Interactive Interface Module for Cerebral Palsy Rehabilitation: Study on the Performance through Machine Learning

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***Abstract*—The paper presents the developed interactive interface module assisting the rehabilitation therapy of children with cerebral palsy. It is part of an intelligent training system and includes a brain-computer interface. The performance of the interactive module is evaluated through the methods typical for explainable artificial intelligence as in this work the Random Forest algorithm is applied. The findings show the better performance at smile recognition in comparison to recognition of the blink and muscle nose exercises.**

***Keywords*—brain-computer interface, cerebral palsy rehabilitation, interactive interface module, machine learning, intelligent training system**

I. Introduction

Nowadays, machine learning is used in a wide variety of areas in the case when a large amount of data is collected and there is a need for their exploration and better understanding. Such a way gives possibilities for extraction of patterns, tendencies or anomalies and very often this knowledge is used for making predictions and analysis [1].

Recently the topic about explainable artificial intelligence is discussed as a scientific field which looks for new methods with capability to interpret and explain different machine learning models. Linardatos et al. study these methods and propose a taxonomy which points out the purpose of interpretable methods and the direction for achieving this purpose [2]. It proves that machine learning is also applied for receiving good interpretability and explanation of created data models as a factor for evaluation their usefulness, sensitivity and scope. A very detailed investigation about the applications of explainable artificial intelligence is proposed in [3], where is outlined that 60% of the published papers are in the healthcare domain for mainly solving classification tasks (88.89%) in intelligent systems (50%) taking advantages of Artificial Neural Networks (81.25%), Support Vector Machines (12.5%), Bayesian networks (6.25%). This analysis reveals suitability of machine learning for explanation of a wide variety of healthcare problems, including for studying and evaluating the brain-computer interfaces [4], healthcare robots [5], neuromotor rehabilitation intelligent systems [6].

Cerebral palsy is related to disturbances which appear in early human biological growth or in the early child ages that could be in different forms and severity. The most discussed form concerns disorder in motor functions of children, reflecting on their movement and spatial orientation. Some research reports that cerebral palsy influences social behavior and communication, as well as cognition, sensation and emotions [7]. The children diagnosed with this disease do not possess correct spatial orientation, body parts perceiving, left and right directions determination.

The rehabilitation therapy must begin as early as possible and it could be very uncomfortable, fatiguing and even painful for children with cerebral palsy.

So, the most important arising question is how to motivate and stimulate children to go through such long, boring and difficult therapy. It is related not only to the children, but also to the therapists and parents. The practice shows that more and more researchers discover the benefits of robotic intelligent systems for establishment of social contact and information exchange through brain-computer interface with children. But it is not enough, there is a need for a human-computer interface for triggering the social interactions and for facilitating the connection between children and therapists. The evaluation of the performance of such interactive interface and workability of intelligent training system is a valuable task that can draw their usefulness, correctness and accuracy.

The aim of the paper is to present the designed interactive interface module for robotized training system, which is used in rehabilitation of children with cerebral palsy and to propose an approach for evaluation of its performance through explainable artificial intelligence methods and in particular through machine learning.

II. Machine Learning in Hardware Systems for Cerebral Palsy Rehabilitation

This section reviews and summarizes the application of machine learning techniques for explanation and interpretation of the performance of hardware based approaches for rehabilitation of children with cerebral palsy.

Ahmadi et al. use motion sensors to detect and assess the physical activities of the children with cerebral palsy as the machine learning algorithms SVM and Random Forest are utilized to classify the recognized activities in different types [8]. The created classification models for group, personalized-group and child-personalized activity are compared and evaluated and the results show that more accurate are models for identification of personalized-group and child-personalized activity.

In another work, Bedla et al. present a method for evaluation the Gross Motor Function Measure, taking into account the collected data from Zebris FMD-T device [9]. The authors conclude that the more complex exercises conducted by children lead to bigger estimation errors.

A methodology, which includes eye images and machine learning is proposed and applied by Illavarason et al. [10] for automatic diagnosis and further rehabilitation of children with mild motor difficulties. The models are characterized with high accuracy through usage of neural networks learner.

Martin et al. describe a solution for rehabilitation therapy by applying a social robotic system with possibility for children profiling and realization of rich human-computer interaction [11]. It includes machine learning for recognition of the user' pose in support of correct diagnose determination.

Usama et al. discuss the evaluation of the performance of brain-computer interface through applying neural networks for solving classification task [12]. The recognition rate of the patients' movement is high.

Faria et al. is talking about the assessment of brain-computer interface, which is used for facial emotion recognition and communication with an intelligent wheelchair [13]. Some algorithms of machine and deep learning are utilized for classification models creation: one for picking out the emotions on the face and another for thoughts determination. The achieved accuracy at emotions recognition is higher than the accuracy at thought identification.

The examined research shows the possibilities of machine learning to evaluate with high accuracy the hardware-based systems and their performance despite the hardware type (motion sensors, social robots, human-computer interface or brain-computer interface) used for rehabilitation of children with cerebral palsy. Such approach is utilized and applied in this work for studying and assessing the interactive interface module at robot-assisted therapy.

