TASK PLANNER FOR HUMAN-ROBOT INTERACTION INSIDE A COOPERATIVE DISASSEMBLY ROBOTIC SYSTEM

Carolina Díaz, Santiago Puente and Fernando Torres
University of Alicante
Crta San Vicente del Raspeig s/n
PO Box 03080, San Vicente del Raspeig- Spain

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Abstract: This paper develops a task planner that allows including a human operator which works cooperatively with robots inside an automatic disassembling cell. This method gives the necessary information to the system and the steps to be followed by the manipulator and the human, in order to obtain an optimal disassembly and a free-shock task assignation that guarantees the safety of the human operator.

1 INTRODUCTION

Disassembly is defined as the process of separating pieces that compose an object (Torres and Puente, 2006). In this 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). Some of those advantages are: making tasks that a single robot can not do; sharing information and resources; greater tolerance to failures; and attending between manipulators and humans for different tasks. Working in a coordinated way also provides the system a faster and an effective disassembly, which allows a consequent saving of money to the industries that apply it.

The value of a group of entities collaborating among them, working in group as a team has been proven many times in many domains. For example, in nature a group of animals working cooperatively as a team, can manage to hunt a stronger and bigger animal. Also in the military service a group of men with limited resources and specific abilities are united to create groups with an incredible capacity. These examples illustrate that a group of entities with similar or different abilities joined to work in a team, can produces a work unit with abilities and capacities greater than the sum of its parts (Navarro-Serment, *et al.*, 2002). Including two or more agents working in a cooperative way increases the performance of the disassembly system, because of the synergy produces a group of units working together as a team.

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, named in this paper robot-human application (Kumar *et al.*, 2000; Hägele *et al.*, 2002).

The remarkable issue that differences these two groups is that when humans and robots interact, the system must consider more external and internal sensors in order to avoid humans suffering any physical damage.

It is important to highlight that this work tries to use the intervention of a human in task in which the person has more abilities and general comprehension than a robot. Robot manipulators transform in intelligent agents that assist humans in all kind of task and activities, taking advantages of the resources and characteristic of each agent and minimizing the negative properties collaborating between them.

In the present paper it is observed the advantages that bring to include a person working in a cooperative way inside a disassembling cell. Until recently in most of industrial environments the robot manipulator was isolated through securities fences,

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avoiding any possible contact or interaction with human operators. These were the methods for guaranteeing the safety of operators inside these environments (Corke, 1999; Kulic and Croft, 2005; Ikuta and Nokata, 2003). The present paper set up a task planner that allows human-robot interaction taking into account safety aspect.

This article is organized as follows: after the introduction in Section 2 the process' architecture is described. Then, in Section 3, the cooperative task planner is developed. In Section 4 an application example is explained. And finally conclusions and future works are presented.

2 PROCESS' ARCHITECTURE

The process' architecture used here is the same developed in a previous work (Díaz *et al.*, 2006); it is shown in Figure 1.

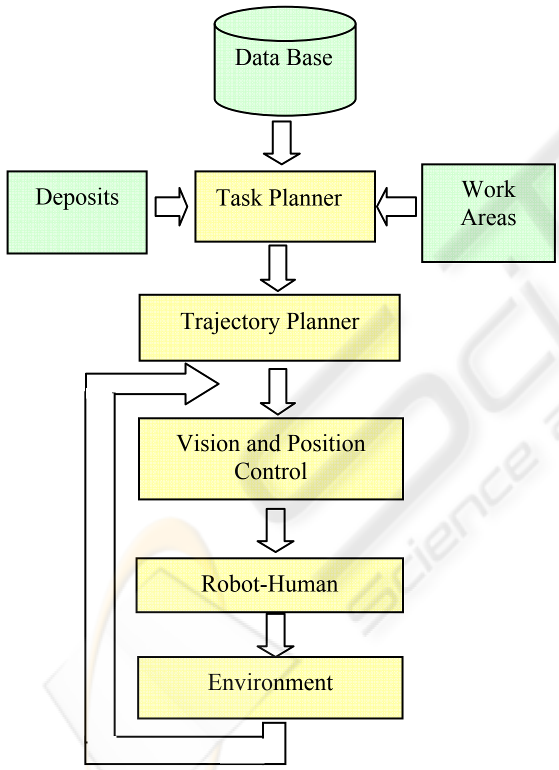

Figure 1: Process' Architecture.

In this scheme the Data Base contains a list of tasks for disassembling products, through a relational model graph developed in (Torres *et al.*, 2003). The Task Planner determines which action corresponds to each agent. Then a position and a vision control are applied to avoid collisions in real time between robots and humans, and also collisions of these with the environment. This grants the system the possibility of doing on-line corrections. This control is not developed in this paper.

