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Two PID-Based Controllers for a tethered Segway on Dome Shaped Structures

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***Abstract*: The UTDTR Robot is a human inspired robotic platform based on a two-wheeled mobile robot. This robot is designed for the purpose of dome shaped structures inspection and maintenance, and it is a tethered robot to stably climb steep surfaces on the top of dome structures. In this paper analysis and controller design of this robot modelled as a MIMO system is represented in order to provide the desired performance on the operating surface with minimum control effort and complexity. Two PID-based controllers are designed such that the stability and desired performance conditions are obtained. In the first design a fuzzy PID controller with self-tuning scale factors is designed to tune the controller gains is forwarded, while in the second approach a multi model gain scheduling controller based on conventional PID controller is considered. Finally, the effectiveness and simplicity of the proposed controller is verified through simulation, comparing the resulting closed loop transient and steady-state response to that of the previously proposed controllers.**

Keyword—Dome, Segway, Climbing Robot, PID Control

I. Introduction and Related Works

Climbing steep structures such as dome shaped structures, is an interesting field for robotics and mechatronic researchers working on climbing and service robots. There is a wide range of applications for these climbing robots such as climbing dome-shaped structures for purpose of cleaning, inspection, and maintenance. Dangers and difficulties in cleaning, inspection, and maintenance performed on tall structures such as domes and poles by human workers, has initiated robotic projects with purpose of climbing these structures. Furthermore, limited operation time and high demand for autonomous operations in most of the actions taken on a tall structure, are other important reasons why different robotic teams started working on designing robots to work on these situations from both theoretical and practical points of view. [1]–[6]

Different robotic mechanisms and methods have been used to design and develop platforms in order to climb walls, poles and steep surfaces. Magnetic systems [7]–[9], systems with adhesive materials [10], [11], and suction and vortex [12]–[14]. Based on prescribed difficulties and dangers in human-based climbing methods [6], a team in Advanced Robotic and Intelligent systems (ARIS) laboratory initiated University of Tehran Dome Climbing Robots (UTDCR) as shown in Figure 1. A multi robot platform is designed and implemented. In this mechanism, with three or more robots cooperate with each other to stably maneuver on the structures with both positive and negative slopes [5]. This robotic system is able to cover all parts of a dome, but its complexity in control has become a challenge. Since most damages and dirt take place in the top part of the dome shaped structures where the slope is positive, the top of domes is the most important area to be inspected and maintained, and a robot that can safely cover the top part of a dome is practical enough for most cases. Therefore, a single tethered robot, "UTDTR", inspired from human dome climbers, with purpose of inspection, cleaning and maintenance was firstly implemented, and successfully tested for dome inspection. As it is prescribed in [6] the UTDTR, consists of a simple two-wheeled mobile robot with differential drive locomotion, and a tether mechanism controlling the length of the rope connecting to the top of the dome. It worth to mention that the tether mechanism is placed on the mobile robot to eliminate the gravity force applied to the robot and prevent from falling from the dome's surface.

A two-wheeled mobile robot may be considered as a popular Segway mechanism, where there are lots of work on controlling them. Despite the vast controllers presented for Segways and other two-wheeled mobile robots [15], [16], control and analysis of a system like this tethered Segway on the dome is a novel problem in which a few control structures have been implemented successfully [6], [17], [18]. In [6] static analysis of the prescribed robot has been presented and existence of the stability condition for this robotic platform

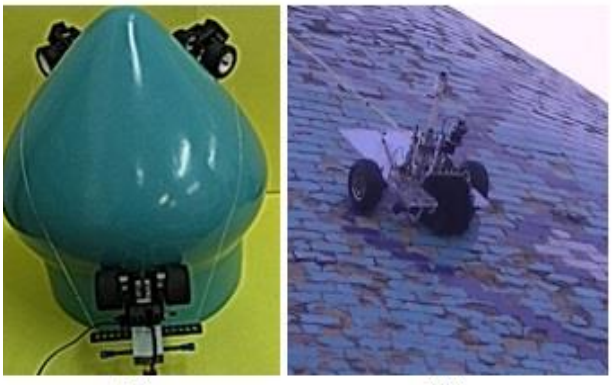

Figure 1. (a) The multi-robot platform to climb the dome-shaped structures. (b) Dome Tethered Robot climbing the dome

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