Control of Aircraft Landing Using Fuzzy Logic

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Abstract: Simulation of the final descent and landing approach of an aircraft has been carried out. Two state variables for this simulation are considered as height above ground and vertical velocity of the aircraft. The control output has been taken as force which alter its height and velocity. The descent profile of aircraft has been plotted and analysed.

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I. INTRODUCTION

Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth-truth values between “completely true” and “completely false”. It was introduced by Dr. Lotfi Zadeh of UC/Berkeley in the 1960’s as a mean to model the uncertainty of natural language [1].With fuzzy logic, the first step is to understand and characterize the system behaviour by using our knowledge and experience. The second step is to directly design the control algorithm using fuzzy rules, which describes the principles of the controller’s regulation in terms of the relationship between its inputs and outputs The last step is to simulate and debug the design.

The fuzzy control is a model free approach. It does not require a mathematical model of the system under control. Fuzzy controllers are supposed to work in situations where there is a large uncertainty or unknown variation in system parameters. Fuzzy control is a potentially powerful approach that can capture human experience and expertise in ntrolling complex processes here by circumventing many of the shortcomings of hard-algorithmic control [2,3,4]. Thus, the fuzzy logic has emerged as one of the active area of research activity, particularly in control applications , where the mathematical model is not available and data available are imprecise.Today’s aircraft designs rely heavily on automatic control system to monitor and control many of aircraft’s subsystems. The development of automatic control system has played an important role in the growth of civil and military aviation. The architecture of the flight control system, essential for all flight operations, has significantly changed throughout the years[9].

This paper presents the automation in control of aircraft landing with fuzzy logic. Simulation of the final descent and landing approach of an aircraft has been carried out. Two state variables [5] for this simulation are considered as height above ground and vertical velocity of the aircraft. The control ouput has been taken as force here that when applied to the aircraft, will alter its height and velocity. Control equations are derived, then the membership functions for the height, velocity and control force have been constructed. Finally IF-THEN rules have been simulated. Complete software is developed to control descent and landing of aircraft [10].

II. AIRCRAFT LANDING MECHANISM

The desired descent profile of aircraft is shown in Fig.1. The downward velocity is proportional to the square of height. Thus, at higher altitudes, a large downward velocity is desired. As the height (altitude), diminishes the downward velocity get smaller and smaller. In the limit, as the height becomes vanishingly small, downward velocity also goes to zero. In this way, the aircraft will descend from altitude promptly but will touch down very gently to avoid damage.

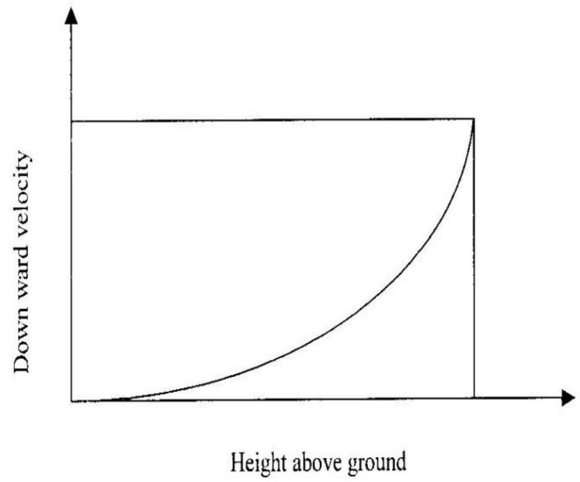

Fig 1 The desired profile of down ward velocity vs. Altitutde

III. PROBLEM FORMULATION

Two state variables [5] for this simulation are considered as height above ground and vertical velocity of the aircraft. The control ouput has been taken as force here that when applied to the aircraft, will alter its height and velocity. Two control equations indicating new downward velocity and new height are derived, then the membership functions for the height, velocity and control force have been constructed.

IV. CONTROL EQUATIONS DEVELOPMENT

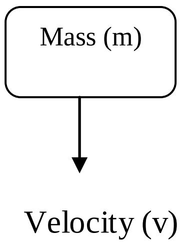

Fig. 2 Aircraft Landing Control Problem

The controlling differential equations are derived as follows:
If, mass= m,
Velocity= v
Then, momentum P = mv
If no external forces are applied, the mass will continue to travel in the same direction at the same velocity v. If a force is applied over a time Δt, a change n velocity of

$\Delta v = \frac{f \Delta t}{m}$

Will result,

Now, if $\Delta t = 1$ sec.

