Soft Computing Control System of an Unmanned Airship

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***Abstract*-Soft computing control system have been applied in various applications particularly in the fields of robotics controls. The advantage of having a soft computing controls methods is that it enable more flexibility to the control system compared with conventional model based controls system. Firstly, soft computing methods enable a transfer of human controls and thinking into the machine via training. Secondly it is more robust to error compared to conventional model based system. In this paper, a UAV airship is controlled using fuzzy logic for its propulsion and steering system. The airship is tested on a simulation level before test flight. The prototype airship has on board GPS and compass for telemetry and transmitted to the ground control system via a wireless link.**

I. Introduction

With the recent booming in robotics and UAV technology, soft computing controls systems were frequently applied in various research projects in UAV development. Fuzzy logic was originally discovered by L.A Zadeh and were later applied in Robotics projects by Sugeno in [1]. Fuzzy logic uses a IF-Then logic to evaluate a set of linguistic sets known as Fuzzy sets. Unlike conventional control system that utilizes crisp value for its control system, fuzzy logic uses vague linguistic expression as its inputs. Hence, crisp sensor values are fuzzified into vague linguistic expressions. In [2] and [3], the fuzzy control system were designed for a RC model plane and tested on a simulink environment.

II. Hardware and sensor intergration

The prototype airship used is a 9 feet rc (radio controlled) enabled airship. The airship utilizes two sets of brushless motors as thrusters. The airship uses a differential propulsion for steering and a vectoring angle of the thrusters for ascending and decending. Figure 2.1 shows the prototype airship for this research work. The on board telemetry module is essentially a microcontroller that intergrates all the sensors and transmits the data via a wireless link.

Figure 2.1 Prototype airship used

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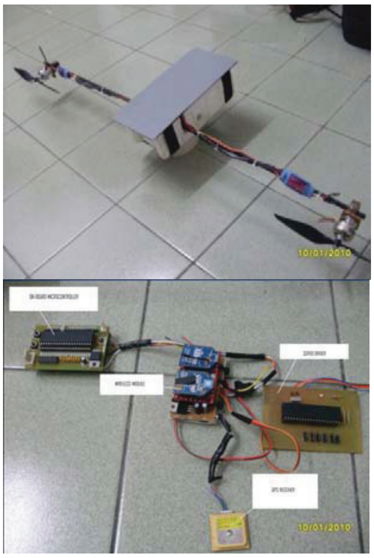

Figure 2.2 Thrusters and propulsion system

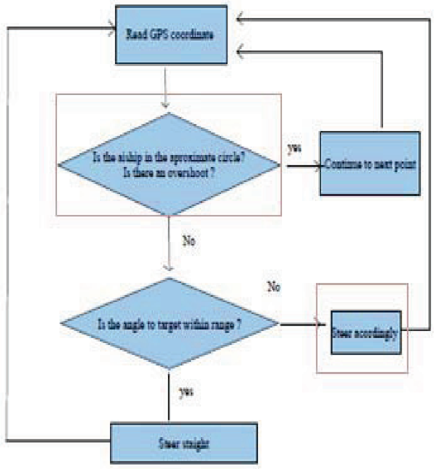

Figure 3.1 Flow diagram of UAV airship navigation controls

III. Control system

The flow diagram in figure 3.1 shows the navigation of the airship. The airship works on point tracking. It manuerves to track a point before proceding to another point.The proposed soft computing componenets were proposed for the highlighted area as shown in figure 3.1. As shown in figure 3.1, the control system decides if the airship has reached a specified distance from the specified GPS coordinate. The aproximate circle in diagram refers to an area from the target with a specified radius. Based on previous manual flights, it is impossible for the airship to reach an exact specified point of GPS coordinate. This is due to mainly to reasons:

- low manueverability of the airship
- inaccuracy of GPS coordinates form the GPS receiver

Hence, the control system would be in an infinite loop if a specified acceptable error margin is not introduced. The two sections requiring the soft computing methods are to decide the overshoot from the predefined GPS coordinate and for the steering controls. Due to the low manuerability the airship needs a control system for decision making in deciding to proceed to the next target point or maintain tracking the current point. The details of this will be covered in detail in the next section. A steering control system is also required for the steering of the airship based on the angle of the angles and height difference to the specified GPS coordinates.

a) Yaw and thrust vector

The primary control system is the Yaw and vectoring thrust controls. As defined in the previous chapter, Yaw angle is the angle of rotation about the z-axis and pitch angle is the angle of rotation about the angle about the x-axis. Before the development of the control system, sufficient flight of the airship is performed to enable familiriazation to the airship.

