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The Concept of Building an Expert-Diagnostic Complex for Analysis of Information Systems

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Abstract. The article considers the concept of an expert-diagnostic complex (EDC) for analyzing the operation of information systems (IS). The current state of the problem regarding the development of an expert-diagnostic system (EDS) for the analysis and failure recovery in the work of each unit of an IS is studied. The study included the development of an appropriate knowledge base and other parts of an EDS, such as a database, operation area, and solver. All these led to significant material and technical costs, complicating the issue of correspondent software performance. The proposed integration of single-profile EDS into an EDC including the monitoring of failure addressing using diagnostic labels will greatly simplify the user's work without large expenditures on product creation. The EDC design differs from that of the EDS by the presence of several knowledge bases and an add-in in the form of an interface for convenience of the user. The article presents the technology of EDC building including several single-profile knowledge bases. An example of building an EDC is given.

Keywords: subject area, concept, expert-diagnostic complex, diagnostic labels

Introduction

The use of an EDS for tackling non-formalized issues in different areas of the national economy has found wide application. The efficiency of such implementation depends on the relation between the provided benefits and the creation, implementation and operational costs of the instrument. One should note that, owing to certain constraints concerning the structural components of the system, EDS is used for solving problems in a narrow subject area. This particularly concerns the central body of the EDS – the knowledge base, the application range of which depends on the gained experience in solving such problems and on the interpretation of this experience by the production model. For this reason, the combined use of several EDS with proper hardware and software is necessary for full-fledged expert service of complex systems. All of this impairs the efficiency of using EDS for complex systems. A possible solution in this situation (in other words, the efficient service of complex systems with the implementation of expert assessment) lies in the development and introduction of expert-diagnostic complexes (EDC) based on separate elements of single-profile EDSs. What is more, the fundamental difference between the designs of the EDC and the EDS is the presence of several knowledge bases describing the situation in the chosen system and an add-in in the form of a control program for creating technological activation chains of corresponding program units.

The present paper gives a conceptual description of an EDC for the performance evaluation of an IS. The BNS ASC is considered in the paper as an example of EDC application.

The choice of the system was conditioned by the following reasons:

- sufficient complexity of the constituent types of ballistic – navigation support that justifies the use of EDC;
- availability of EDS developments for analyzing issues of concern that arise in some BNS concepts;
- BNS is the most studied (for the authors) hardware and software system in terms of performance issues.

The following terms and notions are used in the present paper:

Ballistic-navigation support (BNS) – an aggregate of hardware-software components and technologies for ballistic information reception that is essential for spacecraft flight control.

TIPP KB – knowledge base of the trajectory information pre-processing program.

Subject area (SA) – an aggregate of interconnected elements, which ensure the fulfillment of the assigned task.

Object – any element of the system.

Object property – a certain quantity that characterizes the state of the object at any moment in time.

Concept — (from Latin *conceptus* – thought, idea) – constituent part of the subject area.

Information parameters – the characteristics of a concept, the deviation from which may lead to system malfunctions.

Diagnostics – the identification of object operation failures by means of comparing the current values of its parameters with normal values.

EDS – an expert-diagnostic system is for solving problematic issues that arise from the operation of separate parts of an IS.

EDC – an expert-diagnostic complex is for solving problematic issues that arise from the operation of information systems.

Distinctive features of the EDC in comparison with the EDS:

- the presence of several KBs;
- the availability of a setup program for the complex meant for solving specific problems;
- the presence of a problem analysis and decision algorithm unit.

ASC – automated software complex

MS – mathematical software

TNPM – trajectory navigation parameter measurements

LD – location determination

Prerequisites for setting up an EDC

1. The system in question should be introduced in the form of a hierarchical structure.
2. For further EDC building, the system should be divided into functional parts that correspond to the last level of the hierarchy.
3. In the course of system operation, it is necessary to carry out monitoring with the help of special labels that characterize the operation of system parts. As the labels are filled out, an output signal is generated that initiates the EDC technological cycle.

4. The constituent parts of the level should be described as subject areas.
5. Each subject area is to be given in the form of an aggregate of concepts with the description of information parameters.
6. A corresponding knowledge base with the ability to connect to the EDS circuit (the elements of which are accounted for in the given structure) should be formed within each subject area.

