

# Designing Fuzzy Logic Controller for Auto Landing of Flight

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Abstract- Landing an aircraft is not an easy task for the pilot, so some assistant from computer or auto pilot with reliable and efficient auto landing controller is needed. This task is not an easy even for the controller as there are many variables considering winds, flare, altitude, approach velocity, heading, vertical velocity and the alignment of the aircraft with runway etc., which result in high cost for conventional controllers to be used in this situation. Therefore fuzzy logic can be used to design a system which has the reasoning ability to act as controller for the landing assistant this result in cost savings, efficient material uses and better time management. Model aircraft is used in this project which is given in Aerosim adds in MATLAB. So the goal of controller assistant for auto landing is achieved, using this simulation, stabilization of aircraft is done with Aerosim add model in MATLAB using classical techniques. Here the fuzzy logics which are used in the controller rectify the errors and the landing is made smooth and easy task.

Index Terms – Air craft , Fuzzy logic, Automatic landing

## I. INTRODUCTION

The paper is to design a fuzzy logic controller which is for landing an aircraft that is used with various rule for programming and designed for simulation test that is done using MATLAB. Here the simulation result is displayed using Rule viewer and surface viewer which are graphical user interface (GUI) in fuzzy logic toolbox in MATLAB program.

The fuzzy logic toolbox is used here for its advantages and the SIMULINK which is a MATLAB programmed in which the functions like graphical editing, customizing block libraries, and solving for modeling and simulating dynamic systems enabling us to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis. The controller is based on the trajectory tracking of the predetermined path for safe landing using fuzzy logic for an aircraft. The integration of SIMULINK and the fuzzy logic tool box allows us to directly test and make calculation in a simulated environment. Landing but also for personal launching system also.

A PLS or personal Launching system is way to transport people and small amounts of cargo to and from low-Earth orbit, i.e., a small space taxi system. As the PLS being not fully stable air vehicles with no flight hardware built in it is vulnerable to various variables during its approach for landing. These types of variable can be counter by using Fuzzy logic controller and using MATLAB such variable can be simulated and the result can be obtained.

Although the PLS program is not active currently, NASA projects used the aerodynamic data from PLS testing which we can used to design our flight landing system using fuzzy logic system. The main objective in this process is to get the best the result as close as the requirement for stability and safe level of control for the landing system with controller making adaptive adjustments.

## I. FUZZY LOGIC

Fuzzy logic is like a combination of human reasoning without certainty and computer precise valuations for manipulating data. Fuzzy logic can handle numerical data as well as linguistic knowledge which can have controlling logic of complicated system without is mathematical description better than the traditional logic.

Fuzzy systems are used in two general contexts:

- Situations involving complicated systems whose variables are not well specified.
- Where there is need of an approximate but fast solution.

A. Fuzzy set theory

A classical set is a set with a crisp boundary and a fuzzy set is a set without a crisp boundary. Let P be "person" and h be "height", now it is an inadequate representation of "not belong to a set" and fuzzy sets are given by the smooth transition by membership function with flexibility modeling. The uncertain and imprecise nature of abstract concepts brings the fuzziness but from the randomness of the members of the sets.

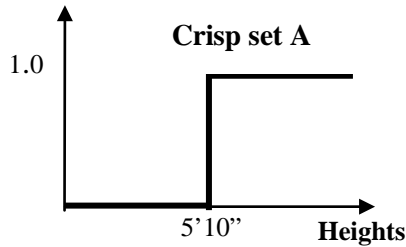


Fig 2.1 Membership functions of crisp set A

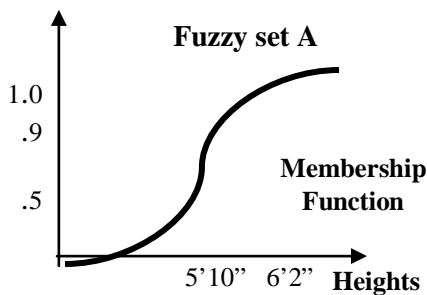


Fig. 2.2 Membership functions of fuzzy set A.

