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Development of the hybrid expert system shell SYNTHESIS for the problems of research design of technical objects

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Abstract

SYNTHESIS is a tool-making expert system (TMES) that ensures building of hybrid expert system shells (HESS). The latter, when being filled in with knowledge and data, allow to solve problems of research design of technical objects. The research design is aimed at creating of conceptual decision of a technical object (technical object's image). In the frame of SINTEZ family's HESS, this problem is solved in two stages: specification of well grounded requirements to the object under design; synthesis of the object's image on the basis of specified requirements. The HESS allows the user to create alternative variants of the image of technical object, to calculate values of the characteristics of various variants using the solver and to find the best variant on the basis of multicriteria analysis and logical inference.

1 Introduction

SYNTHESIS is a tool-making expert system (TMES) which provides a construction of hybrid expert system tools (HEST) tuned on solving tasks of either early stages of CAD or diagnostics of complicated technical system. TMES SYNTHESIS supports a possibility of transfering of knowledge and data obtained in CAD-type ES to diagnostic-type ES and reverse in order to use this information in the next cycle of design.

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Generated HES tool consist of subsystems of: dialogue, knowledge and data bases management systems, solver, explanation, knowledge acquisition, knowledge and data bases supplementation and testing. HES tool "hybridity" consists in the fact that HEST can have both computing and logical inference components at the same time, uses multicriteria choice component on all stages of problem solving, provides processing of partially defined knowledge and data during solving. Besides this every HEST generated by TMES SYNTHESIS may be tuned on solving of tasks of one or another class. In the sequel all variants of HES tools which can be elaborated with help of TMES SYNTHESIS will be called HEST SYNTHESIS.

2 Description of problem area of SYNTHESIS system

In order to choose the tools needed let us consider the problems arose on the border stages of the living cycle of technical system, i.e. computer aided design of technical system image and diagnosis of it's state under using. These tasks may be implemented with help of a set of means of the same type, i.e. variants generation, computing of variant parameters based on construction and implementation of computation plan, multicriteria comparison and choice of the most preferable variant. Building of the computation plan can be done using computation theory of the given class of technical systems and expert knowledge.

In the task of comparison and choice of design decisions every variant is represented by the set of economical parameters values. Absence of objective model is compensated by the rules, assumptions and dependencies built on the base of expert knowledge. In the task of comparison and choice of diagnosis schema every variant is also represented by the criteria set. When designing, variants generation is implemented on the AND/OR tree base. The nodes of this tree are technical decisions, possible physical principles of implementation of technical system components etc. Variants generation in diagnostics is also based on AND/OR tree. But here it has some different features, i.e. the lowest level of tree consists of possible disrepairs, the nodes of other levels present verification actions.

From the decision theoretical point of view the conceptual design stage includes the following main steps: specification of requirements to the design object and corresponding constraints in terms of criteria values; construction of the morphological set of design solutions and specification of the designer's preference system; determination of the feasible set of design alternatives and choice (or inference) of the most preferable design solutions.

Generation of diagnosis schema variant includes the two stages. The first one is AND/OR tree creation using disrepairs' shows, restrictions on the presence of diagnosis equipment and possibility of verification action execution. The second stage includes generation of diagnosis actions sequence in accordance with restrictions on the placement of mentioned actions. Note that procedures of diagnosis scheme generation may be used for the generation of design decision variants based on reference object.

Analysis of the above questions showed that effective accounting of all the features dealt with CAD and diagnostics is possible in the framework of ES technology only.

3 HEST SYNTHESIS architecture

The HES tool consists of the following subsystems [4]: interaction, knowledge representation, solver, library of modules, monitor, explanation, knowledge acquisition, training.

Interaction subsystem provides links between user and ES contains elements supporting user interaction with other subsystems.

Knowledge representation subsystem includes languages of description and manipulation with data and knowledge, respective translators, data and knowledge bases management systems. The subsystem supports following base data types: numbers, strings, formulas, tables.

External (user level) information representation is based on frame and production approaches. Internal representation is implemented using jointly core memory and data base management system. The subsystem provides formalization of partially defined information with the aim to use it during problem solving. The formalization can be done in HEST SYNTHESIS on the base of probability theory, fuzzy sets theory or interval mathematics [1,3]. When generating HEST the user may include in it logical inference unit (LIU), multicriteria choice unit (MCU), computational unit (CU).

