INTELLIGENT TUTORING SYSTEM FOR BELARUSIAN AS A FOREIGN LANGUAGE

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Abstract: *The paper presents the concept of an intelligent tutoring system for learning Belarusian as a foreign language. At the heart of the system is a model of learning consisting of the following models: tutor model, learner model, model of Interaction, learning process structure model, learning activity forms model, academic discipline model.*

Keywords: *learning model, tutor model, learner model, model of Interaction, learning process structure model, learning activity forms model, academic discipline model.*

ACM Classification Keywords: *I.2 ARTIFICIAL INTELLIGENCE - I.2.1 Applications and Expert Systems - Natural language interfaces General.*

Introduction

Preserving the Belarusian language is nowadays a pressing problem. On the other hand the number of its foreign learners has recently seen a significant increase. This results in a high demand for quality digital educational resources for Belarusian as a foreign language.

The use of computer technologies in foreign language teaching has already proven to be efficient [http://www.itlt.edu.nstu.ru], [Karamysheva, 2001]. However there is still a significant number of unsolved problems related to linguistics, pedagogics, didactics, psychology and many other fields, which results in the development of applied disciplines (e.g., applied linguistics), or even new schools (such as the computer assisted language teaching [Bovtenko, 2006]). The terminology becomes more precise [http://llt.msu.edu], the problems of semantical language description are being solved [Fillipovich, 2002], methods of automated task generation are being developed [Bashmakov, 2003], significant advances are being made in the understanding of texts by the computer [Leontyeva, 2006], machine translation [Stepanov, 2000] and natural language user interface [Popov, 2004], [Yeliseyeva, 2009], [http://nai.shergin.com/head.htm], [http://iii.ru/garage]. In order to increase the efficiency of computer assisted teaching new remote forms of teaching are being implemented [Brusilovsky, 1994], new generations of digital tutoring systems., i.e., intelligent tutoring systems [Brusilovsky, 1990], [Petrushin, 1993], [Helander, 1997], [Golenkov, 2001], [Graesser, 2005], [Chad Lane, 2006] and expert tutoring systems (ETS) [Petrushin, 1991], [Rybina, 2008] are being developed.

One of the biggest issues in the development of intelligent tutoring systems (ITS) is that such fields as pedagogy and psychology are still not sufficiently formalized, as instructors can't describe with necessary detail their teaching methods. When creating ITS for foreign language instruction, the problem of automatical text processing add up to the above [Skorokhodko, 1983], [Jurafsky, 2009] as well as problems related to its formalization and the creation of appropriate knowledge bases [Gavrilova, 2001], [Golenkov, 2004], [Russel, 2006]. Therefore such systems can be developed only as a joint effort of linguists, foreign language instructors and IT-specialists. This work presents the concept of an intelligent tutoring system for Belarusian as a foreign language (ITS BFL). The main purpose of this concept is to provide all ITS BFL developers with a general formal description of its components in order to enable them to pursue their work independently.

To create a computer tutoring system one needs to model the learning process. From the very first computer learning systems the following aspects have constantly changed: system development approaches, computer assisted teaching methods, computer technologies. The evolution of computer technologies is probably the most important, as it defines the viable models. However, some systems developed 10 - 15 years ago can still serve as a standard in the modern research. The most precious part of such systems are teaching methodologies that were carefully elaborated for particular subjects.

The Learning Process Model

Above we have pointed out the main issues that we will deal with further. First we will need an exact definition of the learning process. We can easily find various definitions in pedagogical, didactic and even psychological sources. However our goal is not to register all possible definitions, but to understand the nature of the learning process in order to eventually model it. From pedagogical writings we can conclude that the learning process is a multidimensional concept. This process involves the following elements that also need to be modelled:

- The participants of the learning process (the tutor and the learner).
- The interaction (between the participants).
- The structure of the learning process (a set of particular stages forming a sequence in time).
- Various learning activities (lectures, seminars, practicals, tests, etc.).
- The educational content (the academic discipline within which all the information has a hierarchical structure based on particular teaching methods).

