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DEXTROUS HAND - GRASPING PRESHAPING

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ABSTRACT

The research conducted in human grasping have emphasized three main phases: the visual location of the target, when the object is analyzed an recognized, the reaching phase of grasping, when the hand preshapes in order to prepare the “shape matching” with the object to grasp, and the third which is the grasping phase. This paper addresses the problem of developing a method that deals with the preshaping phase of grasping and for that we present an indirect approach. For that it is used an image processing algorithm for reconstructing the object that will be grasped and a VR based grasping simulator for validating the stability of the grasp. The result represents a strategy (preshaping and finger trajectories), needed for grasping the object with a real gripper. An evaluation study was conducted investigating the time needed to grasp an object using the presented approach compared with other methods for generating a grasping strategy. The results have shown a significant improvement regarding the time needed for grasping operations on a real gripper.

1. Introduction

It was showed that a prehensile movement can be decomposed in three main stages: (1) visual location of the target, including object recognition, orientation determination and shape and size analysis from visual information, (2) reaching of the target including a ballistic movement, when the hand preshapes according to the shape and size of the object, and fine movements near the target, (3) grasping corresponding to the fingers adjustments against the target. [7], [2] , [10].

In a dextrous manipulation, one of the major problems that remain to be solved is the determination of an appropriate preshape for grasping given the object, under a given manipulation task. In order to have a successful grasp execution, the system should have a successful grasp preparation at preshaping phase. Hence, the grasp preparation or preshaping is one of the critical issues for manipulation with a dextrous robot hand [6].

In previous research [3] the stability analysis was de-emphasized because the preshapes were devised to make it likely that any grasp thus formed is stable, but this analysis is very important because it can validate a successful grasp.

Napier [7] introduced the concept of precision and power grasps. In a precision grasp the object is grasped by only the tip of each digit while a power grasp wraps around the object such that more than one segment on each digit and possibly the palm contact the object. The precision grasp allows maximum manipulation as the tips of each digit can roll along the object surface in any direction the power grasp is more stable. Lyons [8] further refined these definitions for robotics by introducing the lateral grasp in which the insides of the distal (i.e. final) link of each digit contacts the object. This lies between the precision and power grasp in terms of manipulability and stability the tip of each digit can roll along the object surface in one direction.

Often when picking objects off the floor, a precision or lateral grasp are the only feasible grasps in order to power grasp such an object it must be lifted by a precision / lateral grasp and then manipulated into a power grasp. Much of the work on robot grasping has been concerned with the generation of stable grasps. Nguyen used static mechanics to synthesize force closure grasps by maximizing the leeway in contact placement and went on to make these grasps stable by modeling the contacts as virtual springs. However as with most stability analysis the work ignored the kinematics constraints on digit position.

In recent years the preshaping paradigm has been widely recognized as a useful way to ease the complexity of the problem of finding satisfactory values for the degrees of freedom. A hand preshape is the digit posture adopted as the wrist moves towards the object. The grasp is then executed by placing the wrist into a position that encompasses the object and then flexing (i.e. closing) the digits until they make contact with the object.

2. Object analysis

For analyzing the object a 3D reconstruction is made using 2D images for each of the three dimensions. One of the goals of this research is to use simple and low cost products and for that we have used a regular web-cam like in figure 1.

Fig. 1. Web-camera

The web-cam sensor is not specialized for taking high quality pictures and the compensation of this drawback was solved using image processing algorithms. First of all the dimensions of the picture were set to 320*240 pixels. The quality of the picture depends very much, on a low cost product like a web-cam, on the lighting conditions in the room. The raw image captured with the web-cam has a lot of noise and too many colors to distinguish the object. For this reason the background was set to a light hue of grey as close as possible to white. The color of the object was set to a strong hue of grey. The first step for processing the sample taken by the web-cam is to transform the pixels in grayscale. This process involves simply summing the three color values of the RGB channel and dividing by three with the respect to the sensitivity of our eyes to different colors. The correct balance was established to be as follows:

pixel_value = red=green=blue=0.299*red + 0.587 * green + 0.114 *blue

The next step is to identify the object from the background. After the grayscale filter has been applied, for each pixel it's components on the RGB channel are the same (Red = Blue =Green) and so after processing the picture all the pixels having a value bigger then a threshold are turned into 255 on RGB channel (255, 255, 255 = white) and the pixels with a value smaller than the threshold are turned into black (0, 0, 0) on RGB like in figure 2.

