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Designing a Stable Model-Based Fuzzy Controller for a Novel 6-DOF Parallel Manipulator with Rotary Actuators

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Abstract— **This paper focuses on the designing of a stable model-based fuzzy controller for a six degrees of freedom (DOF) parallel manipulator with rotary actuators. This type of parallel manipulator has a challenging dynamics to control. Based on the nonlinear dynamical model of the system a Takagi-Sugeno fuzzy model of the system is presented through a combination of linear systems. The concept of Parallel Distributed Compensation (PDC) is used to design a fuzzy controller from the Takagi–Sugeno fuzzy model of the manipulator. Stability of the designed fuzzy control system is guaranteed via Lyapunov approach. The sufficient conditions for the existence of an appropriate controller are presented in terms of Linear Matrix Inequalities (LMIs). To show the efficiency of the proposed approach, numerical simulations are performed for a typical system.**

I. Introduction

THE parallel manipulators attract many researchers since the early 1990's due to their advantages of high stiffness, high payload and high accuracy and so on. Parallel robots mainly consist of two platforms and several legs, where one platform is generally fixed to the ground, called the base platform, and the other is movable, called the moving platform. The typical parallel manipulator is Gough Stewart Platform which is constructed by D. Stewart in 1965 [1]. It consisted of six legs which are actuated by hydraulic actuators. In the area of 6-DOF Parallel Manipulators, most of the research has been particularly aimed at this type of Gough Stewart Platform. Another less-studied is the 6-DOF Parallel manipulator with revolute actuators. These manipulators are faster since they use electrical motors and these motors mounted on the base [2]. Several versions of the 6-DOF Parallel manipulator with revolute actuators are suggested with various directions for the joints axis. This type of parallel manipulator was introduced by Hunt [3] in 1983 for the first time. Some other prototypes have been constructed by Sarkissian [4], by Zamanov [5] and by Mimura [6]. Finally, a more recent and commercial design has been introduced by Servos & Simulation Inc. [7].

In this paper, we focus on a new type of this parallel manipulator which has a few differences with other design (Fig. 1). Complete description of this manipulator with new design is presented in Section II.

To the best of our knowledge, the control of 6-DOF parallel manipulator with rotary actuator has never studied. However, there are too many literatures during this decade in which the control of conventional type of Gough Stewart Platforms are studied. Furthermore, a few of these papers are related to fuzzy control.

For the first time, Mann [8] and Chung [9] designed a fuzzy PID controller for a Gough Stewart platform. After that, Garagic [10] developed a fuzzy controller where adaptively learns unknown friction behavior and compensate for it. After that, Bo [11] presented a robust sliding mode controller with fuzzy tuning for this parallel manipulator. As one of the latest approach, Remillard [12] used PDC approach to control of Stewart platform. However, he simplified the control problem by considering only horizontal movement of the moving platform.

In this paper, we use PDC approach to design a fuzzy controller for a 6-DOF parallel manipulator with rotary actuator. This approach is a nonlinear control approach which is simple to implement because of fast computation. Therefore for implementation it does not need powerful computer hardware. To design this controller, we have to choose some points in workspace of the manipulator. Then, we linearize dynamical model at these points. Finally, we design the fuzzy controller based on Lyapunov approach. The stability conditions have been characterized in terms of LMIs.

The organization of the paper is as follows. In Section II the mechanism of this manipulator is introduced. Section III presents the platform dynamic model and it is used in Section IV to design the controller. Utilizing the concept of PDC is given in Section IV. Section V presents the results obtained in the numerical simulation of the system. Finally, the last sections are made up of conclusions and Appendix.

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