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To the development of intelligent adaptive learning systems

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To the development of intelligent adaptive learning systems

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Abstract. The article describes the prospects for creating an informational adaptive automated learning system (based on the English Language) using advanced artificial intelligence technologies. In particular, the work shows that the quality of education largely depends on the form of educational content and the parameters of the learning object (a student) associated with its perception of information. The formulated hypothesis of this work indicates that according to the written speech of the learning object, it is possible to classify it (the learning object) by the type of perception of educational content. For the first time, the paper proposes the use of the apparatus of artificial neural networks to solve the problem of automatic classification of learning objects according to the parameter indicated above, while analyzing the text written by this object. For the formation of educational content in the required form, it is proposed to use the system-object method of knowledge representation. The logical architecture of an adaptive teaching automated system is being considered.

1. Introduction

Suppositions that different people perceive information in different ways have been challenging scientists since VI century BC. And if at the beginning the formation of this approach was based on the *person-society* correlation, later (in XVIII century) the personal benefit and the assessment of all phenomena based on their usefulness and acceptance by an individual (Bentham, Smith) became paramount. Further, during the development of social psychology in XIX-XX centuries, psychology moved from a priori conclusions to laboratory experiments, and just at this time, attempts to investigate the difference in people's perception began to appear in priority. At this very time, tests that predetermine different types of perception of people appeared and this all became the prerequisite for the emergence of socionics.

Modern teaching methods, including the didactics of foreign languages, are based on the latest developments of scientists of related branches of science and thus are being improved. So, one of the important directions of didactic dogmas of today is the understanding of the existence and domination of various types of perception. It has been proven that people with different types of perception differently perceive the oral text, its graphic arrangement, work with a book, computer, oral and written communication. Moreover, such people not only master tasks *suitable* or *unsuitable* for their temperaments at different rates, but also receive results with varying degrees of success, strive to adapt any given tasks to their own type of perception.

If we conduct a psychological test to clarify the type of perception, we can talk about a conditional independent subjective assessment of students themselves. However, this test is also relevant in the early stages. This is a psychological test according to the methodology *Diagnostics of the Dominant Perceptual Modality* by S. Efremtsev. However, this is not the only test available for establishing a person's perception type. Nevertheless, such tests are endowed with a special error, which in the case of the study of foreign languages has the most disastrous results.

For example, it is difficult for *the visual* to perceive by ear without illustrative graphical support, while *the auditory* is mostly capable of perceiving oral information and have the corresponding fixation in memory. Taking into account these features, the teacher can build an individual trajectory of learning, however, at school or university there is often not enough time to identify the type of perception that follows from generally accepted practice. It would be good if the teacher had the opportunity to conduct specific testing for the type of student's perception or to establish this circumstance during individual lessons (normally several lessons for the sophisticated teacher are quite enough to do it), but in terms of saving time the teacher does not have enough energy to clarify the appropriate parameters.

In connection with the above, a promising task is to introduce various artificial intelligence technologies for organizing and creating adaptive teaching automated systems that can adapt to a specific student and form convenient educational content. The most important task in the development of such an automated system is the process of determining the type of information perception, on which in the future the form of educational content will depend.

2. Materials and methods

Traditionally, it is possible to establish four basic types of perception. Here, of course, it should be stipulated that all of them are not the Absolute and undergo changes, are supplemented in the process of life. However, with all existing metamorphoses, students retain the innate type of perception: *auditory* (the auditory system of information processing is dominant: sounds, melodies, their tone, volume, timbre, purity); *visual* (when the visual system of information processing is dominant: shape, location, color); *kinesthetic / tactile / emotional* (sensory information is dominant: touch, taste, smell, feeling of texture, temperature); *digital* / through the construction of an internal dialogue (associated with the logical construction of an internal dialogue). This division is based on the principle of human perception of information by receiving information from the outside world from five main channels: visual, auditory, tactile, gustatory, olfactory.

Analyzing the accumulated teaching experience [1, 2], the authors formulated a hypothesis that the style of presentation of written speech depends on the type of perception. For example, the *visual* in written speech skips prepositions and adverbs, uses simple speech patterns. The *auditor*y is more inclined to use complex and correct grammatical expressions in writing. The *kinesthetic* is explained by short, grammatically incorrect sentences. This opens up the prospect of text mining using the apparatus of artificial neural networks in order to identify the most acceptable form of educational content for each specific learning object. It is worth noting that previously such a problem was solved, as a rule, using special tests.

To describe the process of text analysis in order to determine the dominant type of perception and the further process of forming educational content, we will use the system-object modeling methodology and the corresponding method of knowledge representation [3, 4]. Within the framework of the approach, a model of any subject area can be represented by a combination of UFO-elements [5], the basic hierarchy of links [6] of the subject area and a set of links of UFO-elements [6], thus, the system-object model of an intelligent system, from a formal point of view , can be defined by three components:

- (stream objects of the system) hierarchy of links of the system;
- nodal objects of the system
- communication system.