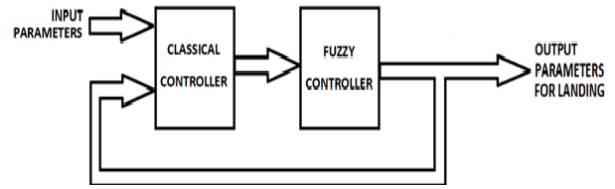


Fig. 2.3 Integrating Fuzzy Controller

B. MF formulations and parameterization

There are several classes of parameterized namely one dimension which is a single input and their expression are given below-

- Triangular MF:  

$$\text{trmf} ( x; a, b, c ) = \max \{ \min ( \frac{x-a}{b-a}, \frac{c-x}{c-x} ), 0 \}$$
- Trapezoidal MF:  

$$\text{trapmf} ( x; a, b, c, d ) = \max \{ \min ( \frac{x-a}{b-a}, \frac{d-x}{d-c} ), 0 \}$$
- Gaussian MF:  

$$\text{gaussmf} ( x; c, \sigma ) = e^{-\frac{1}{2}(\frac{x-c}{\sigma})^2}$$
- Generlized MF:

$$\text{gbellmf} ( x; a, b, c ) = \frac{1}{1 + \frac{x-c}{b}}$$

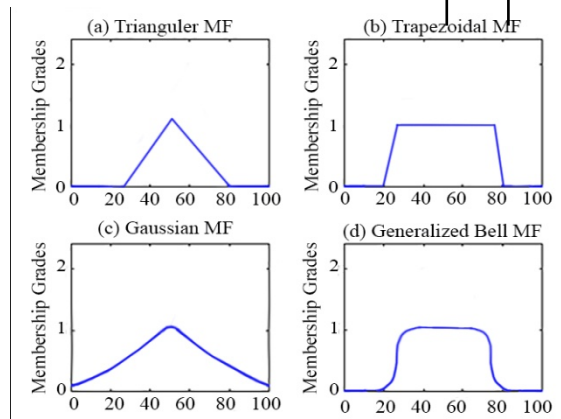


Fig. 2.4 Examples of membership function

### C. Basic Idea

The imitation of the control action of human operator forms the basic idea of fuzzy logic controller (FLC). It is a collection of if-then rules. In this rule if part is called antecedent and then part is called consequent. These parts have vague, linguistic terms for the reflection of the operators' knowledge for the process. Fuzzy sets are represented by linguistic terms where AND OR operations represents combination of the linguistics terms.

## II. FUZZY LOGIC CONTROL USING SUGENO TYPE

Michio Sugeno suggested a membership function of the rule consequent to use single spike and a singleton which is a fuzzy set with a membership function where single particular point on the universe of discourse as a unity and everywhere else is zero.

The Mamdani method is similar to Sugeno-style fuzzy inference just only a change in rule consequent he used a mathematical function of the input variable instead a fuzzy set.

The Sugeno-style fuzzy rule is

IF  $x$  is A  
 AND  $y$  is B  
 THEN  $z$  is  $f(x,y)$

where  $x$ ,  $y$  and  $z$  are linguistic variables; A and B are fuzzy sets on universe of discourses X and Y, respectively; and  $f(x,y)$  is a mathematical function.

The zero-order Sugeno fuzzy model is applied in the following form:

IF  $x$  is A  
 AND  $y$  is B  
 THEN  $z$  is k

where k is a constant.

In this case, the output of each fuzzy rule is constant. All consequent membership functions are represented by singleton spikes.

Since each rule has a crisp output, the overall output is obtained via weighted average.

$$\text{Weighted average, } z = \frac{a_1 z_1 + a_2 z_2}{a_1 + a_2}$$

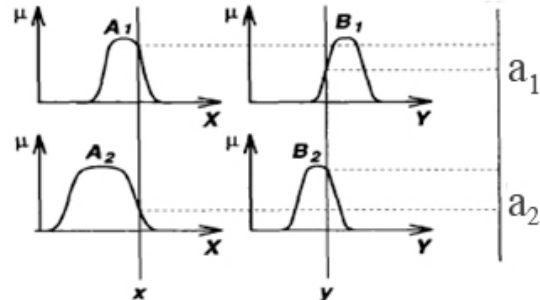


Fig. 3.1 Sugeno fuzzy model

## III. AIRCRAFT MODEL AND LANDING TASK

Landing an aircraft involves 6 phases as nominal case as follows:

- Level flight at 600m at a velocity of 83m/s with a heading  $-90^\circ$  from west to east.
- Then a left turn with a bank angle of  $40^\circ$  aligning with the runway  $0^\circ$  heading north at 600m with velocity still 83m/s.
- Then a level flight at 600m with velocity 83m/s toward north at  $0^\circ$ .
- Decent on glide slope of  $-6^\circ$  to altitude of 300m.
- Decent on glide slope of  $-3^\circ$  to 12m.
- Flare with velocity decrease from 83m/s to 79m/s and touchdown with sing rate from about 4m/s to 0m/s.

During this landing trajectory a cross wind incorporating turbulence may happen which result in non linear interference to the aircraft. Here the FLC adapts and adjust the interference in aircraft nominal functions such as altitude, airspeed, sideslip and trajectory errors.

These adjustments and rectifications are achieved by the FLC using TSK algorithm to adapt and rectify the errors as follows:

- Altitude control is done with the correction of elevators to increase or decrease the lift generated at wings.
- Airspeed control is done by adjusting the throttle of the aircraft engine.
- Sideslip is adjusted by using the rudder control command to estimate the sideslip rate and lateral acceleration as feedback.
- Trajectory is corrected by tracking the X-Y plane using heading angle and bank angle as loop for the system.

As a result FLC can adapt and adjust the non linear interference of aircraft landing using TSK algorithm.

Construction and simulation of final decent of an aircraft is shown below.

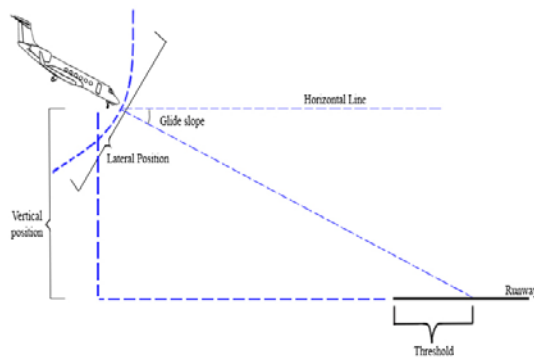


Fig. 4.1. Desired final approach path

The velocity which is desired is proportional to the square of the aircraft's altitude. A larger downward velocity is desired at higher altitudes. With the decrease in aircraft's altitude the requirement of the downward velocity becomes smaller and smaller. The downward velocity becomes zero when the altitude is vanishingly small as it is to prevent aircraft decent promptly and the touchdown will be as gentle as possible to avoid damage to aircraft.

There will be two stated variable which are height or altitude "h" and vertical velocity 'v". out is the force when applied to the aircraft alters its altitude (h) and velocity (v). the equation is

derived as Mass (m) moving velocity (v) has momentum (p) which is given by  $p=mv$ . The mass will continue in the same direction with same velocity as long as there is no external force acting on it. During a small time interval  $\Delta t$  a force (f) is applied then the velocity will change as

$$\Delta v=f\Delta t/m.$$

Let  $\Delta t=1$  sec and mass (m) =1 (lb-sec<sup>2</sup>/ft), we can get  $\Delta v = f$  (lb) i.e. the change in velocity is proportional to the applied force.

We can show it as

$$v_{i+1} = v_i+f_i$$

$$h_{i+1} = h_i+v_i(1)$$

where  $v_{i+1}$  is the new change in velocity,  $v_i$  is the old velocity,  $h_{i+1}$  is the new altitude and  $h_i$  is the old altitude.

## V. FUZZY CONTROLLER DESIGN PROCEDURE

Step 1: All the membership functions are defined for state variables.

Step 2: Membership function is defined for the control output.

Step 3: The rules are defined and summarized in FAM table. The FAM table value shows control output.

Step 4: The landing of aircraft starts at 600 m with a constant velocity of 83 m/sec up to 300 m. After 300m the velocity decrease to 79m/sec and gradually becomes zero when the aircraft stops.

