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EXPERT SYSTEM OF INTELLIGENT PILOT SUPPORT IN ON-BOARD COMPLEXES AND ITS SOFTWARE

The basic structure of the expert-advisory system of the crew's intellectual support for the diagnosis and prediction of aircraft subsystems and its software is proposed. The system uses a user interface using artificial intelligence when searching for causes of malfunctions on an airplane. If there is any difficulty in controlling the aircraft with the help of the pilot-navigation complex, the pilot addresses the ES for help, answering system questions via the operator interface. Using the completed knowledge base, the system will generate and provide the user with recommendations with the localization of malfunction.

Keywords: *aircraft control systems, intelligent control systems, artificial intelligence systems, expert systems.*

Introduction

One of the key trends of the future progress of aircrafts is the development of the basics for building the flight control and decision support systems. These systems for operative interaction with the object control (including aircraft and its subsystems) use the knowledge and experience of experts targeted at the analysis of constantly changing model of external and internal systems. In abovementioned systems, also called intelligent systems, knowledge about unknown features of object control and the environment is formulated in the process of training and adaptation, while the obtained information is used in the process of automated decision-making raising the quality of control.

The process is performed by the aircraft's crew, the main task of which is directly related to the solution of pilot-navigational tasks. The detailed information about the development of pilot-navigational complexes (PNK) is provided in [2], whereas the analysis of quantitative, measuring tools, and the tools for information display in PNK is given in [3]. Furthermore, regardless of the aircraft type, it is control is performed by the crew, which leads to the faults related to human behavior. During the flight, the aircraft crew interacts with the information-control field of the cabin by deflecting the control knobs of the aircraft, entering data into the subsystems of the PNC, and also receiving information from multifunction indicators, keypad indicators, etc. [1]. At the same time, the peculiarities associated with psychophysiology of a pilot affect this interaction. Many available PSCs notify the crew about reaching the extreme flight regimes, failure of navigational equipment and overall condition of PNC, or provide recommendations established in the flight manual. In case of certain combinations of external factors and failures of navigation equipment that arise in specific flight situations, the crew undergoes strong psycho-emotional overloads and has limited time to make a decision. This leads to the emergence of critical errors in the aircraft control (human factor) [4].

Since the crew's ability to parry specific situations arisen on board is limited, it is necessary to introduce an intelligent component into PNC, i.e., "virtual expert", which accumulates the experience of real experts in the field of navigation and piloting aircraft in specific situations. This circumstance necessitates the development of on-board systems equipped with board expert systems (ES). These systems reduce the psychophysiological load on the aircraft's crew and enable to conclude that the further development of PNC is closely related to the introduction of intelligent support for crew, situational awareness systems and further intellectualization of aircraft control [5, 6].

Problem statement

Proceeding from abovementioned reasoning, the problem of development and use of a specialized human-machine expert system for the analysis of the causes of faults both in material part and control of the aircraft arises. The main goal of developing an expert system is to increase the efficiency of search through a mobile user interface with the use of artificial intelligence when searching for the causes of malfunctions on an airplane. In case of any complications in aircraft control, a pilot calls on the ES by means of pilot-navigation complex for help answering the system's questions via an operator interface. With the use of completed knowledge base, the system generates and issues recommendations on the localization of the fault for the user. Meanwhile, in subsystems of the aircraft, it explains the course of its reasoning via the explanatory module (even with incomplete information) indicating the level of expert's confidence [7].

Problem solution

The expert-advisory system and its software for diagnostics and prediction of aircraft subsystems are proposed. A generalized scheme of the basic structure of ES of intellectual crew support and its interaction in the composition of PNC for the aircraft is shown in Fig.1.

As it is seen from the chart, the data sensed from the sensors and board equipment comprising the flight-navigation complex are received and processed first in the corresponding block, and then sent to the working memory of ES as the evidences. Further, using logical inference machine and knowledge base, the system generates an assessment of the situation and seeds it to the reporting unit to the crew. Then the messages are sent via the communication channel to the control information field of the cabin for direct display to the aircraft's crew.

