GRASPING POINTS FOR HANDLE OBJECTS IN A COOPERATIVE DISASSEMBLY SYSTEM

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Abstract: this paper proposes a method to obtain grasping points oriented mainly to disassembly cooperative tasks. It is based in applying morphological operations to binary images, which represent the inertial plane of the product to be disassembled. The method is concern in disassembled application with two or more robotic manipulator working cooperatively, and in task in which robots interact with humans. It takes into consideration constraints like: load balance, cooperation type, and accessible surface. Copyright © 2007 IFAC

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1. INTRODUCTION

Including two or more agents working in a cooperative way increases the performance of the disassembly system because of the synergy that produces a group of entities working together as a team. The value of a group of entities collaborating among them, working as a team, has been proven many times in many domains. For example, in nature a group of animals working cooperatively, can manage to hunt a stronger and bigger animal. Or in the military service a group of men with limited resources and specific abilities are united to create groups with an incredible capacity.

Two groups can be distinguished in cooperative robots work field:

• Two or more robots working cooperatively to solve different tasks. This group is called robot-robot application for forward examples (Tinós and Terra, 2002; Fonseca and Tenreiro, 2003).

• Cooperative tasks in which robots manipulators and humans interact, called in this paper robot-human application (Kumar et al., 2000; Hägele et al., 2002).

The main issue that differences these two groups is the addition of more external and internal sensors when humans and robots interact, in order to avoid humans could suffer any physical damage.

Working in a cooperative way has been growing continuously given the advantage that offers. Some of these advantages are: making tasks that a single robot can not do (for example, a single robot can not transport a beam that exceeds its load capacity, but two agents working in a cooperative way can); sharing information and resources; greater tolerance to failures; and attending between entities for different tasks. Working in a coordinated way also provides the system a faster and effective disassembly, which allows a consequent saving of money to the industries that apply it.

In the disassembly process, it is very useful to consider the advantages of cooperative tasks in which two or more robots take part. Or tasks in which the intervention of a human being is required (Adams and Skubic, 2005).

When robots and human interact determine the suitable grasping points for handling the object to be disassembled it is very important, mainly to provide safe grasping points to the person that work cooperatively with robots. And also to set a grasp position for each agent that make easier the execution of the task.

According to the contact grip established between the end effector and the object, different types of grasps can be distinguished: enveloping grasp, power grasp, or whole hand grasp (Harada and Kaneko, 1998);
and fingertips grasp, or pinch grasp (Inoue and Hirai, 2003). For enveloping grasp the object grasped is surrounded with all the palm hand. For pinch grasp the object is grasped only with the fingertips. In this paper only the second type of grasp contact is considered.

Generally inside an industrial area for cooperative disassembly tasks, the end effector used is a parallel jaw. The parallel jaw establishes a fingertips contact with the grasped object. It is important to highlight that currently many kind of robotic hands existing in the market use dexterous manipulation, however for automatic assembly and disassembly applications, at an industrial environments, the end effectors usually used is the parallel jaw. Dexterous manipulation is rarely used at industrial applications, and it is used more frequently in artificial intelligence, for specific task that requires more accuracy and a precise execution, as a human hand provides. The present work propose in this kind of action use the intervention of human, working cooperatively with robotics manipulators to execute simple actions, that require fixtures manipulation

This article is organized as follows: after the introduction, the system architecture is described in Section 2. Then, in Section 3, the method proposed is developed. In Section 4, applications examples are explained. And finally, conclusions and future works are presented.

2. PROCESS’ ARCHITECTURE

To solve cooperative tasks between robot-robot and robot-human in (Díaz et al., 2006) a task planner is developed. Then it is necessary to find the grasping points to contact the products to be disassembled. For robots that work in semi-structured environments, the adapted grasping points for handle the product to be disassembled are found in function of:

- Cooperation type task: robot-robot or robot-human.
- Product geometry.
- Characteristics of the disassembly task.
- Load balance according to the product to be disassembled.

As shown in Fig. 1 in/out scheme of the Grasp Planner. It is observed that the movement constraints and the type of cooperative work are inputs of the system and determine the grasp point resulting to the different products to be disassembled. The Data Base contains all the geometric information about the characteristics of these products, more precisely a three dimension CAD model for each product, some product are shown in Fig. 2. This model is later divided in three possible inertial planes, which are transformed in binary images, which are used to obtain the corresponding product grasping points.

