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Planar Object Manipulation with Multi Fingers Robot Located on a Moving Hand Under Rolling Grasp Constrains

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ABSTRACT: Object grasping by robot fingers with purely rolling constraints is one of the most interesting issues under consideration by many researchers. In earlier studies, the main goal was the manipulation of the object under purely rolling constraints to reach the final stable configuration. In this paper, in addition to deriving kinematic and dynamic equations of the system dual fingers robot and grasping semi-circular object located on a moving hand on the plane with rigid hemispherical fingertips under pure rolling constrained, we investigate object manipulation on the desired path maintaining dynamics stability. Modified multiple impedance control is used for object manipulation and robot fingers by considering the required reforms in this control law. In this method, multiple impedance control is performed by applying the desired behavior of the entire system, including moving base, fingers and object, and dynamics stability condition is satisfied. Power adjustment and the place where forces are applied could have considerable effects on minimizing the fingers slip on the surface. The results of simulations show the eligible object manipulation and dynamics stability by robot fingers and moving base under pure rolling grasp.

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1- INTRODUCTION

Today, multi-finger robot hand control is one of the challenges in the field of robotics. Some articles have examined the issue of grasping and controlling the object in recent years and the challenges in this area have been investigated [1-2]. Chen and Zribi [1] considered a multi-finger robot hand is based on the kinematic and dynamical analysis of the system in which the rolling and sliding conditions between the fingertips and the surface of the object are considered.

Yoshida et al. [3] have examined the subject of grasping an object with a two-fingered hand, that one side of the object is considered curved; the results of this paper indicate that the controller could maintain stability but it is largely dependent on the force required to do this, which means that if the force exceeds the desired level, the stability of the object will be disrupted and it will be exited from the robot. Moosavian and Papadopoulos [4] used the multiple impedance control method to grasp the object by several fellow robot arms. Caldas et al. [5] investigated the displacement of an object grasped by the fixed hand of a robot by applying impedance behavior on the object. Ahmadi and Rastegari [6] used the multiple impedance control method with the necessary modifications on a fixed hand.

2- METHODOLOGY

Fig. 1 shows a moving hand system with an object grasped by the fingers. The object is captured and the tip of the fingers is assumed rigid and hemispherical. The contact between the fingertips and the surface of the object is assumed dot, for this contact, the rolling assumption is considered non-slip.

The Lagrange formula is used to derive the system dynamical equations as follows.

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) - \frac{\partial L}{\partial q_i} = u_i + \sum_{j=1}^{m} a_{ji}\lambda_j + \sum_{j=1}^{m} b_{ji} f_j \ , \quad i = (1 - 9) \qquad (1)$$

In Eq. (1), the term u_i describes the work of the external forces of the system which is the torque produced in the joints of the fingers and the moving base λ_j and f_j also indicates tangential and vertical forces, respectively. It should be noted these forces are formed at the place of contact of the point of fingers with the object surface.

According to Eq. (1), the resulting twelve dynamic equations are sufficient only to identify the position of the fingers, the object and the moving base of the plate. Accordingly, more equations are needed in order to determine the constrained forces λ_j and f_j mentioned above. Therefore, the constrained equations are added to the sum of the dynamic equations.

In this paper, in order to maintain the dynamic stability of the grasped object and also to move the whole system, a multiple impedance control algorithm with the necessary

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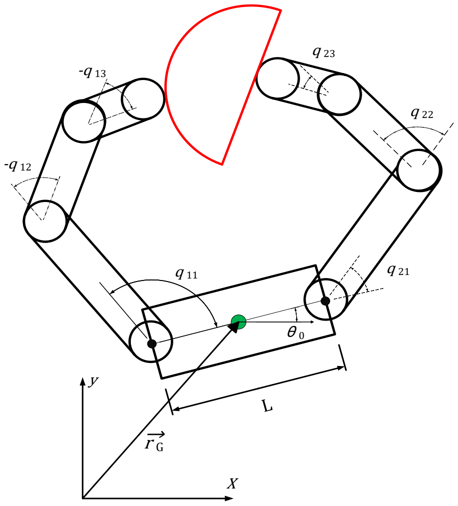

