A FUZZY EXPERT SYSTEM APPLICATION FOR MISION PLANNING TO AEROSPACE VEHICLES

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ABSTRACT

In this study, Fuzzy Expert Systems in Aviation is inspected and a fuzzy expert system is designed to provide solutions on aerospace vehicles' airworthiness evaluation and mission planning. In aviation aspect, mission planning is a rather complicated process consisting two main parts, operations management and maintenance, and requires many different criteria must be evaluated and met. This research is intended to be a supportive solution for the mission planning process, to which the flight safety is the most important issue, and for the planning task that is human-based and expects many inputs and needs to be done flawlessly. A fuzzy expert system structure has been developed according to the process. Stages applied respectively; creating a database, fuzzification, rule based inference process and defuzzification. The research shows, this process can be solved effectively by using a web based fuzzy expert system.

Keywords: Aerospace vehicle; fuzzy expert system; mission planning; Python

HAVA ARAÇLARININ GÖREV PLANLAMALARI İÇİN BİR BULANIK UZMAN SİSTEM UYGULAMASI

ÖZET

Bu çalışmada havacılık alanında bulanık uzman sistemler incelenmiş ve hava araçlarının uçuşa elverişlilik değerlendirmeleri ve görev planlamaları için çözüm sunan bir uzman sistem tasarlanmıştır. Havacılık açısından görev planlaması, işletme ve bakım olarak iki ana bölümden oluşan ve pek çok farklı kriterin değerlendirilmesini ve karşılanmasını gerektiren karmaşık bir süreçtir. Bu çalışma, uçuş emniyetinin en önemli unsur olduğu, insan temelli yerine getirilen, bir çok farklı girdi alan ve kusursuzca tamamlanması gereken görev planlama sürecine bir destek çözümü sunmayı amaçlamaktadır. Sürece uygun bir bulanık uzman sistem yapısı geliştirilmiştir. Sırasıyla; veritabanı oluşturulması, bulanıklaştırma, kural tabanlı çıkarım süreci ve durulaştırma işlemleri yürütülür. Bu araştırma ile web tabanlı bir bulanık uzman sistem kullanarak etkin bir çözüm sunulabileceği gösterilmiştir.

Anahtar Kelimeler; Hava araçları, fuzzy expert system; görev planlama; python

1. INTRODUCTION

In the aviation sector, in order to perform the task in the most secure and effective way possible, well trained pilots in the front are essential, not to mention the aerospace vehicles which are as much crucial. One of the most challenging decisions to make is to choose the correct aerospace vehicle. There are a number of criteria that should be taken into consideration simultaneously. The personnel that work in this field manage this situation by means of computer based guidance, tables and graphics and also they spend effort to arrive at the best conclusion by making use of their experiences.

However, it is a fact that certain points can sometimes be overlooked. This research is an attempt to help make the decision making process most effective by displaying the situation most clearly to the practitioners as this professional system was developed relying on fuzzy logical principles.

In this study, by developing a fuzzy web based system, it attempts to define the mission planning of these aerospace vehicles, an area where there is lack of information. In the system, firstly, the necessary mission, personnel and aerospace vehicle information are defined. After that, the relevant criteria are given and a regulation base is formed relying on professional views. The values of the aerospace vehicle are made obscure by making use of the necessary algorithms. By processing the regulation base concerning the mission and the personnel, inferences are made and the result of the evaluation is clarified.

2. PRELIMINARY INFORMATION

Aviation defines a comprehensive sector that covers all types of aviation vehicles and all the other units that support these vehicles. “Aerospace vehicle” refers to all vehicles that have the ability to take off and fleet in the air, “Airplane” refers to an aviation vehicle that is heavier than air, that fleets by the help of engine power, that can land on land or water, or both land and water, “Helicopter” refers to a vehicle that can land to a point or take off from a point on land or water without requiring a specific landing field, and “Flight

crew" refers to the people necessary to make the flight possible such as the pilot, navigator and the flight technicians. [1].

AIRWORTHINESS AND THE CONCEPT OF SORTIE

The concept of airworthiness defines the situation when an air vehicle is ready to perform its duty in a safe manner. In aviation terminology the mission is generally referred to as "sortie". In fact, the term sortie originally belongs to the naval sector and from the Second World War onwards it was started to be used in the aviation sector and was defined as a single flight of a single plane [2].

