물체형상 기반 로봇 팔 제어

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Robot Arm Control using Optimized Pinch Grasp Posture Based on Object Shape

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Abstract - Human like robot arm posture for grasping by considering the shape of the target object is quite a challenge in the field of robotics. In this paper, an optimized grasp posture with respect to the shape of the object considering the wrist joint angle and elbow elevation angle, in order to verify that the grasp posture is human like has been proposed. Given a target object, the candidates for grasp are computed by the method described in this paper. For each candidate, the closed loop inverse kinematics has been solved for the corresponding hand position and orientation. From the obtained joint angles through inverse kinematics, the elbow elevation angle has been computed and compared with the elbow elevation angle obtained through human movement data by the characteristic equation. After considering all the candidates, the hand position and orientation with minimum wrist joint and difference in elbow elevation angles has been utilized as the optimized grasp posture. Simulation results are presented.

1. Introduction

Grasp posture planning is a complicated problem and is closely interrelated to the shape of the target object to be grasped. This paper discusses a pinch grasp posture planning for a dual fingered robot arm according to the shape of the target object. When a grasp configuration is generated, it becomes a goal for the path planning of the hand_arm robot[1]. Alternatively, designing a grasp posture planning is challenging due to the complexity in determining the contact points and contact normal of these irregular objects. This difficulty has motivated us to consider an alternative approach based on shape of the target object to be grasped and that too the intension of the grasp posture planning is to be human-like. In order for the grasp posture to optimized, we considered the minimization of elbow elevation angle and the angle between the wrist joint and the fore arm.

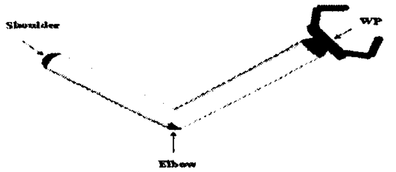
The grasp planning strategy has been proposed in recent years. Kawarazaki, Hasegawa and Nishihara [1]have proposed a grasp planning method for a multifingered hand-arm robot in the presence of obstacles. The collision free grasp configuration was achieved based on the evaluation of the structure of the local empty space around the object to be grasped by using a geodesic dome and distance transformation. Nevertheless they did not consider the shape of the target object. Taylor and Kleeman [2]have presented a grasp planning strategy for a humanoid robot in visual servoing task by applying a heuristic: the target pose that minimizes the angle between wrist and forearm is chosen as being the most comfortable grasp. But their system was restricted to the modelling of rectangular prims. They did not even include primitives such as cylinders and spheres. K. SeungSu [3]stated that the human arm motions are characterized by the elbow elevation angle which is determined using the position and orientation of human hand. Y. Li and N. S. Pollard [6], describes a shape matching algorithm for synthesizing human-like enveloping grasps. But their grasp strategy considered only the multifingered hand robot, ignoring the arm part. Tomovic [5]proposed an approach for synthesizing the control for reaching and grasping objects based on the studies on human motor coordination strategies. K. Kondo [8]stated that the selection of grasp is mainly related to the design of objects to be manipulated and assumed that potential grasps are given as an input. Also Miller [7] proposed an automatic grasp planning strategy by modelling the given target object into primitive objects. Our paper focuses on grasp posture planning for a whole hand-arm robot. Even though the kinematics of the hand part has not been considered, the geometry of the hand part plays vital role in determining the grasp candidates. We divide the grasp posture planning into several sub-problems such as determination of contact point couple, grasp candidate and optimized grasp posture.

This paper is organized as follows. The problem description of a grasp planning for a 6 degrees of freedom robot arm is provided in section 2. The procedure used to generate the grasp configuration is provided in section 3. Grasp posture planning using optimization is discussed in section 4. Implementation aspects are discussed in section 5. Finally, conclusions are presented in section 6.

2. Problem Description

The problem addressed in this paper is to find a pinch grasp posture configuration in which the grasp posture can be accomplished with respect to the shape of the object to be grasped. Before discussing the grasp posture planning, some basic assumptions need to be clarified.