The knowledge base of the expert system [8, 9] records a list of possible problem situations. A specific response to each of them and a recommendation or an event to be directly performed is compared. Having received a response from a user about a real problem situation, the system exceptionally determines the correspondence of this information with one or more "templates" stored in the knowledge base. The information is obtained as a result of asking questions in a sequential order. Since, as a rule, the content of subsequent questions depends on the answers to the previous questions. Each piece of new information sent in the form of answer to a specific question reduces the uncertainty about the problem situation. Obviously, uncertainty reduces only if the expert system has relevant knowledge. A correctly constructed system has to be able to accurately identify the problem situation with the minimum number of questions.

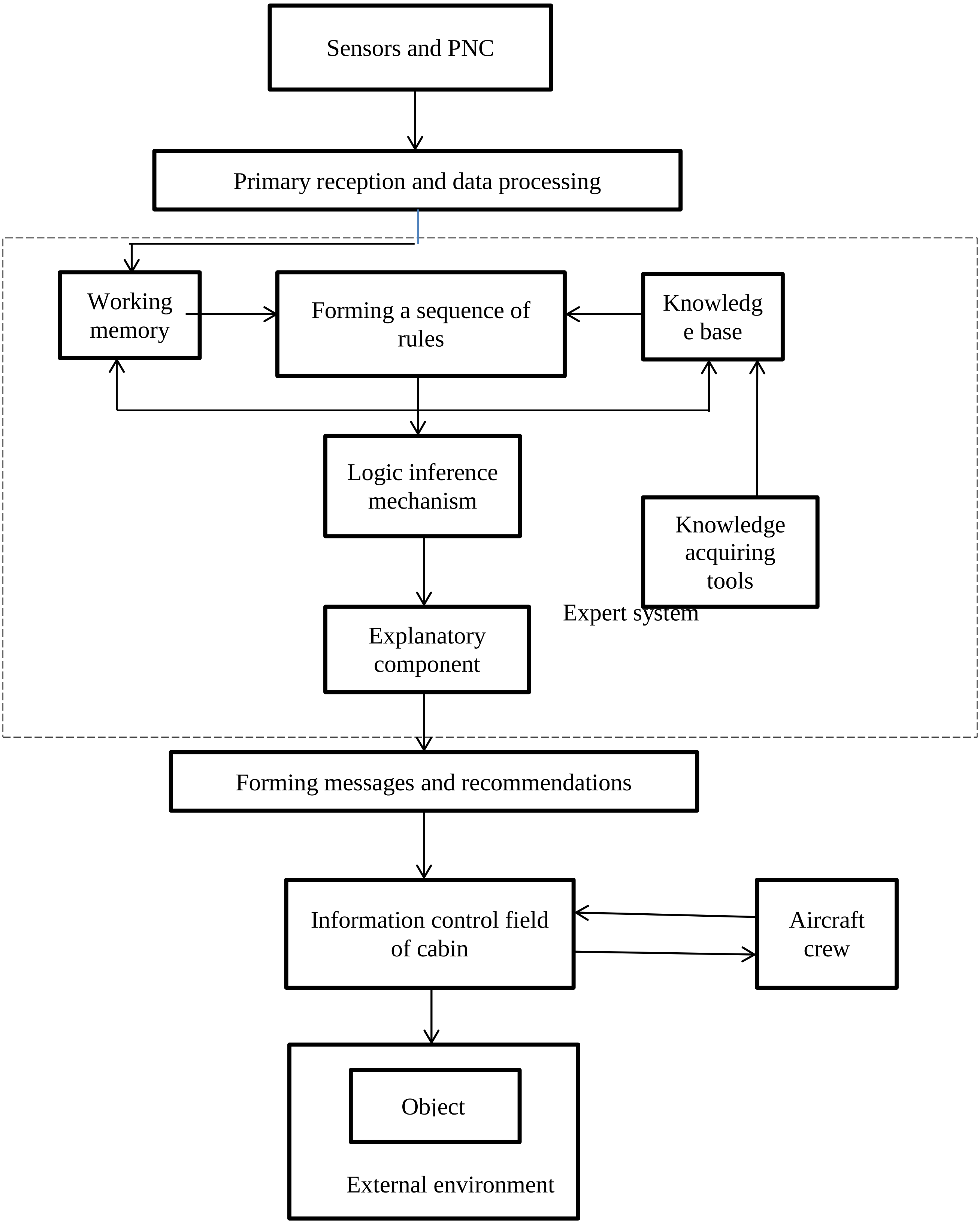

Fig.1. Basic structure of ES of intellectual aircraft crew support

A flow chart of the algorithm for expert system functioning is shown in Fig.2

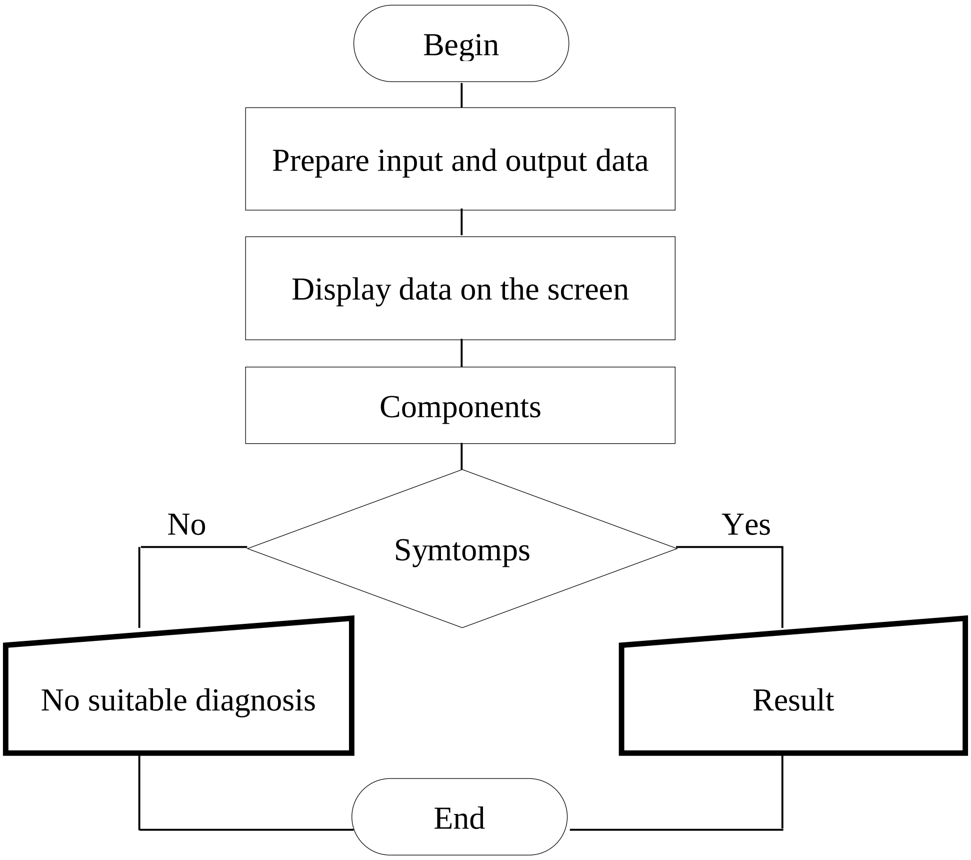

Fig.2 A flow chart of the algorithm for ES functioning

Before visualizing the program, its base is created first. The base is mostly prepared on Microsoft Access. This database includes three interconnected tables. The first table contains a list of problems that arise in board equipment during an aircraft flight. Typical problems that arise in front of a user (pilot) are displayed in Table 1.

