Features of Informational Control Complex of Autonomous Spacecraft

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Abstract: Structural and functional features of informational control complex autonomous spacecraft are discussed. New features and structural means were selected to meet requirements of application oriented systems. Also, interaction and highly intellectual support of system and operator was considered. Problems of design an intellectual interface of operator and control complex system were determined. Structure and means required for the control complex of autonomous spacecraft are introduced.

Keywords: Autonomous spacecraft, control complex, expert systems, intellectual interface

1. INTRODUCTION

Complex computer systems, used for control of autonomous spacecraft (AS), further called as informational control complex (ICC), has number of special features arisen from its application. Reactivity of the systems of this kind is achieved by either and highly intellectual special means for analysis of wide changes of technical environment, when the system is devoted to autonomous operation, without user (operator) intervention or access. These systems further will be called as autonomous ICC.

Or, when interaction with operator is possible, system structure and features are devoted to assist properly an operator for matching of appointed functions of the ICC. This is especially important due to growth of complexity of the controlled technical object.

Reactivity of the operator and system here depends on intellect and features of interface and determine applicability of the ICC for control of the object. Having in mind this some polarity of autonomous ICC and ICC for complex technical object this paper concerns some principles of its design and functioning.

2. INFORMATION CONTROL COMPLEX

ICC of this kind are widely used in the applications such as autonomous avionic, space and military moving objects. Requirement of autonomous functioning comes out from the fact that operator control of the mentioned objects becomes practically impossible from central stationary control unit. Therefore, operative control, interruption of subsystems and the whole ICC has to be developed as completely autonomous one. It should be realized as real-time control of all subsystems and ICC taking into account three main features: autonomous without operator real-time control of the ICC, exception handling and resource degradation of ICC elements.

2.1. Differences

As a distinction of considered here ICC is an application of highly intellectual hardware and software subsystems enable to solve previously absent tasks. These tasks previously were under operator supervision: reaction on extreme situation, resource degradation and allocation, control decision of raised situations. Known foreign prototypes of similar systems are based on the application of distributed processor systems without algorithms of deep diagnostics and hybrid experts systems. Proposed structures of multilevel ICC, based on artificial intellect approach enable to solve a problem of dependability and fault tolerance of the designed ICC.

2.2. Functions and structural features of ICC

ICC of autonomous spacecraft (Fig. 1) has the following features:

- *control* (target control, optimization of operation for functional subsystems, program control inside functional subsystem, primary regulators – operation mode support and stabilization);
- *information* (sensors and measurement subsystem control, primary processing of information (using system of distributed microprocessors, system of multilevel diagnostics and prognosis of technical state).

2.2.1. Hierarchy of ICC control part

Control part of ICC has three level hierarchy. First level of control (level of primary regulators) of ICC where each functional subsystem should solve precisely determined local tasks of automatic control:

- support of parameters for processes;
- protection of hardware from damages;

- information interchange with higher level of control.
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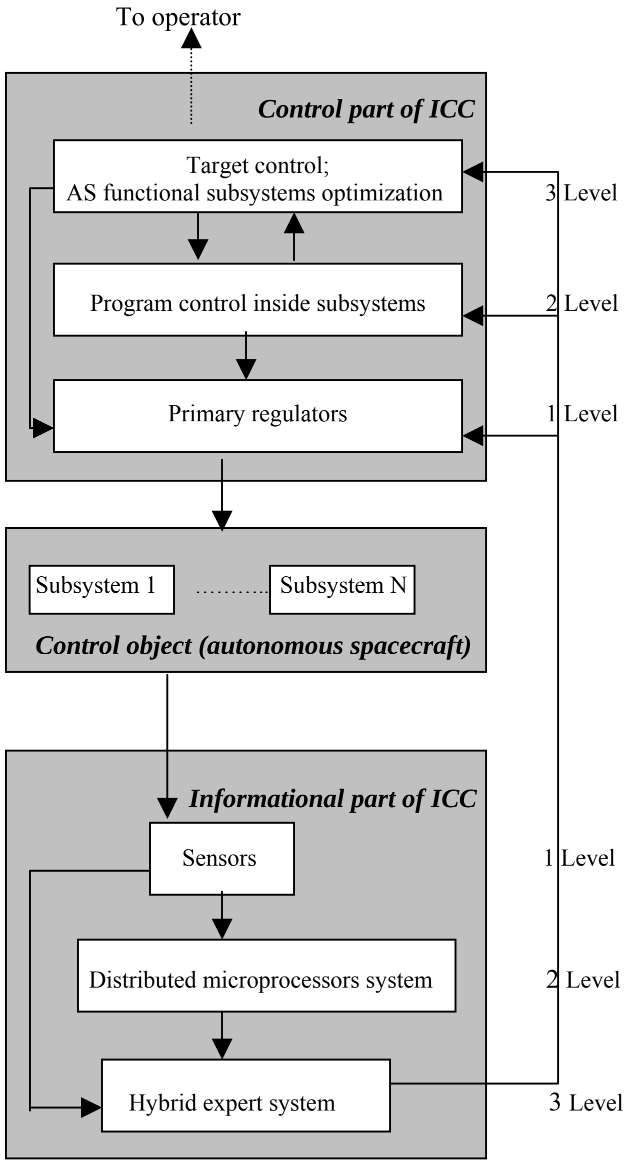

