Some Aspects of Intelligent Technology of Construction of the Tutoring Integrated Expert Systems

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***Abstract*—We analyze the experience of development and use of tutoring integrated expert systems in MEPhI educational process. These systems were created on the basis of problem-oriented methodology and intelligent software environment of AT-TECHNOLOGY workbench. The emphasis is on the peculiarities of the implementation of certain tasks of intellectual training, related to the identification of students' knowledge and skills to solve non-formalized problems.**

***Keywords*— artificial intelligence, integrated expert systems, problem-oriented methodology, AT-TECHNOLOGY workbench, intelligent software environment, automated planning, tutoring integrated expert systems, intelligent training.**

I. Introduction

Methods of intelligent planning, and their integration with knowledge engineering, proposed and described in detail in [1], [2]. and in other works, are the basis of a new technology for building one of the most common classes of intelligent systems - integrated expert systems (IES) [1]–[3] , the demand for which in modern conditions of extraordinary attention to the use of methods and technologies of artificial intelligence (AI) has increased significantly, especially in the light of priority areas of development and use of technologies defined by the Decree of the President of the Russian Federation (No. 490 of 10.10.2019).

For the construction of IES is created, actively used and constantly evolving problem-oriented methodology [1], the essence of which consists in modeling the conceptual architecture of IES at all levels of consideration of the integration processes in IES and focus on modeling specific types of non-formalized problems (NF-problems), relevant technology,knowledge based systems(KBS). AT-TECHNOLOGY workbench [1]–[4] provide intelligent support for the development of the IES at all stages of the life cycle (LC) of building and maintenance of the IES (a detailed description of the intelligent software environment of the AT-TECHNOLOGY workbench can be found in [1]–[4]and other works).

The problem of *tutoring* is the least formalized among the "typical tasks" considered in the problem-oriented methodology [1] , which is associated with the insufficient development of pedagogical and psychological theories of knowledge acquisition, formation of concepts, construction of conclusions and other problems. However, as shown in [1] ,this problem is easily decomposed into a sequence of simpler tasks (*diagnosis, interpretation, planning, design*, etc.), which in general allowed us to develop a new approach to the construction of intelligent tutoring systems (ITS) based on the architecture of *tutoring* IES, linking the solution of these problems with the construction of appropriate models - *tutoring* (diagnosis), *trainee* (planning, design), *explanation* (interpretation), etc.

Currently, considerable experience has been accumulated in the use of tutoring IES developed using the basic tools of the AT-TECHNOLOGY workbench in the educational process of the MEPhI. *Applied* ontologies are implemented and dynamically supported for all basic courses / disciplines, which together form a *generalized* ontology "Intelligent systems and technologies". A unified ontological space of *knowledge* and *skills* was created for the automated construction of *competence-oriented* models of specialists in the field of AI and software engineering.

A significant place in the framework of problem-oriented methodology is given to methods and means of intelligent support of the most labor-intensive all stages of LC construction of IES - analysis of system requirements and design. Here, as a conceptual basis of intelligent technology is the concept of the *intellectual environment model* [1], [2] , the main components of which are the *technological knowledge base* (KB) and *the intelligent planner*.

The accumulation of experience associated with the development of various architectures of the IES for specific problem domains (PrD) and classes of solved problems showed that the *prototyping* processes of tutoring IES [1]–[3] have the greatest complexity due to the great complexity of building a *model of the architecture* of tutoring IES, performed, as a rule, by a subject teacher with the help of a knowledge engineer, as well as the need to use a large number of separate software and information components of the AT-TECHNOLOGY workbench, implementing the basic functionality of tutoring IES (*building a model of the trainee, tutoring model, ontology of courses/disciplines*, etc.).

Therefore, the focus of this work is on the issues related to the experimental program research of prototyping processes of tutoring IES based on the use of intelligent technology for the development and maintenance of applied IES.

II. Features of intellectualization of prototyping processes of tutoring IES

Let us consider the features of the new technology for supporting prototyping processes of applied IES using the main components of the intelligent software environment [2]–[4].

The basic declarative component of the intelligent software environment model in accordance with [1] [1] is the *technological* KB, which contains knowledge about the accumulated experience of building the IES in the form of a set of *standard-design procedures* (SDP) and *reusable components* (RUC). An important operational component of the model of intelligent software environment is the means of intelligent planning of actions of knowledge engineers, which provide generation and execution of plans for building prototypes of IES, i.e. *intelligent planner* developed on the basis of integration of models and methods of intelligent planning with knowledge engineering methods applied in the field of IES [1], [4].

As input to generate plans for the development of prototypes of IES are an *architectural model* of a prototype IES described by a hierarchy of *extended data flow diagrams* (EDFD [1]), and technological KB contains set of SDP and RUC. Accordingly, the model of prototyping processes of IES [3], [4] includes the function of planning the actions of knowledge engineers to obtain the current prototype of ES for a specific PrD. The main task of the intelligent planner is to automatically generate plans (*global and detailed* [4]) based on the model of the architecture of the IES and a set of RUC from the technological KB, which significantly reduces the risks of erroneous actions of knowledge engineers.

