

Implementation of fuzzy logic method for automation of decision making of Boeing aircraft landing

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Submission date: 23-Aug-2021 10:19AM (UTC+0700)

Submission ID: 1634589512

File name: 20873-39443-1-PB.pdf (419.62K)

Word count: 3981

Character count: 20955

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Article Info

Article history:

Received Mar 6, 2020
Revised May 22, 2021
Accepted Jun 3, 2021

Keywords:

Aircraft
Fuzzy logic Mamdani
Landing
Pilot experience
Weather

ABSTRACT

In the landing process, airplanes have many safety factors that must be protected. Weather advice and information is very important as a consideration in determining the feasibility of landing an aircraft. The main objective of this research is the implementation of Mamdani fuzzy simulation in determining the feasibility of landing aircraft at Ahmad Yani Airport in Semarang using ATC police and pilot coordination on runway number 31. Wind direction, wind velocity, visibility, and pilot experience are used to determine eligibility aircraft landing. An intelligent system based on fuzzy logic produces three decisions that are feasible, careful, and not feasible in landing an aircraft on a runway. The results of the study concluded from an intelligent system based on fuzzy logic can be used to determine aircraft landing decisions on the runway of Ahmad Yani Airport Semarang on runway number 31.

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1. INTRODUCTION

In modern times airplanes are both a means of transporting goods and humans that can shorten travel times, so they are often used to travel from one place to another in a much shorter time compared to using land or sea travel. The aircraft requires a high safety factor including the process when landing [1]–[7]. In the landing process of an aircraft, many factors must be considered such as the weather and pilot experience in controlling an aircraft [1], [3], [8]–[14]. In the landing process, an aircraft is assisted by an officer from the air traffic controller (ATC) whose duty is to guide the landing such as providing advice and information. This is useful for the safety and efficiency of air traffic control. ATC officers will provide information in the form of weather conditions on the runway such as wind velocity, wind direction, and visibility [8], [12], [14]–[17] to a pilot who will make an aircraft landing. A pilot can make a decision from this information whether a runway is appropriate to land an aircraft under certain weather conditions. Pilot experience in operating the aircraft is also an important factor in landing decision making [18], [19]. During the aircraft landing process, a pilot and ATC officer require data information related to the latest weather conditions on the runway quickly and accurately to determine flight decisions. The information comes from BMKG (Meteorology, Climatology and Geophysics Agency). The information is processed by the ATC officer so that it can be informed to the pilot [1], [3], [14], [19]–[21]. The information is analyzed by the pilot so that it can be decision support in predicting the safety factor of landing an aircraft on a runway.

At present, there is a lot of research on aircraft landing decision making with several parameters used. One of them is titled “Take Off and Landing Prediction Using Fuzzy Logic” [15], in this study discussing decision making that helps ATC officers and pilots in making decisions whether a runway is

appropriate to land or fly an aircraft with certain weather conditions. Some parameters used are visibility, wind direction, and wind speed. This research uses Mamdani fuzzy logic. The results of the decision are divided into feasible, careful, and not feasible for landing and take-off aircraft. The results of this research, show that this system can help ATC officers and pilots to make landing and flight decisions more quickly.

By referring to some journal results, using the concept of fuzzy logic is easier and the results are quite accurate. This study aims to produce a simulation of landing decision making systems based on the expertise of the ATC officer and a pilot. This research was carried out on runway number 31 an aircraft at Ahmad Yani Airport in Semarang [22]. In this study, Mamdani's fuzzy logic intelligent system is used to describe problems regarding weather and pilot experience in landing aircraft that contain uncertainties that can be applied in the decision making process [23]–[25]. In this research, the weather parameters used are wind velocity, wind direction, visibility, and pilot experience. Fuzzy intelligent systems can describe, know, and model human thought processes and design a system so that it can mimic human behavior. With the fuzzy process which consists of fuzzification, inference, and defuzzification [25]–[28], it is expected that the level of truth in the decision of landing aircraft becomes more accurate.

At present, there is a lot of research on aircraft landing decision making with several parameters used. One of them is titled "A Practical Weather Forecasting for the Air Traffic Control System using Fuzzy Hierarchical Technique" [27]. This study discusses the weather prediction and decision making of an appropriate or unfit airport for landing or take-off of an aircraft with certain changing weather conditions. In this reference using the fuzzy logic Mamdani hierarchical technique. Each parameter that is owned is combined in a group to produce an intermediate output. Environmental parameters consist of wind velocity, visibility, and wind pressure. Turbulence parameters are sky conditions, thunderstorms, and precipitation. Finally, the fog parameters include air temperature, dew point, and humidity. The results of this study indicate that the output is very accurate in decisions about weather forecasts.