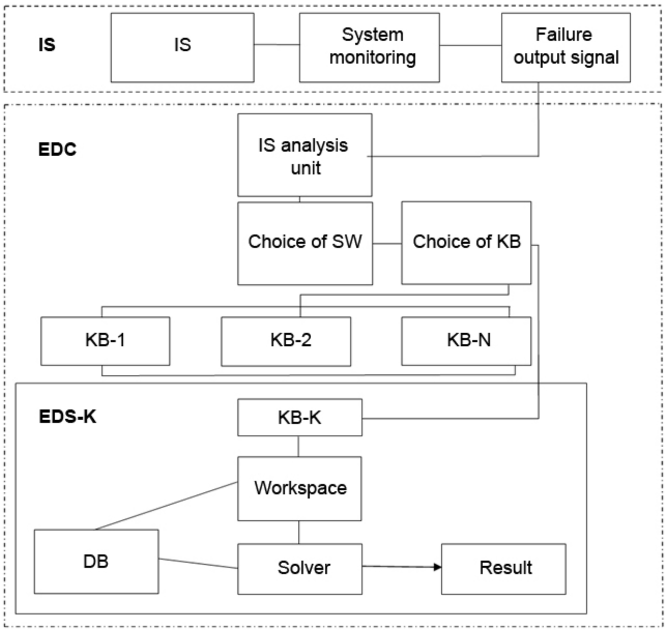

Fig. 1. EDC block diagram.

Description of the EDC block diagram

The EDC diagram given in Figure 1 consists of two parts: 1 – an information system as a source of information (includes a monitoring system that generates an output signal in the case of an IS failure) and 2 – an EDC as an instrument for processing the aforementioned information.

The following components are part of the EDC:

— IS analysis unit. The function of the unit is to analyze the characteristics of the output signal with the aim of choosing a correspondent KB. The descriptions of SAs that characterize the main parts of the IS are part of the analysis unit. Considering this, KBs that correspond to the content and quantity of SAs are formed.

At this point, the most difficult part of the task is the choice of SAs that would correspond to the system's main parts. With the purpose of clarifying this issue we shall turn to the IS typical diagram (Figure 2).

The choice of the main parts of an IS is analogous to the choice of the level of detail of the IS structure that is determined by autonomously functioning units. In this case, the 3rd level consists of units, the functioning of which does not depend on the specifics of the IS. For every 3rd level unit a set of information parameters that characterize its stability may be determined, and accordingly, production models for filling up knowledge bases are formed.

KB (1…N) containing formalized operating experience of such ISs are part of the EDC. Based on the selected SA, the KB is determined according to the following rule: "SW index should match the KB – SA_K - KB_K index", which is used in the further solution of the problem according to the EDS-K scheme (Figure 1).

A detailed description of EDS units is given in [1].

As an example, we shall consider the design of an EDC for BNS ASC.

Figure 3 provides a diagram of BNS, where the ASC is located on the 2nd level (as a component of the MS).

A block diagram of the ASC is given in Figure 4 for further consideration.

Each ASC unit is a separate subsystem independent of the specifics of input parameters. It may be considered as an object for separate analysis by the EDS. Subsequently, a separate KB should be developed for every unit.

More specifically, in works [2, 4, 5] the description of EDS prototypes for ASC operation failure analysis and correction is provided. Namely, "EDS for the search and correction of non-difference phase measurement jumps" is one of the sections of the TIPP unit, "knowledge base for receiver location determination software module" is a BVP section, and "EDS for trajectory measurement information analysis" is a section of TIPP.

In normal operating mode (when failures are absent) the result of ASC functioning are refined orbit parameters saved in corresponding DB tables and file archives. Apart from that, intermediate results are formed TNPM sessions (before and after filtering), sessions of difference measurements, LD results and statistics, etc. In the event of failure, the ASC either stops (variant A) or carries on providing results of unsatisfactory quality (variant B). For successful troubleshooting it seems appropriate to, first, determine which ASC component the failure concerns and, after that, it will be possible to pass on to analyzing the causes of failures and failure recovery.