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The experiences from the manual flight are used to configure the membership functions of the fuzzy system. The propulsion values needed to execute a yaw angle or pitch angle is noted and used to configure the respective membership function. As can be seen, the Yaw and vector thrust angles that needs to be executed are calculated from the GPS error calculator module. The formula to calculate the bearing and the distance between the two points can be found in equation 3.2, the Haversine Formula.

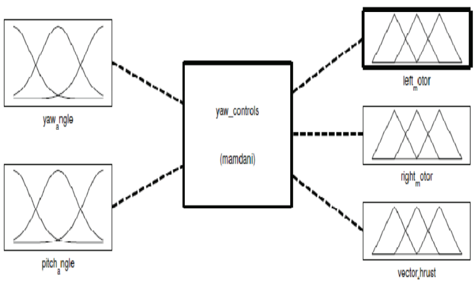
$$\theta = atan2(sin(\Delta long).cos(lat_2),cos(lat_1).sin(lat_2) - sin(lat_1).cos(lat_2).cos(\Delta long))$$

$$d = R.c$$

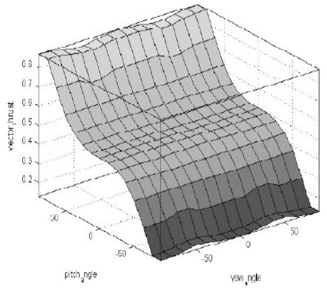
$$a = sin^2(\frac{\Delta lat}{2}) + cos(lat_1).cos(lat_2).sin^2(\frac{\Delta long}{2})$$

$$c = 2.atan2(\sqrt{a}, \sqrt{(1-a)})$$

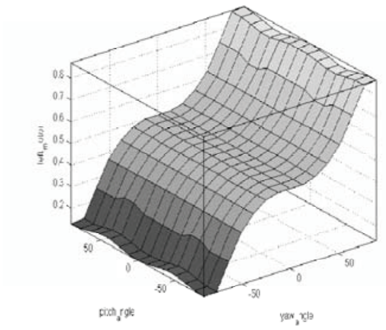
Where Θ=bearing between the two GPS Coordinates, D=Distance between the two GPS coordinates, R = earth's radius (mean radius = 6,371km), $\Delta lat = lat_2 - lat_1$, $\Delta long = long_2 - long_1$The output of the proposed fuzzy system has to receive two input (bearing and altitude) and gives and output of the respective actuators (PWM-Duty cycle). The output will be in percentage of Pulse Width Modulation -0% to 100% as shown in figure 4.2 (b). The membership functions are configured manually from the results obtained from the manual flight. The surface plots can be seen from 4.5(b),(c) and (d).



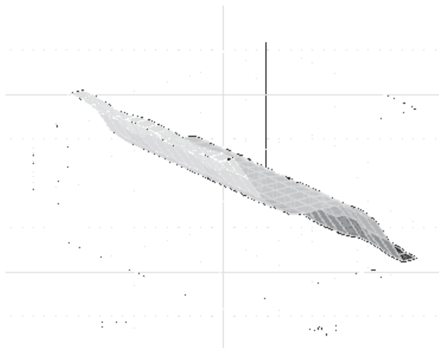
(a)



(b)



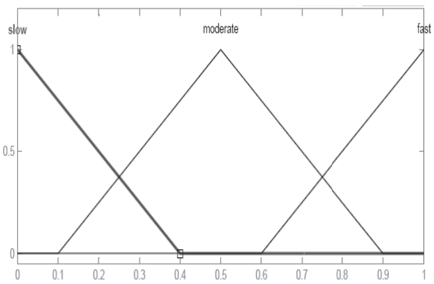
(c)



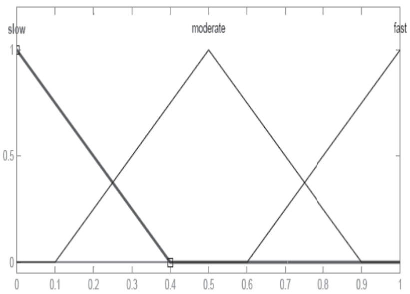
(d)

Figure 3.2 Fuzzy logic block diagram and surface diagram for yaw controls

The fuzzy sets were configured as shown in figure 3.3. Figure 3.3 (b),(c) and (e) shows the output to the actuators left thrusters, right thrusters and vectoring trust. Figure 3.3(a) shows the altitude difference between current height and target height while figure (d) shows the difference between Target bearing and the current bearing. The fuzzy expressions used can be seen from the membership functions.



