A fuzzy logic approach for the design of an expert system

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Abstract

In this study, it is aimed to propose an approach for the fault detection during the aircraft maintenance. For this purpose, an expert system optimized with the web-based fuzzy logic approach is designed and presented. The approach presented here is based on fuzzy logic. The fuzzy logic module benefits from information on the forum where the users enter information on plane failures. Furthermore, it is intended to express the capabilities of current expert systems, to display the proposed system superiorities and to verify the system proposed under implementation. The design of the expert system is conducted successfully and taken into live environment. The targeted characteristics are tested and the veracity of results is met as on the page where the implementation is told. The interface of this design is again prepared in this study. Both theoretical and software interface studies are conducted. It could be said that development of the system in this manner will enable the currently commercialised system to become more attractive.

INTRODUCTION

The purpose of this study is to design an expert system optimized with the web-based fuzzy logic approach. Furthermore, it is intended to express the capabilities of current expert systems, to display the proposed system superiorities and to verify the system proposed under implementation.

The expert systems are defined as computer programmes that are equipped with the information related to a certain field and that could propose solutions to problems solely as proposed by people specialised in the field of interest or that are including documented solutions. Expert systems provide great advantages particularly for solving problems progressing semantically in the form of question and answer. As it is observed from the definition, expert system is based on human knowledge. An expert can analyse, learn about his own performance and improve it for use in future. Expert systems show similar behaviours. Self-improvement of the system is a subject related to learning.

The most important subjects related to an expert system are maintainability and continuity. In this sense, information flow and knowledge base are important. The aim of the web based solution proposed in this study is to provide fundamental needs of an expert system as online. So, information flow with various methods may bear the characteristics of a portal in order to provide web based participation of experts from all over the world.

The other main task of an expert system is the capability of interpreting. The capability of interpreting is defined as a computer program which presents a methodology to think over the information involved in knowledge base and operational area and which decides about the results. In other words, it is a mechanism producing solutions to problems. Here, a decision is made regarding how the information obtained from the system is used. The proposed system uses fuzzy logic so that the interpreting mechanism could produce the optimal solution, therefore, if there is more than one proposed solution, the best solution is provided.

In this study, the web-based online expert system is developed. The methods and technologies applied in this study are expressed under the title of interface components of expert systems in a way to include the essence of information. First of all, a literature survey on the expert systems and the use of fuzzy logic is presented. In the literature scan, fuzzy logic is given in a perceivable manner, first of all by composing in brief. The expert system considered in this study is planned as a guide to solve the problems arising during the aircraft maintenance. An application to the aircraft maintenance is presented. It is also explained how the fuzzy logic is used for the fault detection during the aircraft maintenance. In the section describing web based expert system developed within the scope of the study, information scanned from literature is also included from time to time in order to explain the system. The fuzzy logic engine is explained. The use of expert system and fuzzy logic is explained. Then, the expert system and fuzzy logic system examples are given. The expert system proposed in this study constitutes an interface for utilisation of neural networks towards studies aimed at enabling systems to learn like a specialist person. As known, an expert system from which outcomes close to truth are expected should certainly include at least one of the soft computing systems. For this reason, this scientific method is examined in detail and constituted a significant base for the study to be performed after this study. The results are presented and concluded.

AN OVERVIEW ON THE STUDIES ON FUZZY LOGIC AND EXPERT SYSTEMS

In a paper on the performance evaluation, a fuzzy logic based model is formed towards utilisation of performances of automobile producers in Japan [1]. The study is said to

include eight service stations located in producing company. The notions of “satisfaction”, “importance” and “relationship” are taken up for each service. Fuzzy sets are formed for each one of these three notions, relations between notions are expressed in the form of rules and finally the result of performance evaluation (in the form of very good, good, average, bad) is obtained for each service. In a study conducted regarding appointment of teachers, determination of professors to be assigned to colleges and universities in Taiwan is reiterated [2]. The success evaluation of professors is made with criteria where each one has a specific level of significance. It is stated that fuzzy logic mechanism functions with respect to level of significance of criteria, a professor who is most successful in his profession is determined through a mechanism of logic and that person is appointed in colleges and universities. In another study conducted for measuring performances of lecturers working in universities of Taiwan by employing fuzzy logic, the procedure of measuring performances of lecturers is made through points given to criteria with specific level of significance and varying between 1 and 5 in value [3]. With regards points obtained by using fuzzy logic approach, success level of each lecturer in their tasks is determined. In the study on the performances of students measured by using fuzzy logic approach, the success of students is determined with respect to homework evaluation at various levels of significance, test evaluation and grades they obtain from final exam evaluation in order to measure their performance [4].