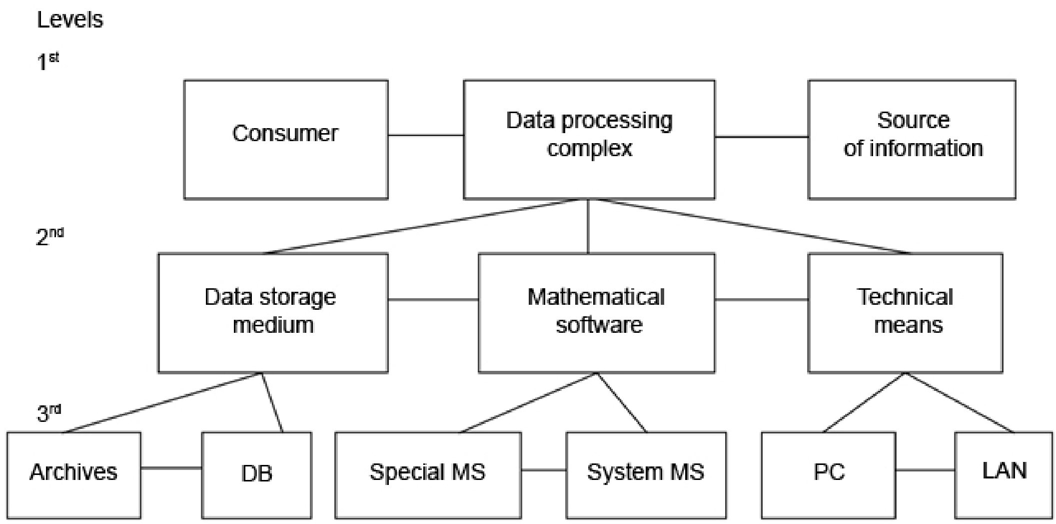

Fig. 2. IS typical diagram.

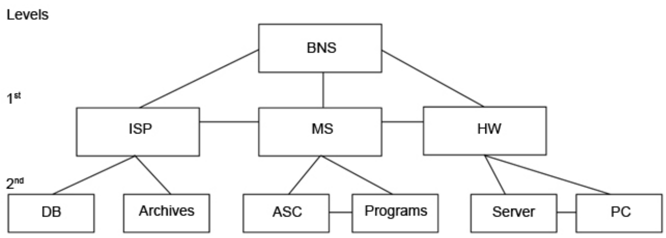

Fig. 3. BNS.

Let us consider the principles of building an EDC-TIPP for analyzing performance of a part of ASC-TIPP (variant A).

The EDC-TIPP building technology cycle consists of the following stages:

1st stage. Determination of detail level for IS hierarchical structure. In accordance with BNS and ASC structure analysis (Figures 3, 4), initially the 2nd level of BNS was defined – within it an ASC was selected for further work.

2nd stage. The division of selected system into functionally independent parts (Figure 4) to a certain level of detail.

3rd stage. Building a SA for corresponding parts.

4th stage. Failure address determination (name of the corresponding ASC, the TIPP in particular).

For failure address determination we introduce *diagnostic labels (DL),* which are, in essence, named cells at the end of each subprogram that take on values of 0 or 1. “1” shows that the program performs calculations. “0” signifies that calculations by the given subprogram have stopped (subprogram – a functionally complete part of the general program that has input and output data).

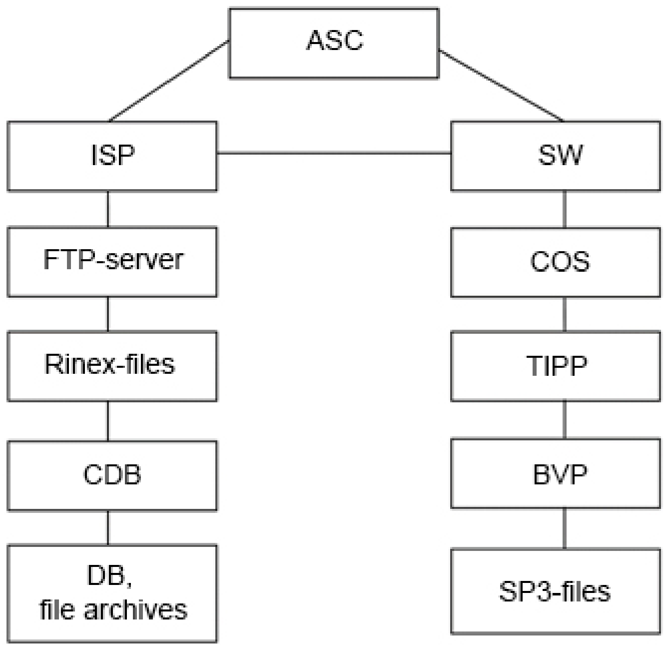

Fig. 4. ASC diagram.

