Human-robot cooperation with AND/OR graphs

Clayton Leite, Aziza Zhanabatyrova

clayton.fk06@gmail.com, aziza91@inbox.ru
University of Genoa

February 27, 2017

Abstract

This paper proposes a solution for the case of a mutual work between a robot and a human by the use of an AND/OR graph to model the desired behaviour of the robot under certain circumstances. A priori, the motivation for studying such a case is justified in a quick introduction. Then the problem is fully described, as well as a solution is proposed. The solution is put into practice and its results are explained and characterized as positive. Nevertheless, limitations in the proposed solution are cited, as well as some possible improvements to address them. Finally, some final notes about the overall work are outlined.

I. Introduction

In the early days of robotics, robots were limited to deal with environments of heavy industrial work, replacing workers in tiresome and repetitive tasks. However with the current expansion in robotics, robots are coming even closer to people by participating in their everyday life. This approximation leads to an inevitable conclusion: robots and humans have to learn to communicate, to interact and to cooperate with each other in order to achieve common goals.

The field that studies and develops paradigms to deal with the mutual relationship between robot and human is growing quite fast and it is becoming essential in robotics as end consumers are more than ever looking for machines capable of helping them in everyday life tasks.

This work studies a case of an interaction of a robot and a human in an everyday situation: setting up a table for a meal. In such a process there should be an agreement between the robot and the human on what to place on the table. The robot should not try to place the object that the human has already placed and the robot should take action at least as soon as the human has finished moving something. Therefore, in this project, before anything, there is the need to develop a method to make it possible for the human and the robot to work together.

II. Methodology

i. Problem description

The human-robot cooperation project consists in a cooperative work between a robot and a human in setting up a table with objects like plate, glass, fork, knife and spoon. The human begins the process by moving an object to a predefined position. Following this, the robot is on its turn and should place one of the missing objects in a predefined position on the table. The robot's decision on which object to place has to be optimal in the sense of making the process of setting up the table easier and faster.

Also the robot should be always aware of the actions of the human in order to have the knowledge of which objects are still yet to be moved.

ii. Solution proposal

The approach to the problem described will be composed by the Baxter robot manufactured by Rethink Robotics and the software will be written in the ROS (Robot Operating System) framework.

The Baxter has the feature of programming by demonstration (PbD) which is the capability of learning new sequences of movements by the means of a demonstration performed by a worker, instead of using programming languages. This paradigm will be used to teach the robot the movements of grabbing and placing objects on the table.

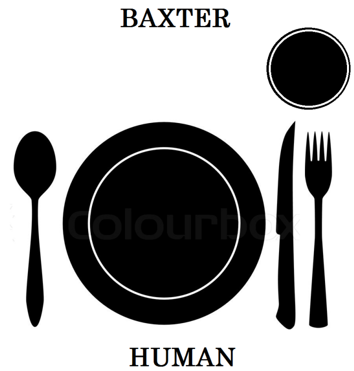
To find the optimal decision that the robot should take, i.e., which object it should move, an AND/OR graph will be designed for the system and the choice of the Baxter should be such that the cost of the path in the AND/OR graph will be minimal.

The final configuration of the table will have a spoon, glass, plate and cutlery (fork and knife together and considered as just one object), thus four objects need to be placed in order to reach the desired state. The positions of each object are fix and showed in the Figure 2.

The diagram of the architecture of the software is illustrated in Figure 1 and it is composed by the following three nodes:

- Main node
- Baxter movement node
- AND/OR node

Figure 2: *Table configuration.*



iii. The software

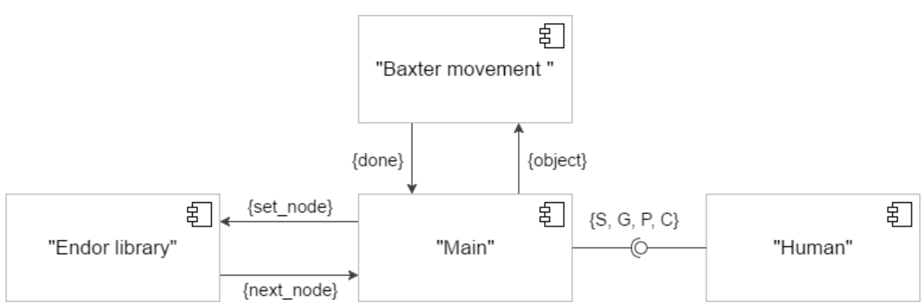
The AND/OR node will be running a service responsible for receiving as a request the node that should be set as solved in the AND/OR graph and as a reply it will inform the node that should be solved, i.e., the next object that should be placed on the table in order to follow an optimal path. The AND/OR node will make use of the ENDOR library[1] written by Barbara Bruno.