- The kinematics of the arm with the hand part fixed and the geometric information about an object are all known.
- The robot arm used here has a total of six degrees of freedom(DOF). All the joints are revolutionary(Fig.1).
- Since the hand part is fixed, the target object to be grasped should be smaller than the gap between the two fingers constituting the hand part.
- The target object should be placed in the reachable workspace of the robot arm in order to accomplish a complete grasp posture.



<Fig. 1> Configuration of the 6 DOF robot arm

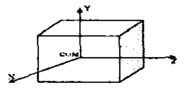
3. Procedure for generating the grasp posture

3.1 Voxelization

Voxelization is nothing but converting geometric object from their continuous geometric representation into a set of voxels that best approximates the continuous object. The target object for which the grasp posture has to be found was voxelized first. Compute the centre of mass of the voxelized object.

3.2 Contact Point Determination

After the estimation of centre of mass, the task is to find the contact points on the target object. This estimation of contact point is done with the aid of Fig. 2.

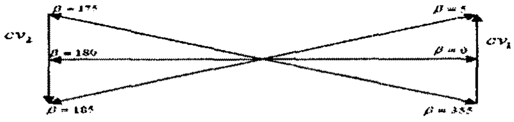


<Fig. 2> Contact point determination

Consider the coordinate frame at the centre of mass(COM) of the object as shown in Fig. 2. Let the angle around the x-axis be denoted as β and the angle around the y-axis be denoted as α. Each value of α denotes the corresponding section of voxel and the contact points in that particular section were represented as per the value of the angle β. More precisely the section represented by α will be further cleaved on the basis of β whose range is (0~360) deg. For each section of voxel, the contact point vector whose magnitude is the distance from the COM to the last cubic cell(voxel) corresponding to β = 0 is given by the general form, $V_1 = (\sin(\alpha), 0, \cos(\alpha))^T$ where V_1 is the starting vector for each section represented by α. Also for each section the normal vector N_1 is given by the general form, $N_1 = (-\cos(\alpha), 0, \sin(\alpha))^T$. The rotation of vector V_1 by β occurs around the normal vector N_1 for each section of voxel represented by α. The last voxel cube corresponding to the vector represented by β denotes the contact point. Thus the number of contact points represented by contact point vectors in each section corresponding to α is given by n = 360/b, where n is number of contact points in that particular section and b is the angle increment of β.

3.3. Grasp Candidate Determination

In order to utilize a contact point on the surface of the object to be a candidate for grasp, the vector generated by this contact point must be perpendicular to the surface of the object and hence the opposite vector which is 180 degree apart from this vector should also be perpendicular to the object surface. Consider the schematic diagram shown below.



<Fig. 3> Determination of grasp candidate

In order to prove that the vector $\overrightarrow{\beta = 0}$ is perpendicular, with respect to the adjacent vectors, vector dot product of the vector $\overrightarrow{\beta = 0}$ and the vector cv_1 connecting the vectors $\overrightarrow{\beta = 5}$ and $\overrightarrow{\beta = 355}$ is computed. Thus the perpendicularity of the vector $\beta = 0$ is verified by checking whether the dot product gives zero or not. Then for the vector, $\overrightarrow{\beta = 5}$ the adjacent vectors $\overrightarrow{\beta = 10}$ and $\overrightarrow{\beta = 0}$ are considered in order to prove whether the vector $\beta = 5$ will be perpendicular or not. When a vector corresponding to β value is perpendicular, then the opposite vector $\overrightarrow{\beta = 180}$ will also be verified whether it is perpendicular or not. When both the opposite vectors are perpendicular to their respective adjacent vectors, as denoted in Fig. 3, then these vectors constitute a candidate couple for grasping. For each section of voxel represented by α, the computation of the candidate for grasping has been done by checking the perpendicularity of both the vectors in the couple. It is quite obvious that the vectors in the couple are 180 degree apart from each other. Till now the grasp candidate for a single section represented by the α value is stated. The same procedure should be continued for the estimation of grasp candidate for the whole object.

