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ORIGINAL ARTICLE

Optimal cascade hydraulic control for a parallel robot platform by PSO

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Abstract A new cascade load force control design for a parallel robot platform is proposed. A parameter search for a proposed cascade controller is difficult because there is no methodology to set the parameters and the search space is broad. A parameter search based on particle swarm optimization (PSO) is suggested to effectively search the parameters of the cascade controller. We used a unified mathematical model of a hydraulic actuator of parallel robot platform. These equations are readily applicable to various types of proportional valves, and they unify the cases of critical center, overlapped, and underlapped valves. These unified model equations are useful for nonlinear controller design. Simulation results show the advantages of the proposed optimal tuned cascade controller to solve the formulated tracking problem in relation to the classical proportional–integral (PI) controller.

Keywords Optimal control · Cascade control · Hydraulically control systems · Parallel robot platform · Particle swarm optimization · Tracking problem

1 Introduction

The hydraulically driven parallel robot platform is obtained through a generalization of the mechanism proposed by Stewart [1] as a flight simulator. As shown in Fig. 1, this spatial platform mechanism consists of a fixed base platform and an upper moving platform. The six extendable legs connect these platforms. Besides greater stiffness and accuracy, these robot platforms have high payload–weight ratio due to parallel linkage. Parallel linkage enables the payload distribution and averaging of the positioning error. The payload and positioning errors would be accumulated without parallel linkage. Accordingly, these types of parallel robot platforms are attractive for certain applications, such as flight simulators, machine tools, and force–torque sensors.

The parallel robot control strategy may be designed from two frameworks. One is to design a controller based on the legspace coordinates and the other is based on the workspace coordinates. The control strategy based on the workspace coordinates has a limitation to the real-time application due to difficulty in obtaining information on the upper moving platform. However, the upper moving platform of a parallel platform can move with the six desired degrees of freedom (DOF) if the lengths of the all legs are well controlled. Bearing this in mind, the control strategy study of the parallel robot platform rather is based on the legspace coordinates. A classical proportional–integral (PI) control technology has been applied in practice for the control of a 6-DOF parallel robot platforms. However, linear control techniques do not always guarantee the desired high performance of a parallel robot platform. Despite having advantages in terms of simplicity, some simulation and experimental results indicate that PI control has limitations in terms of tracking performance for hydraulic control and that these limitations are the consequence of the nonlinear nature of hydraulic systems. Hence, a high-level control strategy is required to increase the control performance of the different types of actuators that are used to drive the upper moving platform [2–4].

The performance of hydraulic systems strongly depends on the control valve and spool geometry and their manufacturing tolerances. The manufacturing precision distinguishes proportional valves from servovalves, in terms of both performance and cost. In hydraulic control applications, proportional valves offer various advantages over servovalves. Proportional valves are much less expensive. They are more suitable for

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