In the contemporary world, sortie refers to one or more landings. In this process, the period between the take off and the landing is called "flight hour". This information about time is taken as an important reference in terms of the experience of the flight crew and the aerospace vehicle. If, within the sortie, there is going to be a take off-landing after the first take off, then these are coined as 'Leg'.

A sortie flight is composed of three main components: Mission, personnel and aviation vehicle.

Figure 1. Main elements of a sortie.

Aviation management covers many main factors. These vary from aviation field management, the tower where take off and landing are controlled to the supplying of ground support. Here, there are two main frames to be taken into consideration. These are operations and maintenance.

OPERATIONS

Operations deals with the planning of missions, time, aim, meteorology, the planning of details; all of which are duty focused evaluations. After all of the above are clarified and determined the personnel to perform the task is chosen. Operations manage to sub categories which are the mission and the personnel.

MAINTENANCE

Maintenance is the department which controls the structure and the inventory. Maintenance frame is the field where aviation suitability is controlled. It provides aerospace vehicle so that the mission defined by the operations can be fulfilled.

AEROSPACEVEHICLE

Table 1. Characteristics of Aerospace vehıcle

Characteristics
Registration Number
Type
Status
Fuel Configuration
System Configuration
Sortie Reliability
MTBF
Abort
Repeat/Recur
Major Repair
Last/Next Scheduled Maintenance
Last/Next Depot Level Maintenance
Flight Hours (Per Available AV)
Sorties (Per Available AV)

SORTIE RELIABILITY:

The result of sortie reliability calculated (1) and assessed as percentage (%).The active sortie is the sortie which has not signified malfunction at the final landing debrief. It is used to get the reliability/efficiency ratio data in

performed duties. The evaluation is made by taking into account the specified period range mostly in 1 year or 6 months.

Sortie Reliability = FMC Sorties Flown/ Total Sorties Flown ** x 100* (1)

** Sorties flown with no pilot reported discrepancies.*
*** Total sorties flown for a specific period*

MEAN TIME BETWEEN FAILURES (MTBF):

Mean time between failures (MTBF) provides periodic mean time between failures based on specified systems at MMEL/MEL. It is one of the important evaluation criteria and it brings up matter of malfunction possibilities during the planning stage. This ratio has significant importance when the uses of mission based systems are required.

ABORT:

The concept of abort is that the flight crew cancels the duty with any reason in the air or land after the taking over of the aircraft (higher authority decisions not counted). During the planning phase, with the appending of sortie to the abort ratio calculated (2) can be used to foresee the compensation of the possible cancellations of the sorties.

Abort Rate = Aborts/ (Total Sorties Flown + Aborts) x 100 (2)

REPEAT/RECUR

The repeat/recur which takes place in the general aviation terminology is the system malfunction recurs in the following next sortie or sorties.

Repeat Rate = Repeats/ Total Sorties Flown x 100 (3)

MAJOR ON-EQUIPMENT MAINTENANCE:

The aerospace vehicle has some major systems , such as flight controls and engines,affecting flight safety closely. If any maintenance done on those systems need close attention.

LAST/NEXT SCHEDULED MAINTENANCE:

Aerospace vehicles require maintenance on a regular basis based on specific criteria. These criteria may be calendar days, flying hours, sorties or cycles (rotation). Last and next maintenance information are important data for mission planning.

LAST / NEXT DEPOT LEVEL MAINTENANCE:

Various levels of maintenance plans need to be prepared. There are flight line level basic maintenance, periodic comprehensive maintenance and manufacturer level maintenance. Highest level of maintenance is done at the manufacturer of the aerospace vehicle or in a designated facility to the finest detail. That is called Depot Level Maintenance(DLM).

FLIGHT HOURS PER AVAILABLE AEROSPACE VEHICLE:

Equation 4 is used for calculating flight hours per available aerospace vehicle. The average value obtained, including the flight group that vehicle belong or by other aerospace vehicles in the squadron/fleet to flight times used in the evaluation.

Flight Hours per AAV = Total Flight Hours /Available Aerospace Vehicle (4)

SORTIES PER AVAILABLE AEROSPACE VEHICLE

The average value obtained (5) is used for assesment of the vehicle's state in the flight group or squadron/fleet.

