Intelligent planning methods and features of their usage for development automation of dynamic integrated expert systems

Galina V. Rybina[1], Yuri M. Blokhin[1], and Sergey S. Parondzhanov[1]

National Research Nuclear University MEPhI, Moscow, Russia
galina@ailab.mephi.ru

Abstract. The problems of intellectualization in the development process of dynamic integrated expert systems basing on the the problem-oriented methodology and the AT-TECHNOLOGY workbench are considered. The experience from carrying out intellectual planning development plan generating of prototypes in integrated expert systems, the intelligent planner usage, reusable components, typical project procedures, and other components of the intellectual software environment in the AT-TECHNOLOGY workbench is described.

Keywords: artificial intelligence, integrated expert systems, problem-oriented methodology, intelligent programm environment, AT-TECHNOLOGY workbench, automated planning

1 Introduction

The most complex class of applied intelligent systems are dynamic intelligent systems (DIS), including real time (RT) DIS. This is one of the most and currently one of the most relevant and in-demand classes of DIS are dynamic integrated expert systems (IES) that use dynamic domain and solving dynamic problems [10]. Analysis of the foreign and domestic level of research and development in the field of DIS, in particular, dynamic IES, has shown that when creating dynamic IES and relevant tools (IS), a large number of scientific and technological problems arise related to the specific features of building both separate components of the IES. This problems determine the high complexity of DIS development as dynamic integrated expert systems that are the most widespread and needed DIS class. Moreover, there is no universal complex method for solving the described problems (or a part of them) that implies the develop ment of an integrated integral methodology and tech nology for creating such complicated systems at all lifecycle stages. Modern commercial software to support the construction of most DISs (G2, Rtworks, RTXPS, etc.) despite its power and versatility, is not able to solve the above problems in terms of integrated methodology fully [13].

A considerable step towards generating such meth odology can be a new stage of developing the theory and technology of IES construction based on the problem oriented methodology, whose main statements are stated in a few monographies [11, 12]. Today, this is the basis that is used to create the intelligent applications and automated workstation of a knowledge engineer, namely, the AT TECHNOLOGY tool com plex, on whose basis several tens of applied IESs have been created, where a wide spectrum of models and methods of solving different unformalized and formalized problems is used in terms of integrated IES architecture.

An important feature of the modern version of the AT-TECHNOLOGY workbench is the automated support of dynamic IES development, using methods of intelligent planning and control of development processes [14–16, 19, 18, 17]. As the conceptual basis of intellectual software technology is the concept of intelligent programm environment model. Its complete formal description and methods for implementing individual components is given in [10].

This work is focused on the further development of methods and tools for the automated construction of dynamic IES using components of the intelligent software environment and taking into account the modern requirements of software engineering, described in detail in [5] and other works.

2 Intelligent planning methods and features of their usage for dynamic IES development automation

In [15] there is a detailed analysis of modern methods, approaches and software tools used in the field of intelligent planning, so here we consider only the most important theoretical and methodological aspects of this problem in the context of the goals and objectives of this paper.

Today automatic generation of plans by a software and hardware system is often meant as the intelligent planning,. Accordingly, plan is a glimpse of future behavior in the context of intelligent planning. In particular, the plan is usually a set of steps with some restrictions (e.g., temporal) for the execution of some agent or agents [6].

Software system that generates plans based on a formal description of the environment, the initial state of the environment and assigned to the planner purpose is meant under planner in practical application. In some works, planner is called the agent [7]; in other cases, the planner also contains the designer carrying out the allocation of resources for the implementation of building plans.

In modern works (for example, [6, 3]), for the formal formulation of the planning problem, a basic notion is often used, such as the Labeled Transition System, which is described as:

$$\Sigma = \langle S, A, E, \gamma \rangle \tag{1}$$

where $S = \{s_0, s_1, s_2, ...\}$ – set of states; $A = \{a_0, a_1, a_2, ...\}$ set of actions; $E = \{e_0, e_1, e_2, ...\}$ set of events; $\gamma : S \times (A \cup E) \rightarrow 2^S$ - transition function. Thus, for a system Σ with an initial state s_0 and a subset of target states S_g, it is required to find a sequence of actions corresponding to successive transitions between the states $s_0, s_1, s_2, ..., s_g$, so that s_g belongs to S_g.

In general, the formulation of the planning problem described in modern works is based on the basic set of such axioms for Σ, as [6, 3]: finiteness; full observability; determinism; staticness; limited goals; plans linearity; implicit time; offline planning. These axioms impose significant restrictions on the formulation of the planning problem, and violation of some of these axioms leads to a complication of the planning task.

The results of complex analysis and conducted experimental studies have shown the expediency of using state space planning in this work. On of the reasons is that the task of planning the processes of prototyping PES as a whole is described quite well in terms of states and transitions. It is necessary to point out that application of intelligent planning for the automated support processes of building intelligent systems is a poorly investigated area, and it is possible here to refer mainly to the experience gained in the creation of applied dynamic IES based on the problem-oriented methodology and AT-TECHNOLOGY workbench. Let us consider the basic concepts of intellectual AT-TECHNOLOGY workbench software in more detail. So far, the main applications of intelligent planning are [6, 3, 15, 21, 4, 1, 8, 20, 22]: autonomous robots control; logistics and the resolution of extraordinary events; semantic web; automated tutoring; calibration of equipment; control of conveyor machines; resource-scheduling; resource allocation in computer systems.