Fig. 1. Informational control complex of autonomous spacecraft.

Next (second) level of control solves less determined tasks. These tasks contain many conditions related to states of hardware, modes of operation for each particular technical system. There are following tasks to be controlled at this level:

- co-ordination of first level control, mode allocation, check hardware states, diagnostics of technical states and conditions of subsystems, checking the order of control in this mode of operation.
- reserve replacement or change of content and state and structure of hardware at the first level;
- change of algorithms to operate for first level in case of hardware degradation;
- control of primary regulators accordingly instructions from higher level;
- communication with higher level.

Top (third) level of control part of ICC coordinates and optimize operations of all subsystems autonomously, doing logical situational control of all processes in technical system, making summary and packing an information related for operation of the system to store and further transfer it to operator.

Connection between different levels of hierarchy of ICC is organized by two ways: by hardware, using local network and by software of control computer. At local network higher level of control is connected with all controllers from lower level.

First level control devices are communicated with sensors directly, as well as executive mechanisms. Therefore, ICC of AS has distributed hierarchic structure and for its design on the second and third levels it is required to use methods of artificial intellect.

Way of realization for these methods are hybrid expert systems, combined software discrete knowledge data bases, data bases about regular and emergency situations, and continuous math models to describe functioning of subsystems, units and elements of AS.

There are following functions (algorithms) of hybrid expert system for the second and third level of ICC:

- diagnostics of technical state for subsystems, units and elements of AS when uncertain results of lower level diagnostic occur;
- planning of strategies for control and consequences of emergency cases for current and further states;
- tests and checking of technical state for subsystems and elements of AS;
- configuration control of AS to minimize consequences of exception situations and resource degradation.

2.2.2. Hierarchy of ICC informational part

Structure of informational part of ICC of AS splits on three layers also. Lowest (first) level of informational part of ICC presents a system of primary sensors and is realized by hardware.

A problem of doubled or tripled sensors to detect faults by majority scheme should be solved for the whole informational part of the ICC because artificial intellect algorithms in hybrid expert system enables to minimize number of sensors and therefore decrease mass and dimensions of the autonomous system.

Next (second) level of the information processing (data from sensors) is used distributed system of microprocessors, which appointed to make control decisions if this level has enough information. Solutions in this case are delivered based on algorithmic approach without application of artificial intellect.

Each processor of lowest level is connected with cross-switch via controller of interface of cross-switch hardware and can be connected with several controllers.

Control of permanent flow of input-output data is critical aspect for the both levels of informational part of ICC. Main function of the controller is to coordinate interaction between several independent control functions.

Controller realizes a scheme of priorities, making time sharing scheme. So, when exceptional situation takes place, controller delays less important functions and monitor the situation as dynamically and in by buffering.

This dynamic programming provides more flexible control algorithm, while buffering gives operability in closed loop, with guarantee consistency of control when loss of messages took place.

Highest level of informational part of the ICC for AS is level of the system diagnostic of technical state and prognosis of workability of AS and is realized as hybrid expert system. For its functioning hybrid expert system uses data from all levels of informational part of the ICC: hardware from lowest level, algorithmic software of second level and methods of artificial intellect of third level.

This hierarchic approach to system diagnostics helps to make decision on the lowest level of the system. Thus, in turn help to avoid snowball of information and provide fast reconfiguration of the system and control of fault in closed loop mode.

Special features of hybrid expert system operation are in joint use of knowledge base about regular and exceptional situations, using math models of units and subsystems of AS with difference in details of presentation. This approach gives an opportunity to diagnose exceptional situations in AS in real time of its development.