Fig. 1. The system dual finger and object with moving base

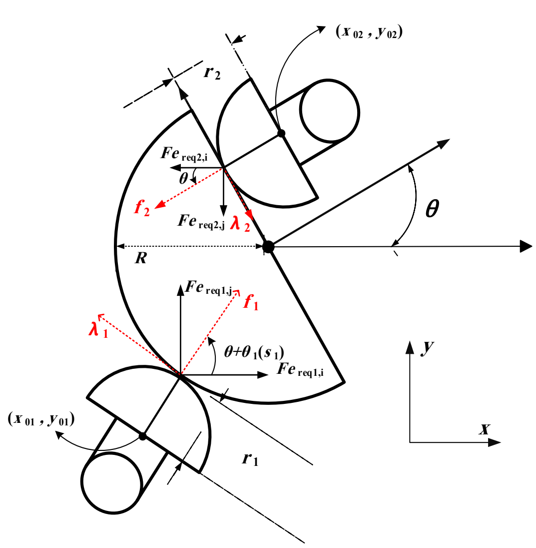

Fig. 2. Transmission of contact force to the center of the final actuator curvature

modifications is used as a control method. According to the multiple impedance control algorithm, the dynamic motion equation, the moving base, and the fingers are considered as Eq. (2).

$$\tilde{H}(q)\ddot{x}+\tilde{C}(q,\dot{q})=\tilde{Q} \tag{2}$$

The dynamic equation of the object is also shown in Eq. (3).

$$M\ddot{x}+F_{\dot{u}} = F_c+F_o+GF_e \tag{3}$$

In Eq. (3), F_e represents the contact forces created between the fingertips and the surface of the object. In order to accurately estimate this force, the necessary modifications in law Multiple Impedance Control (MIC) have been done. For this purpose, Fig. 2 in this equation is considered.

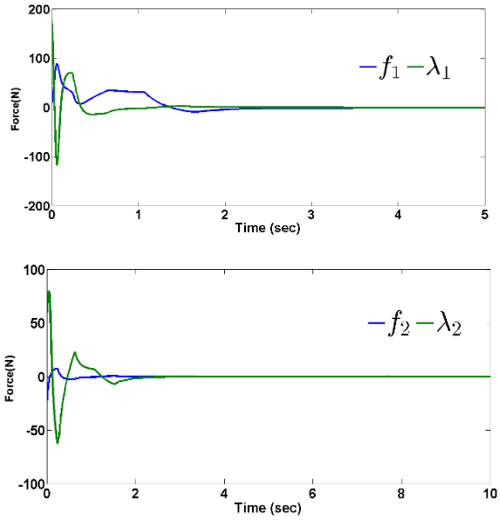

Fig. 3. Grasping force response

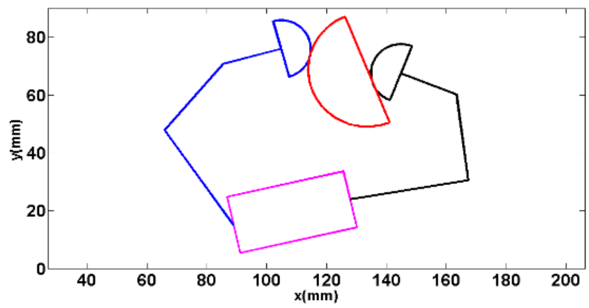

Fig. 4. System position End

According to Fig. 2, first, the image of forces $F_{e_{eq}}$ on both sides in forces of λ_j and f_j to be calculated and then transferred to the specified points (x_{01}, y_{01}) and (x_{02}, y_{02}).

3- RESULTS AND DISCUSSION

As noted, the proper positioning of the contact forces created at the fingertip contact with the surface of the object will have a decisive role in capturing the object, stability, and displacement. The variations of these forces are shown in Fig. 3.

In order to follow the path of the system movement during the simulation process, the status of the system at the end is shown in Fig. 4.

4- CONCLUSION

In this article, grasping and moving an object by two moving fingers of a robot on a plate is examined. After kinematic and dynamical modeling of the system by applying non-slip constraints and maintaining fingertip contact points with the object, a control law has been applied for dynamical stability with the displacement of the whole system. In fact, in most similar works in the last few years, objects have been selected for capturing that have flat surfaces. As it is obvious that the object selected in this research is a semicircle, it is naturally difficult to grasp and sustain due to the curvature of the object, also mainly in the research related to capture object by robot, a constant hand is used for this purpose, while in this article, a moving robot hand is used. In order to achieve the objectives of the research, multiple impedance control method has been implemented by applying necessary modifications on the system. It should also be noted that given the assumptions of kinematic modeling in object capture, multiple impedance control strategy has been developed and expanded. As it is shown in the simulation results, the multiple impedance control algorithms by applying necessary modifications, in addition to the desired dynamic stability, was able to move the robot's moving hand system according to predetermined paths and at the same time, the force required to grasp the object to be used.

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