Sorties per AAV=Total Sorties Flown/ Available Aerospace Vehicle (5)

3. FUZZY LOGIC AND EXPERT SYSTEMS

FUZZY LOGIC AND MEMBERSHIP FUNCTIONS

Fuzzy logic was introduced by Lotfali Askar Zadeh first in 1965 in his article titled "Fuzzy Sets", and then concept has been widely used [4].

A fuzzy logic system is usually designed to be user-friendly by conforming with human linguistic thinking [5]. Fuzzy logic is a special many-valued logic

addressing the vagueness phenomenon and developing tools for its modeling via truth degrees taken from an ordered scale. It is expected to preserve as many properties of classical logic as possible [6].

Fuzzy logic, includes fuzzy sets and membership ranking. In traditional logic concept, each object can only be a member of a single group(or set). However, in the concept of fuzzy set approach, an object can be a part of different groups at a certain degree using the membership functions.

For example, consider the concept of air temperature. According to assessment of traditional logic available, the air temperature is said to be hot or cold. But this situation may vary depending on the person to whom the question was asked and the environment. Here we have the concept of fuzzy sets, which was defined as an aid in particular ranges with an assessment of the situation that produces the result by calculating how close it is. Figure 2 shows comparative representation of the traditional and fuzzy sets.

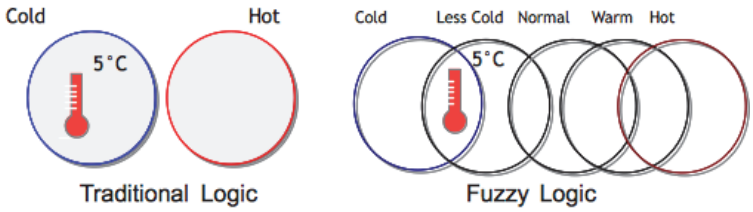
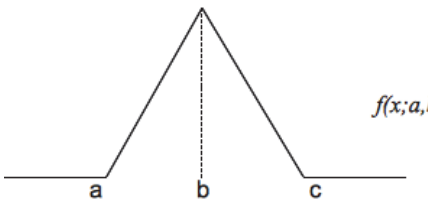


Figure 2. Traditional logic vs. fuzzy logic

Membership functions for fuzzy sets membership grading is done with mathematical transformations. Some common membership functions [7];

- Triangle,
- Trapezoid
- S-function,
- Pi-function,
- Exponential,
- Gaussian functions.



$$f(x;a,b,c) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a} & a \le x \le b \\ \frac{c-x}{c-b} & b \le x \le c \\ 0, & c \le x \end{cases} \quad (6)$$

Some fields that fuzzy logic applied:

- Automatic Control Systems: Robotics, automation, intelligent control, monitoring systems, commercial electronic products,
- Expert systems: Information storage and recall, expert systems, knowledge-based systems,
- Image Identification: Image processing, machinery imaging.
- Optimization: The function optimization, filtering, curve fitting.

4. EXPERT SYSTEMS

The expert system is a system approach aimed at achieving more efficient systems using mathematical (calculated) models together with the relevant experts in the field so that people's experiences are reflected. Expert systems are human-knowledge-intensive programs mainly at the level of a human expert in solving problems. Knowledge on the expert system is stored in the computer and users call upon the computer for specific advice as needed [8-10]. In other words expert systems require containing the knowledge from expert for a specific problem domain in order to make inference and decisions [11]. Expert is the person who has a particular level of knowledge in a certain field that can be found in very few people. So, the person who can solve a problem, not many people able to or can solve the problem much more efficiently and quickly than others, is called expert. If we redefine "Expert Systems" in the light of the expert concept,we can say ,these are computer systems that allows us to solve problems that complex only a professional humanbeing (as we call expert) can provide a solution. Well-designed systems to solve specific problems imitate human thinking. The term expert system is

used because the system having the knowledge one or more of experts try to replace them. The goal is to develop an Expert System such as or better than a human expert. Having such a system does not make people experts, but helps to complete a part of the job only an expert can do[12].

MAIN COMPONENTS OF AN EXPERT SYSTEM

Expert System has the following components [13];

KNOWLEDGE GAINING :

Some information transfer and conversion processes are performed from different sources on a computer program for problem-solving. Potential sources of information are experts, books, databases, private research reports and may be the user's own experiences.