Explanatory notes to Figure 4:
ISP – Information support
SW – Software
FTP–server – website with measurement data
COS – program for configuring operating settings of the complex
Rinex–files – trajectory measurement information
TIPP – trajectory information pre-processing program
CDB – central database
BVP – boundary-value problem (orbit parameter determination program)
DB, file archives – current information repositories
SP3–files– orbit parameters in a generally accepted format

5th stage. Formation of KBs that correspond to SAs. The technology for filling up KBs consists in the sequential performance of the following operations: SA building, concept definition, setting of information parameters and their specific values, production model formation – the KB.

6th stage. Addition of KB to the technological scheme of the EDS for analyzing and correcting particular failures.

As an example, we will consider the stage-by-stage formation of a KB for an ASC unit, omitting stages 1 and 2 (Figures 3, 4).

The TIPP subject area consists of:
- Trajectory measurement information (TMI);

Subprogram [5]:
- measurement session formation
- processing and filtering of measurement sessions
- formation of baseline sets
- difference measurement formation
- filtering of difference measurement sessions
- LD based on code range measurements
- statistical evaluation of location results

For our convenience, the concepts are grouped the following way:

1st group – trajectory measurements
- trajectory measurements (TM)
- measurement session formation
- processing and filtering of measurement sessions

2nd group – difference TM (DTM):
- formation of baseline sets
- difference measurement formation
- filtering of difference measurement sessions

3rd group - LD
- LD based on code range measurements
- statistical evaluation of location results

The TM group is characterized by the following information parameters (IP):
- nominal quantity of measurements per session
- measurements received via noisy signals
- marginal errors of receiving station coordinates
- critical values of phase cycle “jumps”
- measurement filtering threshold values

The DTM group is characterized by the following information parameters:
- baseline threshold values
- nominal settings for difference formation
- nominal settings for reduction of measurements
- matching factor for measurement reduction settings and difference formation

Table. F_i reaction description

IP group	V_i	F_i reaction
1	V_{11}	Sessions, the number of measurements of which is less than the nominal value, excluded from processing
	V_{12}	Measurement obtained at $\gamma \leq 70$, excluded from processing
	V_{13}	Receiving stations with coordinate errors exceeding limit values, do not participate in processing
	V_{14}	Phase measurements with critical jump values, excluded from processing
	V_{15}	Measurements not included in filtering thresholds, not included in processing
2	V_{21}	Baselines, the length of which differs from the nominal value, excluded from further decision-making
	V_{22}	Phase differences, the settings of which differ from the nominal value, excluded from processing
	V_{23}	If the current measurement reduction does not match the nominal measurement, the corresponding measurement range is excluded from processing
	V_{24}	If the value of the matching factor for reduction settings and difference formation is less then given, measurements belonging to this range are excluded

Since the parameters of the 3rd group (LD) do not directly influence the decision-making process of the unit in question and are information on the quality of the overall decision, they will not be analyzed any further.

The next stage is the creation of a knowledge production model.

A production model (PM) is a rule-based model for the representation of knowledge in the form of sentences: "if (condition) then (action)". In this case, the main elements of the production model are the information parameters of the 1st and 2nd groups.

For the sake of convenience we will introduce the following notations: 1st group IPs – V_{1i} , 2nd group IPs – V_{2i}.

Then, the conditions for analyzing production model data can be presented in the following form:

A. If $V_C = V_{1i}$ then 0.

B. If $V_C \neq V_{1i}$ then F_{1i},

where V_C is the current IP value, F_{1i} is the reaction to the discrepancy between IP current and control values, which indicate failure, "0" stands for a normal decision, reaction F_i is absent.

The given actions are analogous for the 2nd IP group provided that index "1_i" is changed to "2_i".

The table gives action descriptions (reactions EDS - F_i) for condition B.

The next stage is KB formation.

Production rules are the main part of a KB. They are needed for reaction formation upon the occurrence of non-standard situations during ASC operation. The information base of TIPP KB formation are conditions "A" and "B", as well as the formulations of reactions F_i set forth in the Table. Thus, the TIPP KB consists of two groups of production rules: TM and DTM. They are capable of functioning as a part of ASC BNS EDS jointly with other KBs [2, 4, 5].

By analogy with the described above, example COS KB and BVP KB can be built.

In the light of all of the above and considering the previous developments of the authors in EDS building [2, 4, 5], we will introduce a general diagram of an EDC for ASC BNS software (Figure 5).