Another study is on the evaluation of electronic courses given in a college in Taiwan by using education quality fuzzy logic approach [5]. The evaluation procedure is performed under criteria with a specific level of importance for each electronic course. Evaluation procedure is made by 85 course students, by assigning points varying from 1 to 5 to criteria values and it is determined by using fuzzy logic approach which one of course criteria is more important with respect to others. In a study performed by using fuzzy logic approach on performances of primary education schools, successes of different schools within or outside the city are determined with fuzzy logic under certain rules [6]. In a study prepared for determination of failures in planes by employing Fuzzy Petri Nets (FPN), a decision-making structure is formed for finding out an error with fuzzy logic algorithms by employing plane failure statistics [7]. The system taking the information of Turkish Airlines at the time of flight as its data, checks whether the parameters of the plane at the time of flight are above a certain threshold and makes warning of errors with fuzzy logic [8]. In a study prepared by using artificial intelligence information system for elimination of failure search in turbo-prop engine, an expert auxiliary system is formed for maintenance of plane engine [9]. The expert system, taking into consideration the information released as a result of general hangar maintenance of T56-A-15 turbo-prop plane engines aims at elimination of failures arising in engine works performed in test unit of plane engine [10]. In a study prepared for diminishing maintenance expenditures in newly designed military planes, use of artificial intelligence is explained for registration and analysis of ground based data and reduction of maintenance expenditures [11].

APPLICATION OF AN EXPERT SYSTEM

The relevant problem is defined by the user on the screen of Problem Resolution. Then, a solution is attempted to be found with question and answer in an interactive manner. At this point, the expert system engine is used. Whilst expert system engine is being designed, clips programme is taken as a reference. Accordingly, the database structure on which the clips keep questions and the interrogation logic are adapted to the system.

Depending on the problem defined by the user, the system forms a tree structure to user and depending on the answers given to questions, the system is branched out on this system.

For replies to questions which are not defined on the system, the system is designed to give indefinite replies with fuzzy logic by using feedback. At this point, a solution is attempted to be found by using first an expert system, or user feedback for problems which cannot be resolved with expert system.

The fundamental details required to be entered by the user through system in order to start the procedure of problem resolution are as follows: Airplane Producer, Type of Plane, Engine Producer, Engine Type, and Definition of Problem.

After definition of problem, the first question is asked regarding the problem, and then the next question is proceeded with "yes" or "no". In the meantime the problem is branched on a tree depending on replies received from user.

As it possible to attribute a transaction to what needs to be done as problem solution, a spare part could be proposed as a solution or a relevant page of manual could be indicated as source.

THE USE OF FUZZY LOGIC FOR AIRCRAFT FAULT DETECTION

Many terms we use randomly in daily life generally have a fuzzy structure. Verbal or numerical expressions we use while defining something, explaining an event, giving a command and in many other circumstances include fuzziness [12]. As an example to these terms, many other verbal terms like old, young, long, short, hot, cold, warm, cloudy, partly cloudy, sunny, fast, slow, very, few, rather, more, too few, too much could be given. People use the no certain terms in such cases; people call a person old, middle aged, young, very old or very young depending on his age. Depending on that the road is slippery or ramped, people can press on gas or brake pedal of car a little bit more or less. If the light of the room we are working is insufficient, we increase it a little bit, if more than enough, people decrease it a little. All these are examples to how human brain acts in unclear or indefinite circumstances and how it evaluates, defines events and makes decisions. After development and publishment of fuzzy logic and the theory of fuzzy logic employing these rules of logic by Lotfi A. Zadeh in his original article in 1965, examination of systems including indefiniteness has gained a new dimension. Despite being set forth in 1965, the notion of fuzzy set was started to be used only after the second half of 1970's. Particularly the articles of Zadeh which was more influential than his first article in 1965 and explaining applicability of fuzzy logic to systems including indefiniteness have been effective. It gained pace with the use of fuzzy logic by the Japanese in their products after the second half of 1980's and reached its peak today [13]. It is now possible to come across fuzzy logic implementations in all areas. Resource is separated with respect to areas of fuzzy logic implementations, and each implementation is listed by stating its resource.