III. Interactive Interface Module

As before it has been discussed the rehabilitation therapy of children with cerebral palsy could be boring and hard for following. This is the reason for looking a motivational, interesting and interactive interface to drive the child to go through the whole rehabilitation process. Thus, the children in their early age could be attracted through interesting cartoon pictures that could improve their enthusiasm for training.

So, in order to reduce the workload of the rehabilitation therapist and for better guidance of children's training, an interactive interface is designed and presented here. The software is created in the Python environment, because Python provides several libraries for graphical interface development, including Tkinter, wxpthon and Jython. Tkinter does not need to be installed separately during use, and can run on Windows, UNIX and other operating systems.

The structure of the interface module is presented on Figure 1 and it consists of a main panel and some panels with cartoon pictures (smile, blink and muscle nose). The action switching button is set in the interface in help of the rehabilitation therapist, who has the possibility to adjust the training sequence of actions according to the actual situation during the training of the children.

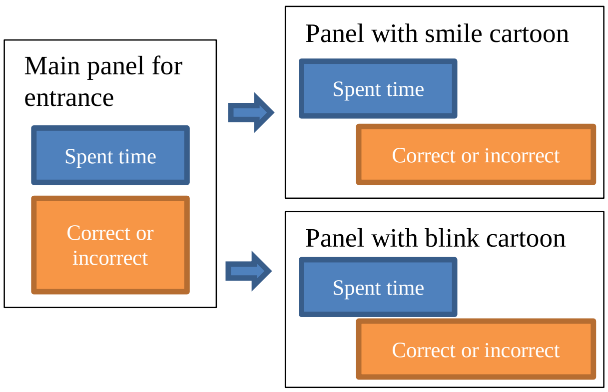

Figure 1. The structure of the software interface

Clicking on the switch button, the panel will switch to the one of the panels, where the action indication picture will change to smile or blink and muscle nose. In addition, the interface also contains the start and end buttons, and the time and action discrimination display function. Clicking the start button will trigger the start of the training and also the time of the training process is counting. The time is displayed in the time dialog box. Clicking on the end button will register the end of the training and the content of the dialog box will be cleared.

For experimentation and software system debugging a brain-computer interface is used in the form of 14 sensors. The workability of the sensors and the quality of the received signal is tested via the Emotiv software for 3D brain visualization. If the sensor has good contact, then the indicator of the light is green as it is shown on Figure 2.

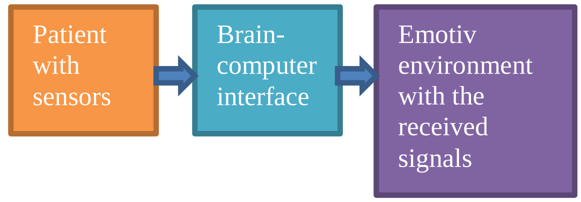

Figure 2. The signal quality test in the Emotiv environment

The interactive module is developed according to the architecture client/server. After the handshaking between server and client, the signal stream brain-computer is recorded in .txt files. Then, also the human-computer interface is tested for its normal workability. The overall test in the case of blink and muscle nose exercise is performed in laboratory settings.

The gathered data are in the form presented in Table 1. It includes the result of the emotion recognition on the child's face (smile or blink and muscle nose). Similar tables are created for all tested users.

Table 1. The result of facial emotion recognition through brain-computer interface for subject A

Time	Smile	Blink
1	Correct	Incorrect
2	Incorrect	Correct
3	Incorrect	Correct
4	Correct	Incorrect
5	Correct	Correct
6	Correct	Correct
7	Correct	Correct
8	Correct	Correct
9	Correct	Correct
10	Incorrect	Correct

IV. Results Evaluation

For evaluation the functionality and the performance of the developed interactive software module the gathered data tables are used. The method of explainable artificial intelligence is also applied. Two classification models are created: the first one evaluates the performance of the software interactive module for recognition of the smile emotion and the second is related to the blink and muscle nose recognition. This is a two class classification task as each record is labeled to be from class correct (recognition) and incorrect (recognition). The utilized classifier is the machine learning algorithm Random Forest and it is chosen, because of its possibility to deal with different data sets, its flexibility and high accuracy.

The results show that the model for smile recognition is characterized with accuracy 83.33% and the model for blink and muscle nose recognition with accuracy of 66.67%. The smile on the children' face is better recognizable in comparison to the blink The results show that the model for smile recognition is characterized with accuracy 83.33% and the model for blink and muscle nose recognition with accuracy of 66.67%. The smile on the children' face is better recognizable in comparison to the blink and muscle nose exercise. It could be explained with the quality of the transmitted signal through the brain-computer interface as well as with the children' mistakes during the therapy.

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V. Conclusion

In this paper, a brain-computer interface and developed interactive software module are presented as well as the test results, which are conducted in the environment Emotiv.

The rehabilitation training system completes the signal reception and processing in the Python programming environment, and realizes the communication.

Through the combination of imagination and movement, we can realize the training of attention and facial muscles in children with cerebral palsy.

Through interesting cartoon pictures and interactive interface, the therapy is assisted to improve the fun of the training process, which can provide new technical support for the rehabilitation training of cerebral palsy.

The performance of the interactive software module is evaluated taking into account the methods of explainable artificial intelligence. The findings point out better recognition of the smile exercise in comparison to the blink and muscle nose one.

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