Explanatory notes to Figure 5:

ASC SW – ASC software;

COS, TIPP, KB, SP3 – constituent part of ASC (see explanatory notes to Figure 4);

"Program operation analysis" – ASC operation failure memory unit and ASC operation "failure" address identification by the values of diagnostic labels;

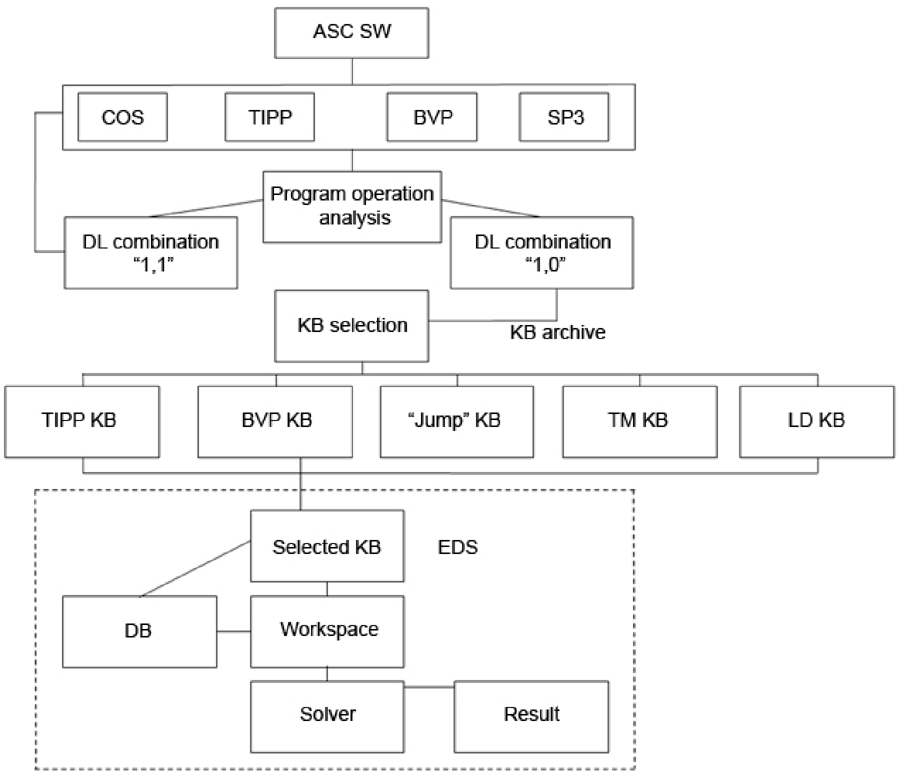

Fig. 5. TIPP EDC general diagram.

DL combination "1, 1" – stands for the normal execution of the current subprogram;

DL combination "1, 0" - stands for solution failure in the current subprogram.

It should be noted that before running a solution program all DLs are set to "1, 0". During normal execution of the subprogram "0" is replaced by "1".

KB selection – the selection of a knowledge base is carried out by "failure" address that is identified by a DL conditional name identifier and subprogram names, the table of which is located in the body of the unit in question.

KB archives:

TIPP KB – pre-processing knowledge base (description is given in this article)

BVP KB – boundary-value problem knowledge base (yet to be developed)

"Jump" KB – phase measurement jump identification and correction knowledge base (developed, set forth in [4])

TM KB – trajectory measurement knowledge base (developed, given in [5])

LD KB – location determination knowledge base (developed, given in [2])

Selected KB – the KB selected from the archives, corresponding to the DL identifier

Standard EDS units: database, workspace, solver with their descriptions provided in [1].

Conclusion

Based on the materials given in the present paper, the following conclusions can be made:

1. The technology for building expert-diagnostic complexes (EDC) for analyzing the operation of an IS that allows to create expert systems for several subject areas (thus, significantly broadening the capabilities for system analysis in comparison with EDS) was developed.

2. The replacement of several EDS by a single complex will allow to considerably speed up IS operation problematic issue solving, as well as reduce time and resources required to develop corresponding software.

3. The proposed procedure for searching for addressing "failures" involving diagnostic labels allows for the prompt identification of the emergency subprogram and response formation for blocking the arisen situation.

4. The technology for building a KB for the "pre-processing" ASC unit that is considered in the paper may be used for forming KBs for other ASC units, thus, noticeably reducing the time required for developing programs analyzing the complex as a whole.

5. The development and implementation of an EDC based on existing EDSs will allow for problems occurring during IS operation to be solved more efficiently.

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