The fuzzy logic module in this study implementation benefits from information on the forum where users enter information on plane failures. Accordingly, it is aimed that any web user could seek a solution on problem of plane failure by using fuzzy logic libraries of ".net" of Microsoft on the system. During generation of a solution, the system is about deciding on a solution to be selected by the implementation through fuzzy logic module via different user data and to propose them to the user.

In order to find out the solution to be proposed to the user, the system conducts a study as follows; Microsoft.net fuzzy logic library operating under implementation conducts a meaningful data search on our database before operation and a meaningful classification is made for these information with an interrogation made on database for the information searched, therefore; first the entire information is searched within the system, if sufficient amount of resources are found, the sources found are directly given as data into fuzzy logic implementation, if sufficient amount of information cannot be found, searches are made again

and again by increasing the number of characters in the system by one until finding sufficient amount of information. Then the information found is given into fuzzy logic implementation, the fuzzy logic implementation generates solutions by conducting a research on these entries. This working structure is explained below with pseudo code in detail;

1) The information searched is taken from the user.
2) An interrogation is operated in the system on the basis of information obtained from the user.
3) If the number of replies found as a result of search is larger than a certain value, it needs to pass on to step 6. If not, continued from step 4.
4) Character length of the information researched is decreased one by one, and then interrogation is made again.
5) The answers found are added to former replies and if the desired number of replies is attained, one passes on to step 6, otherwise returns to step 4.
6) The replies found is given as outcomes which may be the reply to information sought for fuzzy logic implementation.
7) Fuzzy logic implementation passes each one of the outcomes received to a different serial element.
8) Decision bringing function is operated on fuzzy logic library.
9) Loops are formed in the number of decision bringing functions and as each candidate makes decision on the reply, the decision number of that reply is increased by one.
10) The serial element with the maximum number of decision as a result of loop, is named as result to be assigned to information sought.
11) Found fuzzy logic decision and candidate replies are shown to user on the screen.

EXAMPLES

Here, two different solution examples, which are an expert system and a fuzzy logic system, are presented. The expert system includes mainly decision tree. A fuzzy logic system includes a fuzzy engine that offers a solution rather than found by an expert system.

An Expert System Example

At the phase of problem solution, the expert system generates outcomes on the tree below on the basis of information received from user as seen in the example shown in Fig. 1.

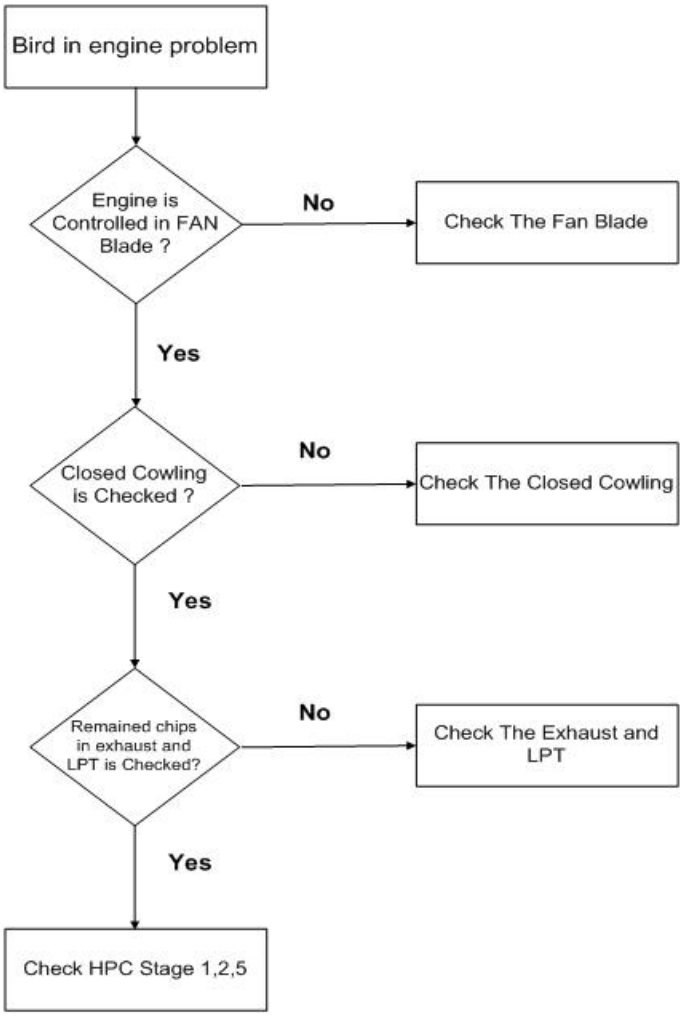

Figure 1. An example for the outcomes of an expert system (The above tree (Bird in Engine Problem) illustrates the solutions of expert system with interaction of user.)