Thus formally, **the learning process model** can be described as follows:

LM = { mT, mL, mI, mSLP, mFLA, mAD }, LM – Learning Model, mT – model of Tutor, mL – model of Learner, mI – model of Interaction, mSLP – model of Structure of Learning Process, mFLA – model of Forms of Learning Activities, mAD – model of Academic Discipline (1)

A model cannot reflect all particularities of a real object. We replace real participants, objects, processes and states completely or partially with their computer models. Thus in the given learning model LM within an intelligent tutoring system we have a complete **model of tutor** mT and only a partial **model of learner** mL. The learner model reflects the tutor's vision of him and thus can be formalized only partially.

Goals and Tasks of Learning. Tutor Model and Learner Model

Just like any other process, the learning process has a goal and intermediate tasks, which are defined depending on the expected results. Therefore within the above mentioned models we need to point out appropriate **goals**, **subgoals**, **tasks** and **subtasks**. It will result in the following:

mT $\supset$ { Gt, SGt, Tt, STt }, Gt – Goals of tutor, SGt – SubGoals of tutor, Tt – Tasks of tutor, STt – SubTasks of tutor, Gt = { Gt_i, $i=1, \dots, Nt$ }, SGt = { SGt_i, $i=1, \dots, Kt$ }, Tt = { Tt_i, $i=1, \dots, Lt$ }, STt = { STt_i, $i=1, \dots, Mt$ } (2)

mL $\supset$ { Gl, SGl, Tl, STl}, Gl – Goals of learner, SGl – SubGoals of learner, Tl – Tasks of learner, STl – SubTasks of learner, Gl = { Gl_i, $i=1, \dots, Nl$ }, SGl = { SGl_i, $i=1, \dots, Kl$ }, Tl = { Tl_i, $i=1, \dots, Ll$ }, STl = { STl_i, $i=1, \dots, Ml$ } (3)

mI $\supset$ { Gi, SGi, Ti, STi}, Gi – Goals of interaction, SGi – SubGoals of interaction, Ti – Tasks of interaction, STi – SubTasks of interaction, Gi = { Gi_i, $i=1, \dots, Ni$ }, SGi = { SGi_i, $i=1, \dots, Ki$ }, Ti = { Ti_i, $i=1, \dots, Li$ }, STi = { STt_i, $i=1, \dots, Mi$ } (4)

Obviously the sets of subgoals and subtasks in each of the models can turn out to be empty. However the sets of goals and tasks cannot be empty. Therefore in order to simplify the creation of an intelligent tutoring system we can concentrate on simplified models containing only non-empty sets of goals and tasks:

$$mT \supset \{ Gt, Tt \}, Gt \neq \varnothing, Tt \neq \varnothing, mL \supset \{ Gl, Tl \}, Gl \neq \varnothing, Tl \neq \varnothing, ml \supset \{ Gi, Ti \}, Gi \neq \varnothing, Ti \neq \varnothing \quad (2'), (3'), (4')$$

2.1. Result of Learning

In order for a learning process to be successful and to generate ultimate outcome all set goals need to be achieved, which in turn requires the accomplishment of all tasks. All the above mentioned goals make up the **result of learning**:

$$RL \Leftarrow \{ Gt, Gl, Gi \}, RL – \underline{R}esult\ of\ \underline{L}earning, LM \supset RL \quad (5)$$

2.2. Refinement of Tutor Model and Learner Model

The success of the learning process depends on the level of coordination between goals and tasks set within each model. For instance the goal that the tutor sets has to be well understood by the learner and moreover be in line with his personal goal. The tutor sets the following global goal: “bring the learner to a level of proficiency in Belarusian sufficient for basic communication”. Based on this, the learner’s goal will be something like: “acquire a level of proficiency sufficient for basic communication”. However if there is a discrepancy between their goals, some of the learning tasks won’t be accomplished or will be only partially accomplished. Therefore the number of goals and subgoals within the tutor and the learner models should be the same. There are obviously hierarchical connections between goals and tasks. We shall call the coordination of goals $\leftrightarrow$, hierarchical connections – $\rightarrow$. We can refine the models mT (2) and mL (3) as follows:

$$Gt \leftrightarrow Gl \Rightarrow Nt = Ns = N, \text{ N stands for the number of goals} \quad (6)$$

