COMPUTATIONAL INTELLIGENCE (CI-MAI)
Project proposal: Fuzzy Control System Design for Aircraft Landing

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Abstract

The goal of this project is to develop a simple automatic aircraft landing system, in which the aircraft follows a desired landing profile. To this end, you should design and develop a fuzzy control system that allows an aircraft descend from altitude promptly in a very soft manner, taking as state variables the height and the vertical velocity of the aircraft. In order to perform the whole system simulation, it is necessary that you model the behaviour of the aircraft in a very simple way, following the movement equations described in this document. The complete simulation should be done under `Simulink`.

1 Introduction

Most control situations are more complex than we can deal with from the mathematical modelling point of view. In this situation, a fuzzy control system can be developed, provided a body of knowledge about the control process exists, and it can be expressed into a number of fuzzy rules. Control applications are arguably the kinds of problems for which fuzzy logic has had the greatest success and acclaim. Many of the consumer products that we use today involve fuzzy control.

In this project you will conduct a simulation of the final descent and landing approach of an aircraft. The desired downward velocity is proportional to the square of the height. Thus, at higher altitudes, a large downward velocity is desired. As the height (altitude) decreases, the desired downward velocity should get smaller and smaller. In the limit, as the height becomes vanishingly small, the 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.

The two state variables for this simulation will be the height above ground, h, and the vertical velocity of the aircraft, v. The control output will be a force that, when applied to the aircraft, will alter its height, h, and velocity, v. The differential control equations are loosely derived as follows. Mass m moving with velocity v has momentum $p = mv$. If no external forces are applied, the mass will continue in the same direction at the same velocity, v. If a force f is applied over a time interval Δt, a change in velocity of $\Delta v = f\Delta t/m$ will result. If we let $\Delta t = 1.0$ (s) and $m = 1.0$ (lb s^2 ft^{-1}), we obtain $\Delta v = f$ (lb), or the change in velocity is proportional to the applied force.

In difference notation, we get:

$$v_{i+1} = v_i + f_i$$
$$h_{i+1} = h_i + v_i \cdot \Delta t$$

where v_{i+1} is the new velocity, v_i is the old velocity, h_{i+1} is the new height, and h_i is the old height. These two control equations define the new value of the state variables v and h in response to control input and the previous state variable values.

2 Assumptions in a Fuzzy Control System Design

A number of assumptions are implicit in a fuzzy control system design. Five basic assumptions are commonly made whenever a fuzzy rule-based control policy is selected:

1. The plant is observable and controllable: state, input, and output variables are usually available for observation and measurement or computation.
2. There exists a body of knowledge comprising a set of linguistic rules, engineering common sense, intuition, or a set of input–output measurements data from which rules can be extracted.
3. A solution exists.
4. The control engineer is looking for a good enough solution, not necessarily the optimum one.
5. The controller will be designed within an acceptable range of precision.

3 Development of the Fuzzy Logic Controller System

You are asked to design a simple fuzzy controller and to implement, using `Simulink`, the close loop system. You can use the basic aircraft behaviour equations decsribed above to define your plant. The main steps in designing a simple fuzzy control system are as follows:

1. Identify the variables (inputs, states, and outputs) of the plant.
2. Partition the universe of discourse or the interval spanned by each variable into a number of fuzzy subsets, assigning each a linguistic label (subsets include all the elements in the universe).
3. Assign or determine a membership function for each fuzzy subset.
4. Assign the fuzzy relationships between the inputs or states fuzzy subsets on the one hand and the outputs fuzzy subsets on the other hand, thus forming the rule-base.
5. Choose appropriate scaling factors for the input and output variables in order to normalize the variables to the $[0, 1]$ or the $[-1, 1]$ interval.
6. Fuzzify the inputs to the controller.
7. Use fuzzy approximate reasoning to infer the output contributed from each rule.
8. Aggregate the fuzzy outputs recommended by each rule.
9. Apply defuzzification to form a crisp output.