MAXIMUM ALLOWABLE DYNAMIC PAYLOAD FOR FLEXIBLE MOBILE ROBOTIC MANIPULATORS

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***Abstract*— Finding the full load motion for a point-to-point task can maximize the productivity and economic usage of the mobile manipulators. The presented paper proposes a technique to determine the maximum allowable dynamic payload for flexible mobile manipulators along with the obtained optimal trajectories. Non-linear modeling of the mobile robotic manipulators by considering both link and joint flexibility is presented; then, optimal motion planning of the system is organized as an optimal control formulation. By employing indirect solution of the problem, optimal maximum payload path of such robots is designed for a general objective function. The paper specially focuses on effects of various important parameters on the maximum payload determination and analyzes them thoroughly. The effectiveness and capability of the proposed method is investigated through various simulation studies. The obtained results illustrate the influences of the performance index, operating time and robot characteristics on the maximum payload path.**

***Keywords*— Flexible Manipulator, Mobile Robot, Optimal Control, Maximum Payload.**

I. INTRODUCTION

Using of lightweight robotic manipulators has been increased in the wide areas, for example manufacturing automation, construction, military and space exploration. Besides the advantages of flexible manipulators such as reducing the energy consumption and safer operation due to reduce inertia, the use of such systems has been recognized as a possible solution to increase the load-to-mass ratio and enhance payload capacity. The first formulation to obtain the maximum payload of a manipulator in the point to point motion was presented by Wang and Ravani (1988). They used the iterative linear programming (ILP) method to solve the problem. But, on their analysis the manipulator links were assumed to be rigid. Tu and Rastegar (1994) investigated the effects of payload on the dynamics of a single link manipulator with the flexible link. Also, the effects of payload on the vibration excitation of a 2R robot manipulator were studied by Parks and Pak (1991). Yue *et al.* (2001) used the finite element method for describing the dynamics of the kinematically redundant flexible manipulators. Then, they computed the maximum dynamic payload trajectory for the flexible robot manipulators.

Mobile manipulators are combined systems consists of a robotic manipulator mounted on a mobile platform. These systems are able to accomplish complicated tasks in large workspaces. They have a compact structure and high maneuverability and are cost effective. Planning a point-to-point task for mobile manipulators has been an important problem that has given rise to much attention. In addition, finding the full load motion on the obtained optimal trajectory in mobile manipulators can maximize the productivity and economic usage of the systems. Finding the maximum payload and corresponding optimal path was formulated as a trajectory optimization problem by Korayem *et al.* (2009). Tanner (2003), by implementing a potential field technique using point-world topology proposed a methodology to motion planning for multiple mobile manipulators. An appropriate mapping was employed to reduce the order of differentials of non-holonomic constraints of mobile manipulators by Papadopoulos and Poulakakis (2001). Then, the path was designed via polynomial functions. A comprehensive literature survey on non-holonomic systems was demonstrated by Bloch (2003).

In particular, the greatest disadvantage of the mobile robotic manipulators is that most of these systems are powered on board with limited capacity. So, incorporating light links can minimize the inertia and gravity effects on links and actuators, and it results to decrease the energy consumption in the same motion. The review of the literature shows that limited research has been carried out for modeling and control of the flexible manipulator mounted on the mobile platform (Modi and Chan, 1991). Moreover, because of the fact that synthesized of flexible character of the links and mobility of the base complicates the dynamics of the system and presents the challenge in the optimization problem, in most cases, link flexibility is neglected in the simulation procedure (Gariblu and Korayem, 2006). Another important aspect in the modeling of the flexible robotic manipulators is considering the flexibility of joints in the robot dynamic equations. However, despite of the fact that it has been determined experimentally that joint flexibility exists in most manipulators, limited researches has been reported on modeling the both link and joint flexibility (Rahimi *et al.*, 2009).

In this paper the non-linear modeling and control of the mobile robotic manipulators by considering both links and joints flexibility have been studied. The paper