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Hierarchical aggregation of multiple fuzzy controllers for global complex control problems

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ABSTRACT

In this paper, we illustrate a proposed method for control that combines the outputs of several individual controllers to improve global control of complex nonlinear plants. In the first part of this paper, we illustrate the proposed method that consists of two levels, where in the top level a fuzzy system represents a superior control that is designed for adjusting the behavior of the individual fuzzy controllers at the lower level. To test the approach, we consider the problem of flight control because it requires several individual controllers. Also a comparison is performed, where the hierarchical control strategy is compared with a simple control approach using the *t* student test. In this paper, we show that the proposed method outperforms the conventional fuzzy control approach. In the optimal design of the proposed control architecture a genetic algorithm was also applied to tune the parameters of the fuzzy systems in an optimal fashion.

1. Introduction

In the real-world, there exist many complex control problems in which using traditional approaches could be producing limited results [1,2,7,8,11]. The main contribution in this paper is a proposed method that consists in dividing a complex problem into many individual control subproblems. In this case, each individual control problem can be solved using a reduced controller [12,13,19–21]. The architecture of the proposed method is considered using two levels in the topology: individual controllers are used to make local control of individual subsystems and after this an aggregation mechanism is used to combine the behaviors of these controllers [22–24,27,28].

This proposed method is of relevant importance when working with complex control problems that need the use of more than a single controller to achieve a total control objective [35,36,38,39,41,44]. There has been several research works in the control area, although each author takes their own approach to carry out the investigation and here we explain some works that consider control problems in a similar way. E. Sanchez, H. Becerra, and C. Velez [30] describe different flight controllers for an X-Cell mini-helicopter. They divided their work in two parts. The first scheme consists of a conventional SISO PID controller for z-position and roll, pitch, and yaw angles. In the second scheme, two of the previous PID controllers are used for roll and pitch, and a linear regulator is added to control altitude and the yaw angle. E. Rachman, J. Jaam, and A. Hasnah [28], in their work used nonlinear simulation for automatic flight control system to the complete control design process. After, they used the linear approach in the design and simulation of the controller (control laws), they simulated the controller on the nonlinear real aircraft model. Y. Zhang et al. [46] show in their work, a simple and useful modeling method to acquire a dynamics model of an aerial vehicle containing unknown parameters using mechanism modeling, and then to design different identification experiments to identify the parameters based on the sources and features of its unknown parameters. As mentioned above, there are several works in aviation that have been mentioned for their importance regarding control, flight control range from small trajectories, using methods, such as fuzzy logic and neural networks [46,47].

The paper is structured as follows. In Section 2, we present some essential concepts of flight maneuvers and control. Section 3 proposed a method, which is explained and a description of the problem and results obtained are covered in Section 4. Finally, Section 5 presents conclusions.

2. Flight maneuvers and control surfaces

Flight mechanics is the science of predicting and controlling aircraft motion [25,31,32]. From Newton's second law we know

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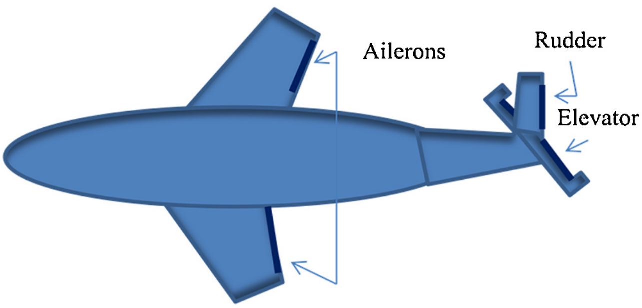

Fig. 1. Conventional airplane.

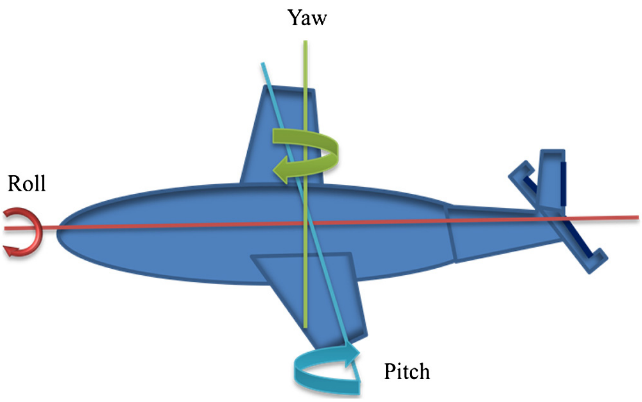

Fig. 2. Movements of the aircraft.