The Task Planner has all the information of the layout of the cell, the storage deposits position, and the location of each agent work area and their intersection (Fig. 2). This information is very important in order to avoid collision, between robot and human and with the environment.

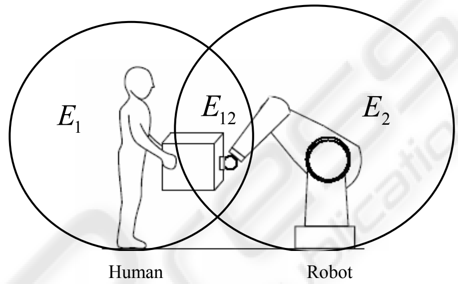

Figure 2: Scheme human robot working areas.

The Task Planner is the one that determines the sequence to be followed by the manipulator and the human who take part in the disassembly task; looking to obtain the maximum advantage of all the resources, and reducing the total disassembly time.

Is important to highlight the Vision and Position Control that is the one on charge to detection and avoid collision, is not develop in this paper. What is looking for is obtaining an optimal cooperative task planning that avoids possible collision in the intersection area, in normal condition. In case, for example, when accident takes place the Position and Vision control is the one that have to take the correct decision. In this project, it is also working with a special environment (Corrales *et al.*, 2006) that allow to monitoring the location of the human operator in real time.

3 TASK PLANNER

The Task Planner developed in this paper for robot human interaction is based on (Diaz *et al.*, 2006) for robot cooperative works; it is important to remark that only a few modifications have been necessary to adapt this Task Planner for human-robot interaction. This brings out the flexibility of the proposed method. The major modifications have to be done in another block of the system's architecture, like in the Vision and Position Control to allow the system monitoring the human and robot movement inside the cell.

To reduce risk factors inside an industrial cell in which robots and humans works Burke *et al.*, 2003 proposed three criteria:

- Redesigning the working cell looking for the way that the danger is eliminated.
- Control the danger thought sensor or physical limits.
- Warn and train the human operator which work in the cell.

In this paper the last two items of these criteria are considered; controlling the danger through a vision and position control and educating the person about the dangers of working cooperatively with robot manipulators in a disassembly system. The dangers are reduced considerably making a suitable task plan. The planner is the system that determines to which agent correspond each action execution and the precise moment to be executed, to obtain a successful disassembly free of collisions.

Given the relational model graph described on (Torres *et al.*, 2003), a hierarchical graph that represent the structure that sets up the product to be disassembled is obtained. This graph also contains all the actions to disassemble a product and gives much useful information, like the precedence and the parallelism between tasks. Crossing this graph the rules that specify the sequence to disassemble a product are obtained. In Figure 3 the component of a PC's mouse are shown and in Figure 4 the relational model graph for disassembly this products is observed.

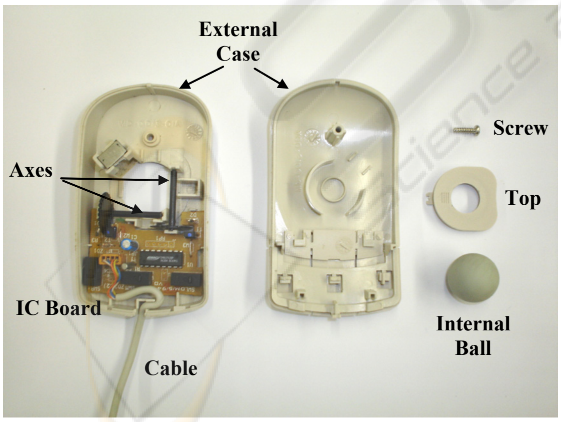

Figure 3: Components of a Pc's mouse.

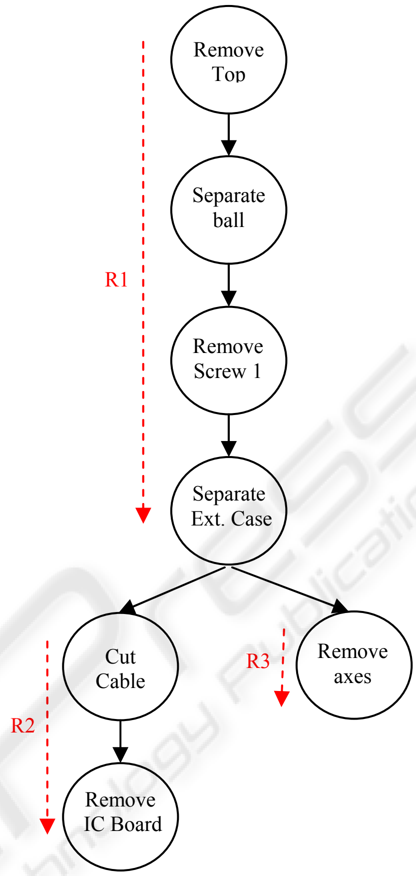

Figure 4: Hierarchical Graph to disassemble a PC's mouse.