This table uses an expression "type" to indicate which subsystem the fault is related to. The expression is of particular importance in safe control of a modern aircraft. The table is linked to other tables via the keywords "FMS", "EFIS", "EICAS". Requests are directed on the "type" field.

*adoquery1.SQL.Text:='select * fromproblemlerwhere**tip**=:**tip**';*

*ADOQuery1.parameters.parambyname('tip').value:='**FMC**';*

adoquery1.ExecSQL (table 1)

adoquery1.Open;

Table 1

Typical problems encountered by a user (pilot)

Проблемы

Код	Проблема	Тип
1	Канал управления	FMC
2	Канал наблюдения	FMC
3	Информационный канал	FMC
4	Неполадка концентратора	FMC
5	Неполадка MCDU	FMC
6	Неполадка в шине ARINC-429	FMC
7	Неполадка PFD и ND	FMC
8	Двигатель самолёта	FMC
9	Неполадка в дисплее предупреждения двигателя	EFIS
10	Неполадка в дисплее PFD	EFIS
11	Неполадка в дисплее ND	EFIS
12	Неполадка в дисплее ECAM	EFIS
13	Неполадка в дисплее FWC	EFIS
14	Неправильное отображение параметров двигателя	EICAS
15	Не чувствуется регулярность в работе двигателя	EICAS
16	Неполность поясняются ошибки системы EICAS во время	EICAS
17	Задержка пожарной сигнализации двигателя	EICAS
18	Не работает сигнализация предупреждения силы тяги	EICAS
(New)		

The second table contains "symptoms". In this table, each problem corresponds to several symptoms. The key field connecting tables with other ones is the "problem" field.