And $m = 1$ kg

We obtain $\Delta v = f$

Or a change in velocity is proportional to the applied force,

Let, v_i = old velocity

v_{i+1} = new velocity

h_i = old height

h_{i+1} = new height

In difference equation notation, we get,

$v_{i+1} = v_i + f_1$ (1)

$h_{i+1} = h_i + v_i (1)$ (2)

Equations (1) and (2) are two "Control Equations" which define the new values of the state variables v and h in response to control input and previous state variable values.

V. COMPONENTS OF FUZZY LOGIC CONTROLLER (FLC)

A fuzzy controller can be designed to roughly emulate the human deductive process i.e. the process whereby we successively infer conclusion from our knowledge. Fuzzy logic controller consists of four main components as shown in Fig.3.

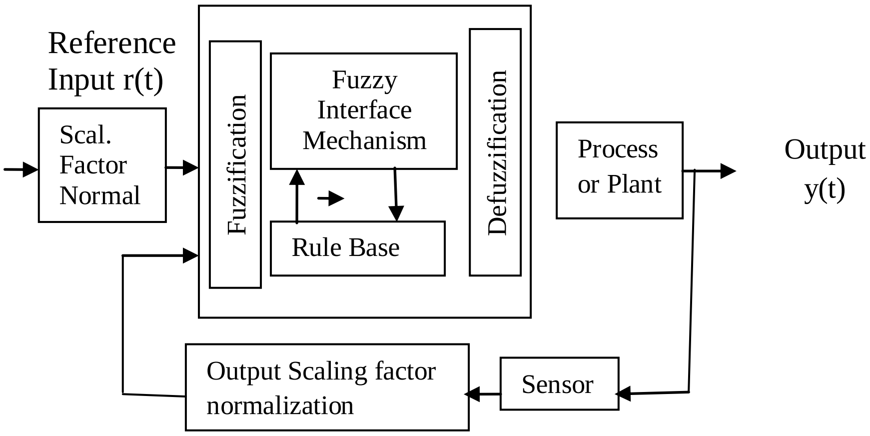

Fig. 3 Components of Fuzzy Logic Controller

VI. AIRCRAFT LANDING SYSTEM CONTROLLER

The block diagram of aircraft landing system controller is shown in Fig. 4. It consists of following main parts:

Personnel Computer

It is used to take crisp value from input analog to digital converter (ADC) and after fuzzy processing (see fig. 3), it gives crisp control output, this in turn passes through D/A converter, amplifier and transmitter to micro wave antenna.

Antenna

Antenna transmits the control signal to the aircraft, which controls the fuel injecting system, hence the accelerating and decelerating torque to maintain the velocity and height at proper values.

This antenna also receives a reflected signal which is fed to relevant transducers for height and velocity measurement which are input for the personnel computer.

Signal Conditioning Circuit
Signal received from antenna is very weak and noisy which is amplified and filtered through this circuit.
Transducers
The delayed reflected signal is used to measure the height and velocity of the aircraft by employing relevant transducers.

