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Intelligent mobile manipulator navigation using hybrid adaptive-fuzzy controller ☆

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ABSTRACT

Intelligent navigation, path following and obstacle avoidance are necessary features for mobile robots to permit the navigation in a dynamic environment and to train intelligent robots. In this context, this paper examines a dynamic feedback control design, firstly to treat the trajectory tracking control of a mobile manipulator with model uncertainties and external disturbances and secondly to avoid collision with obstacles during the navigation to add more functionality to mobile robots. In order to overcome the unknown perturbation effects and uncertainties, we use an adaptive estimator such that the mobile manipulator velocity converges to the desired trajectory. Furthermore, we apply a fuzzy controller to avoid collision. The contribution of this work is that the mobile manipulator executes two acts together which are the tracking of the desired trajectory despite of the uncertainties and disturbances, and the avoiding of obstacles during the trajectory tracking. Simulation results are given to illustrate the efficiency of the proposed adaptive-fuzzy controller.

1. Introduction

The trajectory tracking control of mobile robots has been the item of various research work [1,2]. As a matter of fact, in industrial applications the mobile robot comes in contact with the environment, so that the state of the system is intended to converge to the desired path in spite of the presence of perturbations and model uncertainties [3]. The control of mobile manipulators with uncertainties is important in different applications, unusually when the force of the manipulator should be considered. To manipulate unknown dynamic parameters of mechanical systems and external disturbances, adaptive controls have been investigated to solve these problems. In [4], an adaptive tracking controller using neural network is presented for a mobile robot with kinematic constraints and unknown dynamic model, in addition to that a neural network sliding mode control is used for the tracking control of a two-links robot manipulator with large uncertainties [5]. To guarantee the rejection of disturbances, a generalized proportional integral observer based controller was used for the trajectory tracking tasks in [6]. Moreover, in [7], an adaptive fuzzy sliding mode control is proposed to stabilize the robotic manipulator to a desired trajectory. To evaluate the unknown position of a mobile manipulator with parameter uncertainties, an adaptive hybrid force-position controller is employed in [8].

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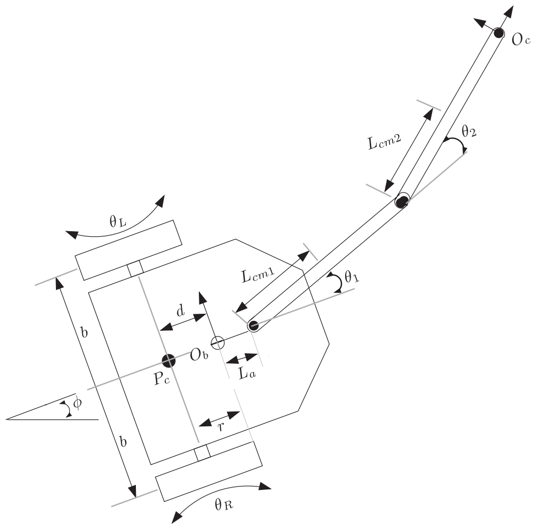

Fig. 1. Schematic of the mobile manipulator.

Generally the aim of research is to allow autonomous systems, equipped with sensors and actuators, to execute complex tasks in unknown and uncertain environments, especially the mobile manipulator which has been considered as an efficient robot. Franzé used a predictive control scheme for ground vehicles operating in uncertain environments to avoid obstacles [9]. In [10], authors allow the robot to move in an environment with obstacles and to use dynamic programming to find optimal path by minimizing energy and avoiding obstacle collision. In [11] authors deal with the problem of navigation (path-following, wheel slippage and skid) and design a controller based on the proposed side friction model and skid check condition.

Fangquin [12] proposed a fuzzy controller to drive a vehicle with obstacle avoidance. This type of controller is also used in the work of M. Njah and M. Jallouli [13] for electric wheelchair navigation in an indoor environment containing obstacles. There is a huge motivation for research in assistance technology to permit more autonomy [14], in this context Fredriksson outfitted the MICA wheelchair with camera and laser scanner in order to follow the desired path and to facilitate its navigation [15]. The difference between this work and the work of other authors [16–18] consists not only in avoiding collision with obstacles and join the target point, but our goal is also, during its motion the mobile manipulator must achieve convergence to the proposed trajectory in presence of the uncertainties of dynamic parameters and external disturbances.

In this paper we try to solve the problem of uncertainties in system model, external disturbances and avoiding collision during the navigation of the mobile manipulator. Tackling cited problems allows to the mobile robot to be autonomous and let to meet the performance level required by applications in order to achieve fast, precise and quality production.

Our paper is organized as follows. In Section 2, the system model is presented. Then we explain the global control system used to converge to the desired trajectory without any collision in Section 3. In the fourth section, the torque controller design is presented. Section 5 is devoted to the fuzzy controller synthesis. In Section 6, simulation results are given to show the efficiency of the proposed controller. And finally, Section 7 contains the concluding remarks.

2. Model of a non holonomic mobile manipulator

The mobile manipulator shown in Fig 1 is composed of two subsystems which are a mobile platform and an end effector (see [19]). The robot parameters are presented by a vector q:

$$q = \begin{bmatrix} x_{O_b} & y_{O_b} & \phi & \theta_r & \theta_l & \theta_1 & \theta_2 \end{bmatrix}^T \tag{1}$$

The dynamic model of the studied system [20] subject to non holonomic constraints is given by the following equation (see [19]):

$$H\dot{\upsilon} + C\upsilon + g = \bar{\tau} + \bar{\tau}_d \tag{2}$$

where $H = S^T MS$, $C = S^T M\dot{S}$, $g = S^T V$, $\bar{\tau} = S^T E\tau$ and $\bar{\tau}_d = S^T E\tau_d$. $S(q)$ is a $\mathbb{R}^{n\times(n-m)}$ full rank matrix and $v(t)$ is a velocity vector time function $\upsilon(t) \in \mathbb{R}^{n-m}$ such that, for all t we have :

$$\dot{q} = S(q)\upsilon(t) \tag{3}$$

The following assumptions are pertaining to many systems of practical interest.

Assumption 1. System (2) is linearly parameterizable (LP), *i.e.*,

$$H(q)\dot{\upsilon} + C(q, \dot{q})\upsilon + g(q, \dot{q}) = Y(q, \dot{q}, \upsilon, \dot{\upsilon})\Theta \tag{4}$$