IMPEDANCE CONTROL OF A CEILING BASED SERVICE ROBOT – SIMULATION AND EXPERIMENT

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1. Introduction

Obstacle avoidance is an important problem in service and mobile robotics. Obstacles on the floor of a room include various objects such as stairs, doorsteps, chairs, tables and even the edges of carpets. Hence, floor based domestic robots need to have strategies to evade randomly placed objects. A new direction in the development of indoor service robots is the use of robotic structures that can move on the, almost obstacle free, ceiling of a room [1], [2].

The present paper describes a new indoor service robot platform developed within the ACROBOTER IST-2006-045530 project [3]. The robot (see Fig.1) consists of an RRT structured climber unit (CU) and a cable suspended swinging unit (SU) that forms a parallel kinematic chain, which is modelled by natural coordinate approach [4]. The SU is actuated by a woundable main cable and 3 secondary cables. Ducted fan actuators are also help to control the orientation of the SU, but despite of the large number of actuators the system is still under-actuated.

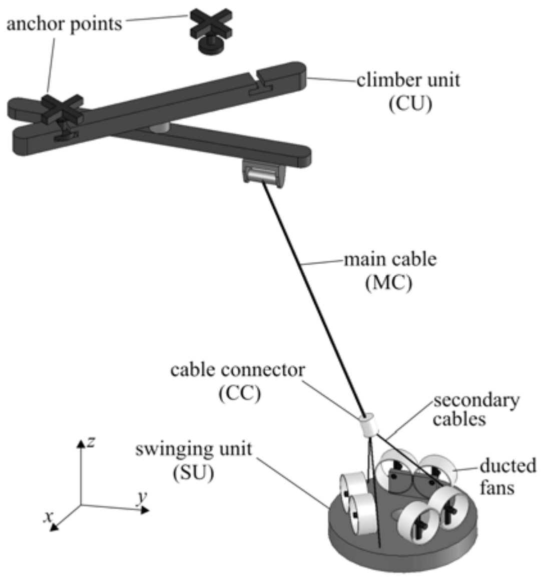

Fig. 1: The structure of the ACROBOTER

2. Motion control approach

The SU is able to move along a prescribed spatial trajectory while it performs various tasks like pick-and-place of objects and manipulating other service robots. The interaction with other objects requires 5-10mm accuracy, which is difficult to satisfy because the system has significant modelling error, and the calculation of the desired trajectory of the under-actuated set of descriptor coordinates is quite complex and computationally expensive. Hence we use impedance control, which handle these uncertainties and unmodeled dynamics of the under-actuated set of coordinates as a perturbation applied on the system.

Commonly impedance control is applied when a manipulator interacts with its environment and the interaction forces have to be accommodated [5], but impedance control is also applied as a robust control method that efficiently handles parametric uncertainties and external disturbances [6]. In the case of a 1DoF linear model the control force F_{i+1} can be computed based on the desired trajectory x^d, the measured position x, velocity $\dot{x}$ and acceleration $\ddot{x}$ and the last value of the computed actuator force F_i:

$$F_{i+1} = \tilde{m}\left(\ddot{x}^d - \ddot{x} + k_D(\dot{x}^d - \dot{x}) + k_P(x^d - x)\right) + F_i \quad , (1)$$

where $\tilde{m}$ is the estimated value of the mass.

3. Numerical simulation and experiment

Fig. 2 shows the simulation results of the vertical trajectory of the SU. The 100mm initial error is eliminated efficiently by a simple PD controller and the impedance control as well. At $t = 2$s the 9.3kg bare weight of the SU was increased by a 3kg payload abruptly. Fig. 2 shows that the impedance control can hold the SU on the desired position exactly, while the PD controller generates a constant error.

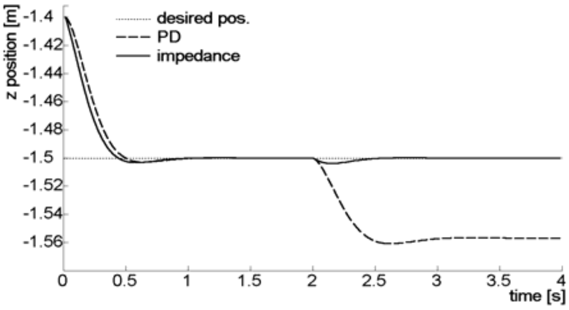

Fig. 2: Simulation of vertical motion

The ACROBOTER prototype can be seen in Fig. 3. The position and orientation of the SU are measured by the pose estimating system integrated by an inertial measurement unit and a vision system. The measured data integration and the control algorithm run on the on-board PC of the CU and the SU distributively.

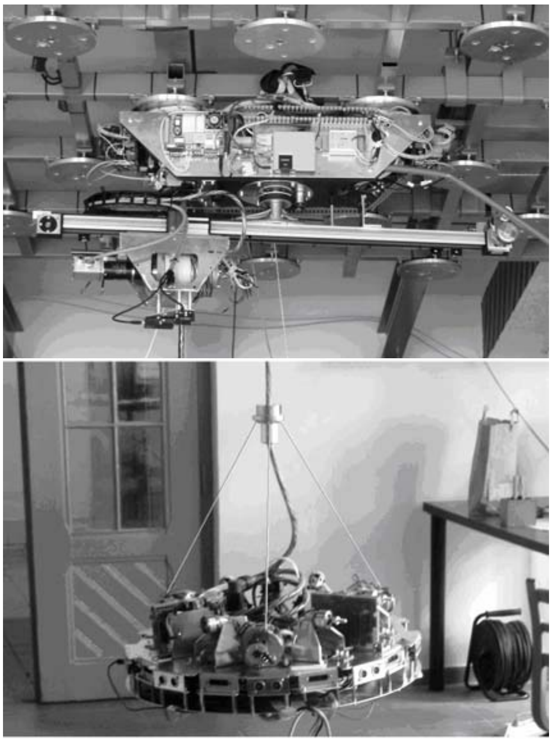

Fig. 3: ACROBOTER prototype

4. Conclusions

The impedance control as an adaptive method was applied for an under-actuated robot considering the parametric uncertainties. A numerical simulation demonstrates the applicability of the presented control concept. The ACROBOTER prototype provides the possibility to obtain experimental results.

5. Acknowledgements

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6. Patents pending

Application No.: HU-P0900466. Application date: July 28, 2009. Title: "Payload suspension system". Application No.: HU-P0900467. Application date: July 28, 2009. Title: "Suspended payload platform thrusted by fluid mass flow generators".

7. References

[1] T. Sato, et al. Construction of ceiling adsorbed mobile robots platform utilizing permanent magnet inductive traction method. In Proc. of *International Conference on Intelligent Robots and Systems*, pages 552–558, 2004.

[2] Balaguer et al. The MATS robot. *IEEE Robotics and Automation Magazine*, 13(1):51–58, 2006.

[3] G. Stépán, et al. A ceiling based crawling, hoisting and swinging service robot platform. In Proc. of *Beyond Gray Droids: Domestic Robot Design for the 21st Century Workshop at HCI 2009*, in press.

[4] J. G. de Jalón, E. Bayo. *Kinematic and dynamic simulation of Multibody systems: the real-time challenge*. Springer-Verlag, 1994.

[5] N. Hogan. Impedance control: an approach to manipulation. *ASME Journal of Dynamic Systems, Measurement, and Control* 107, 1-24, 1985.

[6] R. Kelly, R. Carelli, M. Amestegui, R. Ortega. Adaptive Impedance Control of Robot Manipulators. *Int. J. Robotics and Automation*, 4(3), 134-141.