A streaming object of a system-object model is a special case of an object in terms of object theory [7], which is a named set of properties of a real object of a simulated domain. For example, a flow object describing a liquid is likely to have such fields (properties) as: density, temperature, color, etc. The set of essential properties of the simulated real world object will depend on the goals of the simulation.

The nodal object of the system-object model is a named object in terms of object theory [7], which is a formal definition of the system of the simulated domain. The nodal object contains two groups of fields: fields that describe the interface characteristics (node); fields describing object characteristics (object). In addition, the function of the system (function) acts as the method of the nodal object.

System link - a named edge that connects two nodal objects of the domain.

In terms of the calculus of systems as functional objects, the system-object model M has the form, as shown in expression 1:

$$M =< L, S, C >, \tag{1}$$

where:

- L is the set of stream objects of model M (hierarchy of links of the system-object model);
- S is the set of nodal objects of model M;
- C is the set of links of system-object model M.

The set of streaming objects contains, firstly, the basic hierarchy of links – the static part of the set (unchanged for any system-object model), and secondly, the streaming objects of the simulated domain (dynamic part of the set).

In general, the set of stream objects has the following definition:

$$\mathrm{L} = \{\mathrm{l}|\mathrm{l} = [\mathrm{r}_1, \dots, \mathrm{r}_\mathrm{n}]\}, \tag{2}$$

where: l is a named stream object, which, in turn, contains many r_n pairs of the following format – "identifier: value".

It should be noted that set L contains named sets that are streaming objects, and, in fact, the sizes of streaming objects (cardinalities l) are different, depending on the modeled object of the domain and the number of its essential properties identified.

Thus, the set L consists of two subsets: the set of basic stream objects (the static part of the stream object hierarchy) and the set of stream objects of the domain (the dynamic part of the stream object hierarchy). Thus, any set of streaming objects has the following structure:

$$\mathrm{L} = \{\mathrm{l_v}, \mathrm{l_e}, \mathrm{l_d}, \mathrm{l_c}, \mathrm{l_1}, \dots, \mathrm{l_n}\}, \tag{3}$$

where: l_v is a stream object-parent that represents a real object class; l_e is a parent stream object which represents an energy object class; l_d is a parent stream object that is an IOC; l_c is a parent stream object that is an information management object class. n is number of system object stream objects.

The set of nodal objects S corresponds to the set of systems as UFO elements. The system as a UFO element is a triune structure, where the structural characteristics of the system, which are determined by the intersection of the incoming and outgoing connections of the system, must be taken into account. Thus, the structural characteristics of the system are the interface of the system, due to which it can be considered in the context of some super system. The functional characteristics of the system are determined by the request of the super system - the external determinant of the system, which is formally presented just in the form of the interface of the UFO element (hereinafter referred to as the nodal object). Also, the functional characteristic is determined by specific procedures for converting the input connections of the nodal object into the output. The object characteristics of the nodal object are a set of parameters of the substance that implements the function of the nodal object. Thus, the set of nodal objects of the system-object model is presented in the following formal type:

$$S = \{s_1, \dots, s_n\}, \quad (4)$$

where: n is a number of nodal objects (systems); s_n is a nodal object.

Each n-th element of the set S is a special nodal object (corresponding to a specific system / UFO-element), which, in accordance with the Abadi-Kardeli object calculus [7], consists of fields and a method and has the following form:

$$s_n = [U, f, O], \quad (5)$$

где: U – is a set of fields for describing interface stream objects of a node object s_n (host object ports), corresponding to the set of functional links of the modeled system. The set U, in turn, can be divided into two subsets: a subset of stream objects that act as input ports and a subset of stream objects that act as output ports of a node object, thus:

$$U = L? \cup L!, \quad (6)$$

where: L? represents a set of incoming interface streaming objects corresponding to the incoming connections of the system, L! represents a set of outgoing interface streaming objects corresponding to the outgoing connections of the system.

The function in expression (4) f is a method of the nodal object sn, which describes the process of transforming resources arriving through the incoming interface stream objects (incoming connections of the system) L? in the outgoing - L !. Further, the method of the nodal object will be represented as a function of the set of incoming stream objects:

$$f(L?)L! \quad (7)$$

O represents a set of fields for describing the object characteristics of the nodal object (system) sn, the elements of which have the format *identifier: value*.

That is set O can be understood as a set of fields of a node object. Moreover, the fields of the nodal object can be conditionally divided into three groups: the first group characterizes the input ports of the nodal object (for example, the throughput of the incoming port), the second group characterizes the output ports of the nodal object (for example, the throughput of the outgoing port), the third group characterizes the object participating in the implementation of the node object method. Thus, the set of fields for describing the object characteristics of the system consists of three subsets:

$$O = O? \cup O! \cup Of, \quad (8)$$

where: set of fields O? contains parameters characterizing system inputs, O! – a set of parameters characterizing the system outputs and Of which is a set of parameters characterizing the object participating in the implementation of the system function. From a formal point of view, the listed sets of object characteristics contain constant values used in the description of the node function (will be discussed in more detail below).