that the motion of any physical body depends on the forces and moments acting on the body. The forces and moments exerted on an aircraft in flight are the aerodynamic forces and moments acting on the aircraft's skin, the propulsive forces and moments created by the aircraft's engine, and the gravitational force between the aircraft and the Earth [34,37]. Because aerodynamic forces and moments are central to the study of aircraft motion [40]. There are three main approaches to the determination of flight vehicle's aerodynamic characteristics: analytical, computational, and experimental. Analytical techniques range from sophisticated theoretical approaches to those based on simple numerical methods to estimate pressure distributions. Experimental techniques include the use of wind tunnels and vehicle flight test to measure or infer the forces, moments, and/or pressure distributions on the vehicle [33].

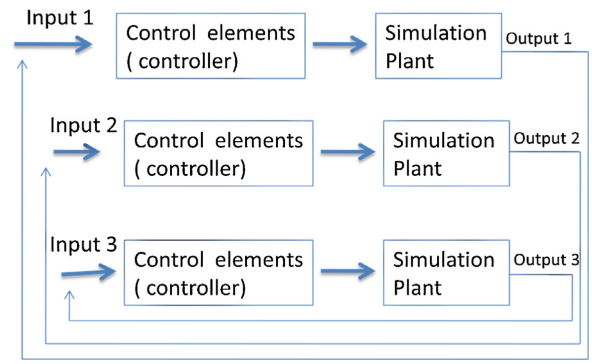

Fig. 4. Architecture with multiple controllers.

In Fig. 1 a conventional airplane is presented with its control surfaces (elevator, ailerons, and rudder). Every airplane can flight using its 3 axes (roll, pitch, and yaw), the pitching moment created by the pressure distribution over the airfoil is another key characteristic, this moment takes about a point along the chord line. A yaw moment on the vehicle may be generated by any surface generating a side force, such as the vertical tail in sideslip or with its rudder deflected. Roll is a movement around the longitudinal axis of the airplane. In Fig. 2 the basic movements of the airplane are illustrated.

3. The proposed control method

Today, there exist many case studies where neural networks, intelligent control, and fuzzy systems have an important role in solving real-world problems, and in some cases other techniques are also used to achieve the required solutions. The solutions of these control problems could be improved by using a new hierarchical structure combining multiple controllers. A simple control structure is presented in many studies, but what will happen when the case of study has more complexity? As a particular case of this situation, in Fig. 3 we present the block schematic diagram of the flight control system and Fig. 4 illustrates a possible solution using an architecture that considers multiple controllers that could be used for a complex control problem. This figure represents a basic scheme of control when we use several controllers for solving a complex problem that can be decomposed in several simpler problems.

However, with the traditional approach of Fig. 4 the main assumption is that the individual controllers can work

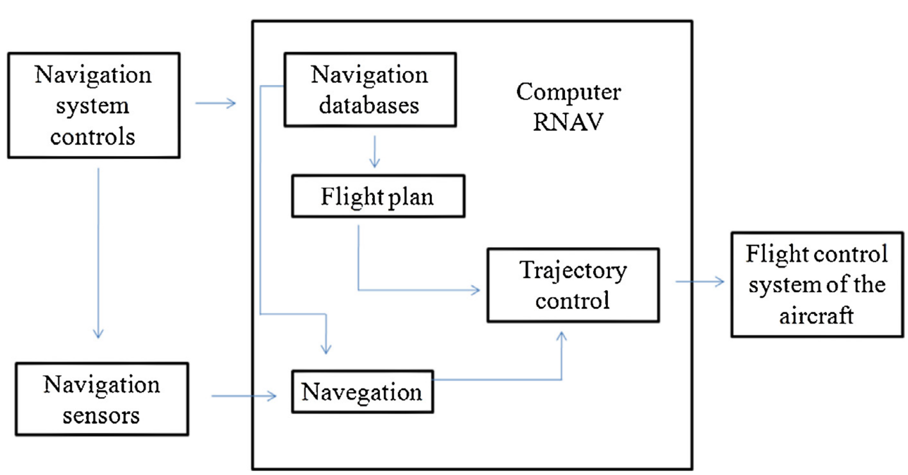

Fig. 3. Block schematic diagram of the flight control system.