*adoquery1.SQL.Text:='select simptomı from simptomı where***problem***=:prob';*
adoquery1.Parameters.ParamByName('prob').Value:=listbox1.items[listbox1.itemindex]
;
adoquery1.execsql;
adoquery1.Open;

Table 2

Table of "symptoms"

Симптомы

ID	Симптомы	Проблема
1	С канала не поступает информация	Канал управления
2	Иформация поступает в искоженной форме	Канал управления
3	Неправильное подключение информационных передатчиков в канале	Канал управления
4	Неполадки в канале коммутации	Канал управления
5	Не осуществляется полное наблюдение в канале	Канал наблюдения
6	Дисплеи неправильно подключены к каналу	Канал наблюдения
7	В диплеях неправильно выбраны алгоритмы обработки данных	Канал наблюдения
8	Ожидается приоритет обработки информации	Канал наблюдения
9	Неполное получение информации об этапах полёта самолёта	Информационный канал
10	Неправильный выбор параметров полета, присущих каждому этапу полета	Информационный канал
11	Учитывание тангажа и крена в каждом этапе	Информационный канал
12	Неверный выбор автопилота	Информационный канал
13	Неверный выбор входов компьютеров наблюдения Slat и Flap	Неисправность концентратора
14	Неверный выбор каналов Slat и Flap	Неисправность концентратора
15	Учитывание изменений в траектории полёта	Неисправность концентратора
16	Неправильный выбор первого концентратора управления полетом данных	Неисправность концентратора
17	Неправильный выбор второго концентратора управления полетом данных	Неисправность концентратора
18	Неправильный выбор кнопок MSDU	Неисправность MCDU
19	Неверный ввод даных полёта в MSDU	Неисправность MCDU
20	Неправильный выбор меню	Неисправность MCDU
21	Неверный ввод данных полётов и аэропортов назначения в MSDU	Неисправность MCDU
22	Неполная работа световых сигналов	Неисправность MCDU
23	Неправильное размещение абонентов сети	Неис-ть в шине ARINC-429
24	Слабая проводимость сети	Неис-ть в шине ARINC-429
25	Слабая скорость передачи информации	Неис-ть в шине ARINC-429
26	Неправильное кодирование передачи информации	Неис-ть в шине ARINC-429
27	Искожение передаваемого слова в канале	Неис-ть в шине ARINC-429
28	Неверный выбор режима дисплея навигации	Неисправность PFD и ND
29	Генерация изображения в дисплеях выполняется непаравильно	Неисправность PFD и ND
30	Неполадки в работе дисплеев предупреждения двигателя (ECAM)	Неисправность PFD и ND

The third table contains "diagnoses", where the keyword is the "type" field.

*adoquery1.SQL.Text:='select * from diaqnozı where say=:analiz and* ***tip=:tip****';*

adoquery1.Parameters.ParamByName('tip').Value:=listbox1.items[listbox1.itemindex];

adoquery1.Parameters.ParamByName('analiz').Value:=analiz;

adoquery1.execsql;

Table 3

Table of "diagnoses"