In the study "Prediction of Landing and Take-off of Aircraft based on the Weather Using Fuzzy Logic" [29] which discusses the decision making of an appropriate or unfit airport for landing or take-off an aircraft with changing weather conditions. In this research Mamdani fuzzy logic method with three parameters of wind speed, wind direction, and visibility. Wind velocity has a low membership function (0-5 knots), medium (3-13 knots), and high (10-30 knots). Wind direction has membership functions safe_1 (0°-120°), danger_1 (100°-180°), safe_2 (160°-300°), danger_2 (280°-360°), and safe_3 (340°-360°). Visibility has close membership functions (100-1100 m), medium (1000 - 7000 m), and far (6000-10000 m). The decision of airport conditions with certain weather is suitable, careful, and not suitable in percentage level. The results of this study the system can provide appropriate landing and flight decisions.

In the study "Fuzzy Logic Approach To Airplane Precision Instrument Approach And Landing" [19] which discusses the simulation using Microsoft flight simulator to estimate the success rate of landing or take-off an aircraft with certain weather conditions and pilot experience. In this study using the ANFIS method, using the backpropagation method to train FIS, in this study there were three parameters used, namely wind speed, visibility, and pilot experience. Wind speed has a membership function of low (20-60 knots), average (40-80 knots), high (60-100 knots), and very high (80-120 knots). Visibility has very low membership functions (0-5 km), low (0-10 km), medium (5-15 km), and high (10-20 km). Pilot experience has a membership function of low (0-2000 hours) and high (500-2000 hours). The results of this study the system can estimate the success rate of a landing and take-off accordingly.

Fuzzy logic is an enhancement of Boolean logic that deals with the concept of partial truth. Boolean logic states that everything can be expressed in binary terms (0 or 1, yes or no), fuzzy logic is used to replace Boolean logic. Fuzzy logic allows membership values between 0 and 1 to be depicted in the form of uncertainty concepts such as uncertainty such as "little", "not bad", and "very". Some aspects of the real world always or usually are outside the mathematical model and are inexact. The concept of uncertainty is the beginning of the basic concept of the emergence of the concept of fuzzy logic. The originator of the idea of fuzzy logic is Prof. Dr. Lotfi Zadeh from the University of California, Berkeley in 1965. In principle, the fuzzy set is the expansion of the crisp set, which is a set that divides a group of individuals into two categories, namely members and non-members [4], [8], [23], [26], [28].

2. RESEARCH METHOD

To identify like a plane landing on a runway with certain weather conditions and pilot experience, a fuzzy logic method that has 4 parameters is used, consisting of wind velocity, wind direction, visibility, and pilot experience. This parameter has a relationship between data variables and aircraft landing decisions based on previous research on landing aircraft. All variables in each criterion will be processed using fuzzy logic. Fuzzy logic has three stages, namely fuzzification, system inference, and defuzzification. Fuzzification is the process of mapping crisp input values derived from a controlled system by the fuzzy set membership

function. Furthermore, the system inference process will process the fuzzification output determined by fact data from experts or institutions and presented in logical sentences in the form of rules. After calculating each variable, the final process is defuzzification. All combinations of variables or parameters will be compared by evaluating existing rules that result in decisions on landing aircraft.

Figure 1 is a system diagram and a detailed description of it is that the data used for fuzzy logic is data from AIRNAV Ahmad Yani Airport in Semarang. The crisp value of each input variable is then processed using fuzzy logic (fuzzification). Furthermore, from the results of the fuzzification, the process of reading or executing the existing rules is carried out. The input of the defuzzification process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a number in the fuzzy set domain. If a fuzzy set is given in a certain range, it must be able to take a certain crisp value as output.

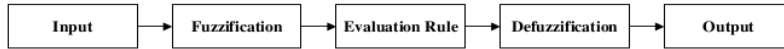


Figure 1. System design decision aircraft landing

2.1. Fuzzification

The linguistic values of each variable can be categorized from classification data based on the value of each variable. Table 1 shows the variables used in this study. Each variable value has been determined based on previous research [19], [27], [29] and a book titled Airplane Flying Handbook Issued by the Federal Aviation Administration [11]. The linguistic values represented in graphic form are shown in Figures 2 to 5.

Table 1. Value of linguistic variables

No	Variable	Criteria
1	Wind Velocity (Knots)	0-5 Low
		3 - 13 Average
		10 - 30 High
2	Wind Direction (Degree)	0-70 Danger 1
		60 - 90 Relatively Safe 1
		80 - 180 Safe
		170 -200 Relatively Safe 2
3	Visibility (Meters)	190-360 Danger 2
		7500 - 10000 Far
		4500 - 8000 Medium
4	Pilot Experience (Hours)	0 - 5000 Near
		500 - 2000 High
		0 - 2000 Low

2.1.1. Wind velocity

In the variable wind velocity, three fuzzy sets are defined, namely low, average, and high. To represent the wind speed variable, a trapezoid curve is used for the fuzzy low set and high, a triangle curve shape for the fuzzy average set. Figure 2 is a fuzzy set for the wind velocity variable.