If we include into HEST only one of the three units, HEST will have a view of usual (not hybrid) ES tool, decision support system, computational system which can use a theory of computations for the given problem area in order to count output variables by given input variables and their values. The solver can find solutions in the deterministic and probabilistic environments using completely or partially defined information.

LIU includes inference supervisor and rule interpreter. The aim of supervisor is to find next rule for execution. The task of interpreter is to process both parts of the rule, i.e. to compute truth degree of premise and to execute corresponding actions.

MCU consists of choice rules builder and best variant selector [1,2].

CU [5] is formed from computation planner and processor. The planner builds a plan of computations using input data, theory of computations (linking the variables of problem area) and a set of required variables. The task of processor is to implement a plan of computations and to make corresponding changes in data and knowledge bases.

If it is required the solver provides as interaction between all three units. As action in a rule (being processed in LIU) can be used a call of CU which will plan computation and compute values of required variables. The CU may involve LIU as one of procedures in order to infer on the base of expert knowledge a value of variable which can not be found from theory of computations. To the end, MCU is used in the tasks of choice of the best alternative from ES problem area and also in the interval tasks of ES (when seeking for: the best from alternative modules in CU, the most appropriate configuration of HEST on the stage of it's generation in TMES, etc.).

A library of modules includes programs solving functional tasks in problem area and consists of the following groups of programs: solving of the design and diagnostic tasks, standard mathematical operations, processing of partially defined information [3].

A knowledge acquisition subsystem consists of module implementing consultations between ES and expert and module which uses procedures of inductive rule formation in automated way. The first module implements interactive and paper-questionnaire ways of consultation with the expert about subjective dependencies, structure of problem area concepts, actions, facts. The second one provides automated synthesis of rules on the base of information collected by knowledge representation subsystem.

Explanation subsystem implements traditional for ES functions, such as WHY, HOW, WHAT FOR, WHAT IS ABSENT.

Training subsystem includes HELP-part and training part based on extended computerized textbook on HEST.

4 Architecture of TMES SYNTHESIS

Tool-making ES is intended for generation of HEST tuned on the CAD or diagnostic tasks. TMES SYNTHESIS includes the following subsystems (see figure): interaction with user, supervisor, ES, description builder, HEST generator, library of modules. Users of TMES are HEST designers and knowledge engineers (ES designers).

An interaction subsystem provides user-TMES dialogue on the base of menu and command languages. Supervisor coordinates interaction of the main TMES subsystems.

Description builder may be used by HEST designer only. He must have knowledge enough to form request for HEST generation by the scheme analogous to the operating systems generation scheme.

ES as a subsystem of TMES is intended to form a request for HEST generation by users which does not have knowledge and experience enough to prepare a request directly, i.e. with the help of description builder. The ES knowledge base contains: the AND/OR tree of technical decisions dealing with possible HEST implementations; knowledge on the combination of HEST elements, diagnostic and CAD tasks and methods of their solving; finally, knowledge allowing to classify user's task, to identify types of knowledge and data corresponding to user's task, to collect all information necessary to form a request. The ES data base contains technical information about elements of modules library.

The HEST generator implements building of HEST using a formed request, data and knowledge bases of ES and library of modules.

A final tuning of HEST is made during filling with data and knowledge, i.e., ES building on the base of TMES is run in four stages: determination of set of necessary components, HEST building, filling HEST with data and knowledge on specific task, ES tuning on particular user and task. The two first stages are running don't often as compared with the two last ones due to HEST is formed for set of tasks.

Library of modules includes programs implementing HEST components.

5 Possibilities of TMES

When building HEST a user may receive the following options:

1. Interaction subsystem. Usage of: menu - keyboard / "mouse", windows - colours / sizes / graphics.

2. LIU of solver. Inference type - backward / direct (modus ponens / modus tollens); scheme type - "at first in depth" / "at first in width"; choice of the next rule - "the first of queue" / "random choice" / choice on the base of vector criteria with scalar components "priority", "mean time of execution", "number of consequences", "number of unknown variables in a premise", "truth value of premise", "truth value of action part" / using metarules; information type - quantitative / ordinal / linguistic.