The works performed in brief;

1) Airplane producer company is selected,
2) Airplane type is selected,
3) Engine producer is selected,
4) Engine type is selected,
5) Problem is defined,
6) System starts asking questions on the basis of problem definition,
7) Depending on replies of "Yes" or "No" received from the user, branches are made on the tree as indicated in Fig. 1 and the next question is answered,
8) After completion of questions defined on database, the solution proposal and/or spare part regarding this question is proposed to user by the system.

A Fuzzy Logic System Example

When the expert system does not produce reasonable solutions, the user can get also solution from fuzzy logic engine. The fuzzy logic system works such as;

1) User request the solution via entering the problem keywords,
2) The engine creates a search request to the database of the forum which entered by other users,
3) The request results give some solutions the fuzzy logic decision system to find an appropriate solution,
4) Fuzzy logic libraries choose a solution and show the solution to user.

Table 1.

Fuzzy Search

KeyWord(s) Engine Control Search

Selected Solution: Inspect Engine For Evidence of Hot Leakage SpecificLeak Points

Msg Id	Msg Text
1	Borescope Inspection for HPC Stage 1,2,3 engine control.
2	Control Fan Blade
3	Chip detector control in engine oil component.
4	N2 vibration error control
5	Hot Engine Start
6	Replace Main Engine Control
7	Replace Engine
8	Inspect Engine For Evidence of Hot Leakage SpecificLeak Points
9	Control Overboard Drains and fan Stator Case for Leaks Are there Leaks?
10	Control CDP system tube and connections for damage and security.
11	Control seating surface of connection
12	Control engine inlet and exhaust nozzle for damage.
13	Replace engine fuel pump.
14	Remove fuel filter and control for evidence of fuel pump failure.
15	Engine Torching
16	Control Specific Gravity Adjustment.
17	Control Turbine Exhaust Area For Metal Particles.
18	Control N1 vibration system
19	Control N2 vibration system

How Fuzzy Logic Engine Works (this is related to the example given above)

The engine gets the possible results from database, and then it gives a number for every solution.
For example;
Solution A = 1, Solution B=2, Solution C=3 .

After every solution is numbered, the random number generator starts to work. It creates random numbers and hits the appropriate solution. The solution which get the most hit is the winner solution. The winner solution is showed to end user as the fuzzy logic solution. The diagram of the fuzzy engine application is given in Fig. 2.