Execution of the plan tasks is carried out with the help of operational (instrumental) RUC. In terms of SDP as a key element of algorithmic, intelligent planner at each moment of time produces a detailed building plan for the development of IES depending on the current state of the project (type of solving NF-problems [1], reflected on the architectural model) , features of PrD, the availability of the architectural model unprojected drives, etc..

In accordance with [1], [2] the general architecture of the AT-TECHNOLOGY workbench is built in such a way that all functionality is distributed, i.e. "spread" on the components registered in the environment of

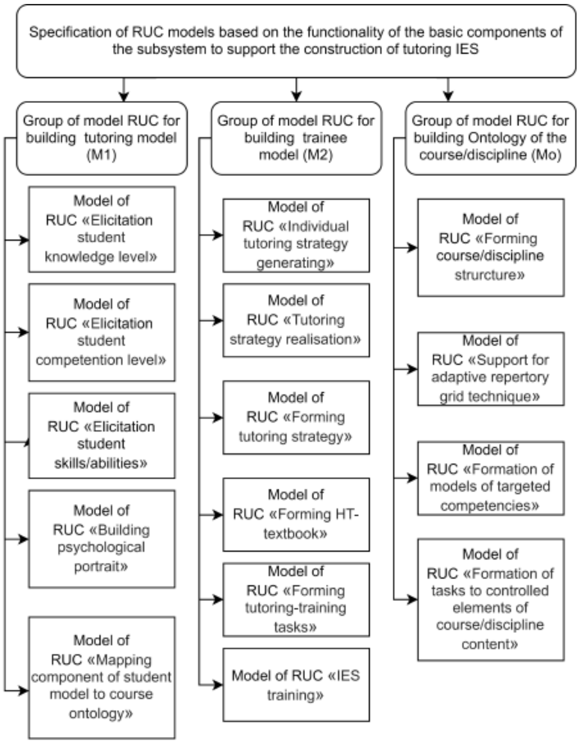

Figure 1. Specification of RUC models based on the functionality of the basic components of the subsystem to support the construction of tutoring IES

the workbench and operating under the control of the intelligent development support environment. In other words, these components are the RUC of the workbench and are implemented according to the results defined for the RUC [1].Currently, within the intelligent technology of building IES used two groups of RUC – components implementing the procedural capabilities of *procedure* RUC, and components that implement the capabilities of *information* RUC [1], [2].

It is important to note that in the course of the research conducted, the basic components of the AT-TECHNOLOGY workbench (information and software) that implement the technology of building tutoring IES (Fig. 1) were specified on the basis of what the ontology of RUC is built. Ontology model RUC is a development of the basic ontology model proposed in the framework of problem-oriented methodology [1], [2], and is a semantic network where the vertices represent the different elements of the model tutoring objectives (tutoring model (M1), trainee model (M2), a model ontology (Mo), etc.), as well as a set of models of different training impact on the identification of knowledge and skills of trainees, and arcs show the variouslink types (relations between RUC, training impacts, educational-training tasks, fragments of of hypertext textbooks (HT-textbooks)). Currently, the RUC ontology has more than 50 peaks.

In the process of prototyping of IES intelligent planner, having knowledge of all SDP forms the set of tasks for the development of any prototype of IES (in accordance with LC of development), and then based on the requirements to the prototype of IES generated in the stage of analysis of system requirements, decompositum the development plan into small tasks (subtasks). All SDP are classified as follows [1]:SDP that do not depend on the type of task, for example, related to the processes of acquiring knowledge from different sources (experts, EY-texts, databases); SDP, depending on the type of task, for example, the construction of components of tutoring ICS; SDP, associated with the RUC, i.e. procedures that contain information about the LC of RUC from the beginning of its configuration to inclusion in the layout of the prototype ICS, as well as information about the tasks solved by this RUC, the necessary settings and, possibly, their values.

Complication of architecture of IES, and the emergence of the technological KB of a large number of SDP and RUC led to an increase of the complexity of the search increased the negative effect of nonoptimality of the solutions. Therefore, several years ago there was a need to improve the methods and algorithms of planning [1]used by the intelligent planner. The results of the complex analysis of modern methods of intellegent planning and the conducted experimental studies [4] have shown the expediency of using to solve the problem a fairly well-known approach associated with planning in the space of states [5]–[9].

The method of generation of the action plan of the knowledge engineer is to perform a sequence of transformations of the model architecture the current prototype of IES performed in 4 stages [4]: receiving generalized EDFD graph; generate an exact *cover* (i.e. a set of instances of the SDP from mutually disjoint fragments containing all vertices of the graph) using a heuristic search; generate plan of knowledge engineer based on the detailed coverage; generation of a presentation plan.

A detailed description of methods and algorithms for the implementation of intelligent planning is given in [1], [4] and others, and below in the context of this work, the results of experimental modeling for the SDP "Construction of tutoring IES"are considered.

