On-board Operative Adviced Expert Systems for One-Seat Aircrafts and Structure of their knowledge Bases.

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ABSTRACT

The general semantical structure of an on-board real-time advisory systems for a choice of the manner of the attainment of the purpose (" R-T-AS for CMAP") is obtained. The knowledge base of the " R-T-AS for CMAP" consist of the productional rules of the activization of the scenario; mathematical models of the important events; the productional rules of the each scenario. It is showing to resulting of this method. The example of the " R-T-AS for CMAP " for a one-seat aircraft was given.

I. INTRODUCTION

The current function purpose is operationally choiced on every complex anthropocentral object (Anth/object). This is the first global level of control (I GLC) on the Anth/object. The rational manner of the goal achievement is looked for Anth/object. This is the second global level of control (II GLC). The I GLC tasks and II GLC one are most more the part of the Anth/object work. This part of the work is less of all dispatched with the on-board computer algorithm now.

The II GLC tasks are going to decide yet "tomorrow". These dicisions are on-board real-time advisory systems for a choice of the manner of the attainment of the purpose (" R-T-AS for CMAP") for typical situations (TS) of the Anth/object function.

The semantical classifications of an Anth/object is given in [1,2]. The " R-T-AS for CMAP " embraces the certain functi -on-clouse field of the Anth/object function which is named by TS.

II. INTELLIGENT SYSTEMS FOR ANTHROPOCENTRAL OBJECTS.

Intelligent systems attract the attention of the users and designer because of the opportunity to improve the functioning quality of the systems operator-object. This is declared in publications and shown in demonstration and test specimens of some intelligent systems. Such systems allow the accumulation, reproducion, and use of the domain knowledge. The change-over from data to knowledge is a natural result of development and complication of on-board information systems.

Let us turn our attention to intelligent systems that are under development in aviation.

Off-board intelligent systems of preparing an operational flight of an aircraft make the crew ready to execute a particular flight mission. These intelligent systems provide

a) analysis of a priori reconnaissance data about the flight area; in particular, analysis of expected counteraction of air and ground enemy;
b) development of optimal routes of flight in a battle area and returning to the airdrome;
c) choice of variants of tactics of arrival at the battle area and that of fighting against the expected enemy;
d) preparation of flight documents and input data required on board (for airborne equipment and a pilot map).

Note that, at present, all this work is always done before the flight; however, the quality of the preparation (which includes a degree of detail and cordination of flight missions for every member of crew, the supervision of understanding of fligth tasks by the members of the crew, and the accuracy and timeliness of preparation of the corresponding documentation) with the use of intelligent systems is by far higher.

It should be emphasized that an intelligent system is not aimed at doing something new that the operator does not usually do. It does those thihgs that the operator must do, but sometimes fails to do or does badly for various reasons. In addition to this, it always maintains the required technology of preparation and implements all necessary works.

The second group of intelligent systems includes on-board real-time advisory expert systems (“R-T-AS “) and expert systems of on-board measuring and executive devices. We will briefly characterize these systems. On-board real-time advisory expert systems belong to the class of so-called hybrid real-time expret systems. The aim of such systems is to make recommendations to the operators of man-machine objects as to how to solve the problems that face the object.

An aircraft falls into the class of complex antropocentral objects. The problems that face a complex antropocentral object can be divided into the three following global control levels (GCL) [1]:

(1) formulation (choice) of purpose of functioning of the object;
(2) choice of the method of attainment of the purpose formulated on the first GCL;

(3) realizition of the method chosen on the second GCL.

These problems are solved jointly by the operator (his actions are determined by the instruction and are supported by the information control field of the cabin) and by on-board software. Only the third global control level is hardware- and software-supported in the existing systems (in the table, such systems are denoted by the term “today”). In the developments that will arise in the nearest future (in the table, the term “tomorrow” is used for such developments), partial hardware and software support will appear on the second level, though not for all problems that are solved on this level.

Why are the problems of hardware and software supporting the problems of the first GCL and a part of the problems of the second GCL not solved today nor tomorrow? The answer to this question, in our opinion, is as follows. By using the traditional approach to building on-board software and hardware, the designer has run into the obstacles that cannot be overcome with the use of such an approach. These obstacles are the poor structuring of the problems of these levels; dissimilarity of the information required for solving fhese problems with regard to its quality, completeness, and hardware accessibility; a large body of the information about the conditions and general ways of functioning of the system operator-object (fundamental knowledge about the “world”).

Is it possible to overcome these difficulties by means of “R-T-AS “s? The answer is yes, especially for problems of the second GCL.

The hardware and software support of the activities of the crew on these GCLs is presented in the table.