$$SGt \leftrightarrow SGl \Rightarrow Kt = Ks = K, \text{ K – stands for the number of subgoals} \quad (7)$$

$$mT \supset \{ Gt \rightarrow SGt \rightarrow Tt \rightarrow STt \}, Gt = \{ Gt_i, i=1, \dots, N \}, SGt = \{ SGt_i, i=1, \dots, K \} \quad (8)$$

$$mL \supset \{ Gl \rightarrow SGl \rightarrow Tl \rightarrow STl \}, Gl = \{ Gt_i, i=1, \dots, N \}, SGl = \{ SGl_i, i=1, \dots, K \} \quad (9)$$

As for the teaching tasks definitions - they need to reflect the learning content. It would be even better to reflect the rating of skills and knowledge expected from the learners at a certain level. For instance, in order to achieve the above mentioned goal of Teaching Belarusian at the level of primary acquaintance to learners who have no prior knowledge of the language, we will need to accomplish the following tasks: “Teaching the pronunciation of separate phonemes of the language”, Teaching the rules of reading a text”, etc. Similarly we can formulate some goals within the learner model mL: “Learning Belarusian at the level of primary acquaintance”, “Learning Belarusian at the level of general mastery”, etc.

These are obviously hypothetical goals, as real-life learners are often unable to formulate their goals. Here we can see the confirmation of the above cited statement, that the learner model is just a reflection of the tutor’s vision of him. They simply reflect the similar tasks of the tutor model mT. These tasks cannot be fully set by the learner because he has only a vague idea of the goals and tasks of the learning process. Therefore an ITS should be able to set goals and tasks by itself. By harmonizing the goals and tasks of the tutor with those of the learner we can tailor goals and tasks for a given learner. Then they are placed in a knowledge base representing a personal learner mode - mS_{pid} (pid - a learner’s personal identifier). The goals and tasks should be defined at the early stages of the system designing.

2.3. Personal Set of Goals and Tasks

Thus the learning model should include the mechanism of coordination between the goals and tasks of the tutor and those of the learner, as well as the resulting generation of a personal set of goals and tasks for each learner. Letter F will stand for these mechanisms, which will be treated as functions contained within the tutor model:

$$mT \supset \{ F(Gt, Gl, \ldots), F(SGt, SGl, \ldots), F(Tt, Tl, \ldots), F(STt, STl, \ldots) \} \tag{10}$$

In order to be able to set personal goals and tasks for a given learner the ITS needs first to have some initial information on him. Therefore the learner model should include the following additional elements:

mL ⊃ { PID, PNS, PD, CLK, PLA, IPC, PP }, PID – Personal IDentifier, PNS – Personal Name and Surname, PD – Personal Data (gender, age, etc.), CLK – Current Level of Knowledge, PLA – Protocol of Learning Activity, IPC – Individual Psychological Characteristics, PP – Personal Preferences. (11)

Then the set of parameters of coordination between the goals and tasks of the tutor and the learner may be further refined as:

$$mT \supset \{ F(Gt, Gl, PID, CLK, PLA, IPC, PP), F(SGt, SGl, PID, CLK, PLA, IPC, PP), F(Tt, Tl, PID, CLK, PLA, IPC, PP), F(STt, STl, PID, CLK, PLA, IPC, PP) \} \tag{10'}$$

The current set of learning goals and tasks defined for the given learner will be the output of the functions.

Almost all formulations of learning tasks within the learner model mL describe expected results of the learning process. It confirms the above mentioned formula (5). Besides, sets of learning goals and tasks as well as expected results correspond to particular stages within the structure of the learning process:

$$RL \leftrightarrow mSLP \tag{12}$$

The Interaction Model

The Interaction model within the ITS represents a real-life process of communication between the tutor and the learner. As in the ITS the tutor is replaced by a computer system, we need to take into account the human-computer interaction. In this paper we will try to refine the existing models of communication and models of human-computer interactions. Besides, bearing in mind the particularities of the ITS BFL we are designing, we will consider that the interaction will be in a natural language. Thus, the interaction model mI will look like this:

mI = { mScI, IPs, mSIn, USM, mDg, mLgs, mW }, mScI – model of Scripts of Interaction, IPs – Interaction Protocols, mSIn – model of the System Interface, USM –User Speech Model, mDg – model of Dialogue, mLgs – models of Languages, mW – model of the World (13)

