On Making a Decision to Correct the Learner Behavior Based on the Signals of their Electroencephalograms When Organizing Interaction with an Anthropomorphic Teacher-Assistant Robot

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Abstract—The work discusses the method of recognizing the state of a learner using artificial neural networks based on the analysis of electroencephalogram signals during the assimilation of educational material using a hardware software complex of a robot – an assistant teacher of anthropomorphic type.

Index Terms—decision-making, anthropomorphic robot, training, electroencephalograms, artificial neural planning networks, artificial neural networks

I. INTRODUCTION

Among the priorities of modern society is the involvement of persons with disabilities in active work, their socialization. One of the ways to achieve this goal is education, which is why considerable attention is currently being paid to inclusive education. Educational robotics is becoming more and more widespread, in particular, robots - teaching assistants with wide prospects for the adaptation of children with disabilities to study with healthy children. Assistant robots can be useful for working with children with mental retardation, autistic children [1]. One of the advantages of a robot assistant teacher is the ability to continuously assess the state of learners based on information not available to the sensory organs of a human teacher. In addition, it is assumed that the robot assistant can perform some actions aimed at correcting the learning process and / or the learner's behavior in an automatic mode, without distracting the human teacher.

Thus, there is a need for research to assess both the possibility of obtaining information about the psycho-emotional state of the learner, and the choice of tactics for corrective behavior.

The analysis of additional information about the subject can characterize the process of assimilation of the material, while it is possible to evaluate the results of intermediate testing, the degree of concentration, involvement in the learning process, etc.

Assessing the state of the learner in the process of mastering new knowledge allows you to adjust the actions of a person, thereby improving the effectiveness of training. Among modern educational methods, today quite often there are solutions based on the analysis of the state of activity of the learner's brain in solving various cognitive problems [2]–[6] followed by analysis of the data obtained to identify the human condition.

The most popular method of obtaining information about the state of the brain is the removal of the electroencephalography (EEG) of the subject due to the simplicity of receiving EEG signals, their sufficient information content and the ability to use wireless designs for data acquisition. [7].

The construction of systems for recognizing the state of a subject by EEG data includes preliminary analysis of EEG data, the identification of significant patterns associated with a particular human condition (motor activity, cognitive processes) and the subsequent construction of a classifier trained on the patterns of the subject for further recognition of him state by EEG -data.

The work discusses the method of recognizing with the help of artificial neural networks the state of the learner based on the analysis of EEG signals during the assimilation of educational material using a software and hardware complex of a robot – an assistant teacher of anthropomorphic type.

II. STATEMENT OF THE RESEARCH PROBLEM

A. Purpose of the Work

The aim of this work is to study the possibility of a decision by the robot assistant teacher about the need and type of corrective intervention in the educational process based on the analysis of electroencephalograph signals (EEG). The EEG signal is used to highlight the learner's motor activity relative to the state of rest and, therefore, to determine the situation of the learner's distraction from the process of mastering the subject material of the lesson.

A method for recognizing the state of the subject associated with the determination of its motor activity in relation to the calm state of the subject is considered. Excessive motor activity of the subject in this case characterizes the state of his demotivation and loss of concentration on the learning process and solving problems.

B. Appointment and Use of the Hardware-Software Complex of the Robot Assistant Anthropomorphic Type

The hardware and software complex of the anthropomorphic robot assistant (HSCARA), which provides support for the educational process, is a complex cyber physical system that implements a number of basic functionalities that determine the result of the learning of learning material in dynamics.

The main functionality of the system is the stage of recognition by the system of the state of the subject in the learning process based on patterns of electrical activity of the brain, which allows to assess the degree of involvement of the student in the learning process. Correct identification of the state of the subject in the learning process allows you to evaluate the dynamics of learning and generate the correct procedures - scenarios of the behavior of the assistant robot in response to situations associated with the degree of assimilation of educational material by the subject.

For the recognition accuracy of the subject state in the learning process, an additional analysis of the video image of the learner's face, taken from an individual camera, is used to assess the emotional state of the subject.

Besides, the system uses additional information about a person's physical activity, analysis of the solution of test problems, speech activity when answering questions.

A combined analysis of all sources of information allows us to make a generalized correct conclusion about the degree of mastery of the material by the subject in the learning process.

Assessing the degree of new material assimilation by the subject, including at the intermediate stages of training, is crucial in the formation of the correct procedures for the assistant robot actions (actually feedback) corresponding to the situation associated with the current state of the subject in the learning process. Correctly selected behavior of the assistant's robot will obviously improve the mastery of the teaching material by the subject.