The on-board real-time advisory expert systens of the kind discussed here are designed mainly for the problems of the second GCL, where “ R-T-AS for CMAP “ must work.

Expert systems of on-board measuring and executive devices (ES of OBMED) provide the most complete information about the environment and the state of the on-board hardware required at the moment, and guarantee the most exact execution of the decisions made. They work closely with the “ R-T-AS FOR CMAP “.

The off-board intelligent system of analysis of the results of the use of the anthropocentral object obtains the information from the on-board system of the unbiased control and from the built-in control system, and then determines, together with the crew, the quality of functioning of the system “operator-on-board hard-ware” (the system “pilot-on-board hardware”, in aviation) and effect on the efficiency of the flight.

The off-board intelligent system of diagnostics of the on-board hardware obtains information from the on-board system of the unbiased control, from the built-in control system, and from the standard monitoring-recording hardware. Based on this information, it provides, together with the technical personnel, the analysis of functioning of the on-board hardware in flight, isolation of the faults, and determines how to remove them.

III. ON-BOARD REAL-TIME ADVISORY EXPERT SYSTEMS AND THEIR FEATURES.

(1) The on-board real-time advisory expert systems are designed for joint work partly with the operator on the first global level and, mainly, on the second global level. In the system design [2-4] og the on-board software and indication hardware, these levels correspond to those called “Choice of a typical situation (TS)/typical battle situation (TBS)” and “Decision-making in subsituations with the chosen TS/TBS”, respectively. Note once more that the present-day on-board software and indication hardware is used only on the third GCL (the level of implementation of the decision taken). The on-board real-time advisory expert system of practical significance musbe in agreement with the current conceptual model of the operator behavior and have imperceptible reaction time for the operator (compared to time characteristics of real changes in the environment and those of the activities of the operator).

While the second requirement is accepted by the designers as a natural and concrete one, the first requirement requires discussion. The operator activity incorporates timely and correct detection and understanding of a problem, search for possible ways of solving it, selection of the most judicious (optimal) way, implementation of the solution, and control of the results of the activity. Note that neither the lack of necessary information nor the shortage og the time for its analysis relieves the operator of the necessity of making a particular (better, optimal) decision by some definite instant of time, which is determined by current conditions. It is under these circumstances that the “ R-T-AS FOR CMAP “ must give recommendations to the operator on how to solve a problem that faces him. In addition to this, one should take into account that the technical possibility of interaction between the operator and “ R-T-AS FOR CMAP “ on board is limited, and that the body of a prioriand current qualitative and quantitative information at the disposal of the operator is very large. With this in mind, let us make the first of the above requirements more specific.

To satisfy this requirement, the designer of the “ R-T-AS FOR CMAP “ should take into account the following:

(1) The operator plays the main part on board, and he must not inform the “ R-T-AS FOR CMAP “ about his current plans and ask the recommendations required at the moment. In other words, the knowledge base (KB) of the “ R-T-AS FOR CMAP “ and its conclusion mechanisms must detect and present to the operator significant (in the current conceptual behavior model) events, interpret them correctly, and make recommendations on how to solve the problem, obtained as a result of in-depth analysis.

(2) For every situation significant to the operator that may arise in the context of the conceptual model initiated by the operator, the “ R-T-AS FOR CMAP “ must give convincing and constructive recommendations. In other words, the subject domain of the “ R-T-AS FOR CMAP “ must be functionally closed for the operator, too.
(3) The “ R-T-AS FOR CMAP “ must be semantically and informationally built in the real (under design) information control field of the cabin. In other words, the recommendations and comments to them must be presented in such a form and place that are natural for a particular work station of the operator and be built in the natural space-time world of the cabin.
(4) The direct regime of communication of the operator with the “ R-T-AS FOR CMAP “ is very limited by hardware conveniences of modern cabins and by strong time limitations.
(5) Every particular copy of the “ R-T-AS FOR CMAP “ will be sequentially used by a few operators, who differ from each other by their professional training, psychophysiological cast, and motivation level.

IV. CONCEPTUALIZATION OF THE SUBJECT DOMAIN FOR A TYPICAL SITUATION. STRUCTURE OF “ R-T-AS FOR CMAP “.

The conceptualization of the subject domain for development of the “ R-T-AS FOR CMAP “ means the process and the result of creation of such a formal model the subject domain that (1) would correctly represent a collection of the objects, motivation, the way and result of their functioning; and (2) would allow the system programmer to develop the software based on this model.

