Fuzzy Compensator Using RGA for TRMS Control

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Abstract. This paper presents a new approach using fuzzy compensator and PID controller to an experimental propeller setup which is called the twin rotor multi-input multi-output system (TRMS). Some previous works ignored the interactions between two axes and the controller being designed in horizontal or vertical direction separately. The goal of this study is to stabilize the TRMS in significant cross coupling conditions and to experiment with trajectory tracking. The fuzzy compensator and PID controller design is performed by a real-valued GA (RGA) with system performance index as fitness function. We apply the integral of time multiplied by the square error criterion to form a suitable fitness function in the RGA. Simulation results show that the proposed design can successfully adapt system nonlinearity and complex coupling conditions.

1 Introduction

Controller design of the TRMS has been studied for years. Huang and Juang [1]-[2] investigated the effect of the binary genetic algorithm (BGA) on controller tuning for improving system performance. The gains of the PID controller are tuned by the BGA with a nonlinear control design scheme. The controllers are better than the Gauss-Seidel Minimization Procedure. Tsai, Huang, and Juang [3] applied a real-valued genetic algorithm (RGA) on PID tuning to the TRMS control both in the vertical and horizontal axes separately. The system was decoupled into two parts, which are the vertical and horizontal, in order to design a one-degree-of-freedom PID controller. They restricted the connect beam between the main rotor and tail rotor to move only on the vertical or horizontal planes. The impact on the two rotors was ignored. The parameters of the PID controller are tuned by the RGA to reduce the total error and control energy. Fan and Juang [4] compared different kinds of fitness functions in the RGA via trial and error for tuning an optimal PID controller on the TRMS. The computer simulations showed that whether the fitness function suited the objective or was not significantly related to the result. In the conclusion of these papers [3]-[4], they constructed four PID controllers for the TRMS (both in the vertical and horizontal spherical surfaces simultaneously). Although these PID controllers could work in two degrees of freedom (2-DOF), they were still weak in tracking a desired trajectory and in reaching a specific attitude. It is difficult to stabilize the influence between two axes and a non-minimum phase in a vertical plane. Liu, Fan, and Juang [5], quoted the system performance index as a part of the fitness function in the RGA.

D.-S. Huang, K. Li, and G.W. Irwin (Eds.): ICIC 2006, LNAI 4114, pp. 120 – 126, 2006.

The system performance index deals with a modification of the known integral of time multiplied by square error criterion (ITSE). It is more efficient in finding the parameters of four PID controllers. Although these controllers could reduce control force and total error better than before, trajectory tracking of a desired path in 2-DOF oscillates for several seconds.

The main purpose in the control of the TRMS focuses on designing controllers to stabilize the impact between two rotors and to track a desired path and specific attitude in 2-DOF efficiently. In this paper, a fuzzy controller is used as a compensator and is combined with a traditional PID controller. It is a cross-coupled multi-variables controller. In order to make the TRMS follow a desired trajectory, a modified ITSE is implemented in the RGA and is utilized to optimize the gain factors of the fuzzy compensator and PID controller. There are 28 parameters for four controllers and four compensators in vertical and horizontal planes of the TRMS control system. These 28 parameters are tuned individually by the RGA. Simulation results indicate that the new approach has better performance than previous works.

2 System Description

The Two Rotor MIMO System (TRMS) is a laboratory set-up deigned for control experiments. In certain aspects, its behavior resembles that of a helicopter. From the control point of view it exemplifies a high order nonlinear system with significant cross-couplings. The approach to control problems connected with the TRMS proposed in this paper involves some theoretical knowledge of laws of physics and some heuristic dependencies difficult to express in analytical form. A schematic diagram of the laboratory set-up is shown in Fig. 1. The TRMS consists of a beam pivoted on its base in such a way that it can rotate freely both in the horizontal and vertical planes. At both ends of the beam, the rotors (the main and tail rotors) are driven by DC motors. A counterbalance arm with a weight at its end is fixed to the beam at the pivot. The state of the beam is described by four process variables: horizontal and vertical angles measured by position sensors fitted at the pivot and two corresponding angular velocities. Two additional states variables are the angular velocity of the rotors measured by tachogenerators coupled with the driving DC motors. In a normal helicopter, the aerodynamic force is controlled by changing the angle of attack. The laboratory set-up from Fig. 1 is so constructed that the angle of attack is fixed. The aero dynamic force is controlled by varying the speed of the rotors. Therefore, the control inputs are supply voltage of DC motors. A change in the voltage value results in a change of the rotation speed of the propeller which results in a change of the corresponding position of the beam.

A system performance index is used for fitness function in the RGA. It is an optimization criterion for parameters tuning of control system, which is suitable for the RGA. It deals with a modification of the known integral of time multiplied by squared error criterion (ITSE). In order to influence a characteristic value of a signal, it is not necessary to add a special term to the ITSE which may increase the selection pressure in the RGA. An evident possibility is to divide the integral criterion in a special error section for each characteristic value. The general form and most used performance index is shown below.