Диагнозы

ID		Счёт	Тип
1	Отказ канала управления	3	Канал управления
2	Канал управления должен быть переправерен	7	Канал управления
3	Неправильная комутация в системе и система ком-ии должна быть переправерена	3	Канал наблюдения
4	Алгоритм обработки должен быть скорректирован с учётном полёта и реальной	7	Канал наблюдения
5	Должен точно определять конт-ые и изменяемые па-ры для каждого этапа полёта	3	Информационный канал
6	В зависимости от режима должен правильно управлять автопилотом	7	Информационный канал
7	Проверка компьютеров Slat и Flap в соответствии с инструкциями	3	Неисправность концентратора
8	Проверка компьютеров Slat и Flap в соответствии с инструкциями	12	Неисправность концентратора
9	Проверка компьютеров Slat и Flap в соответствии с инструкциями	15	Неисправность концентратора
10	Неверный ввод инструкций полёта в MSDU	3	Неисправность MCDU
11	Неверный ввод инструкций полёта в MSDU	7	Неисправность MCDU
12	Неверный ввод инструкций полёта в MSDU	10	Неисправность MCDU
13	Выбор шины подходящий типу самолёта	5	Неисправность в шине ARINC 42
14	Неправильный выбор типа сети	10	Неисправность в шине ARINC 42
15	Неправильный выбор шины подходящей типу самолёта	7	Неисправность в шине ARINC 42
16	Проверка и устранение неподалок в PFD и ND	3	Неисправность PFD и ND
17	Проверка компьютера управления полетом в соответствии с инструкциями	7	Неисправность PFD и ND
18	Должны быть точно переправерены наблюдаемые параметры двигателя	3	Двигатель самолёта
19	Не работает система EICAS	7	Двигатель самолёта
20	Программное обеспечение EFIS неправильно скомпилировано	1	Неисправность в дисплее предупр
21	Подключение соответствующих устройств и интерфейсов к EFIS не верны	5	Неисправность в дисплее предупр
22	Непаравильно передаётся информация от передатчиков к устройствам	3	Неисправность в дисплее PFD
23	Посадка и заход на посадку выполняется неправильно	7	Неисправность в дисплее PFD
24	Ошибки в показателях устройств	3	Неисправность в дисплее ND
25	Существует разница в отчетах в режиме реального времени по Глиссаде	7	Неисправность в дисплее ND
26	Передатчики,характеризующие параметры двигателя неправильно подключены к	1	Неисправность в дисплее ECAM
27	Отсутствует контакт между дисплеем ECAM и системой EICAS	5	Неисправность в дисплее ECAM
28	Неправильно отрегулирован дисплей FWC	3	Неисправность в дисплее FWC
29	Параметры опасного подхода к земле неверно доставлены в систему	7	Неисправность в дисплее FWC
30	Неиспарвность в работе передатчиков параметров двигателя	1	Mühərrikin parametrlarinin düzgün

The primary program window opened during compilation is shown in Fig. 3.

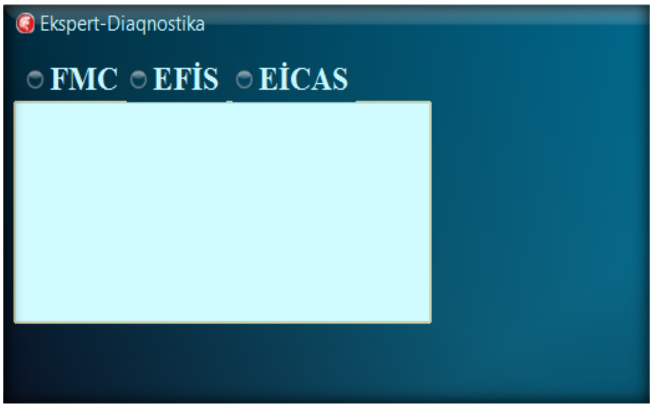

Fig.3. Primary program window

As it is seen from the opened window, the program consists of three parts, each part of which characterizes the problems arising in the individual aircraft subsystems.

A brief description of the main subsystems of the aircraft is given below:

1. **FMC** - *Flight Management Computer* - designed to assist pilots in the implementation of flight modes. The main function of FMC is to precisely define location and direction of the aircraft on a given route.
2. **EFIS** - *Electronic Flight Instrument System* –consists of a *Primary flight display (PFD)* and a *Navigation Display (ND).* These displays are designed in pairs for both the Captain and Firstofficer.
3. **EICAS** - *Engine Indicating and Crew Alerting System* - principally designed for controlling engines and their parameters. Two system computers receive analog and digital data from various aircraft systems and sensors, analyze them and generate signals for indication. One of the computers controls both displays, and the other remains in reserve.

The opened window displays corresponding problems when clicked on its any corresponding section (FMC, EICAS, EFIS) (Fig. 4, Fig. 5, Fig. 6).

