A Semi-Manual Master-Slave Algorithm for Control of Flexible Micro-Macro Manipulators

Mohammad Jafar Sadigh, Ali Salehi, and Mehdi Keshmiri

***Abstract*— Micro-Macro manipulators are considered as a solution for applications which needs precise manipulation within a large work space. Such systems consists of two parts i.e. a flexible large manipulator – Macro – and a rigid short manipulator – Micro. For two reasons it is difficult to control such systems as a slave. First because of their rather complicated configuration which makes it difficult for operator to manipulate the master, and second because of flexibility of macro manipulator which prevents the slave to follow the typically rigid master. To circumvent this problem, a method based on artificial constraint motion is presented which can semi-manually control the system. To this end, operator controls the macro manipulator by a macro-like master close to the desired path, and a close loop computed-torque like controller which is designed based on constrained motion makes the end-effector precisely track the desired path.**

I. Introduction

Large work space and precise tracking capabilities are two main advantages of micro-macro robots. Macro robot is a large, light weight manipulator which caries micro manipulator as payload. Where macro manipulators are flexible; micro manipulators are small and rigid. Due to flexibility of macro manipulator the whole system is under actuated, which means the number of independent actuators are less than the number of degrees of freedom. Despite its good motion characteristics, control of micro-macro manipulators is quite complicated. Control of such systems in master-slave mode faces additional challenge which is due to complicated configuration of system, and the natural difference between the behavior of rigid master with flexible slave. To solve this one might think of keeping the end of macro manipulator close to the desired trajectory and use a suitable control algorithm to eliminate deviation of end-effector of micro manipulator from desired path. The task could be regarded as simply control the macro manipulator using a master, and compensate for its measured fluctuations using a closed loop control algorithm for micro manipulator, this type of decoupling could only work, if the macro manipulator was not highly flexible. However, for highly flexible systems, conventional control algorithms can not compensate for fluctuations due to coupling of micro and macro manipulators. Many control algorithms which are aimed on control of flexible manipulators are based on active damping control of the flexible links. This, however, forces the manipulator to practice slow and smooth motion. In contrast, one might think of a controller which tries to keep the end-effector on the prescribed trajectory; while the flexible arm is freely fluctuating around the desired path.

A vast number of researches are conducted on the subject of dynamics and control of flexible manipulators, some of these works are mentioned here. Kwan [1] presented a robust adaptive algorithm for hybrid force-motion control of constrained manipulators. Mingli et. al. [2] applied an adaptive controller to the motion of planar two-link flexible manipulators. Xu et. al. [3] developed a controller based on rigid body dynamics of a micro-macro robot. the basic idea was to move the macro robot close to the desired path and employ the micro robot to eliminate tracking errors. Yu and Loyd [4] studied direct and indirect adaptive control of constrained manipulators and based on that they proposed a control scheme for constrained manipulators with uncertainties in mass parameters. Sadigh and Misra [5] presented a method for deriving the minimum-order set of equations of motion for dynamic systems subject to artificial constraints. Sadigh and Zamani [6] proposed an open-loop control based on artificial constrained motion which keeps the end-effector on prescribed trajectory while leaves the flexible arm to fluctuate freely. The method was further developed by Sadigh and Salehi [7] to add an outer-loop control to eliminate deviations of micro manipulator from desired trajectory. Flemmer et. Al. [8] studied stability of teleoperation of surgical manipulators. Weber et. Al. [9] proposed a flexible algorithm for control of telemanipulators. Nogouchi et. Al. [10] presented a method for control a master-slave robot system with moving base. They proposed two mode for the motion namely the GOTO mode and FOLLOW mode, which are used for moving the robot to a certain point and to control its motion in the destination.

The method presented in this paper divides the system in two parts i.e. the macro manipulator which is controlled by master to move close to the desired trajectory while fluctuating freely, and the micro manipulator which is controlled to eliminate any deviation from desired path. Dynamic coupling is considered in equations of motion through an artificial constraint algorithm.

Manuscript received March 18, 2007.

Mohammad J. Sadigh, Assistant professor, Mechanical Engineering Department, Isfahan University of Technology, Isfahan, Iran, (email: mjsadigh@istt.ir)

Ali Salehi, PhD student, Mechanical Engineering Department, Isfahan University of Technology, Isfahan, Iran, (email: asalehi@me.iut.ac.ir)

Mehdi Keshmiri, Assistant professor, Mechanical Engineering Department, Isfahan University of Technology, Isfahan, Iran, (email: mkeshmiri@istt.ir)