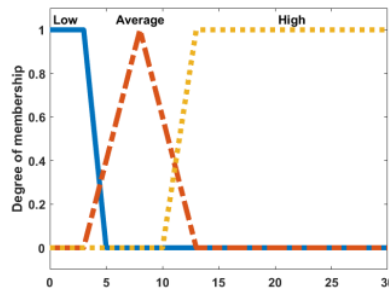


Figure 2. Wind velocity graph

2.1.2. Wind direction

In the wind direction variable, five fuzzy sets are defined, namely danger 1, relatively safe 1, safe, relatively safe 2, and danger 2. To represent the wind direction variable a trapezoid curve is used for all fuzzy sets. Figure 3 is the fuzzy set for the wind direction variable. Wind direction and win velocity are closely related and will affect the landing of the aircraft because it will produce a crosswind [11], [17].

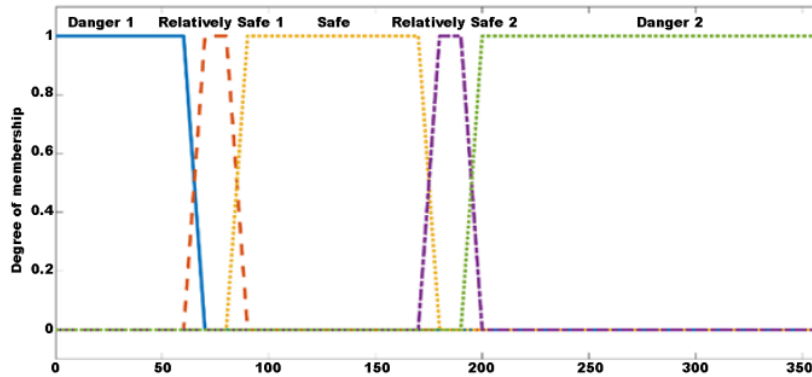


Figure 3. Wind direction graph

2.1.3. Visibility

In the visibility variable three fuzzy sets are defined, namely near, medium, and far. To represent the visibility variable the trapezoid curve is used for the fuzzy near set, and far, the triangle curve shape for the fuzzy set is rather clear. Figure 4 is a fuzzy set for the visibility variable.

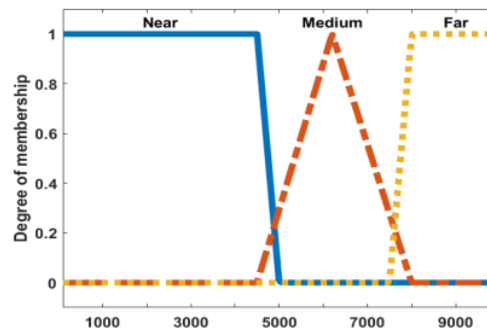


Figure 4. Visibility graph

2.1.4. Pilot experience

In the pilot experience variable, two fuzzy sets are defined, namely low, and high. To represent the pilot hour flight variable the triangular curve is used for both fuzzy sets. Figure 5 is a fuzzy set for the pilot experience variable.

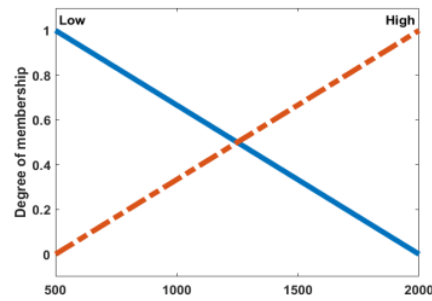


Figure 5. Pilot experience graph

2.2. Evaluation rules

References and guidelines for determining evaluation rules are shown in Table 2. These evaluation rules were developed based on the rule approach and correlation calculation to find the priority of variables. Thus, after the process, evaluation rules are developed into 25 evaluation rules.

Table 2. Evaluation rule

No	Wind velocity	Wind direction	Visibility	Pilot experience	Aircraft landing
1	Low	Safe	Medium	Low	Feasible
2	Low	Danger 2	Medium	Low	Careful
3	Low	Danger 2	Medium	High	Feasible
4	Low	Danger 2	Medium	High	Feasible
5	Low	Danger 2	Medium	High	Feasible
6	Low	Danger 2	Medium	High	Feasible
7	Low	Danger 2	Medium	High	Feasible
8	Low	Safe	Medium	Low	Feasible
9	Low	Danger 2	Medium	High	Feasible
10	Low	Safe	Medium	High	Feasible
11	Low	Danger 2	Medium	High	Feasible
12	Low	Safe	Medium	High	Feasible
13	Average	Relatively Safe 2	Medium	High	Feasible
14	Low	Danger 2	Medium	High	Feasible
15	Average	Danger 2	Medium	Low	Not Feasible
16	Average	Danger 2	Medium	Low	Not Feasible
17	Average	Danger 2	Medium	High	Careful
18	High	Danger 2	Medium	High	Not Feasible
19	Average	Danger 2	Medium	High	Careful
20	Average	Danger 2	Far	High	Careful
21	High	Danger 2	Far	Low	Not Feasible
22	High	Danger 2	Far	High	Careful
23	High	Danger 2	Far	High	Careful
24	High	Danger 2	Far	High	Careful
25	High	Danger 2	Far	High	Careful