III. Research of possibilities of application of intelligent technology of prototyping of tutoring IES (on the example of plan generation)

All of the above steps are performed by intelligent planner that fully implements the functionality associated with the planning of processes of prototyping IES. With the help of the EDFD hierarchy preprocessor, the DPD hierarchy is preprocessed by converting it into a single generalized maximum detail diagram (Fig.1). The task of covering the detailed EDFD with the existing SDP is implemented using the global plan generator, which on the basis of the technological KB and the built generalized EDFD provides the task, as a result of which the exact coverage is built, which is later converted into a global development plan.

The generator of the detailed plan is carried out detailing each element of the coating, i.e. on the basis of the obtained coating EDFD and technological KB is made detailing each element of the coating, thus forming a preliminary detailed plan.

Then, based on the analysis of available RUC and their versions (data about which are requested from the development process management component), the plan interpretation component generates a detailed plan, where each task is associated with a specific RUC and can be performed by a knowledge engineer. With the help of the building component of the final plan, the necessary representation of the plan is formed for its use by other components of the intelligent software environment (the visualization component of the plan (Fig.3), etc.).

The following example describes the representation method

First, we describe how to store the RUC ontology that the planner works with. The RUC ontology is stored as an XML-document [10] that defines how all elements are described using tags. First, the description of 4 types of ontology elements is presented (Fig. 2): operation - function, unformalized operation-nffunction, entity-entity, storage-store. The following is a description of the relationships between the elements-flow (Fig. 3), followed by a description of a group of strongly connected RUC - fragment (Fig. 4), where document is the file created as a result of the RUC work, and extension - its type. The end describes the chronology of the execution of RUC groups - network (Fig. 5), where the task - description of the work performed by the group RUC (input - description files necessary for the correct operation, output the description of the files created as a result of work, predecessor - a description of what the RUC group should interact to perform his current job, executor - name operational RUC, which will carry out the ongoing work).

```
<procedure name="Построение обучающей ИЭС">
 <nodes>
   <node id="41" name="Преподаватель" type="Entity" />
   <node id="31" name="создать &quot;тренинг с ИЭС&quot;" type="NFFunction" />
   <node id="21" name="создать УТЗ" type="Function" />
   <node id="22" name="создать ГТ-учебник" type="Function" />
   <node id="11" name="БД онтологий" type="Storage" />
```

Figure 2. A fragment of an XML document describing the PIC ontology (elements)

```xml
<flows>
  <flow data="задание" src_id="41" dest_id="21"/>
  <flow data="знания" src_id="41" dest_id="22"/>
  <flow data="знания" src_id="41" dest_id="31"/>
  <flow data="знания, опыт" src_id="41" dest_id="24"/>
  <flow data="знания, опыт" src_id="41" dest_id="23"/>
  <flow data="знания" src_id="41" dest_id="25"/>
```

Figure 3. A fragment of an XML document describing the PIC ontology (links)

```xml
<fragments>
  <fragment id="0" name="Основной" primary="1">
    <nodes>
          <node_ref id="32"/>
          <node_ref id="42"/>
          <node_ref id="12"/>
    </nodes>
    <documents>
      <document id="0" name="Поле знаний" extension="log"/>
      <document id="1" name="Протокол верификации" extension="log"/>
      <document id="2" name="База знаний"  extension="kbs"/>
```

Figure 4. A fragment of an XML document describing the PIC ontology (group of strongly connected RUC)

```xml
<network>
  <task id="0" fragment_id="0" name="Приобретение знаний"
        stage="Анализ системных требований" executor="KMPZ">
    <output>
      <document id="0"/>
      <document id="4"/>
    </output>
  </task>
```

Figure 5. A fragment of an XML document describing the PIC ontology (chronology of the execution of RUC groups)

IV. Conclusion

Thus, the experimental base in the form of accumulated information and software tutoring of IES for individual courses/disciplines that are used in the educational process of the department of Cybernetics at MEPhI since 2008 proved to be a good "testing ground" for the continuation and development of studies in developing elements of a new intelligent planning and control processes of building intelligent systems, including tutoring of IES.

It is important that a single conceptual basis for their development is a problem-oriented methodology, and as a tool - AT-TECHNOLOGY workbench.

In fact, there was a technological transition from "automation" to "intellectualization" of labor-intensive processes of design and maintenance of information and software tutoring IES, by creating conditions for effective use of the intelligent planner, in particular, to create a technological knowledge base (SDP, RUC information and operational nature), and then conduct full-fledged research on the creation of elements of new technology.

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Некоторые аспекты интеллектуальной технологии построения обучающих интегрированных экспертных систем

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Мы анализировали опыт разработки и использования интегрированных экспертных систем обучения в учебном процессе НИЯУ МИФИ. Эти системы были созданы на основе основы проблемно-ориентированной методологии и интеллектуального программного обеспечения среды инструментального комплекса АТ-ТЕХНОЛОГИЯ. Выразительность речь идет об особенностях реализации тех или иных задач организации интеллектуальное обучение, связанное с идентификацией личности обучающихся знания и умения решать неформализованные задачи.

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