The analysis of EEG data is an important component in recognizing the state of the learner to select the next procedure that corrects the behavior of the subject in the Teacher-HSCARA -Learner system. Therefore, an unambiguous determination of the state of a person by EEG data is very important in the overall assessment of the degree of assimilation of the material by the subject.

EEG is a method for recording signals of bioelectrical activity of the brain [8], [9]. Electroencephalography, as a way of determining the activity of the brain in the performance of various cognitive tasks, has become quite widespread [10]–[12]. Removing an electroencephalogram has a significant advantage over other methods of obtaining a state of brain activity, since it allows you to take information without causing discomfort and changing the normal behavior of the subject. In particular, there are portable electroencephalographs located on the subject, which are used, for example, to record EEG in athletes when the subject is not limited in movement and can behave quite actively. In addition, this method is distinguished by its relative cheapness and simplicity of obtaining EEG signals in real time.

C. Method of HSCARA Use

The group of trainees is located in the classroom, without significant external distractions that can affect the decrease in concentration of attention. The teacher conducts a lesson, explaining and analyzing educational material on a particular topic and offering training tasks for its consolidation.

A portable encephalograph is fixed on each learner, which makes it possible to carry out information in real time and evaluate the state of the brain, which is typical, for example, for solving cognitive tasks, or a state of relaxation and tranquility.

The HSCARA system, which is used during classes, includes an actuator, which is actually an anthropomorphic robot, which is a vehicle equipped with a manipulator. At the same time, the robot is able to execute commands in accordance with the procedures. Procedures (actions of the robot) are tied to some situations that may arise in the framework of the educational process. For example, we can identify the state of loss of the learner's concentration (sleep, relaxation) on the basis of the EEG signals received from the learner and assessing his emotional background from the video image received from the individual camera, and adjust the learner's behavior by the actions of the robot receiving the appropriate command. In addition, it is likely that the student may not listen to the teacher while doing something abstract, such a condition may be characterized by excessive motor activity, in this case, the robot, identifying this condition, acts in accordance with the procedure aimed at increasing the learner's attention.

D. EEG Signals Receiving

To obtain the subject's EEG signals, the classic arrangement of the 10-20 electrode system is used using a portable electroencephalograph (Encephalan -EEGR -19/26, Medicom-LTD), which has the necessary certificates, which is located on a special fixing belt on the subject's body, not restricting its movement. The electrode system is installed on the scalp of the head of the subject using electrically conductive paste and is fixed with a special cap. A similar arrangement of the electrodes allows you to get complete information from all parts of the brain with the best quality of the received EEG signals in comparison with fixing the electrodes on the gel. EEG data analysis is performed in real time.

Since for different people the EEG data associated with similar states of the subjects and the corresponding brain activity, including the state of rest, can differ significantly, the method of recognizing the student's state involves an additional preliminary stage of some "scaling" of the subject's EEG data, namely, obtaining EEG data for each person at rest (recording the background activity of the brain) and in the state of motor activity of a particular subject. Further, these data are used in training the classifier of the identifying state of the subject directly in the learning process. As a classifier, artificial neural networks are used, which, after training on previously obtained data, work with EEG signals received during the training of the subject.

To confirm the possibility of using EEG data in detecting the learner's motor activity, an experiment was conducted using the Encephalan-EEGR-19/26 electroencephalograph (Taganrog, Russia). During the experiment, multichannel EEGs with 31 electrodes, which were placed according to the standard (Fig. 1) scheme, were removed from the test subject and recorded with a sampling frequency of 250 Hz. The duration of the experiment was approximately 10 minutes, during which the subject performed movements with his left and right hands or was at rest. The experiment consisted of 10 sessions of each kind of state. Each task in the sessions was preceded by a sound signal, after which the subject had to complete the task within 4 s. Between the sessions there were short breaks (2 min) during which calm music played. The experiments took place in the morning in a specially equipped laboratory, in which the influence of external stimuli was minimized.

III. Computational Experiment and its Results

Further analysis was carried out on a personal computer in relation to the captured signals of multichannel EEGs. EEG patterns were classified using artificial neural networks (ANNs) of direct signal propagation, taught with a teacher using algorithms with back propagation of errors, the most common and often used types: linear network (LN), multilayer perceptron (MP), radial basis function (RBF) [13]–[20].