As further closest perspective one can consider here a growth in performance of on-board hardware. For proposed structures and schemes it gives a good opportunity to increase precision and correctness of diagnosis by better comparison of state vectors for AS.

3. USING OF EXPERT SYSTEMS TO SUPPORT THE ICC OPERATOR

Existed statistics of accidents and data taken from cognitive psychology are voted for impossibility of effective and reliable knowledge intensive function of operator without intellectual support by knowledge data base (Hollnagel et al., 1990).

Most matched for these targets are systems based on knowledge, namely expert systems. During formation of expert system (ES) to support operator it is expected to use architecture presented below in Fig. 2. From one hand this architecture does not differ much from standard architecture of data processing, planning and control. From the other hand, this architecture is quite close to “blackboard” architecture (Jagannathan et al., 1989; Devedžić and Velašević, 1990).

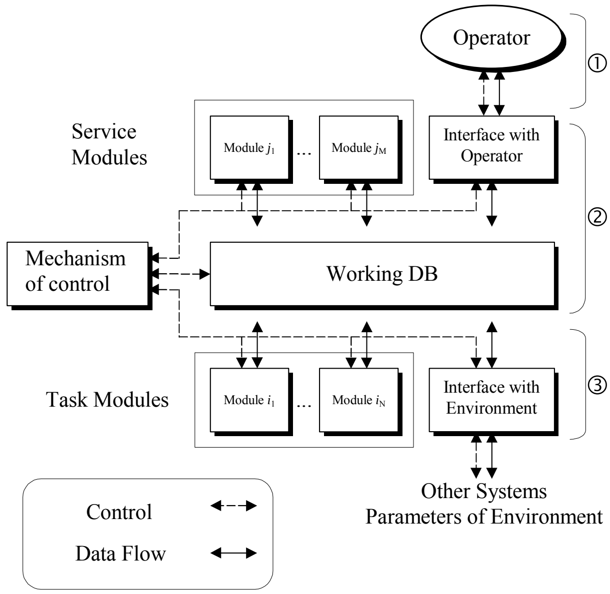

Fig. 2. Using of expert systems to support ICC operator.

3.1. Levels of Expert System for ICC

One can differ three main interconnected levels in expert system for ICC: (1) human-operator, (2) mechanism of control with service modules and operational Data Base, (3) modules to solve local tasks and subtasks.

Two upper levels organize interactive subsystems, in which human-operator takes leading position. Intellectual mechanism of control with service modules was called intellectual monitor (IM).

Three levels of presentation help to design common scheme of support for operator by ES:

Level of the task modules. Solution of local tasks, input and output data processing. Support of operator with calculation, logic conclusions, local decisions.

Level of intellectual monitor:

- arrangement of joint operation for modules. Support for operator planning, task coordination, task execution and global decision-making;
- formation of interaction with operator. Support of operator with interface and interface subsystems.

Most obvious area of ES to support operator is a level of local task modules. At this level intellectual support concerns the development of ES to solve local tasks.

Different schemes of knowledge presentation should be used in different modules-ES, as well as different methods of elimination uncertainties. Classes of tasks, which can be solved using ES, advantages and disadvantages of ES application, are well known of (Devedžić and Velašević, 1990). Additional problem, which arise in use of ES at local tasks level is in interface development, to enable interaction of modules-ES is in interface development to let interaction of modules-ES with work Data Base and Interface Monitor.

A large amount of data for ordinary calculations, which use to accompany aerospace systems suppose big number of modules required to solve different special algorithms: computational, optimization, searching, simulation etc. As well as for modules-ES for algorithmic modules it is required design and development of interface.

Large amount of algorithmic modules leads to serious growth for IM of volume and complexity of task problems. This leads to switch to IM to solve main strategic tasks of local level. Complexity is growing, number of service messages is growing also. Modification of local modules can demand of serious changes in IM. Therefore, it is required to reload functions of local control into modules itself.

At the same time, main task of hybrid module is to realize existing algorithm, while ES forms the tasks, targets, set limits and evaluate the results forms data messages. To realize hybrid modules it is required to have ES, which help to create ES, and enable to operate with complex algorithms. It is required to have powerful procedures, either interface with language of high level. Level of local tasks is obvious area for ES application. But it is clear enough that this does not limit problems of intellectual support for operator.