KNOWLEDGE BASE:

Knowledge base contains all the information which necessary to understand, to formulate and to solve the problems. For example, it contains information (knowledge/data) about events and circumstances and the logical relationship between these structures (rules). Furthermore, it includes the standard solution and decision-making models.

INFERENCE MECHANISM:

Expert system is the brain. It is a computer program for working in the field of information contained in the knowledge base and providing a methodology and formatting the results. In other words, a mechanism for generating solutions to problems. the decision is made how to use the knowledge of the system.

WORKSPACE:

Workspace is a corner of the memory for definitions of the problem determined by the input data. This area used to save the results of intermediate levels of the processes.

USER INTERFACE:

Expert systems includes a handler for a language to facilitate communication between the user and the computer. This communication is done with the most healthy natural language. In short, the user interface between the user and the computer has assumed the role of a translator. As modern computer programs, expert systems have an interface in the user's comfortable use and easy to understand. The user interface is easy and straightforward, but this does not mean that the system structure is not complex. But the end-users using the system can easily define the problems and easily understand the solutions provided by the system.

DESCRIPTION UNIT:

Expert Systems has a module with explanation feature, which makes it different from the other systems. Description unit offers the user a variety of benefits and explanation of the questions, as well as how and why expert system issued the result. Expert system explains the behavior of the system in the form of mutual question and answer.

5. FUZZY EXPERT SYSTEM FOR MISSION ASSIGNMENT (FESMA)

A computer software was written to perform the task of mission assignment Within the context of this study. The software uses fuzzy expert system, one of artificial intelligence techniques which has widespread use in recent years. Fuzzy expert systems developed based on fuzzy logic, unlike traditional expert systems, utilize symbolic reasoning rather than numerical reasoning [14].

The operation of a fuzzy expert is composed of fuzzification, knowledge (rule) base,inference and defuzzification stages (Figure 3).

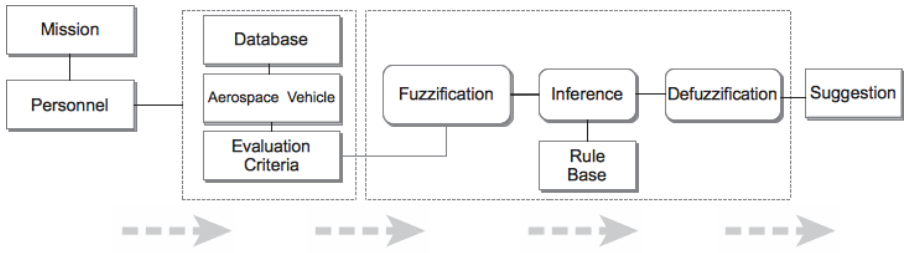


Figure 3. Operation of fuzzy expert system

FUZZIFICATION

Fuzzification is to calculate membership value by applying relevant membership function for entered value. Equation (6) defines triangle membership function. Three-set-function was designed and sets are negative, normal and positive.Based on a set for each given a, b, c according to the value used in the tables created.

Table 2. Example table for trıangle membershıp functıon applıcatıon to sortıe relıabılıty

Negative	Normal	Positive
0-40	35-65	60-100

The sample membership value calculation (7) and Figure 4 clearly express based on evaluation criteria included in the study of sortie reliability on definitions in Table 2.

$$f(x;a,b,c)=max\left(min\left(\frac{x-a}{b-a},\frac{c-x}{c-b}\right),0\right)$$

$$\mu\, Negative\,(39;0{,}20{,}40)=0{,}05$$
$$\mu\, Normal\,(39;35{,}50{,}65)=0{,}26$$
$$\mu\, Positive\,(39;60{,}80{,}100)=0$$

(7)

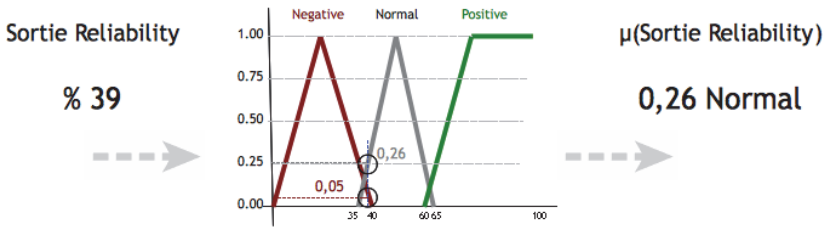


Figure 4. Example membership value for sortie reliability

RULE BASE

Rules are created with the support of experienced experts in the field of application. List of rules should be prepared according to the desired criteria. although all the rules in general have equal weight, a weight factor can be useful to determine the priority within the rule base.

