論文 / 著書情報
Article / Book Information

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Title(English)	Trajectory Optimization and Control of Robot Systems with Temporal Logic Tasks
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	システム制御系 システム制御コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ 工学 ）
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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

In recent years, robots play increasingly important roles in society, not only in the industrial field but also in the service industry. With the spread of robots, opportunities for non-professionals are increasing to operate robots and introduce them to services. However, teaching robots to perform desired tasks safely is difficult, and this is one of the obstacles to the introduction of robots. One of the reasons for the difficulty in teaching tasks to robots is the need to simultaneously consider the logical consistency of the task and its feasibility considering the dynamic characteristics of the robot. Therefore, we need to use a control architecture that considers simultaneously both.

The use of modal logic such as linear temporal logic (LTL) and signal temporal logic (STL) has attracted much attention as a way of logically representing tasks in robot systems. These modal logics represent the properties of sequences of state transitions. By describing the rules and constraints of a task as logical expressions, we can determine in advance whether the assumed task is logically sound or not. When generating a sequence of state transitions satisfying the temporal logic on a robot system, we need to generate robot trajectories on an abstracted system, rather than on the actual robot system.

In this case, depending on the state and the definition of the approximated system, the extent to which the abstracted system can emulate the characteristics of the actual robot system differs. In addition, the method of generating robot trajectories differs depending on how the abstracted system is constructed. Therefore, the nonlinearity of the abstracted system and how it is constructed are important depending on the actual robot systems or tasks. Especially, when the trajectory optimization is formulated as a mixed integer programming problem, it is necessary to construct a dynamical linear system that emulates the dynamical characteristics of the actual robot as an approximated system.

To achieve tasks, we need to control the actual system based on trajectories generated by the abstracted system. Control methods for satisfying tasks expressed as temporal logic specifications include model predictive control (MPC) and control barrier functions (CBFs). CBFs are used as constraints in determining control inputs to keep the system trajectory within a certain region, and the constrained optimization problem with CBFs can be formulated as a quadratic programming problem, which requires less computation time than the nonlinear MPC. In designing a controller to achieve tasks represented by temporal logic specifications using CBFs, the issue is how to set up the CBFs. In the case of a task with a time limit expressed in STL, the design method of CBFs proposed in the previous studies requires several processes to design the CBF from the robustness functions of STL. Therefore, we propose a new design method for CBFs. Furthermore, there are cases in which robots cannot achieve a given task with the task plans. Especially, if there are multiple robots, the robots need to change their motions to achieve the task considering the other robots.

In this paper, we propose trajectory optimization methods and control methods for robot systems for tasks expressed as temporal logic specifications. We focus on the task represented by syntactically co-safe LTL, generate trajectories in response to their tasks, and control robots.

The high-level controller defines an abstracted robot system for the actual robot system. We generate trajectories and motions for this abstracted system to achieve tasks expressed by LTL or STL specifications by optimization. Then, the extent to which the abstracted system can emulate the actual robot depends on the abstraction method of the abstracted system. Therefore, we discuss abstraction methods for robot systems. In addition, we show that we can compute trajectories that satisfy the given temporal logic specifications for the abstracted system. Furthermore, we propose a

trajectory optimization method for tasks involving external events represented by event-based STL specifications.

The low-level controller uses the task plans and trajectories generated by the high-level controller to control the actual robot systems. In this paper, we propose a control method that considers time constraints to satisfy a given temporal logic specifications using CBFs. In addition, we also consider methods to represent trajectories as distributions, and to update the distributions based on the observation information obtained during the operation to change the motions.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

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