(a)



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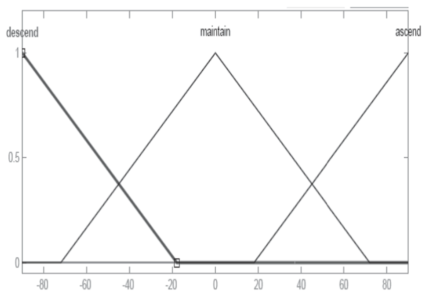
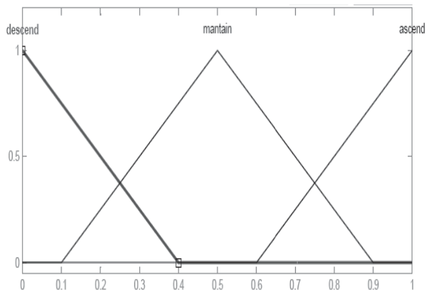


(c)



(d)

Figure 3.6 Membership function of fuzzy

b) Decision making In Flight path

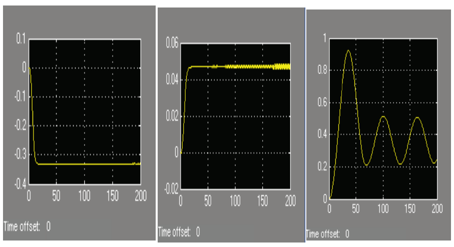
Despite its comparatively long loitering time Airship are extremely inefficient in manueverability. This is due to the reason that airships are extremely sensitive to gust and winds in addition to the limited degree of freedom of the actuators available in the airship. Hence the airship needs a decision making for its flight path to deal with this shortcoming in point and path following. As can be seen from figure 4.5, the airship in most circumstance deviates from the target point. In order to prevent the airship from constantly loitering in previous point, a neural network decision making module was proposed. The three input to the neural network is latitunal overshoot distance, longitunal overshoot distance and bearing. Based on this inputs, the neural network is trained to decide the status of the airshipif the There is a major longitunal overshoot, the airship will track target next point.

- If there is a major latitunal overshoot, the airship will track the target next point.
- If the there is a major longitunal and latitunal overshoot, the airship will track the next point.
- If there is minor longitunal and latitunal airship will track a new point.
- If there is there is no overshoot, the airship will continue to track existing target.

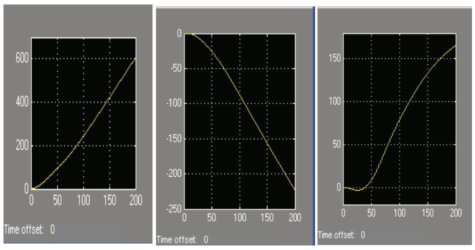
The decision making neural network is train using the pattern recognition toolbox in Matlab®. The neural network is trained using 3 inputs which is the longitunal distance from the target, latitunal distance from the target and the bearing. The inputs are normalized into scales of 0 to 0.1. The input for longitunal/latitunal distances which vary from 0 meters to 100 meters are scaled to 0 to 1.0.The bearing which varies from -90° to 90°(positive denotes East heading). The training sets are manually configured based on the experiences acquired during simulation and test flight. As a rule of thumb, at any longitudal/latitudal overshoot, the airship will decide to track the next target. Hence there exist 2 classes of action that needs to be identified-'continue to track the existing target' and 'move on to the next target'.