The rules shall be prepared as follows;

- First, each rule begins with IF statement,
- Evaluation of the desired value is written to the desired item,
- All items are subject to AND,
- OR or other logical operators can be used with some special definitions. But instead of these procedures, A new rule implemented more quickly is thought to be more effective.

Example rule statements:

IF Mission is S010 AND Personnel Experience> = 100 AND Sortie Reliability is POSITIVE AND Maintenance is POSITIVE AND Abort is POSITIVE Proposal is POSITIVE.

IF Mission is A010 AND Personnel Experience> =500 is AND Fuel Y01 AND Status is FMC and Maj.On.Eq.Maint is NORMAL AND Abort is POSITIVE Proposal is HIGH.

The evaluation criteria are listed in Table 3 for FESMA in this study. Figure 5 shows how criteria defined in application.

Table 3. Criteria for Preparation of rules

Criteria
Mission
Personnel
Status
Fuel Configuration
System Configuration
Sortie Reliability
MTBF
Abort Rate
Repeat Rate
Major On-Eq. Maintenance
Last/Next Scheduled Maintenance
Last/Next DLM
Flight Hours per AAV
Sorties per AAV

Tablo 8: Kriterler

KRITERLER	OLUMSUZ			NORMAL			OLUMLU		
	(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)
Sorti Sonu Faaliyeti	0	20	40	35	50	65	60	80	100
MTBF	10	15	20	6	9	12	0	4	8
Abort	4	6	10	2	3.5	5	0	1.5	3
Mükerrer	4	6	10	2	3.5	5	0	1.5	3
Önemli Arıza	0	20	40	35	50	65	60	80	100
Bakım	0	4	8	7	15	30	25	75	100
FASBAT	0	25	60	50	75	100	80	250	1000
THB Saat	100	35	17	10	15	20	0	8	12
THB Sorti	100	35	17	10	15	20	0	8	12

Figure 5. Rule definition window screenshot from application.

INFERENCE

The available data are compared with rule base prepared with expert knowledge and experience, and an inference is made.

Inference results can be in 4 different ways. These are:

- "Negative"
- "Normal"

- "Positive"
- "High"

Here, "Normal", "Positive" and "High" results show the proposed results. Negative ignored. "Normal" conditions for the mission, the most basic needs are met, the "positive" among the other candidates suitability to work, "High" means that one of the most appropriate options.

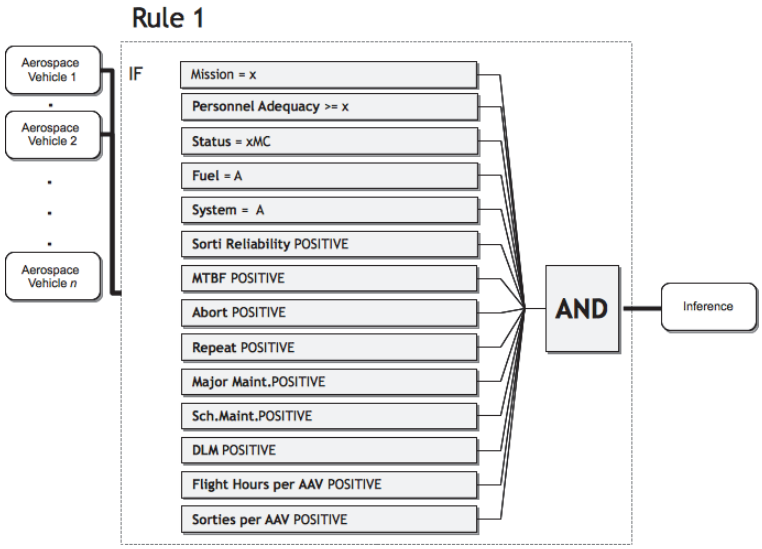


Figure 6. Inference example

Instead of known methods such as Mamdani max-min or max-product, A special inference method ,sort of weighted average, was used in FESMA due to application's special use in mission assignment and not all criteria are equal. In this method, the rule is evaluated in the expression of a weight factor that indicates the importance of criteria was added, and an inference score is calculated (8).

$$Inference\ Point = \sum(\mu(x) * Weight(x)) \quad (8)$$

Lets have a closer look to the inference mechanism with an example below.