Before proceeding to the conceptualization of the subject domain, one should

(1) extract some domain of functioning of the future “ R-T-AS FOR CMAP “ which is functionally closed for the operator;
(2) develop for this domain a generalized graph of activities of fhe system “operator-object-functioning domain”;
(3) outline an available level of the hardware used for the interaction of the operator with the “ R-T-AS FOR CMAP “:
(4) before the functioning of the object (e.g., before the flight) and (b) in process of the object functioning (in-flight conditions);
(5) outline a possible (i.e., hardware acceptable) mechanism of improving the knowledge base of the “ R-T-AS FOR CMAP “ in the process og its functioning.

Such a description of the subject domain is given in a natural professional language; the body of the description must be enough to make the situation clear for the system engineer.

Proceeding to the process of the conceptualization of the aviation subject domain, note that professional pilots always get ready for a flight by carefully clarifying the aim of the flight and expected flight conditions (both favorable, such as external information support and the aid of another aircraft, and unfavorable, such as counteracting objects and bad meteorological conditions). They think of the flight as a number of typical situation (TS) ordered by causal relations.

It should be noted that the preparation procedure itself, regulated and supported by the corresponding technical documents (e.g., the field manual and directions for use), makes the problem and flight conditions well-structured. This structurization and preflight information tactical preparation of the crew must be presented in the knowledge base of the “ R-T-AS FOR CMAP “.

For our purposes, the notion of typical situation (TS) is important. By this we mean a functionally closed part of the work with an explicitly formulated purpose implemented by the system “pilot-on-board hardware-aircraft”. The TS occurs in various possible (real) flights, taking a concrete form in a particular flight. The set of TSs for every aircraft type consists of a minimum necessary number of elements that are required to represent any flight mission.

It seems likely that the case of a completely intelligent object, there will exist a separate “R-T-AS FOR CMAP “ for every TS.

A formal description of a TS written with a natural professional language must contain the following:

(1) The conditions of occurrence of the TS.
(2) The main purpose of the TS.
(3) The performance index and admissible ways of attainment of the purpose of the TS.
(4) Representation of the TS as a set of subsituations ordered according to the relationship of cause and effect.
(5) Participants of the TS and information about them. Purposes of the participants in this TS and the ways of realization of these purposes.
(6) Partners, opponents, external information support, and their general characteristics from the standpoint of attainment of the purpose of functioning of the object.

Note that the representation of the TS through the ordered set of subsituations outline the strategy of attainment of the purpose of the TS itself. The formal description of the subsituations is made as an elaboration of the corresponding part of the formal description of the TS. The formal descriptions of the TS and subsituations are accompanied by a glossary of notions and relations between them, which is necessary for the further development of logical lingustic models [8] for each subsituation and for the whole TS. Let us illustrate this by the example of an aircraft.

The components of the “ R-T-AS FOR CMAP “ for a fighter aircraft are presented in Fig. 1 (only those TSs that will be mentioned below are depicted in the figure).

In the first place, our aim is introduce elements of airficial intelligence and expert systems into the levels “choice of the way of attainment of the purpose taken” (the level of the TS) and “realization of the way of attainment of the purpose taken” (the level of the TS) and “realization of the way of decision-making in the current subsituation”. By that moment, the following typical battle situations (TBS) are best understood and most ready for development of the “ R-T-AS FOR CMAP “ (that is why they are chosen for representation in Fig. 1).

“Throwing the group into a battle” (TGB): (1) with air targets and (2) with surface targets.

“Long-range rocket battle (an attack against one air target)” (LBA-1).

“Long-range rocket battle (an attack against N air targets)” (LBA-N).

“Long-range rocket battle (an attack against surface targets)” (LBS).

For an antropocentral object, every typical battle situation will be “serviced” by its own “ R-T-AS FOR CMAP “ and expert system of on-board measuring and executive devices.

Let us consider the methodology of development of the knowledge base of the “ R-T-AS FOR CMAP “ for some TS. For each subsituation of this TS, let us make a list of objects-participants and significant events. Let us represent each subsituation of this TS by a set of mathematical models (MM), which describes the space disposition of the participants of the subsituation, predict its change in time, and determine possible moments of occurrences of the events which are significant for the subsituation under consideration. This set will be referred to as the scenario corresponding to the subsituation. The subsituation often needs some preliminary investigations on a number of mathematical models, which, as a rule, are formulated in the form of optimal control problems, problems of game theory, and various decision-making problems [9]. Some “judicious” solutions for this subsituation, which was obtained as a result of these investigations or simulation modeling, is used in the mathematical model. The union of the mathematical models, together with a reasonable (with respect to the performance index) behavior of the object carrying the “ R-T-AS FOR CMAP “ and objects-opponents, form the space-time framework of the scenario. Scenarios of the subsituation are related to each other in the “ R-T-AS FOR CMAP “ by such a causal relation that allows the description of the proceeding of the TS in the varying environment by switching from one scenario to another.

