EXPERT SYSTEM AS A TOOL OF HELICOPTERS ACCIDENTS INVESTIGATION.

A.M.Volodko, R.V.Kouprishkin State Research Institute of Aircraft Maintenance Moscow, Russia.

Abstract

The proposed expert system is user-friendly interactive software for the exchange of information between a computer and user, the initiative being taken by the computer. This expert system comprises Russian and international practice of helicopters accidents investigations, especially on the site of crash or emergency landing, that is long-term experience and profound knowledge of the experts. So it would amplify and supplement the specialists rather than replace them.

A labour-saving object-oriented programming technology used for development of the expert system blocks allows updating, correction and elaboration of the software. The expert system has been realized in the Borland C++ programming language and intended for the IBM-compatible PCs.

Introduction

Helicopters of all types are widely operated in military and civil aviation, however they are involved in a number of flight incidents and accidents. Note should be taken that as a rule the accident rate of helicopters is some higher than plane's one.

As an flight accident takes place, no matter how serious are the consequences, it must be properly investigated and classified in order to analyze its cause(s) and prevent them in future.

Flight accident is a complex event that concludes a chain of causes and effects and occurs as a result of their interdependence; one of them being usually the primary cause, others provoking or attendant. Note that:

• Flight accident investigation enlists services of numerous experts, with the problems being solved relating to various areas of knowledge. Some of them require a time-consuming analysis, whereas others need only brief consultations.

• As a rule, experts working in the field have to make multiple inquiries about additional detailed information, which they are not able to keep in memory or just do not know, thus dragging on the investigation.

 Particular training of experts in flight accidents investigation and consequent gaining of necessary experience take many years, while many of them quit due to various reasons, which results in deficiency in highlyskilled personnel.

Anyway flight accident investigation is a ramified process comprising heterogeneous activities yet

pursuing a single goal of revealing:

• serviceability and operating condition of the main aircraft systems at emergency or collision with an obstacle;

• the fault operational system, subassembly, unit or component and the cause(s) for the failure;

• a breach of the assigned operational limits or piloting/maintenance errors;

• environmental effects, their nature and consequences;

• the primary cause of the flight accident and attendant ones;

 recommendations and requirements imposed to prevent similar flight accidents.

Eventually the true unambiguous cause for the accident should be established in the shortest possible time, as a rule in the field conditions near the crash site, which requires a complex of approved scientific techniques and sophisticated facilities, highly skilled specialists, and considerable expenditures.

Long - term Russian and international practice of flight accidents and serious incidents investigation, especially on the site of crash or emergency landing, shows that key experts of the investigation team must have special knowledge, experience and training exactly in helicopter's emergencies not common aircraft accidents.

As it is known [1–3], a number of circumstantial evidence to reconstruct operational conditions of the aviation machinery, pilots poses and control actions at an impact on the ground are typical exactly of a helicopter due to availability of rotor and tail rotor with flapping elastic blades. There is a similar domain of indications for the human factor analysis.

This reasoning has given an impetus to development of an evolving helicopter emergency-oriented information system, which would comprise long-term experience and profound knowledge of the experts, and on the other hand, would amplify and supplement the specialists rather than replace them.

General propositions

An expert system is a software, information carrier competent at symbol reasoning in a particular area of knowledge, solving complex problems and substantiating the found solutions, which allows objective analysis, generalizing and establishing of the flight accident probable causes, drawing conclusions and their thorough substantiation.

For creation of a knowledge base of the expert model the extract of knowledge with application of the complex textual and communicative methods was executed. To filling in questionnaire the leading experts in investigation of helicopters accidents were attracted. The obtained results were handled with usage of appropriate methods of expert information processing [4 - 5].

The base of knowledge for the expert system comprises the following:

- a control system for the computer database on the accident rate of the Russian single rotor helicopters;
- the enumeration of characteristic and statistically substantiated pilot's errors in particular conditions;
- heuristics of the functional dependence between failure indications and parameters of the damaged helicopter condition and causes of the accident;
- the domain of decisive indications of the serviceable or fault operational condition of the helicopter units and parts at an impact on the ground;
- the domain of decisive indications of the crew postures and causes for the injury/death at an impact on the ground;
- the statistical distribution laws for the characteristic parameters typical of helicopter collisions with ground obstacles, such as distribution laws for the roll and pitch angles depending on various typical causes of accidents;
- heuristics of experienced experts reasoning accumulated at flight accidents investigation – at examining the abnormal movement in the air and condition of damaged helicopters on the ground, also drawing conclusions of the accidents causes;
- appropriate descriptions, manuals, reports, scientific papers, layouts, photos, etc.