3. MCU of solver. Choice procedure type - axiomatic / heuristic; type of comparisons - on the scale of one criterion / on the scale values of pair of criteria / trade off / indifference curves; type of information - quantitative / ordinal / linguistic; type of questioning - interactive / questionnaire; type of tasks - deterministic / probabilistic.

4. CU of solver. Completeness of solution of the equations system - all solutions / one solution; type of information: quantitative / linguistic; necessity of input data checking - yes / no; optimization procedure type: by Rozenbrock / by Nelder-Mead / golden section.

5. Knowledge representation subsystem. Type of information - quantitative / linguistic; placing of all the knowledge base in RAM - yes / no; the same on data base.

6. Teaching subsystem. Necessity of prompts - yes / no; necessity of teaching - yes/ no.

7. Knowledge acquisition subsystem. Type of questioning - interactive / questionnaire; inductive generation type - statistical / potential functions / syntactic recognition, etc.

6 Concluding remarks

The tool-making expert system SYNTHESIS (version 1.1) is implemented using MS-DOS environment. The main components have passed an autonomous testing and were used in solving practical tasks [6]. SYNTHESIS project have also passed testing of all the system and now is ready for application. One of them is under implementation.

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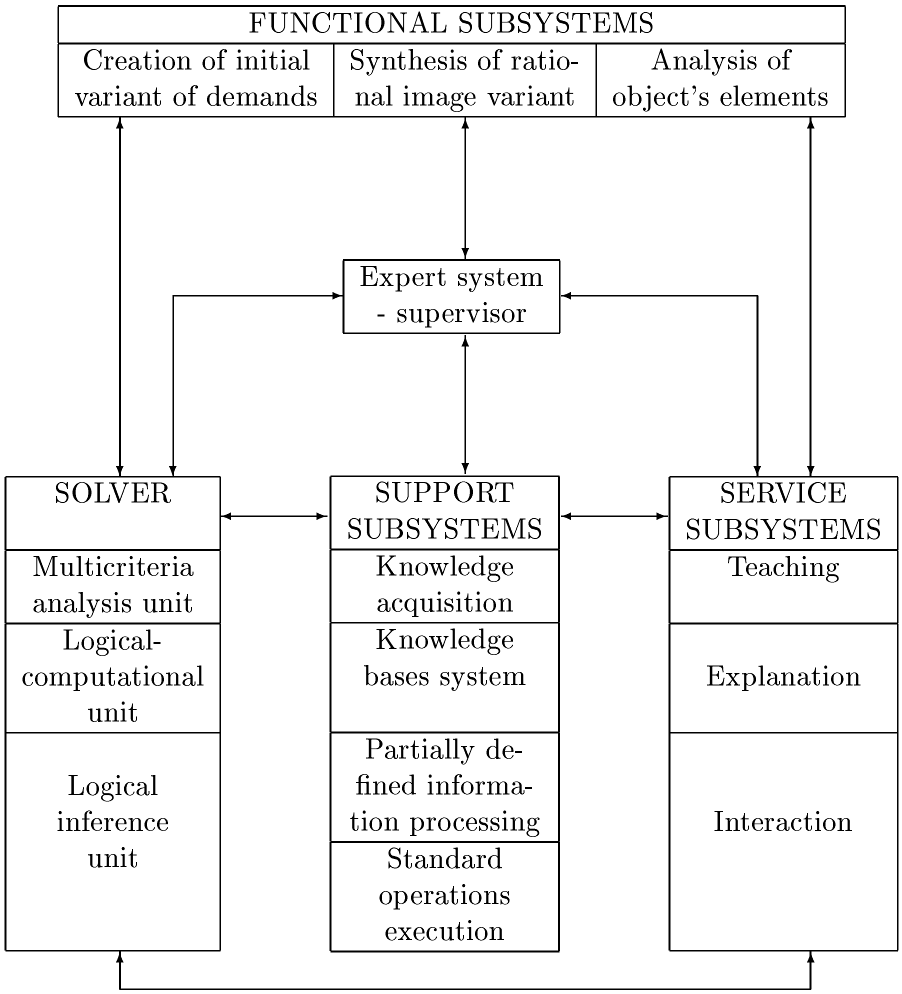

Figure 1:A structure of HEST for conceptul design of image of technical object.

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