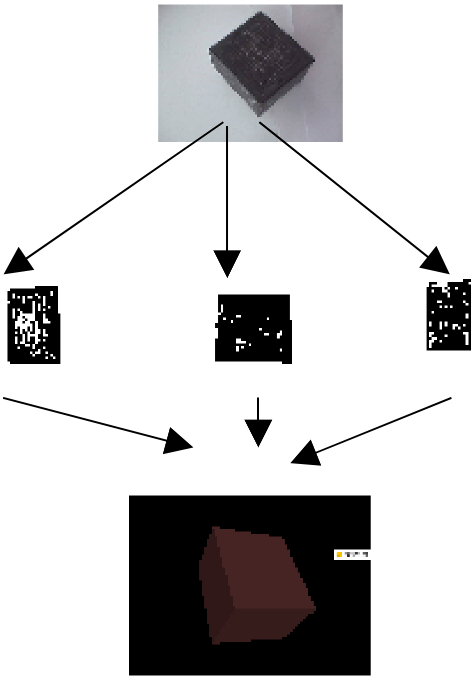

Fig. 2. Reconstruction of the object

The final step is to determine the objects dimensions in pixels and then in the metric system. For that the bounding box is constructed by processing the picture and find the coordinates of the first and the last pixel with the value (0, 0, 0) on X and Y. The distance from the web-cam to the object remain constant when the 2D samples are taken and in this way a relation can be establish between the pixel and the object dimensions as shown in figure 3. By measuring the object and knowing the gripper opening it can be establish if the object is prehensile or not.

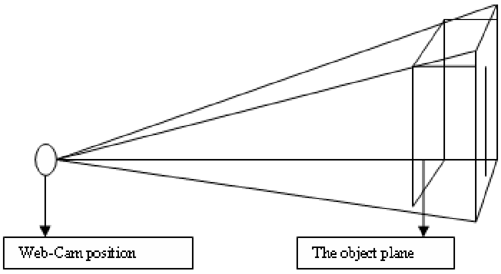

Fig. 3. Distance between web-cam and object

For the purpose of preshaping it is not mandatory to determine the exact dimensions of the object. Depending on the lighting conditions the measurement error was +/- 2mm.

The object reconstruction system has some limitations. The reconstruction is possible only for primitive objects: boxes, spheres, cones and cylinders.

3. Virtual simulation

First step for virtual simulation is designing the CAD model of the gripper which will be tested and simulated. Although CAD software offer support for functional simulation, collision detection and contact points are some problems which can be solved much easier using Grasp It. Grasp It is a grasping simulator that can aid both robotic hand designers and those planning grasping tasks. It provides the user with an interactive environment where he or she can manipulate the degrees of freedom of any given hand model to form grasps. As contact between the links of the hand and an object occur, the simulator analyzes the new grasp on the Y and provides the user with instant feedback concerning the quality of the grasp. This information includes not only numerical quality measures, but also an indication of the grasp's weak point as well as projections of the 6-dimensional space of forces and torques that can be applied by the grasp. For the purpose of this research we are concerned only for testing the grasp stability and to determine the ballistic movement of the gripper towards the object, figure 4.

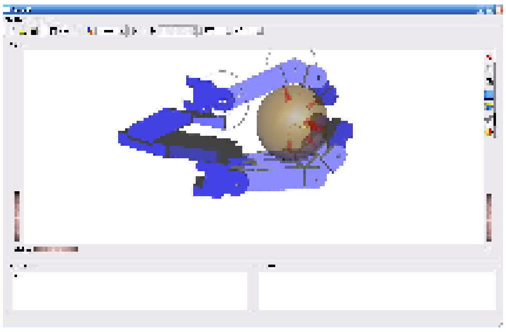

Fig. 4. Grasp It simulation

Grasp It doesn’t support a direct import of the CAD model. First step is to export the designed model into a VRML file, version 1.0. The second step is to transform from the .wrl format into .iv format. This is done very simple by renaming the header of the file from #VRML V1.0 ASCII to #Inventor V2.1 ASCII. The final step for functional simulation in Grasp It is to attach a file to the gripper model which specifies the used links of the hand, their kinematics and position when assembled inside the simulator.