These domains of standard indications have been systematized from the analysis and generalization of the data obtained from flight accidents investigations in the former Soviet Union, and later in Russia and CIS countries, as well as from special ground and flight experiments carried out both in the course of the investigations and intended for working out preventive safety measures. In particular, there is a computer database on the accident rate of the Mi-2, Mi-6, Mi-8, Mi-14, Mi-17, Mi-24, Mi-26 single-rotor civil and military helicopters flown both in Soviet Union (Russia) and in foreign Air Forces & companies during the latest thirty years. This database comprises all flight accidents and serious incidents, including the following information:

• the type of the helicopter involved in a flight accident, its registration number, manufacturer and date of manufacturing, belonging, date of the last repair and maintenance, operating time and hours flown after the last repair;

• the pilot's data, such as his age, rating, overall flying hours, and hours flown on this helicopter and as a pilot-in-command;

• number of passengers and presence of a supervisor on-board the helicopter;

the flying task or combat mission;

• the underlying surface at the flight accident scene;

flight stage and regime at the emergency;

• weather conditions (clouds, visibility, wind speed and direction, pressure and humidity of the air, natural phenomena);

 data of the flight recorders and cockpit voice recorders;

 helicopter gross mass and e.g. position at emergency;

• crashed aircraft position (on the wheels, capsized, on the right/left side);

directional rotation at the moment of crash;

symptoms of in - flight or ground fire;

maximum scatter of the helicopter heavy and light fragments;

 indications of the rotor and tail rotor blades impacts on foreign objects or helicopter body;

 data on the spar destructed sections and damage to the blade tips;

 kinking in the engine drive shafts and tail rotor drive system shafts;

power plant and electric equipment service;

 occurrence and development of the emergency;

 classification of the flight accident (a fatal accident, a non-fatal accident, or a failure);

 results obtained from special examinations of the fault aviation machinery;

 conclusion drawn on the cause of the flight accident and provoking factors that had served to aggravate the emergency;

• comments and recommendations to the flying and engineering personnel and manufacturers on taking measures to ensure flight safety.

This database with its exhaustive information on the flight accidents, in which a particular type of aircraft have ever been involved, combined with an aggregate of operational conditions reconstructed for the helicopter units and assemblies and data on the crew at the impact on an obstacle together with the particular domain of gnosiology (descriptions, manuals, reports, scientific papers, layouts, photos, etc.) and friendly user interface all together form an expert system, which allows objective analysis, generalizing and establishing of the flight accident probable causes, drawing conclusions and their thorough substantiation.

The substance of expert system

An expert system is software, information carrier competent at symbol reasoning in a particular area of knowledge, solving complex problems and substantiating the found solutions [6-12]. Such systems fall in the category of artificial intelligence working in direct connection with experts. A pattern of the knowledge representation is of essential importance for any expert system; it should enable statement of the problem being analyzed so that it can be solved in the simplest possible way. A fundamental analysis the authors have carried out testifies in favor of so-called "if .. .(condition), go to ... (action)" pattern, i.e. when the situation being analyzed satisfies the left-side scenario, then actions described in the right side are fulfilled. Applying sequentially, this rule results in a deduction chain; the investigators employing two opposite conceptions - the direct and inverse deduction chains.

It is accepted to divide all factors promoting originating and development of an emergency, into three basic groups: failures of engineering, effect of the factors of an environment and human factor.

Apparently, that alongside with determined emergencies, when only one of the indicated group's factors manifest, significant number of emergencies have arisen because of effect of the factors of several groups. Such cases cause the greatest difficulties at investigation of flight accidents, and the solution of the expert system is most valuable. The degree of influence of various factors thus expresses in percentage concerning their common influence and development originating on of emergencies.

The proposed expert system is user-friendly interactive software for the exchange of information between a computer and user, the initiative being taken by the computer. Users need not to be any particularly good at computer programming, the dialog is constructed in such a way as to alleviate answering the program's questions. The hard limits are literal-free spelling and adopted terminology at input data on the sources of information, circumstances of the flight accident, etc. The expert system includes the following modules:

- the unit of the collecting and analysis of input data about flight accident;
- databases of defining tags of flight accident;
- knowledge base;
- the editor of a knowledge base;
- the unit of self-training;
- the unit of a conclusion.

The investigation of flight accident through the expert system starts with the collecting of the initial information, which can be received to this moment from various sources and inputting it in the program. The received items of information are bunched in the array called as a set of input data. Further the substantial circumstances of accident are compared to the information of the own database representing unified space of defining tags on three abovementioned basic groups of the factors. List of versions about all possible reasons of the given accident also is formed.

The elaboration of versions is executed simultaneously on all directions of investigation. Usage of known methods of calculation of reliability of tags and versions of flight accident causes certain difficulties connected to necessity of introduction of a number of simplifying assumptions. So we use the statistical method of rating of reliability of indications and versions about reasons of flight accident on the basis of known rules of probability theory. The reliability of input data was estimated from a degree of confidence to sources of this information, and reliability of the version - on the basis of reliability of input data and link of indications of flight accident with its probable reasons. The basic assumption thus consists that the group of indications describing a certain possible reason of flight accident, is considered as full group of events unequivocally defining failure of engineering, error of crew or effect of the factor of an environment as certain event.

The degree of confidence to sources of the information was determined in result of questionnairing of the experts involved in a great number of investigations of flight accidents of various types of helicopters. As a result the values of a degree of confidence in an interval from 0 up to 1 were assigned to each source of the information about flight accidents.