A series of computational experiments on a PC was carried out to classify the movements of the left and right hands between themselves and relative to the state of rest according to the corresponding EEG signals. For this purpose, the implementations continuously recorded during one experiment from the selected EEG channels were "cut" into segments (fragments) of a given duration $Tf = 3$ s, each of which contained one event (movement or rest). An important role in the training and use of neural networks is the choice of data. For training and testing, we used data arrays containing 6000 points each (24 from recorded data). Arrays consisted of prepared 3-second fragments of EEG signals corresponding to one of the indicated states. Half of the array data, randomly selected, was used to train the ANN; the remaining half is for the control and test samples (in the ratio of 50 % to 50 %).

The results show that when using all 31 channels, the classification of the movements of the left and right hands relative to each other and the state of rest is correctly carried out in 99 % of cases for all types of applied ANNs. When using EEG signals from 3 electrodes of the occipital area, the correct recognition of hand movements for RBF and MP is performed in approximately 98 % of cases, and for drugs in 65 % of cases. When recognizing the movement of the right or left hands relative to the resting state, the recognition quality for MP and RBF is 90–95 %, and for drugs 73–78 %.

IV. Subsystem of Decision Making Robot Assistant for Teacher

A. General Scheme of Functioning

The most important subsystem of a robotic complex for support of educational activity of the teacher is the subsystem of planning of actions and decision making for achievement of a goal, what are providing possibilities of autonomous behavior of the robot in the dynamic environment of educational process. The subsystem of decision-making of the developed robot of the teacher's assistant uses a production model of knowledge representation. Knowledge is presented in the form of axiomatic system [20] products in form

$$o_1 f_1 v_1, o_2 f_2 v_2, ..., o_n f_n v_n \rightarrow d_j \Rightarrow f_{j1}, f_{j2}, ..., f_{jk} \quad (1)$$

where f_i is factor, o_i is a logical operator (& – AND, | – OR, $\sim$ – NOT), v_i is weighting factor f_i, d_j is the action to be performed in the current situation, f_{ji} is ith result of application of the action d_j.

The decision-making process is based on the calculation of the assessment of the conditions of applicability of products. The result of the subsystem planning robot assistant is automatically built procedure, hereinafter referred to as the active procedure, and includes a set of products that are adequate to the current situation of the educational process. At the stage of execution of the constructed procedure, a set of factors may change. Therefore, the evaluation of the values of the factors is carried out continuously. The current values are entered into the database of the robotic complex. In the parallel processing mode, the values of the applicability conditions of the products included in the active procedure of the robot actions are recalculated. At the same time, the software and hardware complex of the robot teacher's assistant performs the following actions in parallel:

- calculation of factor values;
- calculation of the conditions of applicability of products;
- selection of products with dominant values of applicability conditions;
- forming a new procedure robot;
- modeling the performance of actions of active procedures [21];
- comparison of simulation results of the active procedure with the desired goal of solving the problem;
- decision to replace the current active procedure with a new newly built procedure.

Therefore, the sequencing process is dynamic. In this regard, planning artificial networks are used to plan robot actions [22], [23]. In general, the software and hardware complex of the robot assistant for the teacher is a distributed computing system. At the same time, computationally complex procedures are implemented on stationary servers of the classroom. The computational resources of the robot itself are used to obtain and analyze the current situation and perform actions automatically constructed active procedure, adequate to the current situation of the educational process.
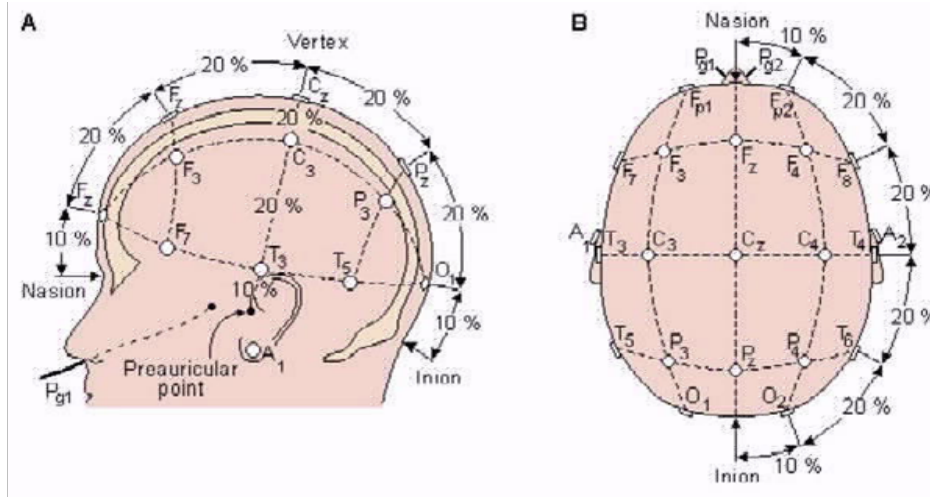
Fig. 1. Layout of electrodes with marked electrodes.