Fig.4. Malfunctions in subsystem FMC

Fig.5. Malfunctions in subsystem EFIS

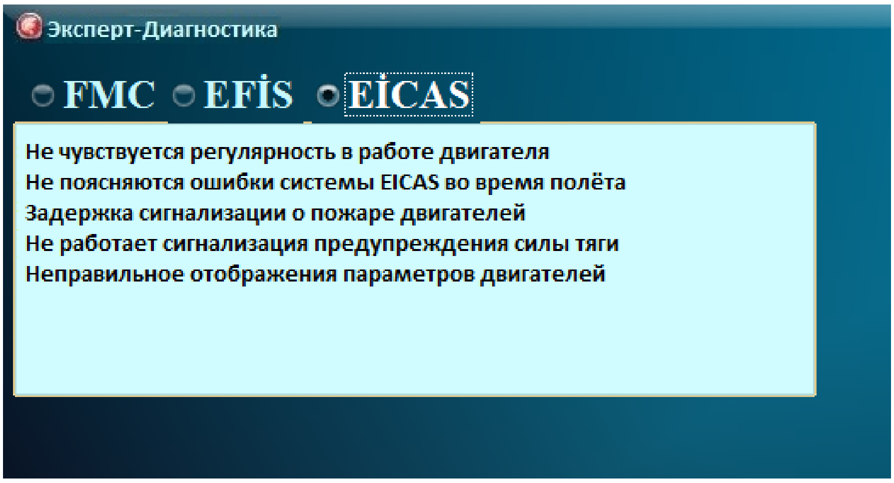

Fig.6. Malfunctions in subsystem EICAS

As it is seen, screen displays problems specific to each field. Here, each problem corresponds to several symptoms. Clicking on these symbols separately for each problem, the followings will display (Fig. 7).

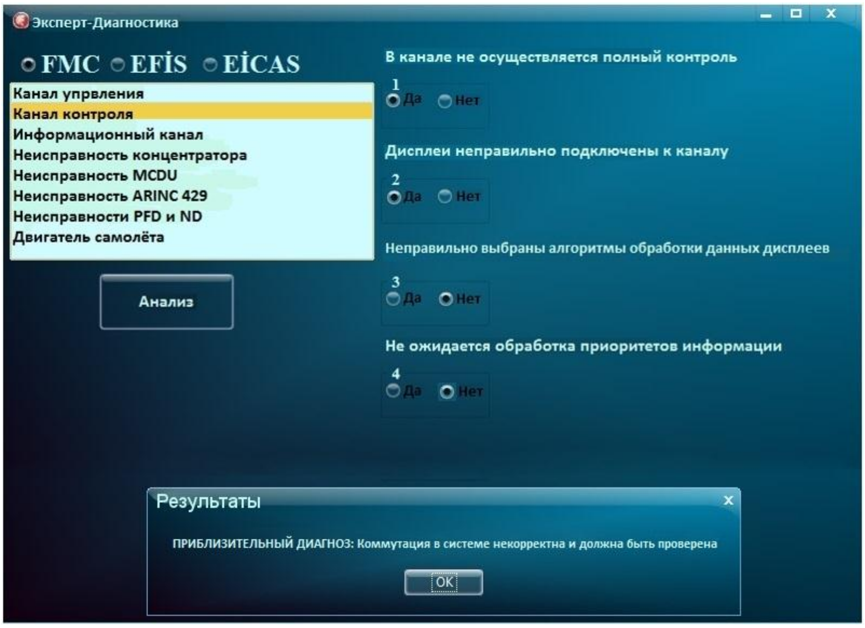

Fig.7. Determination of the diagnosis on corresponding symptoms in section "Control channel" of "FMC"

The figure illustrates a problem in section "Control Channel" of system "FMC". Here, several estimated symptoms corresponding to the occurrence of the problem are identified (highlighted). The program will give different diagnoses depending on the symptom selected. Once the diagnosis corresponding to the problem is selected, "Analysis" button is clicked.
The diagnosis corresponding to the 1st and 2nd symptoms is provided below (Fig. 8).