Input Information



Fig.1. The model of expert system

At the substantiation of entirety of group of events unequivocally defining failure of engineering, error of crew or effect of the factor of an environment as certain event, the situation was considered, when the version about a cause of accident (event B_1) is put forward on the basis of the accident's indications, detected during investigation (events A_i). The probability that the cause of accident really was B_1 , is determined under the formula:

$$p(B_1) + p(B_1/A_i) * p(A_i) + p(B_1/\tilde{A}_i) * p(\tilde{A}_i)$$
 (1)

On the basis of an assumption, that the cause B_1 practically always calls appearance of indication A_0 the formula (1) will accept a view:

$$p(B_1) = p(B_1/A_i) * p(A_i).$$
 (2)

In a real case for definition of a reason of accident (event B_1) several indications (A_1 , A_2 , ..., A_n) will be utilized, thus the expert will orient by correspondence of the detected indications of some combination, known for him, of indications witnessing of a certain most probable cause of accident. The experienced enough expert can generate set of indications presenting full group of events unequivocally defining a particular cause of accident. That is, if during investigation all of such set of indications are detected, and their reliability will not arouse doubts (p (A_1) = 1), a cause of accident defined by this set we shall count authentic:

$$p(B_1)=p(B_1/A_1)+p(B_1/A_2)+...+p(B_1/A_n)=1$$
 (3)

Then the probability that B₁ is a true reason of accident we determine as:

$$p(B_1) = \sum_{i=1}^{n} p(B_1/A_i) * p(A_i)$$
 (4)

The expert system on investigation of flight accidents with helicopters is realized at a level of the exploratory prototype, is developed [13] in the environment Microsoft ® Visual C ++ \circledast 6.0, has the window interface and is intended for activity on PCs with the processor Intel Pentium \circledast or better, under the control of an operating system Microsoft \circledast Windows \circledast 9×(ME).

How the expert system works

The obtained formula (4) is utilized by the expert system during the analysis of the information about flight accident for calculation of reliability of each of considered versions (Fig.1). If necessary, the expert system accesses to the user behind the padding information about known to it, but not

submitted in this case possible circumstances of flight accident, for what accesses to a knowledge base, retrying this process a necessary number of times. On the basis of the answers the expert system independently supplements a set of input data. Thus, the process of comparison by the expert system of the own information with the real facts derivates that is named as a chain of conclusions, which will subsequently be utilized for presentation to the user, in reply to his inquiry, how the system has come to such conclusion. Accessing to the database on flight accidents, the expert system receives the statistical data for a prospective cause of accident, which will be utilized for updating probability of the considered version about causes of given accident. The version which was not gained of certain threshold value probabilities, is eliminated from further consideration. The threshold value is set by the user and can be adjusted during activity of the program.

The verification of the test version of the expert system was carried out at investigation of flight accident with the Russian helicopter Mi-26 in December, 2001.

As sources of the information in this case were considered:

- the certificates of the eyewitnesses of accident (determined on a stage of the experts inquiring a degree of confidence to the given source - 0,2);
- the reports of the members of crew of the helicopter (degree of confidence - 0,7);
- the official data on meteorological and ornithological conditions (degree of confidence - 0,9);
- the reports of inspection of a place of accident (degree of confidence - 1,0).

As a result of the analysis of the information obtained from listed sources, the enumeration of indications of flight accident in question was composed, on the basis of which the expert system has generated the following set of versions about its possible reasons:

- icing and hit of ice in engines with reliability 0,35;
- bit of a foreign object in engines with reliability 0,20;
- self-cutoff of two engines because of a short circuit in an on-board electrical network with reliability 0,30;
- failure of the main gearbox with reliability 0,15.

In connection with the deficit of the information on the given flight accident for shortening of number of seances of the expert system the following conditions of termination of activity were provided:

 value of threshold value of reliability of one of versions more than 0,5; change of reliability of each of considered versions less than on ±5 % for the last three seances.

In total during investigation of the given flight accident 5 seances were carried out. From an adduced phase portrait of change of reliability of considered versions during activity of the expert system (Fig. 2) is visible, that on 5th a seance the preliminary version « an icing and hit of ice in engines », having the greatest reliability in a start of activity of the expert system, became main with value of reliability equal 0.58. The conclusions of the test version of the expert system have coincided with results of activity of the experts on investigation of the given accident.



- hit of a foreign object in engines
- self-cutoff of two engines
-failure of main gearbox

Fig. 2. A phase portrait changes of reliability of versions during activity of the expert system.

Ability to expand the database and to enlarge a knowledge base during activity allows the independently expert system to gain experience, which will be utilized in further activity. Skill to explain the operations and course of reasonings increases a degree of confidence to it, that has the large value for the program intended for rendering assistance in such area, as investigation of flight accidents. For debugging and verification of the expert system the database of flight accidents with

helicopters of the Russian production will be utilized which, as was marked, is the basic component of a knowledge base in considered domain.

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