First the Grasp Planner analyses which of the three possible inertial planes according with the inside constraints is most suitable for finding the grasping points. As it is observed in Fig. 3 where a three dimension model of a CD Player is represented. Here it is observed the three possible inertial cut hyper planes (xy Plane, zy Plane and zx Plane).
Assuming an object in a free space with no constraints, the cut plane chosen is the plane with the greatest surface. If other restrictions have to be considered, this plane can change. For example according to the accessible surface of the object, or geometry of physical restrictions, like hot or sharp surfaces, that must to be taken into account mainly when a human is introduced to manipulate an object. The selected plane gives a binary image. For this image, it is calculated a morphological operation skeletonization to determine the main characteristics of the object that allow finding the possible grasping point. The skeletonization, also called medial axis transform, is a thinning procedure that is usually used in pattern recognition and shape analysis. It is a method that allows extracting the features of an object preserving its homotopy.

2.1 The skeletonization.

To calculate a region skeleton thinning algorithms are used. The skeletonization is defined as the process that eliminates boundaries and borders of a planar figure preserving its connectivity without eliminating the ending point until get the figure skeleton, while preserving the structure and the homotopy of the figure that represent a specific object (Dougherty and Lotufo, 2003).

Fig. 4. Different objects skeletons.

5 PROPOSED ALGORITHM

The proposed algorithm is based in obtaining the skeleton of a two dimension binary image that represents the object to be disassembled, and calculate the centroid of this figure. Assumed that the geometric centroid of a physical object coincides with its mass centre, because the object has uniform density, and the object shape and density have symmetry which fully determines the centroid, here in this application the centroid is considered like the centre of mass. The gravity centre also is considered given that all products are under the uniform earth gravitate field.

The grasping points are obtained having into account the skeleton, the object centroid called \( c \), and criteria shown in Fig. 5, where \( p \) identifies the grasping points for robots, and \( h \) represents the most suitable grasping point for human operators. The grasping point location is searched inside the skeleton, this grants the points always lay in the object to be disassembled.

One Robot:
\[
\min \frac{p_c}{p} \quad (1)
\]

Two Robots:
\[
\begin{align*}
\min & \frac{m_c}{p_1p_2} \quad (2) \\
\max & \frac{p_1p_2}{p_1p_2} \quad (3)
\end{align*}
\]

Three Robots:
\[
\begin{align*}
\min & \frac{m_c}{p_1p_2} \quad (4) \\
\max & \frac{p_1p_2}{p_1p_2} \quad (5) \\
\max & \frac{p_1p_2}{p_1p_2} \quad (6) \\
\max & \frac{p_1p_2}{p_1p_2} \quad (7)
\end{align*}
\]

Robot-Human:
\[
\begin{align*}
\min & \frac{m_c}{p_1h_1} \quad (8) \\
\max & \frac{p_1h_1}{p_1h_1} \quad (9)
\end{align*}
\]

Robot-Robot-Human:
\[
\begin{align*}
\min & \frac{m_c}{p_1h_1} \quad (10) \\
\max & \frac{p_1h_1}{p_1h_1} \quad (11) \\
\max & \frac{p_1h_1}{p_1h_1} \quad (12) \\
\max & \frac{p_1h_1}{p_1h_1} \quad (13)
\end{align*}
\]

Where:
- \( c \) : centroid
- \( p_1 \) : grasp point robot 1
- \( p_2 \) : grasp point robot 2
- \( p_n \) : grasp point robot \( n \)
- \( h_1 \) : grasp point human 1
- \( h_2 \) : grasp point human 2
- \( h_n \) : grasp point human \( n \)
- \( m \) : center rect that form two entities working cooperatively e.g. \( p_1p_2 \circ p_1h_1 \)
- \( t \) : centroid triangle that form tree entities working cooperatively e.g. \( p_1p_2p_3 \) or \( p_1p_2h_1 \)

Fig. 5. Algorithm Criteria.
Grasping points for robots cooperative work are obtained carrying out the (1), (2), (4) and (10) conditions that minimizes the distance between the grasp points and the centroid of the object providing more stability to the grasp. Conditions (3), (5), (6), (7), (9), (11), (12) and (13) maximize distance between the grasp point of the entities that are working together in the same object, providing more security to the system and reducing the collision possibilities in the work areas intersection (Díaz et al., 2006). These conditions are mainly important when humans cooperate with robots to execute actions working on the same object.

Assuming that robots with similar characteristics are being used in two robots application, as shown in Fig. 5, to obtain an equitably balance of the charge, $m$ is located at the medial point of the segment formed by the grasping points of each robot. In three or more robots applications, $t$ is the centroid of the new figure formed by the grasp points of each robot.

Obtaining the grasping points for cooperative tasks between robotics manipulators and humans, $m$ and $t$ can change according to physical constraints of the object and according to the load balance to be done. As shown in Fig. 6 for Robot-Human interaction $m$ moves near the robot grasp point, therefore the robot manipulator supports most of the object weight, releasing the human of carrying heavy objects. If two robots work cooperatively with a human (Robot-Robot-Human), executing an action on the same product, $t$ moves to the medial point between the two robots grasping points, that practically releases the human of supporting any load. In this way a load balance that facilities the human intervention in a working cooperative cell is executed.

