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Experimental identification of inertial and friction parameters for electro-hydraulic motion simulators

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ABSTRACT

The fullness of dynamics equations and the degree of uncertainty in dynamic parameters are important factors in application of the identified models to model-based control strategies. Therefore, in this paper, the experimental identification of inertial parameters and friction coefficients are dealt with for an electro-hydraulic motion simulator, normally consisting of the Stewart platform. The model with arbitrary geometry, inertia distribution and frictions are obtained based on a structured Boltzmann–Hamel–d'Alembert formulation, and then the estimation equations are explicitly expressed in terms of a linear form with respect to the base parameters of minimal dimension to be identified. The identified parameters are obtained through solving the estimation equations by simple least square method. Moreover, exciting trajectories are also designed respectively in the actuating space and task space. Finally, the identified parameters are used to validate the developed model by comparing the predicted forces with respect to the actuating forces for a random trajectory.

1. Introduction

A motion simulator is a virtual reality device in which an operator can feel as if they are actually driving a plant such as aircrafts and vehicles. In general, electro-hydraulic Stewart platforms, which are a class of six degree-of-freedom (DOF) parallel mechanism, are designed to generate dynamic response for the desired behavior of the motion simulator; therefore, the study of simulation fidelity is dependent upon the existence of an accurate model of the Stewart platform driven by hydraulic cylinders. In this regard, it is necessary to establish close and detailed dynamic models to make a simulation more realistic. Essentially, an accurate estimation of the physical parameters like inertial and friction parameters which appear in the models plays an important role for the realistic simulation of such motion simulators. Moreover, parameter estimation is an important element in generating model-based driving forces for motion simulators.

The issue of the estimation of dynamic model parameters for serial mechanisms has been extensively investigated. Usually the inverse dynamics model is expressed in terms of a linear form with respect to the base parameters to be identified [1], and then the least square (LS) estimation algorithm is used to calculate these base parameters by minimizing the residual error predicted by the model at a sufficient number of points along some trajectories [2–9]. Moreover, to overcome the sensitivity to measurement noises, data filtering can be used to improve the input data, then the base parameters are obtained using the least square method [10,11]. An alternative is to incorporate the measured noises with known statistical characteristics for random measurement errors, and the reliable parameter estimates are derived through the maximum likelihood (ML) estimator [12–14].

In comparison to open-chain manipulators or serial mechanisms, there are very few researches on the estimation of dynamic parameters of parallel mechanisms. In [15–18] the on-line parameters estimation is applied for adaptive control algorithms, load monitoring or failure detection. Further, these estimation models are restricted to very simple models so that only the dynamics of the moving platforms are considered.

Following the used techniques for the parameter estimation of serial mechanisms, Guegan et al. [19] present the identification of the dynamic parameters of the Orthoglide, a three-DOF parallel robot. A. Vivas et al. [20] deal with the experimental identification of the dynamic parameters for a four-DOF parallel robot H4-classs. However, an accurate or additional measurement for the accelerations of the moving platform is required, but not always fulfilled [21]. It is noted that these dynamic identification models are based on the inverse dynamics models which are developed using the Newton–Euler formulation under some simplified assumption. Then a numerical analysis is used to determine the base parameters of the formulated estimation equations in a linear form of the identified parameters. Furthermore, Bhattacharya et al. [22]

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