Combining Action and Motion Planning via Semantic Attachments

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Planning in real-world domains requires to solve problems of different granularity: On the one hand, high-level actions like driving to a certain position or grasping a certain object are atomic actions with well-defined symbolic preconditions and effects. On the other hand, how to actually perform such an action might be a difficult subproblem in itself: To reach a certain position it is usually required to invoke a path planning subroutine, and before an object can be grasped a collision-free trajectory needs to be computed.

In principle there are two approaches to tackle such types of problems: In the *top-down* approach, a solution to the abstract problem is generated first and the subsolvers are used afterwards to find solutions for the low-level problems. In that approach, however, situations might occur in which the subsolvers are not able to find valid solutions since the high-level planner made some incorrect decisions according to the lack of low-level knowledge. In the *bottom-down* approach, on the other hand, all low-level information is passed to the high-level planner. The biggest drawback of that approach is obvious: The problem unnecessarily becomes very complicated since most of the low-level information is not needed by the high-level planner: If the solution of the high-level planner does not require a drive action, the geometric properties of obstacles are not relevant at all.

In previous work we presented an alternative approach to solve such types of problems: The use of *semantic attachments* (Dornhege et al. 2009). A semantic attachment is an external procedure called during the planning process to evaluate specific conditions or to directly alter the planning state. By using semantic attachments for subproblems like path planning we combine the advantages of both approaches while circumventing their disadvantages: on the one hand, the high-level planner does not need to care about subproblems since they are dealt with in the semantic attachments, on the other hand, only information actually needed to solve the problem is generated at the time the semantic attachment in invoked. We have implemented semantic attachments in the classical planning system FF (Hoffmann and Nebel 2001) and the temporal and numeric planning system Temporal Fast Downward (TFD) (Eyerich, Mattmüller, and Röger 2009).

The overall aim of the German project DESIRE (Plöger et al. 2008) was to develop an autonomous robot capable of performing service tasks in a typical kitchen environment. To increase the level of intelligence and the flexibility of the overall system, a planning system based on TFD was used. To deal with the mentioned issue of solving problems of different granularity, we implemented several semantic attachments, in particular for manipulating objects.

When planning for *grasping* an object, it quickly falls into place that a purely symbolic representation is insufficient for the task. Having said that, the complete integration of a manipulation planner is far too inefficient, as one call to such a planner usually requires runtimes in the magnitude of seconds and in non-trivial problems hundreds to thousands of such calls are required. Therefore, we used a solution in between by utilizing an approximation procedure as a semantic attachment. This gives us more precise results than purely symbolic planning while staying efficient even in problems of considerable complexity. In dependence of the object's location and the shape of the surface it is located on, the semantic attachment checks whether a given docking position of the robot is appropriate for grasping. For that purpose, it is checked whether the object is within reach of the manipulator in question and whether it is not covered by other objects nearby it. Furthermore, it is ensured that the angle between the robot and the object's position is within some predefined range.

To find an appropriate position on a given surface to *place* an object on, we used a semantic attachment that works as follows: First, the surface is partitioned into grid cells of one square centimeter. Then, the occupied cells are determined on the basis of all other objects on the same surface. Finally, a free area big enough to hold the object and maximizing the remaining free space is chosen as the position to place the object on. Note that all these computations are performed only when they are required.

References

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