An Inverse Kinematic Method for Performance Determination of Flight Simulation using Stewart Platform

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Abstract

In this paper, a theoretical analysis of the Stewart platform operation with constraints on actuator speed and force is described. The limitation of platform in the generation of surge, sway, and heave motion as well as roll and pitch angular oscillating motions is analyzed using the inverse kinematic equation of Stewart platform and a numerical method. The proposed method also accounts for both inertial mass and rotational mass of actuators in the determination of operating limitation. The implementation of the proposed method is presented in examples and the determination results are discussed.

Keywords*:* Stewart Platform; Rigid Body Dynamic Simulation.

1. Introduction

Flight simulators are being widely used in the modern world. Not only for training purposes, they are also used for evaluation and research purposes. The Stewart platform [1] is a classic mechanism widely used for a motion control device. Not only used in flight simulation, the platform was also utilized for other applications such as high precision positioning devices [2] and machining centers [3]. The advantages of this mechanism are on the wide range of motion, high rigidity, and accurate positioning capability.

This work focuses on the use of Stewart platform mechanism to simulate basic flight maneuvers for hardware-in-the-loop (HITL) simulation purpose for autonomous aerial systems and flight instruments. The load (device/vehicle) is attached to the moving platform to simulate response due to flight maneuvers. In order to achieve accurate flight response, it is important to know the operation boundary of the platform hardware. A simple formula for computing actuating forces and speed for a Stewart platform presented in [4] assumed negligible actuator inertia in which sufficient accuracy could be obtained for the case of high load inertia. However, accounting of actuator inertia in dynamics model is required for control performance [5].

In this work, we focuses on finding the operation limitation for Stewart platform using given actuator characteristics (actuating speed and force). The mathematical model and a brief derivation of the dynamic equations are presented in Section 2. Section 3 describes details of the proposed method for Stewart platform limitation determination. Section 4 presents the implementation of the proposed method in example cases and discussion. Finally, the conclusion is presented in Section 5.

2. Mathematical Model

The Stewart platform considered in this study is a 6-DOF parallel mechanism. A moving rigid platform is connected to a fixed base through six independent, identical linear actuators (Fig. 1). Spherical joints are applied to the connection at both end of each actuator. The change in the length of the linear actuators is the command variable used to control the motion of the moving platform.

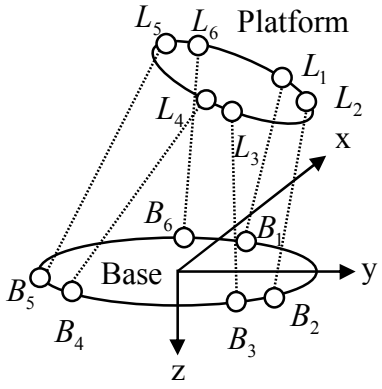

Fig. 1 schematic diagram of Stewart platform