3.1. The Interaction Scenarios Model

Within the **interaction scenarios model** mScI we build scenarios of interaction between the ITS and a given learner ScI_{PID} in accordance with current learning tasks. Every step of the scenario is associated with the structure of the learning material within the model of a given academic discipline mAD. For instance, for the task "Teaching the pronunciation of separate phonemes of Belarusian" we can build the following scenario: "1. Suggest the learner learning content relevant for the topic "Phonemes". 2. Suggest the learner relevant exercises. 3. Suggest the learner a test to evaluate the knowledge".

This scenario is very simplified. But it shows that before creating scenarios within the ITS design process one should first have thoroughly elaborated the structure and the content of the academic discipline. In order to build individual scenarios ScI_{pid} within the interaction model first we need to implement the following functions:

$$mScI \supset \{ F(GI, PID, SAD) \}, SAD – \underline{S}tructure\ of\ \underline{A}cademic\ \underline{D}iscipline, SAD \subset mAD \quad (14)$$

3.2. Interaction Protocols

In the process of interaction between the ITS and the learner special **interaction protocols** (IPs_{pid}) are created: they will be identical to scenarios if the learner followed exactly all the recommendations from the system. But as in real-life learning process, the learner can skip some tasks or get a score lower than required, or start learning materials not included in the current learning scenario etc. Such situations should be reflected in the interaction protocol, based on which sets of learning goals and tasks can be modified later. Thus, learning goals and tasks are based on the analysis of interaction protocols:

$$\begin{aligned} mT \supset \{ & F(Gt, GI, PID, CLK, PLA, IPC, PP, IPs), F(SGt, SGI, PID, CLK, PLA, IPC, PP, IPs), \\ & F(Tt, TI, PID, CLK, PLA, IPC, PP, IPs), F(STt, STI, PID, CLK, PLA, IPC, PP, IPs) \} \end{aligned} \quad (10'')$$

3.3. The System Interface Model

Within the mSIn **system interface model** we need to describe all supported modes of interaction between the ITS and the user (interface elements: windows, menus, toolbars, text fields, etc.), as well as the structure and design of the interface:

$$\begin{aligned} mSIn \supset \{ StrI \supset \{ IEIs, LSI \}, IDsgn \}, & StrI – \underline{St}ructure\ of\ the\ \underline{I}nterface, IEIs – \underline{I}nterface\ \underline{E}lement\underline{s}, LSI – \\ & \underline{L}inguistic\ \underline{S}upport\ of\ \underline{I}nterface, IDsgn – \underline{I}nterface\ \underline{D}esi\underline{gn} \end{aligned} \quad (15)$$

We will not enumerate all possible **elements of the interface** (IEIs). In the standard Windows interface it will be a commonly known set of elements, each of these elements will have a unique ID a predefined set of functions within the model. All interface elements identified in this way will be included in the description of **the interface structure** StrI, a tree of elements and their vertical and horizontal connections. In order to implement the natural-language interaction within the interface model appropriate elements need to be included.

3.4. The Interface Linguistic Support

Particularly important in the interface model mSIn is **the interface linguistic support** LSI. Unfortunately many developers still underestimate this component. This negligence makes many applications almost totally occult for users or at least seriously degrades the user experience. It is even more important in the ITS, because the efficiency of the learning process depends on the overall usability, simplicity and relevance of menu items, pop-up tips, messages, warnings, dialogs and other linguistic components.

Now, as we are dealing with the creation of an ITS for learning Belarusian as a foreign language, the linguistic support of the interface should include a possibility to use an interlingua, i.e., the mother language of the learner or any other language which he commands well.

The interface model may be incomplete, but this component of the ITS seems to be one of the most important ones and requires special attention: after all, the efficiency of the learning process relies on the level of the system usability. This is in a direct connection with motivating the learner. Besides all issues experienced by user due to the interface inconvenience or unintelligibility will have an overall negative impact on the teaching of the given subject, i.e., in our case of Belarusian.