In Figure 4 the product considered corresponds with a PC's mouse. In this case the rules for this object are:

Rule 1= Remove Top + Separate internal boll + Remove Screw 1+ Separate external case.

Rule 2 = Cut Cable + Remove CI Board.

Rule 3 = Remove axes.

The Task Planner based on these rules to constructs the decision trees that allocate the different tasks between robot and human, to obtain a cooperative and successful disassembly of a product.

In a working cooperative environment and taking into account the workspace intersection, two types of task are defined:

- Common Tasks: are those in which is required two or more entities working in the same specific object. For example the extraction of a CD player.
- Parallel Tasks: those in which each entity does a specific task. The presence of only one entity is required. It can be executed in simultaneous way. For example the extraction of a Card Slot and simultaneously the extraction of the Energy Source.

Modelling these rules and according to the type of task to be executed (*Tc* o *Tp*) the decisions trees are constructed. These determine the assignment of all the actions to be done; to disassemble the product in an optimal and cooperative way.

From the relational model graph the different rules are obtained. These rules are divided into actions **A**, for each action corresponds a tool **T**, and each action is divided into sub-action if it is possible.

In general, to construct the decision trees and to model the system, the following sets are defined:

Number of Robots = $\left[R_1, R_2, ..., R_i, ..., R_j\right]$

Number of Humans = $\left[H_1, H_2, ..., H_i, ..., H_j\right]$

Task's Type = $[Tc, Tp]$

where: *Tc:* Common Task.
Tp: Parallel Task.

Rules = Task = $[Ts_1, Ts_2, ..., Ts_m]$

each task is divided in actions.

Actions = $[A_1, A_2, ..., A_n]$

and each action is divided into sub-actions

$$\Rightarrow \quad A_1 = \left[A_{11}, A_{12}, ..., A_{1p}\right]$$
$$A_2 = \left[A_{21}, A_{22}, ..., A_{2q}\right]$$
$$\vdots$$
$$A_r = \left[A_{r1}, A_{r2}, ..., A_{rs}\right]$$

For each action, a respective tool exists. In other words, it exist the same number of actions as tools:

Tools = $[T_1, T_2, ..., T_n]$

In tasks in where robot and human cooperate. The actions are assigned to the human due to their qualities and abilities. It is obvious that the hands are considered as the tool that the worker used to execute action.

According to the sets described before and to the type of task, the trees that determine the optimal allocations of the actions were constructed like are developed in (Díaz *et al.*, 2006). In order to determine the optimal path an information gain is empirically assigned for each robot or human. In this work the costs are assigned according to the characteristics of each action. Time is the most important characteristic in this application.

There are to highlight that the system does not handle with synchronizing the task between human and robot, it only perform the distribution of task between them. The synchronization between them is ensured by the vision and position control system.

4 APPLICATION EXAMPLE

Here a disassembled cooperative task is executed working in a cell compose by only one human operator and one robot manipulator Mitsubishi® PA-10. Named H_1 and R_1 respectively

Modeling from Rule 1 obtained from the relational model graph shown in Fig. 4 it is obtained:
Rule 1= Remove Top + Separate internal boll + Remove Screw 1+ Separate external case.

It is sub-divide into two tasks:

T_{s1} = *Remove internal ball*
= Remove Top + Separate Ball

T_{s2} = *Separate external case*
= Remove Screw 1 + Separate Case.

Executing T_{s1} for this application is divided into two actions according to the corresponding tool used to execute each action. To execute T_{s1}, first one of the entities has to hold the mouse while the other removes the top, then:

T_{s1} = *Remove internal ball*
= Grasp mouse + Remove Top + Separate Ball

where: A_1 = *Grasp mouse and Separate ball* (Parrallel Jaw)
A_2 = *Remove top* (Handing Extraction)

$A_1 = A_{11} + A_{12}$ it is sub-divided in two actions:
where: A_{11} = *Grasp Mouse*
A_{12} = *Deposit Ball*

$A_2 = A_{21} + A_{22}$ it is sub-divide into two actions::
where:
A_{21} = *Extrac Top*
A_{22} = *Deposit Top*

In this application the task is a Common Type Task *Tc*. The human and the robot work simultaneously on the same object, and the work area must be the intersection E_{12} as shown in Figure 2. The decisions trees where the actions are assigned result obviously, given the simplicity of the working cell, then result:

$R_1 \rightarrow A_1$ the first action is asigned to the robot PA-10.

