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DISSERTATION ABSTRACT

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学 位 論 文 題 名

Title of dissertation submitted for the degree

Motion Control and Stability Improvement of Autonomous Mobile Robots with Suspended Wheels

(サスペンションを有する移動ロボットの運動制御および安定性向上に関する研究)

Autonomous mobile manipulators have been given extensive attention in recent years since they have many applications such as transporting operation of materials in modern factories, handling radiation infected objects in specific environments, and serving disabled persons at home. In order to satisfy the mobility performance requirements of a challenging rough terrain, a suspended wheeled mobile robot with a dexterous manipulator becomes an appropriate mobile robot design. This thesis focuses on the suspended wheeled mobile robot and deal with the following problems: Firstly, mobile robots with suspension system can absorb vibration induced by rough roads, but due to center-of-gravity (CG) shift and the dynamic of manipulator, the suspended platform is subject to vibration when the robot moves with acceleration. Secondly, trajectory tracking of a mobile platform and a manipulator simultaneously is a challenging work because of its complex nonlinearity and dynamic interaction between the platform and manipulator. Thirdly, when robots move through rough terrain, it is necessary to improve their stability to eliminate external interference that degrades the performance of vision systems. Finally, although application of the teleoperation has been a benefit to remote control, how to reduce the time delay and the errors of communication is still a troublesome problem. In order to solve these problems, this thesis is organized as follows:

The research background about the suspended wheeled robot with a manipulator is introduced in Chapter 1. In addition, the contributions and outline are presented in this chapter.

On the aspect of vibration suppression, Chapter 2 presents approaches based on the particle swarm optimization (PSO) algorithm to overcome the following vibration problems: (1) when the suspended platform moves with static manipulator, vibration of the suspended platform occurs due to CG shift; (2) when the suspended platform and the manipulator move simultaneously, the vibration is caused by the movement of manipulator. For the first problem, a method for the optimization of multi-input shapers is designed by using PSO with chaos to reduce the residual vibration. For the second problem, an approach based on PSO with chaos is developed to suppress the vibration by searching for the time-jerk synthetic optimal trajectories of the manipulator. Then, the resulting shapers and optimal trajectories are performed on the presented models and demonstrate that the vibration can be controlled to a desired level effectively in both problems.

Chapter 3 presents an adaptive control strategy for trajectory tracking of a mobile manipulator system that consists of a wheeled platform and a modular manipulator. When a robot system moves in the presence of sliding, it is difficult to accurately track its trajectory by applying the backstepping

approach, even if a non-ideal kinematic model is employed. To address this problem, a combination of adaptive fuzzy control and backstepping approach based on a dynamic model is proposed. This control scheme considers the dynamic interaction between the platform and manipulator. To accurately track the trajectory, a fuzzy compensator is proposed to compensate for modeling uncertainties such as friction and external disturbances. Moreover, to reduce approximation errors and ensure system stability, a robust term is included in the adaptive control law. Simulation results obtained by comparing several cases reveal the presence of the dynamic interaction and confirm the robustness of the designed controller. Then, the effectiveness and merits of the proposed control strategy to counteract the modeling uncertainties and accurately track the trajectory are demonstrated.

In Chapter 4, semi-active suspensions are mounted between the wheels and platform of a robotic vehicle to absorb the vibrations caused by rough terrain. The semi-active suspension consists of a spring and a magneto rheological damper. By combining the dynamic model of the suspended robotic vehicle and the control model of the damper, a new methodology is proposed to evaluate the dynamic stability of the vehicle. The model considers the configuration of semi-active suspensions and the road-holding ability of robotic vehicles. Based on the stability criterion, the chaotic PSO (CPSO) method is used to search the optimum semi-active damping characteristics. The control model of the semi-active damper is checked by sinusoidal response analysis. To verify the dynamic stability criterion and the control method, the proposed methodology is evaluated by simulating a rough pavement condition and comparing the effectiveness of the method to a passive suspension. The results show that the proposed stability criterion is feasible, and the optimal control method yields a substantially improved dynamic stability when the vehicle moves through rough terrain.

Chapter 5 reports the construction and the remote control of a nonholonomic robotic system. The system consists of a three-wheeled mobile platform to keep the robot stable and a 6-degree-of-freedom (DOF) articulate manipulator on top of the platform. First, how its design and work are explained, then the kinematic model of the robotic platform is presented considering nonholonomic constraints and the inverse kinematics of the manipulator is described. In order to generate a visualized user interface, a new development in information technology, which is known as virtual reality, is adopted. All different movements and manual control of the manipulator are shown in a 3-D virtual environment. Teleoperation is realized by using WiFi to transmit the commands and remote desktop from the lower computer to the upper computer. Then, experiments are conducted to prove that the proposed remote operation of the robotic system is reliable and efficient.

Finally, the conclusions of the whole study are presented and the further works are described in Chapter 6.