TABLES AND FUNCTION OUTPUT

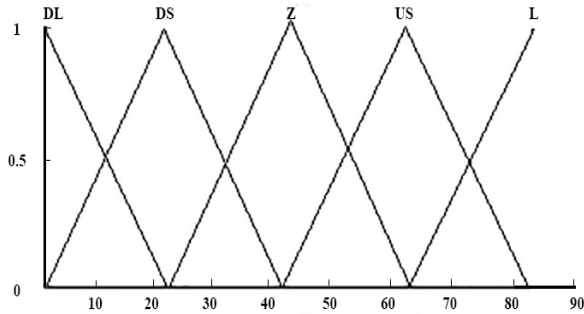


Fig. 5.1. Membership function for control Force

Height	Velocity				
	DL	DS	Z	US	UL
L	Z	DS	DL	DL	DL
M	US	Z	DS	DL	DL
S	UL	US	Z	DS	DS
NZ	UL	UL	Z	DS	DS

Table 5.1 FAM Table

SUMMARY AND SIMULATION RESULT

	Height (m)	Velocity (m/sec)	Control force
Cycle 1	600	83	0.48
Cycle 2	450	83	0.37
Cycle 3	400	83	0.35
Cycle 4	300	83	0.32
Cycle 5	12	83	0.23
Cycle 6	1	79	0.225

Table 5.2. Summary of simulation result

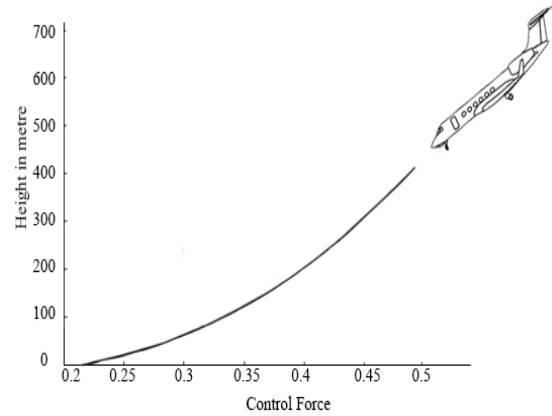


Fig. 5.2. The profile of height and control force using fuzzy logic control

VI. FUZZY LOGIC DESIGN USING MATLAB

Fuzzy Logic Toolbox software can create Fuzzy inference systems with graphical tools or command-line functions which can generate this system with either clustering or adaptive neuro-fuzzy technique. The FIS Editor is a high-level display for any fuzzy logic inference system which can edit the fuzzy inference system at highest level features.

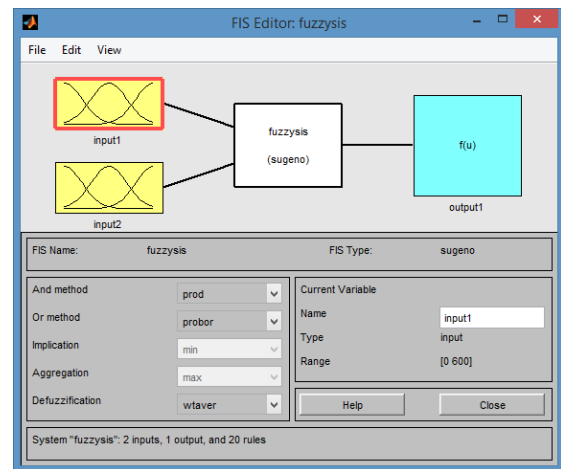


Fig. 6.1. FIS Editor

A. Membership functions editor

The given figure below is the Membership functions editor with 2 inputs and 1 output.

From the four membership functions we are using triangular membership function. Membership functions represent the degree of truth. Membership functions cover a range from 0 to 1.