B. Scheme of a solution of tasks with use of the artificial neural planning networks

Artificial neural planning networks (ANPN) using the artificial neural archival network (ANAN) as the memory device for storage of the decisions obtained in the artificial neural deciding network (ANDN). Hence, it does not render influence on convergence of decision process stability of a task in artificial neural planning network as a whole. Therefore, the main attention will be paid to the investigation of properties of artificial neural deciding network (ANDN) [21]. Let us denote the following variables: $S^i(z) = \langle F_z; d^i; o^i; p^i \rangle$ is state of ANDN on i-th decision step of a task z; $F_z = \langle s_z, r_z, t_z, c_z \rangle$ is statement of a task z; s_z is source data of task z; r_z is desirable result of a task z; t_z is z-task requirements to solution; c_z is z-task applicability conditions; $d^k = \langle d_R, d_T, d_C \rangle$ is state of ANDN data-layer neurons (further referred to as "data-neurons"), which include desirable results, requirements to the results, and conditions of applicability), at the k th step; o^k is state of ANDN operations-layer neurons (operations-neurons) at the k th step; p^k is current plan of the task decision plan, constructed after the k th step; $o : C(o) \to D(o) \Rightarrow R(o) \leftarrow T(o)$ is the format of own decision theory record; o is name of the action (operation) described by an axiom; $C(o)$ is function for returning applicability conditions of an   axiom o; $D(o)$ is function for returning source data of an axiom o; $R(o)$ is function for returning required results of an axiom o; $T(o)$ is function for returning requirements to results of an axiom o; $card\ A$ is set A quantity of elements (cardinal number); $\emptyset$ is an empty set; $w_d z(z) : s_z, r_z, t_z, c_z \mapsto d_R, d_T, d_C, (d_R \cong -s_z + r_z, d_T \cong t_z, d_C \cong c_z)$ is the operator, establishing data-neuron states according to z-task attributes; $w_d o : o \mapsto d, (d_R \cong -R(o) + D(o) + T(o) + C(o), d_T \cong T(o), d_C \cong -T(o))$ is the operator, establishing data-neurons state according an operations-neurons states; $w_o d : d \mapsto o, (o \cong \{o_i | R(o_i) \subseteq d_R, T(o_i) \supseteq d_T, C(o_i) \supseteq d_C\})$ is the operator establish operations-neurons state according an data-neurons states; $S_z^o = \{s | s(z) = \langle F_z; [0]; [0]; [0] \rangle\}$ is initial state set of ANDN to z-task, where symbols $[0]$ designate zero vectors accordingly dimension; $S_z^f = \{s | S(z) = \langle F_z; d_z; o_z; p_z \rangle\}$ is the final ANDN-states achieved upon termination of the z-task decision. Among final ANDN-states we shall allocate set of target states $S_z^g = \{s | S(z) = \langle F_z; [0]; [0]; p_z \rangle\} \subset S_z^f$, which achievement testifies to successful construction of the plan of a z-task decision. Achievement of final states of the kind $s(Z) = \langle F_z; d_z; o_z; p_z \rangle \notin S_z^g, d_z \neq [0], o_z \neq [0]$, not being target, testifies to absence of the z-task decision. Convergence of process of search of the decision, with reference to a planning artificial neural network, in fact, means resolvability.

Convergence of decision search, with reference to the ANDN, actually, means resolvability. I.e. for each task z, having the decision in the corresponding axiomatic theory of the decisions, the artificial neural deciding network will pass from the initial state $s(z) = \langle F_z; [0]; [0]; [0] \rangle \in S_z^0$ in corresponding target $s(z) = \langle F_z; [0]; [0]; p_z \rangle \in S_z^g$ I.e. for each z-task, having the decision in the corresponding axiomatic decisions theory, the ANDN will pass from the initial state $s(z) = \langle F_z; [0]; [0]; [0] \rangle \in S_z^0$ to corresponding target $s(z) = \langle F_z; [0]; [0]; p_z \rangle \in S_z^g$ state.

V. CONCLUSION

From the conducted studies, it can be concluded that the EEG signals can be used to highlight the learner's motor activity relative to the state of rest and, therefore, to determine the situation of the learner's distraction from the correct perception of the lesson material. The general scheme of functioning of a subsystem of decision making of a hardware-software complex of the anthropomorphous robot for the teacher is also submitted. The operating procedure of the artificial neural planning network is considered.

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