Analysis of on-board and off-board conditions, as well as making of the corresponding recommendations to the operator, will be done by means of production rules. A set of such rules for the “ R-T-AS FOR CMAP “ are included in its scenario. The rules of scenario initiation are placed in a separate block.

Functional blocks of the “ R-T-AS FOR CMAP “ are presented in Fig. 2. These blocks contain the knowledge necessary for the functioning of the “ R-T-AS FOR CMAP “ given in the form of production rules and mathematical models.

Figure 2 illustrates how the “ R-T-AS FOR CMAP “ of a typical situation is related to the information control field of the operator cabin and expert systems of on-board measuring and executive devices.

Let us sum up the above discussions.

(1) The “ R-T-AS FOR CMAP “ should be built for a functionally closed part of the work of the system “operator-on-board hardware”. The process of formalization of the subjec domain is divided explicitly into two stages. At the first stage, a semantic net of frames and a set of mathematical models of the subject domain, which represent its space-time “world”, are built. The substages of this stage include the description of the subject domain in a natural professional language with the subsequent change-over to protolanguages, making a generalized graph of the functioning of the system “operator-on-board hardware”, development of a semantic net of frames, and determination of the necessary collection of mathematical models.

At the second stage, a logical linguistic model of the subject domain is built, and hierarchically ordered sets of inference rules and mathematical models are developed.

To design the “R-T-AS FOR CMAP “of practical significance, such descriptions must be specified, and their completeness and consistency should be supervised.

(2) In preparing the anthropocentral object for use (in a flight), the crew think of the mission as a sequence of typical situations (TS) related to each other by the relationship of cause and effect.

Any mission can be represented as a set of such typical situations. We think of the TS as a part of the functionally closed work of the system “operator-on-board hardware”, for which the “R-T-AS FOR CMAP “ is developed. There must be a set of “R-T-AS FOR CMAP “s of TS on board. A particular OBRATES of TS is activated by the crew (operator) or by a special OBRATES of the first global level (“R-T-AS FOR CMAP“ of GCL1).

The process of attainment of the purpose in a chosen TS is represented naturally as a sequence of subsituations-scenarios of the “ R-T-AS FOR CMAP “. Mathematical models and a system of production rules are grouped in the “ R-T-AS FOR CMAP “ according to the scenarios. The rules of initiation of a particular scenario are contained in a separate initiation block.

The mechanisms of the conclusion in knowledgebase on-board operative advising expert system are given in [4,5].

TABLE I
THE HARDWARE AND SOFTWARE SUPPORT OF THE CREW ACTIVITIES ON THE FIRST, SECOND AND THIRD GLOBAL CONTROL LEVELS (GCL)

Global con-trol levels for antropo-central object	Hardware and software on-board facilities	
	"tomorrow"	"the day after tomorrow"
1st GCL Choice of the purpose	" "..."	"_>A&DS_" "R-T-AS" "Choice of a TS"
2nd GCL Choice of the way of attain-ment of the purpose	"_>>A&DS_" "..."	"_= A&DS_" " R-T-AS FOR CMAP "
3d GCL Inplementation of the chosen way	"_= A&DS_" "..."	"_= A&DS_" ES OBMED

Notation:

"_" - no support is available;

"-A&DS" - support by standard an algorithms and display support (A&DS)

">A&DS" - partial support by A&DS

">>A&DS" - almost complete absence of the support by the standard A&DS

"..." - there exists a possibility of development of an " R-T-AS FOR CMAP " of TS and an expert system (ES) of on-board measuring and executive devices (OBMED).

Summing up the above-stated, we introduce into practice a registration certificate of the common semantic structure of the knowledge base of the real-time advisory system (R-T-AS) for a choice of the manner of the attainment of the purpose (CMAP). It presents on the table 2. Values of the « Duel» are given in the right column of the table 2 as a example.

Table 2.
THE REGISTRATION CERTIFICATE

Description	Value (number for the Duel)
A rule base : • structure of the main hierarchy levels on the rules set , • quantity of rules on each level	1+5 20+(from 20 to 200) x 5
Quantity of the important events Quantity of the mathematical models of the fragments of the problem situation	6 7
Quantity of the independent decides	6+1

In work [3,6-10].they are given fragments knowledgebase on-board operative advising expert systems and some results of modeling.

V.Conclusion.

Present of the on-board place and the structure of the on-board real-time advisory systems for a chice of manner of attainmment of the purpose. The examples of this systems for a one-seat aircraft are discribed in [10 -12].

VI. REFERENCES

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