Configuration Control and Dynamic Analysis of Redundant Link-type Manipulators

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Summary We present numerical simulations for configuration control and dynamic behavior of redundant link-type manipulators which are boarded on the spacecraft and are operated avoiding obstacles in the work space. Simulations consist of determination of orbit and configuration, and dynamic analysis with/without the elasticity of links. Numerical works have made clear that configuration control using artificial potentials of obstacles is possible and the elasticity of links influences avoidance and final positioning of the manipulators.

INTRODUCTION

Space manipulators are characterized by their lightweight and redundancy because of a quite low load level in the orbit. Utilizing this redundancy of the dynamical system, we can add various functions to the manipulators. Another feature of them is expressed by having no point constrained to the inertial space. If a manipulator changes its configuration in operation, the spacecraft changes its attitude due to the counter force. In this work avoiding obstacles is examined utilizing this dynamical redundancy of the link system which is floating in the non-gravitational space. First, a method for determining the orbit and the configuration of redundant manipulators is studied by point-to-point control approach [1] using the artificial potentials which make possible for the links to avoid obstacles. Second, this configuration change is solved as a dynamical problem of the rigid link system introducing the concept of time. Finally, motion of an actual link system, which has elastic deformation, is discussed focusing on the capability of avoiding obstacles and final positioning as a manipulator.

MODEL AND ANALYSIS

Analytical Model A simulation model, which is in two-dimensional space, consists of a spacecraft main body, a redundant multi-link manipulator, obstacles with the array of line and a target as shown in Fig.1. Configuration and motion of the manipulator system (including a spacecraft main body) are expressed by variables which consist of the translational coordinates and the attitude angle at the center of gravity of each link. The redundant degree of freedom is constrained by geometrical relations among the variables.

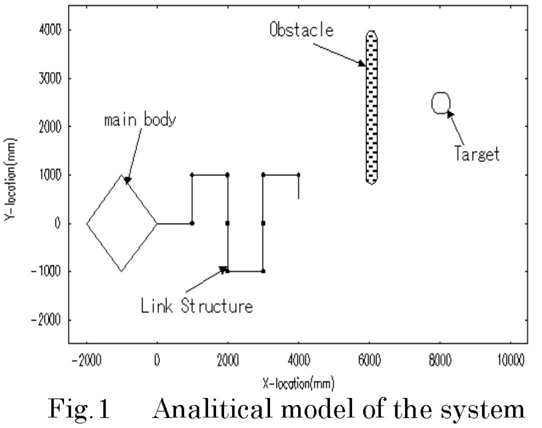

Fig.1 Analitical model of the system

Determination of Orbit In order to start from the initial position, avoid obstacles and converge to the target, artificial potentials are formed in the objective function. The steepest descent method is used to minimize the objective function and obtain the orbit of end effecter. The orbit is divided into finite segments by some points (called orbital points).

Determination of Link Configuration The objective function is formed by artificial potentials in order for all links to avoid obstacles and the sum of change in attitude angle between the adjacent orbital points. Moreover, constraint conditions for constant momentum and angular momentum are given to the variables depending on the free-free condition in the orbit. The configuration of the link is obtained by solving the nonlinear equations which are based upon the stationary condition of the objective function.

Dynamics of Rigid System Rigid multi-body dynamics is adopted to solve the equations of motion for the link system. A series of link configurations corresponding the orbital points is assumed as the time change of hinge angle (difference of attitude angle between the adjacent links), and enforced acceleration functions are given as the polynomial of time.

Dynamics of Flexible System The elasticity and inertia property of flexible links are modeled by using the finite elements for the beam which represent the large bending deformation.[2][3] Nonlinear equations of motion for rigid and flexible link systems are solved by Newmark's iterative time integration scheme .

NUMERICAL RESULTS

Link Configuration A series of link configurations from the initial position toward the target is shown in Fig.2. Not only the orbit of end effecter but also all links of the manipulator can successfully avoid the obstacle. By appropriate choosing the weighting parameter of the objective function, it is possible to find a link configuration by which the end effecter and all links of the manipulator avoid the obstacles. In dynamic analysis for rigid links it was confirmed to obtain the same configuration at each time as the configuration analysis though the figure is not shown here.

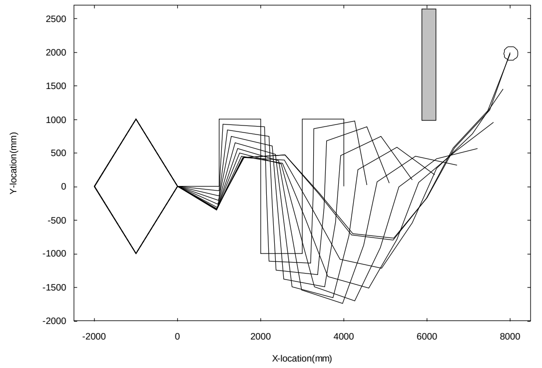

Fig.2 A series of link configuration

Influence of Elasticity When considering the elastic deformation of the link, we can do nothing but change the above conclusion. Influence of the link elasticity appears in two directions; capability of obstacle avoidance and final positioning of the end effecter. As shown in Fig.3, the orbit of end effecter differs between for the rigid and flexible link formulations. This can easily lead to the risk of collision between the link and the obstacles under manipulation. When the elasticity of the link is considerably low, vibration is generated over the manipulator and the final positioning of end effecter becomes quite difficult after stop of manipulation. If the elasticity of the link is properly designed, these can be predicted and easily avoided.

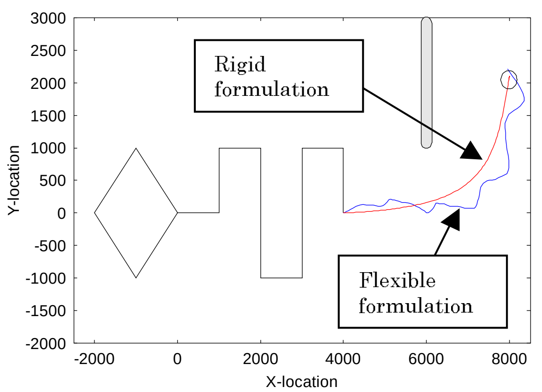

Fig.3 Difference of orbit between rigid and flexible links

CONCLUSION

As results of simulations, end effecter orbits and link configurations were obtained which can avoid the obstacles, and influence of the link elasticity were clarified for the avoidance of obstacles and the final positioning.

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