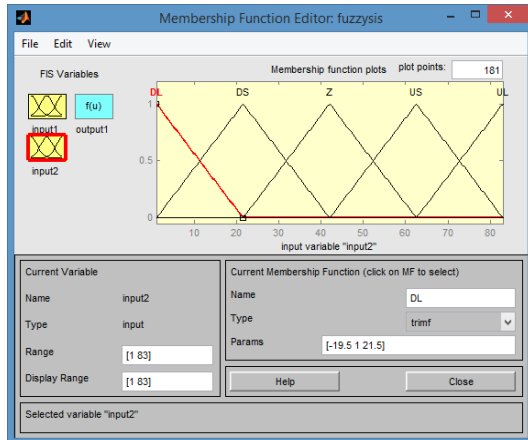


Fig. 6.2 MF Editor for input

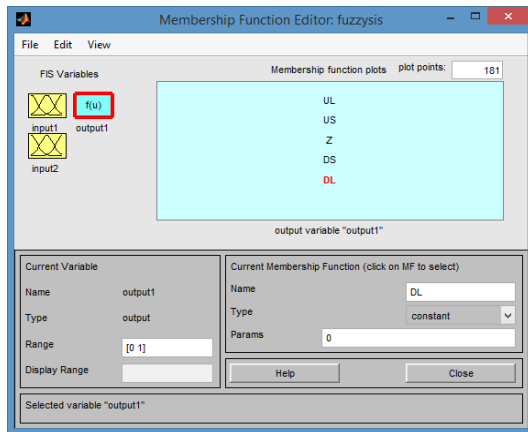


Fig. 6.3 Membership functions for output

The above figure is the membership function output diagram. The output's membership functions plots are Upper Large (UL), Upper Small (US), Zero (Z), Down Small (DS) and Down Large (DL). The range is from 0 to 1.

#### B. Rule editor

Rule editor is used to define the membership functions level. The "if" option and "then" option is selected by clicking "add rule" at bottom to enter the rule. The following diagram

shows the end of entering if option and then option.

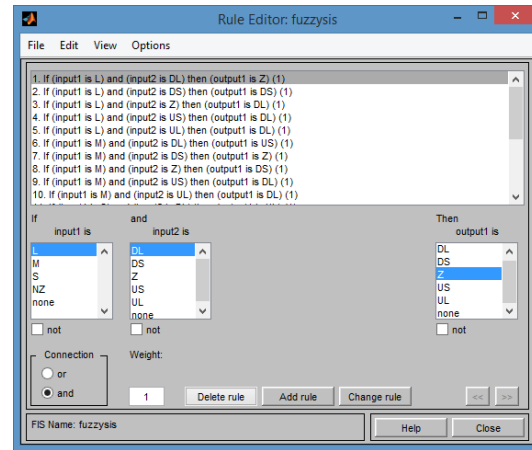


Fig. 6.4. Rule editor

## VII. CO ORDINATE SYSTEM FOR MODELLING

Using co ordinate system fixed on aircraft body allows us to model in simplest way. the presence of wind modify the forward direction of the aircraft and the motion through the aircraft differs from the motion relative to ground.

The different orientation of the wind coordinate axes is fixed by the velocity  $V$ . X-axis points in the direction of  $V$ . Y-axis is points to the right of the x-axis (facing in the direction of  $V$ ), perpendicular to the x-axis. Z-axis is point's perpendicular to the xy plane in whatever way.

#### A. Body co-ordinates

The body co ordinate is based on the aircraft body as follows. The x-axis points the aircraft through the nose. The y-axis points the right of the x-axis (facing in the pilot's direction of view), perpendicular to the x-axis. The z-axis points down through the bottom the aircraft, perpendicular to the xy plane.

#### B. ECEF co-ordinate

The Earth-center, Earth-fixed (ECEF) system is a non inertial system that rotates with the Earth. The origin is fixed at the center of the Earth. It is the navigational co ordinate of the aircraft. And it is describes as the  $z'$ -axis points to northward along the Earth's rotation axis. The  $x'$ -axis points to outward along the intersection of the Earth's equatorial plane and prime meridian. The  $y'$ -axis points into the eastward quadrant that is perpendicular to the  $x$ - $z$  plane .

## VIII. RESULT

From the simulation we found out that the fuzzy logic controller performs better than conventional controllers. The results for the roll, angle of attack, angle of sight, guidance performance are achieved and altitude accelerations and Mach number are obtained with smooth values. With the computer modeling of aircraft control test starting from an altitude of 600 m, the simulation can obtain realistic view of safe landing approach to the runway.

## IX. CONCLUSION

The landing phase of aircraft has been designed and tested on PLS using Fuzzy logic based controller in the simulation using Matlab aerospace Block Set. The outcome of the simulation is satisfactory and adequate and quite accurate. Evaluation of the simulation has been noted and evaluation of other similar or different aircraft model with PLS can be done in future.

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