3.2. Intellectual Monitor

Biggest problems for operator will take place in planning, task coordination, and procedure execution especially in unexpected situations. Intellectual support of operator to solve these tasks is grouped in IM. Between its main service modules there are two main groups of control modules:

- modules to control operations (coordination of tasks, scheduling etc.);
- modules to control interface with operator.

Main role have control modules, because their responsibility for organization of effective operation for the whole system. Together with mechanism of control these modules solve main task of control, by determining (1) which tasks should be done, (2) when these tasks should be done and (3) when acceptable solution for these task are found. Modules of control give operator a support with planning, task co-ordination and control, and global solutions.

Another group of service modules is responsible for support of operator with work of interface. They do the following:

- checking of output information (informational manager);
- menu monitoring and checking, dialogue panels and other control elements of graphic interface (dialogue manager);
- control of operation of information system (information system manager);
- control of other subsystems of interface.

3.3. Information Manager

Main task for Information Manager is to decrease a working load of operator, increase of quality and reliability of operator functioning by means of decrease data volumes required to be evaluated and analyzed. It concerns dynamic changing of list and format of visualized data, that's depended on the current tasks, which are under control of operator. Actions of operator that go through input devices are decoding and go to unit of evaluation of operator intentions. Here they are compared with current context and other data (stage of solution, mode of operation, element of plan or procedure, message etc.). On this base operator intentions are determined and mode of visualization is selected (Fig. 3).

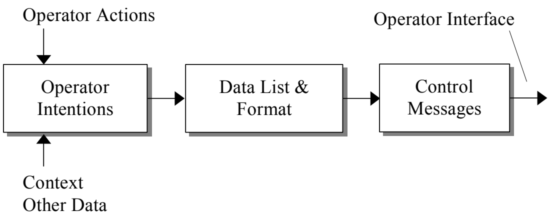

Fig. 3. Information manager flowchart.

Main feature, which distinct proposed here system from ordinary systems is knowledge based unit of determining the operator intentions, which enable in full size to take into account a current context and use it to control interface. Received information of operator intentions increase context and quite important for modules of control the interface and other service modules.

3.4. Dialogue Manager

Main task of Dialogue Manager is in increase of reliability and effectiveness of operator with elements of graphic dialogue – menu, panels, and forms. This problem became hot in the second part of 90's, caused by wide application of OS Windows 95/NT.

Exactly because this very fast growth of complexity of graphic dialogue took place. Rough evaluation show that number of possible traces in the space of elements of control has been increased from 50-70 (in late 80's) up to several thousands in nowadays applications. Effective using by operator of graphic dialogue with this level of complexity seems to be extremely problematical.

Common scheme of dialogue manager differs from scheme of informational manager only by central block, which called next step dialogue selection block. Intentions of operator are compared with current content and other data (step of solution, mode of operation, element of plan, message etc.) and using this next step of dialogue is selected, as well as its view and active elements of control.

3.5. Information System Manager

Main task of request manager is decrease of load and growth of effectiveness of operator work with request information subsystem. Modern request subsystems are created around hypertext concept. Hypertext systems increase access to information, but at the same time they do not have selective mechanism to choose required information. This causes problems for operator when he applies request hypertext system: disorientation – a tendency to loose orientation and direction of motion in hyperspace:

- additional working load – concentration of attention and additional thinking efforts, required to remember traces and analysis of temporary results;
- informational noise - looking through big volumes of data which do not relate to the subject;
- substantial amount of searching and related time overheads, weak possibilities to operate with complex requests.

Proposed architecture with intellectual monitor enables to decrease existed disadvantages of hypertext information system by means of its tuning to operator intentions and current context. This task appointed to request manager. Request manager scheme differs from scheme of informational manager only there where instead of visual format selection block is used information system tuning block.

To realize IM it is required to have special instrumental means, with following features: high efficiency, modularity, imbedded data base, universality.

4. CONCLUSION

Informational control complexes of autonomous spacecraft appointed to run autonomously nowadays are required realization of highly intellectual features for autonomous functioning with widely changed environment. Logic hierarchy of this system part related to control and information serve here for best structure of these systems.

Self-diagnostic, monitoring of graceful degradation to provide longest autonomous functioning can be described by use of artificial intellect. That is enable to achieve real time reaction on exceptional situations.

In turn, there and when operator interaction for informational control complex is possible an artificial intellect approach should be used to design the system as a whole and interface with human-operator in particular. Applying this instead of well known graphic interfaces one can avoid growth of complexity of monitoring the system and provide better user features for standard and exceptional handling.

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