3.5. Flexibility and Customization of Interface

As we are discussing the concept of an intelligent system, it's natural to suppose that its interface has to be flexible and customizable to fit the particularities of individual users (PD, IPC), as well as to meet their preferences PP - (11). Therefore when elaborating the interface structure StrI we must provide a possibility for various types of branching. Just as flexible should be the interface IDsgn - it should be customizable when switching between different users, modes of use included in the learning process structure model mSLP, different forms of learning activities mFLA or academic disciplines mAD. One can't describe all possible interface configurations in advance. Therefore, within the interaction model one should include mechanisms for customizing the structure and design of the interface:

$$\text{mSIn} \supset \{ F(\text{StrI, IDsgn, PID (PD, IPC, PP), SEP, FLA, SAD}) \},$$
$$\text{SEP} - \underline{\text{S}}\text{tructure of } \underline{\text{E}}\text{ducational } \underline{\text{P}}\text{rocess, SEP} \subset \text{mSLP, FLA} - \underline{\text{F}}\text{orms of } \underline{\text{L}}\text{earning } \underline{\text{A}}\text{ctivities,} \quad (16)$$
$$\text{FLA} \subset \text{mFLA, SAD} - \underline{\text{S}}\text{tructure of } \underline{\text{A}}\text{cademic } \underline{\text{D}}\text{iscipline, SAD} \subset \text{mAD}$$

Obviously there has to be coordination between the mechanisms construction of custom interaction scenarios or structure interface structure. Thus the following models are coordinated:

$$\text{mScI} \leftrightarrow \text{mSIn} \quad (17)$$

3.6. User Speech Model and the Dialog Model

User Speech Model USM is introduced in the interaction model mI in order to point out that ITS takes into account the learner's individual characteristics when communicating with him using natural language. The user speech model will include the following characteristics of the user: vocabulary; complexity of grammatical constructions used; the speech rate (this includes not only the actual speech but also the keyboard input speed); speech perception rate. This evaluates the speed at which the learner can comprehend the spoken language as well as how fast he can read; speech defects, including frequent grammar mistakes in the written input.

As the system in question should enable natural language dialogue functionality, the interaction model mI includes **the dialogue model** mDg. In the majority of natural language dialogue systems the interaction is almost completely defined by the particular topic of the system. It's quite easy to describe, for example, the dialogue of the user with a ticket-reservation system. In the ITS BFL it's hard to define one particular subject. Thus within the dialogue model mDg it makes more sense to speak of a set of models, each corresponding to a particular subject area. This concerns especially the dialogue subject. However there are general principles for creating the dialogue interaction. Researchers distinguish particular phases of a dialog, different types of dialogs, make attempts to model dialogs, etc. In the present work we are not trying to give an overview of all achievements in the dialogue theory. This would require a much larger volume. We will only try to point out particular components of the dialogue within the ITS discussed. We will take into account the fact that the communication is taking place within the learning process. Thus, the dialogue model mDg can be represented as follows:

$$\text{mDg} = \{ \text{TD, LD, SbD, PEC, MacroD, MicroD} \}, \text{TD} - \underline{\text{T}}\text{ype of } \underline{\text{D}}\text{ialogue, LD} - \underline{\text{L}}\text{anguage of } \underline{\text{D}}\text{ialogue,}$$
$$\text{SbD} - \underline{\text{Sub}}\text{ject (topic) of } \underline{\text{D}}\text{ialogue, PEC} - \underline{\text{P}}\text{urpose } \underline{\text{E}}\text{ntities } \underline{\text{C}}\text{ommunicate, MacroD} - \underline{\text{Macro}}\text{structure of} \quad (18)$$
$$\underline{\text{D}}\text{ialog, MicroD} - \underline{\text{Micro}}\text{structure of } \underline{\text{D}}\text{ialog}$$