Selected mission : S010 ,

Selected pilot : Volkan ,

Consider we have the following rule in our rule base;

IF Mission is S010 AND Personnel Experience>=100 AND Sortie Reliablity is POSITIVE and Abort is POSITIVE AND Maintenance is POSITIVE then Inference is POSITIVE.

In our available vehicle list, we have tail numbers as follows: A101, A102 and A103.

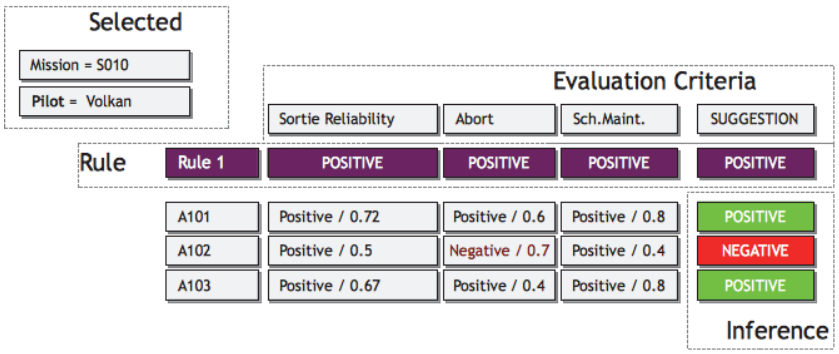


Figure 7. Inference example with sample data set

Figure 7 shows that according to the inference results, A101 and A103 are proper canditates , but A103 does not comply with all the conditions.

DEFUZZIFICATION

Fuzzy inference results obtained with the re-sharpening the values are converted to numeric expressions at defuzzification step. Higher numerical expression of inference points is used together with the proper expression ("High", "Positive" or "Normal").

Then we keep using the results from the inference example (see Fgure 7).

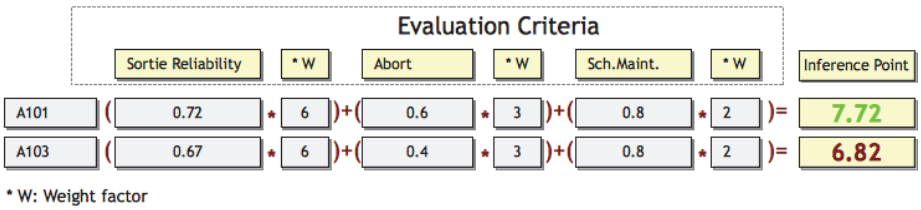


Figure 8. Defuzzification example with sample data set

With the help of Equation 8. and results from Figure 7, we have a more meaningful inference result after defuzzification.

According to the results A103 comes first in suggestion list. Next option could be A101.

When FESMA runs, it outputs a message like:

According to the input values [Selected Mission: S010 and Pilot:Volkan] Rule based Inference system evaluation results:

RESULTS

S010 A103 [Rule #1] rule applied [Positive] [7.72] [1.] suggestion

S010 A101 [Rule #1] rule applied [Positive] [6.82] [2.] suggestion

6. CONCLUSION AND SUGGESTIONS

In this study, using fuzzy logic and expert systems together in the field of aviation is being studied. For this purpose, FESMA software, which is a fuzzy expert system application for the purpose of attributing aviation vehicles for mission, was prepared. Instead of the using already existing software , the system uses Python which is an object oriented programming language and Google Application Engine infrastructure, together with a software written especially for this system .

As a result of the tests conducted with this application, it is assessed that the software will be especially useful in determining the correct aircraft because of the wide vision and quick foresight it provides. While the database is being prepared, because the descriptions and values being used directly

affect the results, the more realistic the values are the more effectively the system will operate and offer solutions.

Because the prepared application is completely web based, the necessary reports and forms can be quickly added and because of the modular structure it can be applied to different fuzzy set functions. It can work in different platforms without necessitating any alterations. If there are any databases that are currently in use, it is ready for adaptations.

For further study in this field, it can be said that it is possible to use it in different aviation fields, depending on the needs by means of resource code's being analyzed without the need to compile its modular structure.

Acknowledgment

To all known and unknown heroes of the aviation history.

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