After that, different objects can be grasped by the gripper and quality measurements can be performed. The simulator provides real-time collision detection and can export the position of the gripper, the phalanx’s angles and the contact points. Also can validate if a certain grasp is stable or not and it can be tested if the DOF’s of the object are canceled.

4. Strategy development

A grasp strategy consists of a preshape and a set of digit trajectories, from which a grasp can be formed without movement of the robot wrist. The preshape is a prescribed hand configuration and the digit trajectories are the motions of the tips of each digit after the preshaped formed and the wrist position has been fixed.

Grasp strategies constrain the range of possible digit movements whilst still allowing a sufficient number of degrees of freedom to be able to cope with a wide range of objects. Finally the grasp stability depends very much on the object geometry. Our approach, figure 5, can generate several grasping strategies for the same object because there are numerous ways of grasping an object and still maintaining the stability.

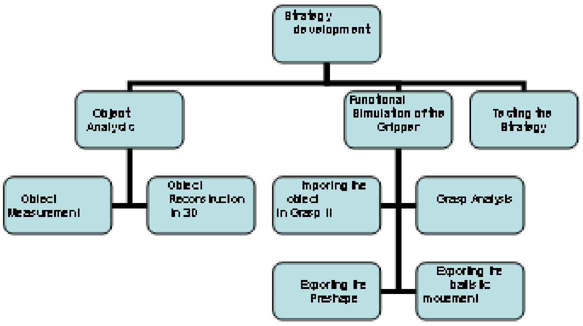

Fig. 5. Strategy of the grasping preshaping

5. Results

The results presented in this research have been tested using the gripper developed at Universidad Politecnica de Cartagena. The UPCT anthropomorphic robot design hand is based on the biomechanics modeling the human hand, as well as on designs by manufacturers of robot hands. The hand has two fingers and an opposing thumb, and four degrees of freedom for each finger. The fingers are mounted on a rigid palm. Each joint of the finger is actuated through 2 polystyrene tendons, routed through pulleys and driven by DC motors. The joints are moved by an agonist-antagonist opponent system. In order to measure joint position, velocity, and direction of rotation, hall-effect position sensors were integrated at each joint of the fingers. Tactile sensors based on FSR (Force Resistive Sensing) technology are mounted on all the joints and on the palm emulating artificial tactile surfaces [4]. The flexibility of these sensors is very suitable for the implementation on the curved surface of the fingertips for precision grasping and manipulations tasks. Each one of the fingers that conforms the biomechanical hand is driven by a mechanism constituted by an assembly of pulleys that control the movements of the different phalanges. Each finger is comprised of three articulations with possibility of turn and an additional articulation that permits to reproduce the movement of abduction, besides serving of element of union of the digit with the palm of the hand. The pulleys (on articulations) are driven by a system of cables like the human tendons. Each articulation possesses two tendons, one flexor and another extensor. The tendon flexor causes the movement of contraction of the articulations while the tendon extensor causes the contrary effect. The mechanical system of actuation arranges of a motor to extend and another to contract the tendon. For control the turn of each articulation, in a synchronized way, the wires remains traction in every instant, and is possible to measure the effort done by the tendons.

The preshape position, figure 6, exported from Grasp It has been tested on the UPCT gripper and a significant improvement regarding the time needed for grasping the object was recorded. The previous approach for grasping the object was to move the fingers from the fully extended position until the tactile sensors were sending the information that the contact is made and a certain value was reached. For that the condition for contact was tested after each rotation of the motors. With the new approach until the preshape position is reached the movement is continuous without any condition to test. The time needed for grasping the object in figure 6 using preshaping is with 14 seconds smaller than the one without. Also by using this approach another important problem was solved, the ballistic movement of the gripper towards the object.

a b

Fig. 6. Preshape Position(a)Grasp Position(b)

6. Conclusions

In a dextrous manipulation, a very important aspect is the determination of an appropriate preshape for grasping a given object, under a given manipulation task. In order to have a successful grasp execution, the system must have a successful grasp preparation at preshaping phase. In this study we have showed that an important improvement regarding the time needed for grasping objects was saved. However there are two main directions for improvement. First is to develop an automatic shape recognition module.

This is already under development and it has a neural network approach at the basis. Also the research will focus on reconstructing different shapes, not only the basic shapes. This requires a specific definition of the surfaces and a more complex shape analysis tools.

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