Steps of the proposed algorithms are:

i) Choose the hyper plane to obtain that represents the object to be disassembled.

ii) Erode the image to avoid the grasp points lay on the boundaries of the object. Taking the tool used into consideration.

iii) Calculate the centroid of the figure that represents the object

iv) Skelnetization of the object.

v) Ask the amount of agents that interact in the task.

vi) Adjust $t$ or $m$ according to the load balance to be done.

vii) Find the possible grasping points and evaluate them according to the task to be executed.

viii) Obtain the corresponding grasping point for each entity that takes part in the disassembly process.

3. 1 Load Balance.

The load balance is analyzed supposing that a bar with length $l$, and uniform load distribution $q$ is handled by two robotics manipulators. The grasping point $p_i$ and $p_j$ are obtained. The load that each robot has to support is represented as $P_i$ and $P_j$ respectively (Fig. 6).

\[ Q = qJ \]

\[ x.P_i + l.H_i - \frac{l}{2}Q = 0 \]

\[ P_i + H_i - Q = 0 \]

\[ H_i = Q - P_i \]

\[ x.P_i + l.(Q - P_i) - \frac{l}{2}Q = 0 \]

\[ x.P_i + \frac{1}{2}lQ - l.P_i = 0 \]

\[ (x - l).P_i = -\frac{1}{2}lQ \]

\[ P_i = \frac{Q}{2(1 - \frac{x}{l})} \] (16)

From the equation (16) the variations of the load that each agent supports according to $x$ is obtained. Moving the grasp point of the robot near to the centroid of the load balance change like is show in Fig. 7.
It is observed that \( x \) moves between 0 and \( c \) (\( 0 \leq x \leq c \)), according to the load balance to be done. If \( x \) is upper \( c \) the load that support \( P_i \) result negative therefore \( H_i \) must support a weight greater than \( Q \). When \( x \rightarrow l \), \( P_i \rightarrow \infty \) that means it is physically impossible to hold a bar with the two grasping points in the same extreme.

From the equation (16) the load balance graph is obtain. It shows the total load ratio that corresponds to each agent that carries the bar cooperatively, according to the \( x \) variation trough the bar length \( l \).

Then according to the geometrical constraints of the object and the size of the finger of the parallel jaw, an inaccessible area result shown in Fig. 9. In this figure the two grasping point for each robot are observed.

Fig. 7. Load balance.

3 APPLICATION EXAMPLE

Parallel jaws and two robotic manipulators, a Intelitek® Scorbot and a Mitushubishi® PA-10 are used in the work cell. The grasp point named \( p \) obtained for each robot represents the location to place one of the fingers of the parallel jaw. The grasp points are obtained considering only the local characteristics of the object. In this application example a CD player is disassembled. First from the 3D data base the work plane is selected.

Fig. 8. Work Plane selected.

In (Díaz et al., 2006) is explain the cooperative task planning to execute this action, the Scorbot removes the CD Player, but the grasp point is forcing the operative extreme to support negatives loads, it is observed in Fig. 10 Therefore a solution is to displace the grasp point near the centroid, to achieve a homogeneous load balance (\( P_i' \) and \( P_i'' \)). It is important to take into account that this point in this case due to the product and the jaw geometry lay into the inaccessible area shown in Fig. 10, therefore alternative accessible grasp point are searched (\( P_i' \) and \( P_i'' \)) until find the optimum grasp point for each product (\( P_i' \) in this case, Fig. 10).

Fig. 9. Grasping points for two robots.

Fig. 10. Moving the grasp points to balance the load.

To achieve correct load balance, first the Scorbot separate the CD from the external case of the PC. And the PA-10 hold the object to allow Scorbot correct the grasp point, to other grasp point that not force the end effector to support bigger loads. This sequence is observed in Fig. 11.
4 CONCLUSIONS

A method to obtain grasping points is set out. The major advantage of this method is that it works with any kind of product, concaves, convex, etc. Working with skeletons of the products guarantee the grasp points always lay on the object. Stability of the grasp is given by considering the centroid of the object to calculate them. This method allows obtaining the grasping point for a single manipulator or more robots working cooperatively. Also allows specifying the grasping points when robots work cooperatively with humans, considering safety parameters and load balance.

This paper proposal is oriented to work cooperatively inside a disassembly cell, but it can also be easily adapted to other areas. A good example is in the area of service robots, in which this method could be applied to use human-robot cooperation for assisting handicapped people.

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