals representing different levels of analysis: the single trial segment, the average set and the large average. Different signal processing techniques are used in this study. At the end of this phase we intended to have the EEG signal characterization. We also expected the interpretation of brain regions activated in EEG and possible patterns of distinct activation.

2.4 PHASE 4 - EXPERIMENTAL PROTOCOL VALIDATION AND THE SIGNAL PROCESSING METHODS

The main objective in this task is to develop an adaptive system based on BCI and HCI. BCI is used to provide information on the learning capabilities of the user. After we identify the different patterns that occur in the electrical brain activity on different learning performances we will use these patterns to build a learning system that will adapt to the abilities of the user. To build this system we will start to develop a typical BCI system that identifies the specific patterns discovered in the previous tasks. As outputs of the BCI we will provide ways to improve the learning abilities of the user, providing for instance tips on how to solve the problem. This BCI system will have the following structure:

- Signal acquisition: one of the main concerns in this project is to build a system that will be easy to use, however the typical EEG acquisition devices are non-portable and have long lasting setup time. We will test several EEG signal acquisition devices trying to find a good compromise between portability and signal quality. - Filtering: in this step we will use several methods like spatial filtering, surface Laplacian filtering, Common Average Reference, Kalman filtering among other methods that can be more suitable.
- Feature Extraction: as features we will use the results obtained in task 3.
- Feature Classification: in this phase we intent to classify the patterns in the several possible outputs. We can use methods like Linear Discriminant Analysis or Neural Networks to classify the data.

At the end of this phase it is expected to have a fully functional BCI system that can provide proper decisions in the different learning abilities that will be used.

2.5 PHASE 5 - DEVELOPMENT OF AN ADAPTIVE SYSTEM BASED ON BCI AND HCI

The categorization of users will be used in an adaptive e-learning system [4]. This e-learning system will adapt to the user in different ways: depending on the cognitive state of frustration/satisfaction, the user's learning preferences, the available resources, among others, to provide the student with pleasant and adjusted experiences. This adaptation will include essentially two main modes of interaction: one involving the analysis of real- time user and other based on the stored profile of the user in question.

Therefore, the purpose of this phase is to do a literature review, design, specification and implementation of an adaptive e-learning system in terms of content and interaction forms. For the base e-learning system one considers the use of an LMS (Learning Management System) as Moodle. However, an adaptive feature implies the inclusion and integration of other modules. There will be an ITS module for the management of the learning scripts library and their relationship with students. A LM (Link Mining) module responsible for monitoring student behaviour during the use of the platform should also be planned.

This phase will involve the following tasks: - State of art survey and competitive analysis of the solution; - Collection, analysis and negotiation of requirements, development of SRS and the acceptance test plan; - Installation of Moodle platform; - Implementation of the front-end and back-office of the platform; - Implementation of the static and dynamic activities of the database; - Implementation of learning scripts that are the student’s pedagogical itineraries; - Implementation of the dynamic generation and self assessment of student activities; - Implementation of feedback mechanisms/interaction appropriate to various user profiles; - Validation (test) and report. At the end of this phase an adaptive e-learning system with the features above-mentioned and its correspondent validation is expected.

2. CONCLUSION

Previous studies show that currently engineering students have great difficulties in solving problems. Highlighted is the difficulty in abstract thinking, necessary for learning programming. The Neuropsychological assessment plays an important role in the diagnosis and treatment of people with disorders at the level of development and learning. The problem being investigated is the study of brain and body functions that may provide indicators of cognitive, mental, emotional and other states. The idea is to obtain indicators that could be used as new strategies to minimize the difficulties presented by the students while programming. This study involves testing and study intended functions, in order to find patterns to measure the ability of individuals to formulate abstract principles, emotional states or other cognitive elements of interest based on the feedback received after each test item. Another problem identified in previous studies is the lack of motivation that students show when learning to program. So we intend to use new forms of interaction for the registration of EEG signals synchronized with the presentation of stimuli (visual or auditory) during the execution of tasks. These make possible the quantification of aspects of interest as immersion, motivation, attention load, cognitive effort, user abstraction capability, among others. One possibility is to use tests that measure the learning of concepts, thinking flexibility and ability to learn and apply new rules. The big idea of this study is to investigate, using the latest techniques of interaction, neurophysiological responses while conducting tests of interest. The initial scope of research is in the area of programming, in which the research team has invested, but the areas of application are vast, not only in education but also in the clinical area. These investigations will allow the acquisition of very important data in order to advance in the area of Computer Science Education Research. At the same time it will be possible to propose new forms of adaptive interaction allowing significant advances in the areas of Human Computer Interaction, with applications in education and later in clinical practice.

ACKNOWLEDGMENT

This work was supported by FCT Grant (Ref:SFRH/BPD/101112/2014) to Ana Rita Teixeira

REFERENCES

1. Acar, Z. and Makeig, S., 2013. Effect of forward model errors on EEG source localization. *In Brain Topography*, Vol. 26, No. 3, pp.378-396.
2. Bennedsen, J. and Caspersen, M. E., 2006. Abstraction ability as an indicator of success for learning object-oriented programming? *In SIGCSE Bulletin inroads*, Vol. 38, No 2, pp 39-43.
3. Carbone, A., Ceddia, J., Simon, D'Souza and Mason, R., 2013. Student Concerns in Introductory Programming Courses. *Proceedings of the fifteenth Australasian Computing Education conference.* Adelaide, Australia, pp. 41-50.
4. De Bra, P., Aroyo, L. and Chepegin, V., 2004. The Next Big Thing: Adaptive Web-Based Systems. *In Journal of Digital Information*. Vol. 5, No. 1, Art. No. 247.
5. Figueiredo, N., Silva, F., Georgieva, P., Milanova, M. and Mendi. E., 2015. *Towards an Adaptive Brain-Computer Interface – An Error Potential Approach*. Multimodal Pattern Recognition of Social Signals In Human-Computer-Interaction Lecture Notes in Computer Science. Springer, Stockholm, Sweden.
6. Fincher, S., and Petre, M., 2004. *Computer Science Education Research*. RoutledgeFalmer, Taylor & Francis Group, Oxford, UK.
7. Gomes, A. and Mendes, A. J., 2007. Learning to program - difficulties and solutions. *Proceedings of the International Conference on Engineering Education*. Coimbra, Portugal, (CD-ROM).
8. Jenkins, T., 2002. On the difficulty of learning to program. *Proceedings of the 3rd Annual LTSN_ICS Conference* Loughborough, United Kingdom, pp. 53-58.
9. Santos, A., Gomes, A. and Mendes, A. J., 2010. Integrating New Technologies and Existing Tools to Promote In *Programming Learning. Algorithms*, Vol. 3, No. 2, pp. 183-196.
10. Tomé, A. M., Teixeira, A. R., Figueiredo, N., Georgieva, P., Santos, I. M. and Lang, E. W., 2010. Clustering evoked potential signals using subspace methods. *Proceedings of Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. San Diego, California, USA, pp. 3986–3989.