Taking into account the components of the nodal object described above, expression (4) can be written in the following refined form:

$$s_n = [L?, L!; f(L?)L!; O?, O!, Of] \quad (9)$$

To take into account the internal connections of the system, a set C is introduced into the definition of the system-object model, which contains all the connections between the nodal objects. Each link is characterized by at least three components: a link source (an instance of a nodal object for which the link acts as outgoing); link recipient (an instance of the nodal object for which the link acts as an incoming link); a link type (an instance of a stream object). Thus, the set of links of the system-object model is defined as follows:

$$C = \{(s_{out}, s_{in}, l) | s_{out} \in S, s_{in} \in S, l \in L\}, \quad (10)$$

where: s_{out} is an instance of a node object - a source of communication; s_{in} is an instance of the node object - the recipient of the link; l is the type of relationship between the above node objects.

3. Results and discussion

Let us consider thoroughly the system-object model of the adaptive training system. A graphical-analytical representation of such a system is shown in Figure 1.

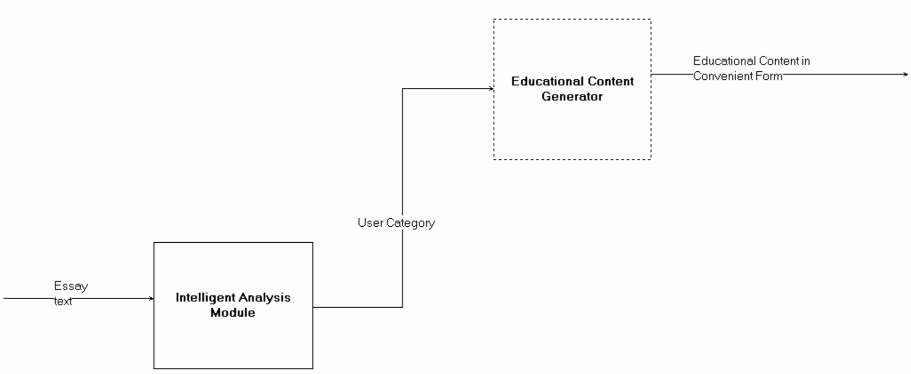

Figure 1. Modular structure of the adaptive learning system

As it can be seen from Figure 1, two logical modules can be distinguished in the adaptive training system. The first module implements the automatic analysis of the student's text-essay and, as a result, assigns the learning object to one of the classes: auditory, visual or kinesthetic. The second module, depending on the class to which the learning object belongs, forms educational content in a form acceptable to it. Let's take a closer look at the text mining module. Its logic diagram is shown in Figure 2.

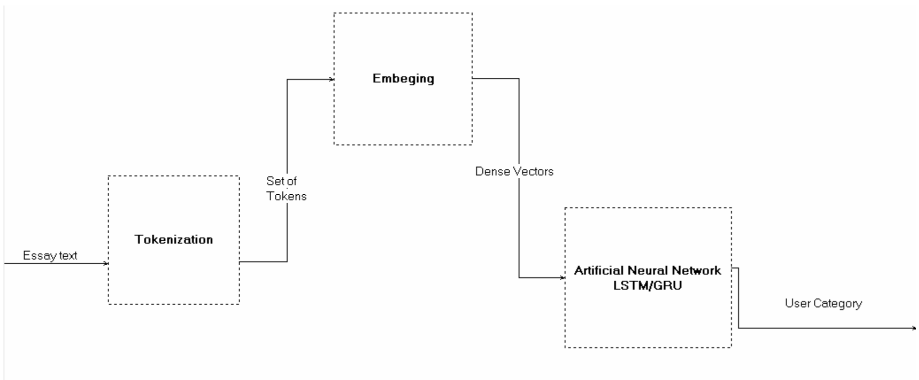

Figure 2. Modular structure of the adaptive learning system

Before processing the text must be split into tokens - elementary units. To solve this problem, it is planned to use either one word or several words as tokens. Next, the tokens need to be converted into vector representation. Of several existing approaches the most acceptable one from the point of view of computational complexity and quality of training neural networks is dense vectors [8]. As a rule, this stage is implemented in the form of an additional layer of an artificial neural network. Actually, for text analysis, it is planned to test two architectures that show good results in natural language processing tasks - LSTM and GRU [9,10].

4. Conclusion

The project of an adaptive learning system considered above opens up prospects from the point of view of the implementation of intelligent educational systems, since previously such tasks were solved only with the use of special tests. Here it becomes possible to develop an autonomous intelligent educational system that can adaptively form educational content based on the predispositions of each specific learning object. In subsequent works, the authors plan to form a training sample, which will contain essay texts prepared by students in English and previously known categories to which the authors of the texts belong. The volume of the training sample at the first stage of the experiments will be about three hundred (one hundred elements of each category). Further, based on the data obtained, the authors will analyze the most effective architectures of artificial neural networks from the point of view of the formulated problem.

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