Mixed-Integer and Constraint Programming Techniques for Mobile Robot Task Planning*

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In this work we investigate the application of optimization-based scheduling technologies to two mobile robot task planning problems. We develop and apply *mixed-integer programming* (MIP) and *constraint programming* (CP) techniques to model and solve these problems, demonstrating through simulation that our methods outperform those previously proposed in the robotics literature. Our simulation further indicates that the inference-based search of CP is the superior approach for the problems studied. Additionally, we implement our CP approach for the second problem as a task planning module within a real robotics platform on the social robot Tangy, validating the physical utility of the method.

In the first task planning problem, a robot plans a set of tasks each with temporal constraints identifying when a task is available for execution and when it must be completed. The task planning module must determine a feasible plan while minimizing the sum of task completion times. Existing approaches use heuristic decisions aimed at reducing problem complexity and improving runtime performance at the cost of optimality. Our methods provide better solutions in shorter runtimes without sacrificing completeness. The second task planning problem involves a socially-assistive robot facilitating everyday activities for retirement home residents. The robot must create task plans while reasoning about temporal constraints, human user timetables, and robot energy levels. We show that our optimization-based methods outperform a previously proposed forward-chaining temporal planning approach, and integrate our CP technique into a task planning module within a mobile robotics platform architecture.

Overall, our results indicate that these optimization-based techniques are promising for solving mobile robot task planning problems. A primary direction for our future research is to investigate the role of these methods for the development of re-planning and plan repair techniques, in efforts to enhance the capability of our task planning module. We plan to further investigate robot task planning problems in order to understand the point at which such problems will require more sophisticated strategies, such as customized search manipulations and problem decompositions.

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