Plan search algorithms have a significant meaning in the chosen approach, therefore a comparative study of the most famous foreign algorithms was carried out [3, 7, 9]: A^* (A star); A^* Best-First Search; Greedy Best-First search; Eager Best-First Search; Lazy Best-First Search; Enforced Hill-Climbing; Restarting Weighted A^* (RWA^*); And / Or graph (AO^*); Loops AO^* (LAO^*); Bidirectional LAO^* ($BLAO^*$); Reversed LAO^* ($RLAO^*$); Path Pruning A^* ($PP-A^*$); Hierarchical A^* for MT-Graphs (HGA^*), etc.

Therefore, a comparative analysis of universal heuristic functions used in planners implementations was carried out within the framework of these studies and using heuristics (relaxed heuristics, heuristics of the critical path, abstract heuristics, landmark) [3, 22, 2, 8]: Blind; Relaxation-based maximum; Merge-and-shrink; Admissible Landmark; Relaxation-based additive; Relaxed plan heuristic; Casual graph heuristic; Context-enhanced additive heuristic; The Landmark Heuristic et al.

In general, the comparison showed that even though the most powerful heuristic functions (for example, from the landmark class) show rather high efficiency, they do not give a fundamentally qualitative leap in the issues of computational complexity of solving the planning problem. Therefore, for specialized domains such as dynamic IES, it is preferable to use problem-oriented heuristic functions instead of universal ones. They can reduce search space size upto several orders, so in this work, two specialized heuristic functions have been developed, the description of which is given below.

3 Methods and approaches used in basic intelligent programm environment components

Significant place in the framework of the problem-oriented IES constructing methodology (basic points are reflected in [10]) is given to the methods and means of intelligent software support for the development processes. It is general concept of "intelligent environment". Complete formal description of the intellectual environment model and methods of the individual components implementation is presented in [10].

Let us briefly examine the methods and approaches used in the implementation of the intellectual supportive environment for the development of IES model. The main components of this IES are the technological KB on the composition of IES project, standard design procedures (SDP) and reusable components, and the intelligent planner managing the process of plans construction and implementation for the development of IES prototypes. These are the main purposes why it is necessary to use different types of knowledge in the process of developing a IES prototype: checking referential integrity of the project on the development of IES; automated construction of components diagrams; layout synthesis of IES prototype architecture; planning a series of steps to create a prototype of IES-specific features and tasks; determining a set of the most relevant sub-tasks for each of the stages (steps) in the development of IES prototype and others.

Thus, the main task of intelligent planner is a dynamic support knowledge engineer operations at all life cycle stages of building prototypes. Dynamic support is done by generating IES development plans for the current IES prototypes and allowing the specific plans execution (made either automatically or interactively). It should be noted that detailed plans and global IES prototyping generation and architecture model synthesis is based on the integration of IES with planning methods.

Let us briefly consider the features of the proposed method for plan generating for the applied IES development. Method is based on state-space planning which generates plan applied IES architecture model and the SDP set. The architecture model IES contains a set of elements that need to be realized and depending on the type of element and its content, different RUCs can be used for implementation, resulting in various components of the IES prototype project. Moreover, the use of knowledge from the technological KB (containing SDP and RUC) allows the implementation of several architecture mode components together with the application of the appropriate RUC. Four special algorithms have been developed to implement the proposed method. With the help of the first one, the model of the prototype architecture of the IES [10] is preprocessed by converting architecture model in the form of a hierarchy of extended data flow diagrams into one generalized diagram by recursive detailing of complex operations.

Another algorithm is designed to search the *coarse coverage* of the generalised diagram. In this paper, a multiple of SDP fragments is meant to cover a diagram, between elements of which a one-to-one correspondence with elements of a generalized diagram is established. Under a coarse coverage is meant a cover only by necessary fragments of a SDP.

Then, with the help of the third algorithm, the *detailed coverage* is generated, which means covering all available SDP fragments from the set of activated SDPs. The second and third steps are implemented with using heuristic state space search, based on the classical algorithm A^*. Generating of new states is associated with the coverage of the diagram by each new fragment (necessary and optional respectively). The fourth algorithm is designed to convert the detailed coverage into a plan, with a set of planned tasks associated with the use of certain operational RUCs from each coverage fragment.

4 Conclusion

At the present time various methods of intelligent planning, algorithms and heuristic functions have been experimentally evaluated for the further development of the intelligent planner efficiency of in AT-TECHNOLOGY workbench. As a result original method for IES development automation basing on intelligent planning (with two special heuristic estimations) was developed and implemented. A new SDP for dynamic IES development was developed and explored. The proposed technology was used to develop two protototypes of dynamic IES for the Russian Center for Disaster Medicine "Zaschita" ("Management of medical forces and means for major road accidents" and "Management and monitoring of resources of the satellite communication system between regional centers"). Their design and implementation stages are characterized by high laboriousness and intellectual load on knowledge engineers.

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