From the obtained grasp candidate, compute the wrist position and orientation.

4. Grasp Posture Planning Using Optimization

To accomplish a human-like pinch grasp posture, optimization has been involved in our approach by minimizing the wrist joint angle and the elbow elevation angle. The human elbow elevation angle $\hat{\gamma}$ is obtained by the characteristic equation given by [3].

The elbow elevation angle obtained through our algorithm is given by

$$\theta_{elbow} = \cos^{-1}(\overrightarrow{N_v} \cdot \overrightarrow{N_f} / \|\overrightarrow{N_v}\| \|\overrightarrow{N_f}\|) \quad \rightarrow (1)$$

Where, $\overrightarrow{N_v}$ is the normal vector of the plane consisting the vector from shoulder to wrist and the vector from shoulder to elbow, which is vertical to the ground. $\overrightarrow{N_f}$ is the normal vector of the plane consisting the shoulder position, wrist position and the elbow position under given input variables($\theta_1 \sim \theta_6$) obtained through solving the Inverse Kinematics. Finally the difference in the elbow elevation angles I.e., the difference in angle between the human elbow elevation angle and the computed elbow elevation angle is given by

$$\theta_{difference} = \bar{\gamma} - \theta_{elbow} \quad \rightarrow (2)$$

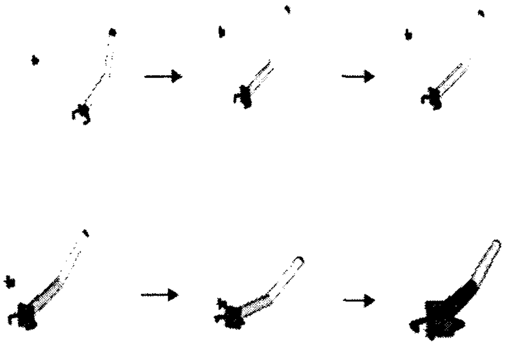
For each wrist posture corresponding to the grasp candidate, the wrist joint angle θ_6 and the difference in elbow elevation angle $\theta_{difference}$ are computed. From these computed values, the optimized pinch grasp posture corresponds to the one with minimum wrist joint angle and minimum difference in the elbow elevation angles between the computed elbow elevation angle and the corresponding human elbow elevation angle.

5. Results and Discussions

In order to clarify the effectiveness of our idea, we have implemented our algorithm to give a human-like pinch grasp posture for the target object shown in Fig. 4.

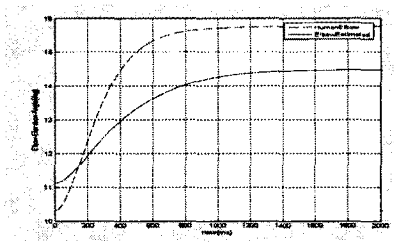
<Fig. 4> Target Object

The trajectory of the robot arm to provide a human-like grasp posture is shown in the following sequence in Fig. 5



<Fig. 5> Trajectory of the Robot arm

The graphical response of the trajectory revealing the estimated elbow elevation and the corresponding human elbow elevation angle is shown below in Fig. 6.



<Fig. 6> Elbow Elevation Angle Response

6. Conclusions

In this paper we have presented a pinch grasp posture strategy based on the shape of the target object to be grasped. We have performed human-like grasp posture by considering the elbow elevation angle and wrist joint angle which play a vital role in natural human grasping. However, this algorithm is not the only method to simulate natural human arm postures and motions. This algorithm may results in collisions between the arm and the obstacles in the environment. We need the inverse kinematics algorithm that utilizes the redundant degree of freedom for the purpose of avoiding obstacles. Also the robustness of the algorithm should be improved a lot so that in human-like postures for some orientation of the target objects may be avoided. In future we hope to explore and devise the algorithm for complete grasping by considering the indispensible factors such as energy, torque and force.

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