The Baxter movement node will be running a service that receives as a request the object that should be placed on the table. The service will then use the Baxter SDK to playback recorded files created by programming by demonstration. Each of the recorded file refers to the movement of the Baxter to move one object to the predefined position.

Finally the main node will communicate with the two previous nodes by the use of two

[1] Available at https://github.com/EmaroLab/endor

Figure 1: *Diagram of the architecture of the software.*



clients - each client for one service - and it will also communicate with the human by implementing a subscriber that will listen to a topic to which the human should publish messages informing the object that he/she has just moved.

iv. The AND/OR graph

The AND/OR graph will serve as a tool to impose a certain behaviour to the robot in order to make the process more efficient. It is expected that if the robot places the plate first on the table, the human will have a better reference to position the other objects, thus avoiding possible misplacements that could cause the process to last longer than needed.

By assigning costs to the hyperarcs and nodes of the graph, it is possible to establish priorities for each object, that means, which objects need to be placed first on the table by the Baxter. By referring to the Figure 2, it is also plausible to impose to the robot that the glass should be placed as the last one, if it's assumed that the robot might hit the glass in the fourth action in the scenario described below:

1. The human places the plate
2. The Baxter places the glass
3. The human places the spoon
4. The Baxter places the fork and knife

Thus overall the robot should have the following list of priority:

1. Plate
2. Spoon or fork and knife
3. Glass

To ensure such priorities, the AND/OR graph depicted in Figure 3 was designed. It is necessary to give lower costs to states (nodes) and actions (hyperarcs) that ensure the desired priorities, so that the algorithm that suggests the optimal path will for sure guarantee the expected behaviour of the robot.

III. Results

The tests[2] were carried out in the laboratory for European Master on Advanced Robotics students located at the University of Genoa. The results achieved were positive and just as expected. As it can be seem from the Table 1, the robot moved the objects following the list of priorities defined in the last section.

Table 1: *Results of the experimental tests.*

TEST I

Order	Executant	Object
1st	Human	Glass
2nd	Robot	Plate
3rd	Human	Cutlery
4th	Robot	Spoon

TEST II

1st	Human	Plate
2nd	Robot	Spoon
3rd	Human	Cutlery
4th	Robot	Glass

TEST III

Order	Executant	Object
1st	Human	Spoon
2nd	Robot	Plate
3rd	Human	Glass
4th	Robot	Cutlery

TEST IV

1st	Human	Cutlery
2nd	Robot	Plate
3rd	Human	Spoon
4th	Robot	Glass

If the plate has not been placed on the table by the human in the first action, the robot will do it, otherwise it will place the spoon. Moreover, the second object placed by the robot will be always the glass, unless it has already been placed by the human.

[2]Video available at https://www.youtube.com/watch?v=F03M4cT2oAY

IV. Limitations

A clear limitation is the fact that the human has to report which object has been placed by him/her. This limitation increases the total time required to set up the table. A possible solution could be resorting to a visual identification module responsible for recognizing the objects already placed on the table. As an alternative, the human could report the action by simply tapping on a smartwatch running an application connected to the whole system. Both solutions could also be implemented together.

Another limitation is that the human and the robot do not perform actions simultaneously. This could be solved if the human, before performing the action, reported his/her intention to the robot. And by adjusting the AND/OR graph, it would be possible to make the robot choose an object to move that would not interfere in the space needed by the human.

Furthermore, the program admits only one final combination of positions of objects on the table and all objects have to be in a well defined initial position in order to the Baxter to reach them.

V. Conclusion

In this paper, it has been studied a case of a cooperative work between a human and a robot whose behaviour was determined by an optimization algorithm applied to an AND/OR graph in which less prioritized actions and states were penalized with higher costs.

Also, to approach the problem, it was proposed a software whose architecture consisted in two servers, two clients, one subscriber and one publisher. And the use of the software provided experimental tests with positive outcomes as expected. At last, some limitations in the solution were described alongside some ideas to address them.

Overall, the project studied in this paper is still in the early stages of development and shall be continued in the future.

References

L. S. Mello *et al.* (1986). AND/OR Graph Representation of Assembly Plans. *Carnegie Mellon University - Robotics Institute*.

Figure 3: *AND/OR graph. C stands for cutlery (fork and knife), G stands for glass, P stands for plate and S stands for spoon.*