2.3. Defuzzification

In this defuzzification process, it is used to find fuzzy membership. From each variable such as wind velocity, wind direction, visibility, and pilot experience. The five variables will be obtained as the output level from a combination of variables that have been calculated using fuzzy logic. There are 3 classifications of output levels: feasible, careful, and not feasible.

3. RESULTS AND ANALYSIS

In this section, we provide measurable results for fuzzy logic calculations. Calculations have been made on 25 data from AIRNAV Ahmad Yani Airport Semarang to represent some of the rules that have been made. Table 3 is the data used in this study and the results of real probabilities and system probabilities.

Table 3. Data measurement and comparison of data results

No	Wind Velocity	Wind Direction	Visibility	Pilot Experience	Real Probability	System Probability
1	2	100	6000	450	Feasible	Feasible
2	2	210	6000	450	Careful	Careful
3	2	200	6000	1000	Feasible	Careful
4	0.8	220	6000	1000	Feasible	Careful
5	2	230	6000	1500	Feasible	Careful
6	2	260	6000	2000	Feasible	Feasible
7	3	260	6000	2000	Feasible	Feasible
8	2	130	6000	450	Feasible	Feasible
9	0.8	210	6000	1000	Feasible	Careful
10	2	160	6000	1000	Feasible	Feasible
11	2	210	5000	1500	Feasible	Careful
12	2	160	5000	1500	Feasible	Feasible
13	3	170	5000	2000	Feasible	Feasible
14	2	260	6000	2000	Feasible	Feasible
15	4	300	6000	450	Not Feasible	Careful
16	6	300	7000	450	Not Feasible	Not Feasible
17	9	310	7000	1000	Careful	Not Feasible
18	10	310	7000	1000	Not Feasible	Not Feasible
19	9	330	7000	2000	Careful	Careful
20	8	300	8000	2000	Careful	Careful
21	13	310	8000	450	Not Feasible	Not Feasible
22	12	310	8000	1000	Careful	Not Feasible
23	14	310	8000	1000	Careful	Not Feasible
24	10	300	8000	2000	Careful	Careful
25	12	310	8000	2000	Careful	Careful

Graphic user interface (GUI) is a graphical display medium as a substitute for text commands for user interaction. Figure 6 is a GUI for the implementation of fuzzy logic method for automation of decision making of Boeing aircraft landing.

The screenshot shows a software window titled "keputusan" with standard window controls. Below the title bar, there are two blue banners: the first contains the text "IMPLEMENTATION OF FUZZY LOGIC METHOD FOR AUTOMATION OF DECISION MAKING OF BOEING AIRCRAFT LANDING" and the second contains the author's name "WINDA PRATIWI (21060116410009)". In the center is the logo of Universitas Semarang. The main interface is divided into three sections: "Input" on the left, "Out" on the right, and "Button" at the bottom. The "Input" section has four rows of input fields, each with two adjacent boxes: "Wind Velocity", "Wind Direction", "Visibility", and "Pilot Experience". The "Out" section has a label "Decision" above two stacked output boxes. The "Button" section contains three blue buttons labeled "Running", "Close", and "Reset".

Figure 6. Graphical user interface of aircraft landing decision using Mamdani fuzzy logic

4. CONCLUSION

This paper presents the proposed fuzzy logic for intelligent aircraft landing decision systems. Several factors that can affect aircraft landing decisions required in this method include wind velocity, wind

direction, visibility, and pilot experience. The landing decision is divided into three classifications, which are feasible, careful, and not feasible. The results of aircraft landing decisions use fuzzy logic compared to real results. There are 25 data collected from AIRNAV Ahmad Yani Airport in Semarang, there are 9 different data results. This difference is not very far because of the difference between the real probability and system probability. So, it can be said that the fuzzy logic system works quite well. In the future, it is expected that research related to the parameters added air density, humidity, and precipitation. Pilots and ATC officers are greatly helped by the existence of an airplane landing system.

ACKNOWLEDGEMENTS

The author would like to thank AIRNAV Ahmad Yani Airport Semarang for the support by providing data sources.

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