Final Position and Trajectory Control of an Object on a Distributed Manipulation System

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ABSTRACT

In this paper, the function of a fuzzy controller in motion control of an object on a distributed manipulation system is investigated practically by an experimental setup. The system consists of four wheels with fixed axis and an object that is carried on them. The angular velocity of the wheels is controlled by a fuzzy controller and the object motion is indeed controlled by the friction forces between the wheels and the object. The results of experimental tests are compared with that of numerical simulations of the system in SIMULINK. The good agreement between the results indicates the effectiveness of the designed controller in actual systems.

1. INTRODUCTION

Distributed manipulation systems generally consist of a large number of identical actuators arranged in a planar array combined with a control strategy to create net movement of an object or objects placed on the array. These systems are manufactured in both microscopic and macroscopic size.

In the macroscopic scale, two groups have done important researches in the field of wheels positioning objects with friction forces:

I. Luntz, Messner and Choset developed a system called Virtual Vehicle that included a large number of wheels connected to electric motors. This group used both open loop and closed loop control for positioning and orienting the object. The main assumption this group adopted is that the friction type between the wheels and the object is sliding friction and remains unchanged over the time [1-4].

II. Murphey made three contributions in this field. First, he used Power Dissipation Method for modeling the contact between the wheels and the object. Secondly, he showed that when the discrete nature of actuators' array is taken into account and the dynamic model of the contact between the wheels and the object is examined by the PDM, the control systems designed by the continuous approximation method would be unstable when deployed on the actual array. Finally, he demonstrated that when feedback is added to such a system, it would be transformed to a stable one [5-7].

There are other works in this field; [8-11] can be mentioned as examples. In this paper, the mathematical model of a distributed manipulation system that consists of four wheels having fixed bases is first investigated. Then, fuzzy control parameters are specified in the next section. Finally, practical results from the experimental setup are brought alongside the simulation ones.

This work is different from previous works in these regards:

I. It does not assume that the system is quasi-static which is actually justifiable only in low velocity conditions and fully takes into account the dynamic nature of the system.

II. It does not assume that the friction condition is constant in a period or on a specific region and takes into accounts the stick-slip fluctuations.

III. The controller parameters are not designed for a specific desired position and orientation and are quite general.

2. MATHEMATICAL MODELING OF THE SYSTEM

The schematic model of the system is shown in Figure 1. For deriving the equations of motion of the systems, a mathematical model is needed for modeling the contact between the object and wheels, which in turn requires the normal forces exerted on the object to be computed.

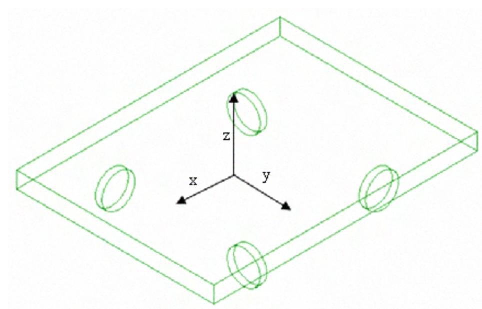

Figure 1. *Schematic model of the system.*

2.1. The Mathematical Model of the Friction

The model used here is selected from the work of Hadian, et al [12]. By assuming that the contact between the object and the wheels is a standard Coulomb friction, the friction force exerted on the object by the contact surface can be described by the following equation:

$$\begin{cases} F_t = -\mu N sign(v) & \text{if } v \neq 0 \\ |F_t| \leq \mu N & \text{if } v = 0 \text{ and } \dot{v} = 0 \\ F_t = 0 & \text{if } v = 0 \text{ and } \dot{v} \neq 0 \end{cases} \tag{1}$$

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