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ORIGINAL ARTICLE

Application of cuckoo search algorithm to constrained control problem of a parallel robot platform

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Abstract This paper presents a cascade load force control design for a parallel robot platform. 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 cuckoo search (CS) is suggested to effectively search parameters of the cascade controllers. The control design problem is formulated as an optimization problem under constraints. Typical constraints, such as mechanical limits on positions and maximal velocities of hydraulic actuators as well as on servo-valve positions, are included in the proposed algorithm. The optimal results are compared to the state-of-the-art algorithms for these problem instances (NP-hard and constrained optimization problems). Simulation results also show that applied optimal tuned cascade control algorithm exhibits a significant performance improvement over classical tuning methods.

Keywords Parallel robot · Constrained optimization · Cascade control · Controller tuning · Cuckoo search algorithm

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.

A classical proportional–integral–derivative (PID) control technology has been applied in practice for the control of a 6-DOF parallel robot platform. 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 PID 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]. Modeling and simulation of actuator systems can be seen in [5, 6].

The parallel robot platform represents an extremely difficult control problem. Strong nonlinearity, time variance, and coupling of the parallel robot platform lead to great difficulty for control. Since dynamics of the hydraulically driven 6-DOF parallel robot platform consists of two parts, the designed controller should take into account not only the mechanical dynamics but also the hydraulic dynamics using the cascade control method (see [7–10]). We decided to implement the feedback linearization for controlling the actuator load force, independent of the resulting motions of the load. This method differs entirely from conventional linearization, in that feedback linearization is achieved by exact state transformations and feedback rather than by linear approximations of the dynamics [8].

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