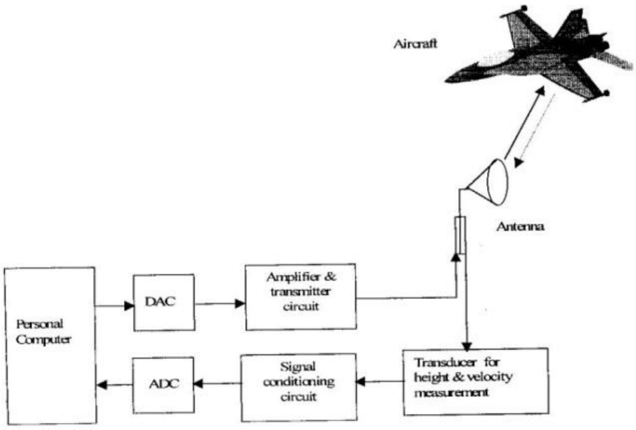

Fig. 4. Block diagram of aircraft landing system using fuzzy logic

VII. FUZZY LOGIC CONTROL MPLEMENTATION

The control of aircraft landing system using fuzzy logic has been implemented as follows:
Steps involved in Fuzzy Logic Control
The following steps are taken for fuzzy logic control:
Step 1: Membership function for state variable height h_i
[$0< h_i$ (m)<1000] is defined.
Step 2: Membership function for second state variable velocity v_i [$0< v_i$ (m/s)<30] is defined.
Step 3: Membership function for the control output i.e. controlling force f [0<f(kg)<30] is defined.
Step 4**:** The rule base has been defined and summarized in to a fuzzy associative memory (FAM) table [6,7].
Inferencing
The entries of FAM table is translated into IF THEN rules as follows:
1. If height is Zero (ZO) and velocity is also Zero (ZO), then control force is also Zero (ZO).
2. If height is Zero (ZO) and velocity is in the range of Positive Small (PS), then control force is Positive Small (PS).
3. If height is Zero (ZO) and velocity is Positive Small (PS), then control force is again Positive Small (PS).
4. If height is Zero (ZO) and velocity is Positive Big (PB), then control force is Positive Big (PB).
5. If height is Positive Small (PS) and velocity is Zero (ZO), then control force is Positive Small (PS).
6. If height is Positive Small (PS) and velocity is also Positive Small (PS), then control force is Positive Medium (PM).
7. If height is Positive Small (PS) and velocity is Positive Medium (PS), then control force is Positive Medium (PM).
8. If height is Positive Small (PS) and velocity is Positive Big (PB), then control force is Positive Big (PB).

9. If height is Positive Medium (PM) and velocity is Zero (ZO), then control force is Positive Medium (PM).
10. If height is Positive Medium (PM) and velocity is Positive Small (PS), then control force is Positive Big (PB).
11. If height is Positive Medium (PM) and velocity is Positive Medium (PM), then control force is Zero (ZO).
12. If height is Positive Medium (PM) and velocity is Positive Big (PB), then control force is Positive Small (PS).
13. If height is Positive Big (PB) and velocity is Zero (ZO), then control force is Positive Medium (PM).
14. If height is Positive Big (PB) and velocity is Positive Small (PS), then control force is Positive Big (PB).
15. If height is Positive Big (PB) and velocity is Positive Medium (PM), then control force is Positive Small (PS).
16. If height is Positive Big (PB) and velocity is also Positive Big (PB), then control force is Zero (ZO).

Deffuzification of Output

In order to increase or decrease the velocity of the aircraft at different heights, one need to control the applied force on aircraft. So far several IF-THEN rules, in which It is worked on fuzzy values of the two state variables i.e. height and velocity and the fuzzy control output force, has been formed. But, the fuzzy value of control force is not required instead, a crisp value of this controlling ouput force, which can be applied to the aircraft physically. In fact, there are several methods of defuzzification to arrive at crisp value [8]. In this paper, height defuzzification method has been used to defuzzify the output controlling force.

VIII. RESULTS

The simulated results of four successive cycles are tabulated below in Table 1:

Table 1: Results of four successive cycles

Cycle	Cycle 0	Cycle 1	Cycle 2	Cycle 3	Cycle 4
Height h_i (m)	200	180	165	151	136
Velocity v_i (m/s)	10	8	5	5.4	4.6
Control Force f(kg)	16.6	9.5	8.31	7.21	7.01

The descent profile of downward velocity vs height is drawn in Fig. 5

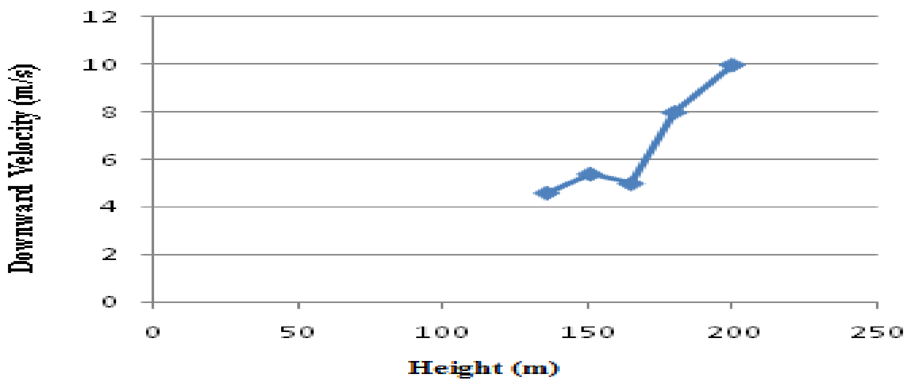

Fig.5 The descent profile of downward velocity vs height using fuzzy logic

By choosing more number of membership functions and linguistic variables for velocity, height and control force, hence more number of IF-THEN rules, a more precise control algorithm can be developed.

IX. CONCLUSION

In present work, a fuzzy logic based control scheme for aircraft landing system has been simulated. An algorithm developed has been found capable of eliminating the hardship of conventional aircraft landing mechanism. The descent profile shown above in fig.5 appears to be a reasonable resemblance with the desired descent profile shown in fig.1.
The control scheme presented here can be considered as a step towards autonomous aircraft landing mechanism, which can successfully adapt in unknown and changing environment.

X. ACKNOWLEDGEMENT

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