IV. Results and test Flight

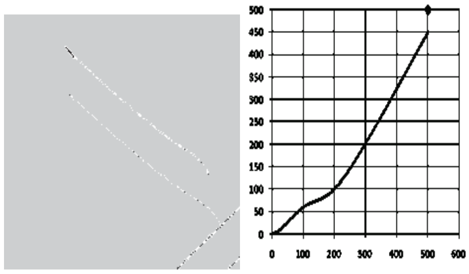
The control system were tested on a simulation level before the flight test. The simulation is developed from matlab simulink. The simulation considers the buoyancy of the gas, air resistance other factors. The yaw, pitch, roll and the three axis acceleration were shown in a simulated scope. The flight is shown in animation using the animation toolbox in simulink. Figure 4.2 shows the results from a simulated flight. In a simulation level, the X. Y and z axis is used to replace coordinates and fed back to the controls to be used as compass and GPS. Figure 4.2 a) b) and c) shows the yaw, pitch and roll which are the moments about the main axis. Figure 4.2 d) e) f) Shows the distance along the x, y , z axis. Figure 4.2 g) shows the animation of the simulated test flight. Figure 4.2 h) show the flight path of the airship in one particular test flight. As shown, the air ship tracks the coordinate quite efficiently on a simulated level. With the verification form the simulation , the outdoor test flight is carried out to test the capability of the airship. The test flight is performed in a sports complex. Figure 4.2 shows the environment of the actual test flight. Due to the limited space and wireless link range, only a point to point navigation is carried out. Figure 4.3 c) show the actual GUI used in this test flight. The current position and the target position is shown in the GUI and the airship continuosly track the specified target coordinate until it reaches to the approximate circle specified



(a) **(b)** **(c)**



(d) **(e)** **(f)**



(g) **(h)**

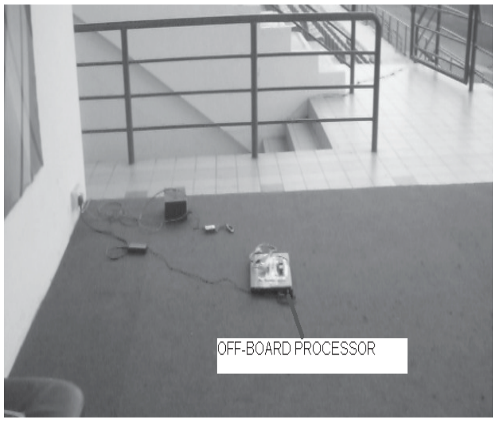


Figure 6.6 Graphic User Interface Environment

IIV Future works

Numerous application can be applied to this project. In the future works, a camera can be added to the airship for traffic monitoring purposes. The specified road can be mapped to a series of coordinates for airship tracking. Further work will also include intergration of commercial maps eg. Google maps, Garmin maps to enable more intuitive and efficient graphical interface with the user.

References

[1] L.A.Zadeh,1965, '*Fuzzy Sets*', Information and Control, 338-353(1965), Department Of Electrical and Electronics Research Laboratory, University Of California, Berkeley, Califonia

[2] M.Sugeno and M.Nishida. 'Fuzzy *control of a model car. Fuzzy sets and systems'*, 16:103-113, 1965

[3] M.Sugeno, H.Winston and I.Hirano, May 1995,Intellligent control of an unmanned helicopter based on fuzzy logic. Annual forum of the American Helicopter Society

[4] Jong Hyuk Kim, Stuart Wishart and Sallah Sukannah, 2008, 'Real time navigation , Guidance and control of a UAV using Low cost sensors ', Australia Center for Field Robotics

[5] Jon C. Ervin and Sema E. Alptekin, 1998 '*Fuzzy Logic Controls Of a Model Airplane'*, IEEE journals, Department Of Industrial and Manufacturing Engineering, Cal Poly –San Luis Obispo, CA 93407,

[6] L.Doisisdis† , K.P Valavanis†,N. C Tsourveloudis•, M.Kontitsis• ,'*A Framewok For Fuzzy Logic Based UAV Navigation and Controls'*., †University of South Fluorida •Technical University of Create

[7] Khoury, G.A and Gillet , J.D, 1999 "Airship technology", Cambridge Aerospace Series

[8] Gordon Wyeth, Greg Buskey, Jonathan Roberts , 2008, 'Flight control using an artificial neural network ',University Of Queensland

[9] Fakhruddine Karray , Clarence de Silva , August 2004,' Soft Computing and Intelligent System Designs' , Pearson Publications