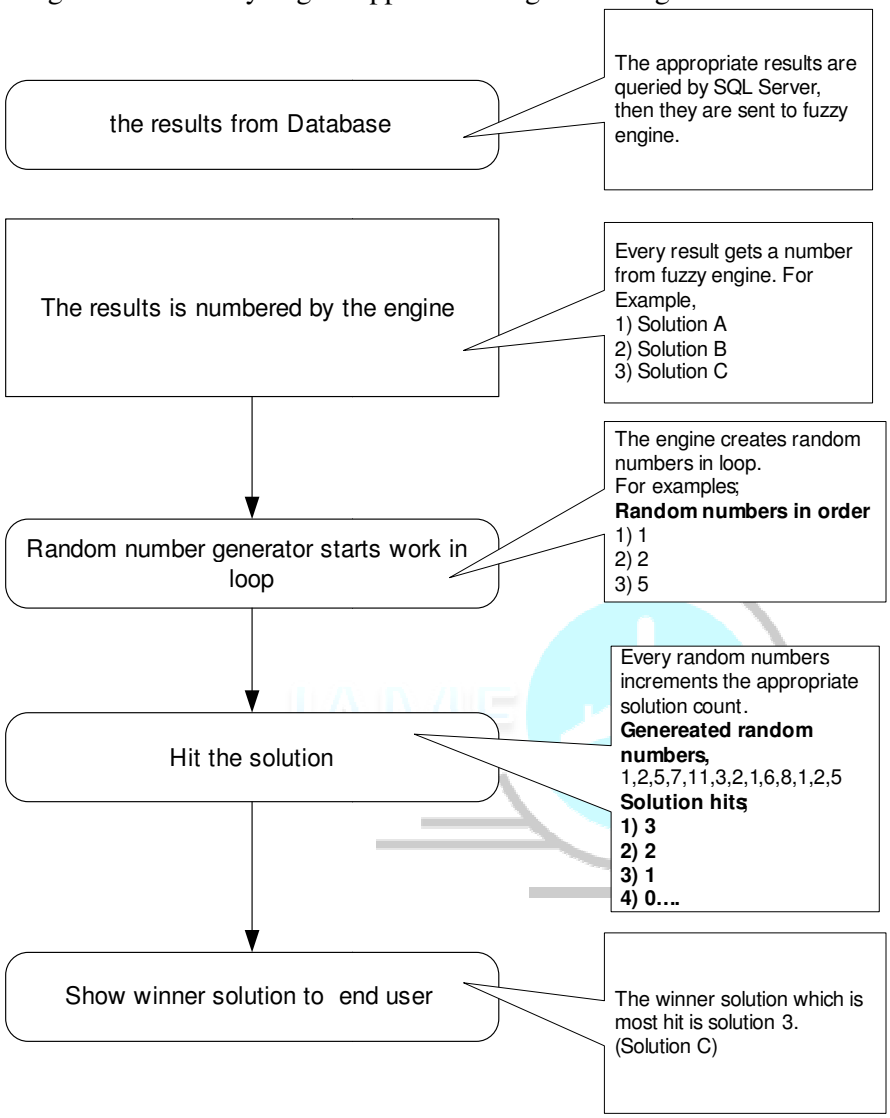

Figure 2. A fuzzy engine application.

5.2.2. Fuzzy Engine Results (the results of the above example)

Table 2.

Search : Engine Control		
Solution No	**Solution Text**	**Hit**
1	Borescope inspection control HPC Stage 1,2,3 engine control.	**2**
2	Control Fan Blade	**5**
3	Chip detector control in engine oil component.	**6**
4	N2 vibration error control	**10**

The fourth row is showed to user as the winner solution with 10 Hits via fuzzy engine. The fault detection system developed in this study has certain supremacies compared to the other expert systems. These are listed below,

a) The current system uses tree for expert system, which shows the user the way of the solution by the respect of user responses.
b) The computer program is web based, that is one of the main advantages, which makes the system accessible by internet.
c) The system offers users to see approved solutions from published guides.
d) The solutions which are provided by users can be searchable from other users.
e) The fuzzy logic engine of the program offers users alternative solutions for every request.

The items listed above can be explained in the following paragraph. Online acquisition of knowledge shall be provided. Acquisition of information from different resources will be prone to an extremely simple integration. It will be possible to present problem solution in the form of a tree structure. Although the subject cannot be known in full by problem search, it will be possible to find solution tree with a research. The aim of this study is to display that it is possible to develop an expert system that could be learned by using additional features such as fuzzy logic. This system is more advantageous with respect to traditional expert systems as it facilitates acquisition of knowledge and improves extraction mechanism. The system will be delivered in a status of complete operable features. The entire set-up will be made in a manner to broadcast via web.

CONCLUSION

As a result of this study, a web-based Expert system design is conducted successfully and taken into live environment. The targeted characteristics are tested and the veracity of results is met as on the page where the implementation is told.

In the continuation of this study, a modern optimal Expert system permanently renewing and training itself with Fuzzy Logic based and Artificial neural network could be designed. The interface of this design is again prepared in this study. Both theoretical and software interface studies are conducted. It could be said that development of the system in this manner will enable the currently commercialised system to become more attractive.

Among places where such an implementation could be suitably positioned, the intranet system of an airline company is at the dominant position. It could be easily integrated, follow-up failure records of an airline company and perform the function of an expert system against similar problems which may arise in future. Follow-up of problems provides traceability. Besides the airline company, it could be entered into operation as a very beneficial implementation particularly in services section of white goods companies. Besides it could be used as automotive sector and electronic parts producer companies.

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