3.7. Models of Languages and the World Model

As the communication is conducted in a language (or several languages, if an Interlingua is used) we have included in the interaction model **models of languages** mLgs. As the volume of this paper is very limited, we will not analyze these models in detail. For the discussed ITS BFL the model of Belarusian is both a studied **domain model** DM (Domain Model) and **an Academic discipline model** (mAD). Obviously modelling a language both for natural language human-computer interaction and for the teaching of the given language requires a particular approach. However primary researches impose that hierarchical levels distinguished by the linguists need to be reflected within the given model. Additionally, a language model as well as an academic discipline model needs to include various levels of complexity of language components and show the frequency of usage of particular patterns and the importance of a given element for the overall learning process (i.e., whether a topic is an absolute must for learning or just an additional element and thus can be omitted). Thoroughly formalizing at least the most common rules of language seems to be a good idea, because it will enable the system to analyze or generate natural language utterances in the course of dialogue with the user as well as for explaining these rules to the learner. Besides these rules must be used for automatic generation of various exercises and the correction of mistakes made by the learner (ranging from grammar to grammar and stylistic-related mistakes).

The last component of the interaction model in question is **the world model** mW. This component of the ITS BFL is probably the largest and the most complicated in terms of formalization, because the main goal of foreign language learning is, as we have stated above the acquisition of speech competence within a wide range of topics. Therefore when discussing the creation of an all-purpose system, in our conception the surrounding world model mW will be a set of models of various subject areas (domains). Depending on the level of the learner or on the subject area in which he wants to use the language, the ITS should activate the model of a relevant **subject domain** (DM).

Learning Process Structure Model

Thus the components of **learning process structure model** mSLP, **learning activity forms models** mFLA, **academic discipline models** mAD depend directly on the goals and tasks set within **the tutor model** mT, **the learner model** mL and **the interaction model** mI. For example, the above mentioned learning goals and tasks already contain corresponding learning stages and elements of the content of the learning material

Within **the learning process structure model** mSLP it is reasonable to consider the time frame of the learning process, split up in terms (terms - Tr) with corresponding goals and tasks:

$$\begin{gathered} \text{mSLP} \subset \{\, \text{Tr} \subset \{\, \text{Gtr} \rightarrow \text{Ttr} \,\}\,\},\ \text{Gtr – Goals of term, Ttr – Tasks of term,} \\ \text{Tr} = \{\, \text{T}_j \,\},\ j=1, \ldots, \text{Qtr},\ \text{Gtr} = \{\, \text{Gtr}_{ji} \,\},\ i=1, \ldots, \text{Ntr},\ \text{Ttr} = \{\, \text{Ttr}_{ji} \,\},\ i=1, \ldots, \text{Ltr} \end{gathered} \tag{19}$$

The time frame of each term are set as exact intervals within a certain calendar system (absolute system) or, in the case of remote learning, as sets of start and end points (relative system). In the second case the start and end points are assigned a set of academic requirements relative to the learner's current level of competence. Depending on the type of the learning process organization, additional parameters could be added, e.g., the criteria of competence evaluation and/or the duration of the term.

The model of an academic discipline mAD, as stated above, is, within the ITS BFL closely connected with the model of Belarusian language mBelLg (model of Belarusian Language) and is based on the subject domain model DM. However all the elements of the learning material, its structure as well as their appropriateness for various levels and stages of learning are just as essential for the academic discipline model.

Conclusion

Unfortunately, due to volume constraints we cannot describe all models in more detail in this paper. However we dare to hope that at least at the conceptual level we have managed to analyze the model of learning process within the ITS for learning Belarusian as a foreign language. We must mention that the system is described here as an idealized project. This is done in order to define the most interesting ideas and to explore alternative solutions for complex problems. We do not affirm that this conceptual description of a ITS BFL is complete nor flawless. It is clear that many of the above mentioned ideas need to be refined and some of them are highly debatable.

In conclusion we need to add that in order to embody this concept of an ITS BFL we need to elaborate a set of knowledge representation languages for various purposes. But the use of different languages that are incompatible with each other is not acceptable, because by analyzing the above described models one can easily understand that many of them are closely related to each other. Therefore the choice of the knowledge representation languages should be determined by one base. For this purpose we can use the basic semantic language of knowledge representation SC (Semantic Code), which has been created and is being developed within the open source project OSTIS (Open Semantic Technology for Intelligent Systems, http://www.ostis.net) at the Belarusian State University of Informatics and Radioelectronics in Minsk.

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