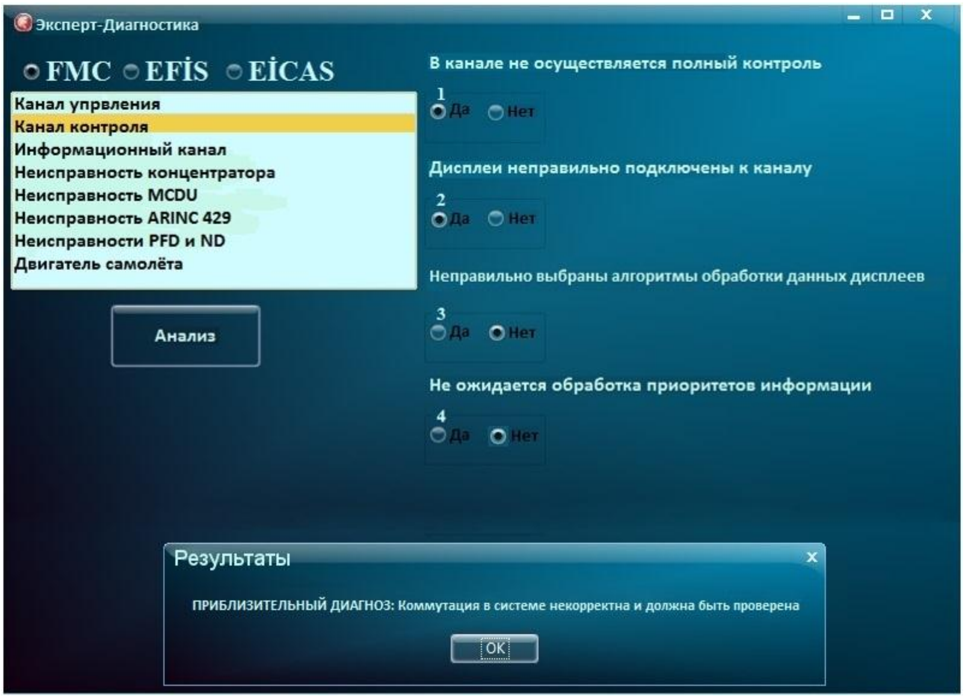

Fig.8. Diagnosis corresponding to the 1st and 2nd symptoms

The diagnosis corresponding to the 3rd and 4th symptoms is as follows (Fig. 9).

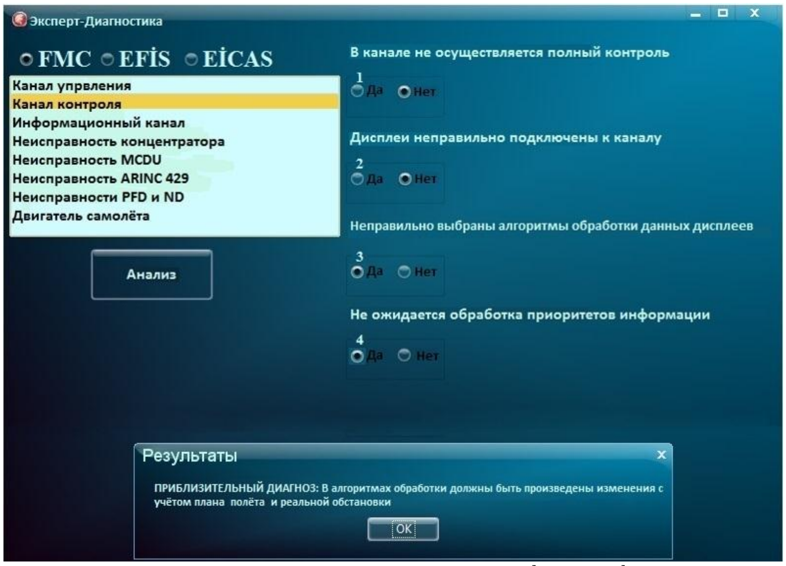

Fig.9. Diagnosis corresponding to the 3rd and 4th symptoms

Thus, the development of the expert advisory system and its software for diagnosing and forecasting important aircraft subsystems such as FMC, EFIS and EICAS provides information support to the pilot and assists to make the right decision.

Conclusion

Based on the analysis that the further development of the PNC was closely related to the introduction of intelligent crew support, situational awareness systems and further intellectualization of the aircraft control, a basic structure of the expert and advisory system of the intellectual crew support for the diagnosis and prediction of aircraft subsystems and its software were proposed. To visualize the program, a database was created, which consisted of three interrelated tables: typical problems that arise in front of user (pilot) during the flight; several symptoms corresponding to each problem, and a table of diagnoses. The order of work with the program and examples of the user's dialogue with the expert system were given.

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