A Novel Software Combining Task and Motion Planning for Human-Robot Interaction

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Abstract

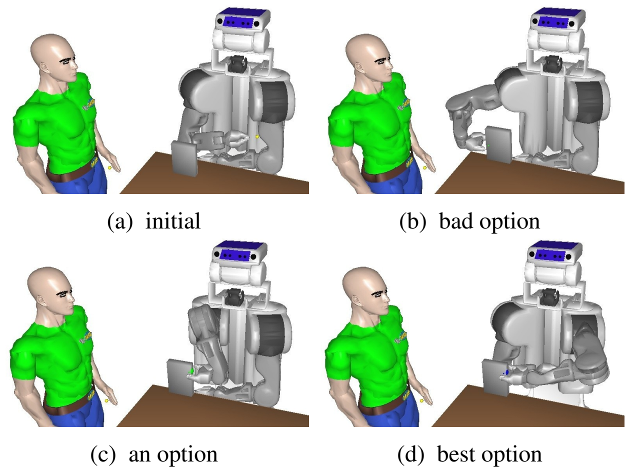
Task planning and motion planning softwares operate on very different representations, making it hard to link them. We propose a software filling that gap in a generic way, mainly by choosing the best way to physically perform a task according to a higher level plan and taking explicitly into account human comfort and preferences.

The literature on task planning abounds in methods to synthesize to symbolic plan that fulfill an objective (e.g. HTN task planners (Ghallab, Nau, and Traverso 2004)). An other domain of the literature proposes methods to solve motion planning problems (such as RRT or PRM (LaValle 2006)). In other terms we know, thanks to task planning, which action to take, and thanks to motion planning we compute how to perform motions. The purpose of the software presented in this paper is to fill the gap between these two planners, providing a generic and easy to use interface enabling task planners to perform tests on action feasibility, and to make relevant geometric choices such as how to grasp an object, where to place it, or where to stop navigation in order to talk to a person.

These choices are made to assess the geometric feasibility of the plan, but the role played by our software, named Geometric Task Planning (GTP), is even more important when humans are involved in the task: one of its main purpose is to choose how to perform a task, and depending on human placement some ways to achieve a task might be more pertinent than others. Figure 1 depicts a set of options computed for a situation where the robot has to pick an object close to a human. According to the task requirements, the software chooses the best solution (configurations and trajectories) that minimizes the disturbance toward the human (figure 1 d), making the overall process human aware.

To the best of our knowledge, there is no other software dedicated to fill the gap in a generic way as GTP does. Most of the available software are specific to the task planner used (Kaelbling and Lozano-Perez 2013; Bidot et al. 2015). GTP design makes it easy to use, and it provides multiple interfaces using several middlewares.

The next section presents the geometric reasoning and planning software, including its algorithms and the features related to human-aware planning. We then briefly discuss an illustrative example and discuss future extensions.



(a) initial (b) bad option (c) an option (d) best option

Figure 1: Options computed for a pick action, with initial situation (a) and 3 grasping configuration from the worst (b) to the best (d), according to human-related cost. Solution c is the best when forcing the use of the right arm.

Geometric Reasoning and Planning

The GTP software takes requests as inputs, in addition to an initial geometric world state (the positions of all objects, obstacles and agents (robots or humans) in the environment). The inputs contains the type of action to perform, the involved agents and objects alongside with their role. The actions available for now are: **pick, place, placeReachable, give, navigateTo**. Here is an input example:

```
action:         placeReachable,
mainAgent:      robot,
targetAgent:    Jane,
mainObject:     box,
supportObject: table2
```

In that example, GTP will compute a plan where the robot places the object named “box” on the “table2”, in a place where it is reachable by a person called Jane. Here, the support object is optional, so GTP would find a suitable support to place the box in the reach of Jane. Other keywords are available for different usage, such as “target” for navigation.

The solution provided by GTP is a labelled sequence of trajectories performing the action specified. For example, the output for a pick action is a sequence of four trajectories: an "approach" trajectory where the robot gripper goes close to the object to pick, the second trajectory is a straight line to reach a grasping position, the "closing" of the end effector is a third trajectory, and finally an "escape" trajectory to lift the object from the surface it is lying on. The next subsections gives a sketch of the algorithms used in GTP.

Main Algorithm

The algorithm is based on four steps:

Choices Making a choice concerning the action: for example in a pick, choosing the grasp to use, for a place, the final object position and so on.

Configuration computation Finding the configuration to use, based on inverse kinematics and on the choices made in the previous step.

Motion planning Computing all the trajectories based on the initial state and on the configurations found in the previous step. We use a cost-based motion planner with human-related costs (Jaillet, Cortes, and Simeon 2010; Mainprice et al. 2011).

Cost computation Computing the cost of the action, e.g. reflecting its safety, legibility, human comfort.

The first iterations are done without step 3 (Motion Planning), which samples alternative sets of key configurations to achieve the task. These alternatives are sorted in term of cost. We then compute the motion of the best alternative and iterate over the following if no valid path is found. We finally compute the full task cost, including the path. When a certain number of choices are explored and no solution is found, the action is set as infeasible.

Details

Costs used The costs are mainly related to human preferences and comfort. They are inspired by (Mainprice et al. 2011; Sisbot and Alami 2012). The main effect is to keep the robot as far as possible from the human. Virtually any cost can be used.

Relations and Affordances GTP is able to compute a set of relations between objects such as *is on* or *is in*, but also relations between an agent (human or robot) and an objects (affordances) such as *is reachable by* or *is visible by*. These relations can be transformed into symbolic facts that can be used at a higher level to determine the effects of actions.

Assumptions We plan in a fixed world, and assume the human is not moving in the plan. We are working on a way to adapt on-line the motion to human movement, in a task-dependent way, but this is not presented here.

Usage and interface

GTP has already been successfully used for different purposes, on the simulation and on the real robot [1] (Gharbi, Lallement, and Alami 2015; Devin and Alami 2016). It has two interfaces: the first one is a GUI available through the software move3d (Simeon, Laumond, and Lamiraux 2001) and the second interface is a ROS interface where the same functionalities are made accessible.

[1] Videos are available at `http://frama.link/2V4ZCOW7` and `https://youtu.be/2iBElhKi-AE`

Conclusion

This software provides to task planners an easy access to a number of functionalities that a service robot must have such as basic manipulation and navigation, and can integrate other, like handovers (Mainprice et al. 2012; Waldhart, Gharbi, and Alami 2015). GTP can be used for human-robot interaction, looking for optimal solutions in a given cost-space. It was designed to interact closely with the Hierarchical agent-based planner (HATP) as depicted in (Gharbi, Lallement, and Alami 2015). As a result, GTP will soon be made available to use as stand alone and can be linked through ROS in order to execute the trajectories.

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