$H_1 \rightarrow A_2$ the second action is asigned to the human.

The decision tree shown in Figure 5 is constructed for planning T_{s1}.

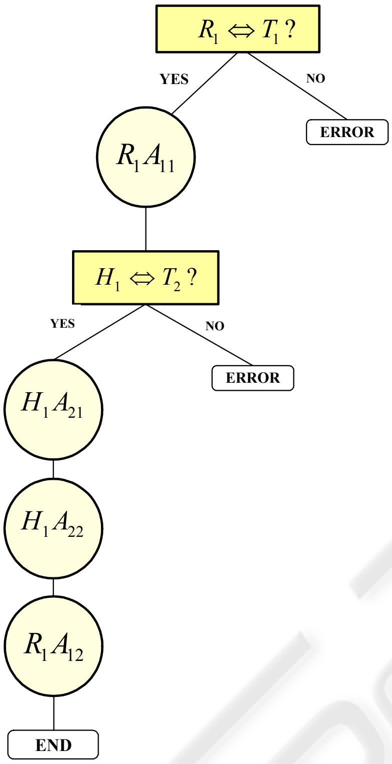

Figure 5: Decision Tree T_{s1}.

In Figure 5 it is observed that the tool availability is checked in each moment to make the system more reliable. There, actions cannot be executed in a parallel way because of the precedence between them or to avoid the human may suffer any physical damage. For example, action A_{12} which corresponds to deposit the ball, cannot be started until the action A_{22} (human extracting the top) has finished.

In Figure 6 the real sequence to execute T_{s1} is shown.

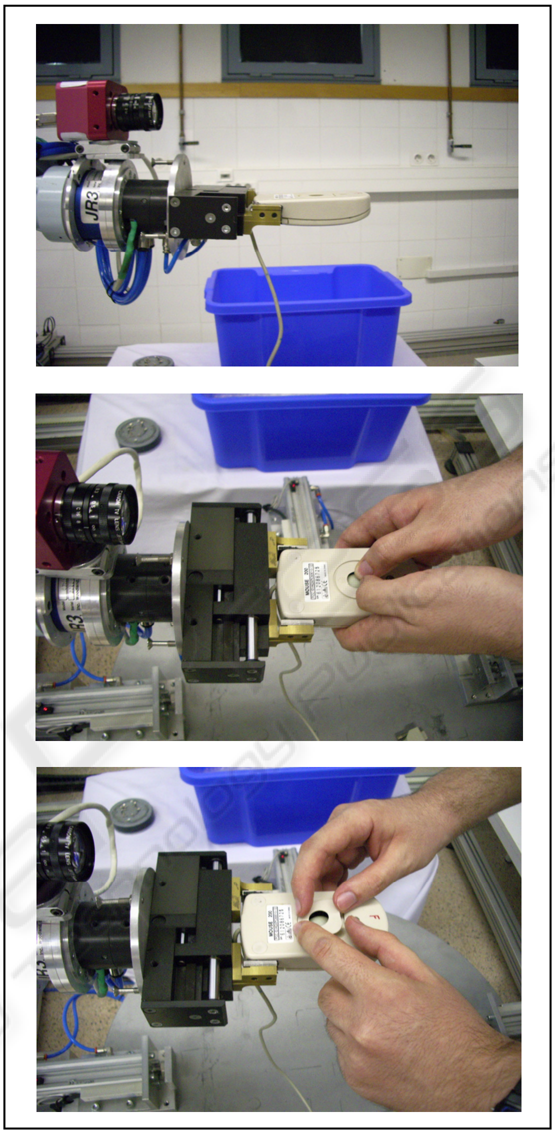

Figure 6: Sequence T_{s1}.

5 CONCLUSIONS

A cooperative Task Planner is set out. It allows developing cooperative task between manipulator and task in which robot and human interaction is needed inside a disassembly system. The main goal is to provide a safe and flexible cooperative system. This system could achieve greater productivity in the industry.

Robots are use to assist the human operators in some specific industrial tasks, reduce the fatigue, and increase the accuracy in areas in which only a human can bring global knowledge, experience, and comprehension in the executing of the task

It is observed, that the modifications made in the task planning block to adapt it to cooperative tasks between man-robot, are minimum. Therefore a future project work might consider extending the use of the Task Planner to other types of applications like services robots, where work between robots and humans has a great potential.

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