Motion Planning Under Temporal Constraints. - Mid Report

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***Abstract*— In this project we try to address motion planning problem with spatial and temporal constraints. While, traditionally motion planning is researched thoroughly most algorithms are developed for simple tasks. In this work we explore the domain of planning under timed constraints using Signal Temporal Logic (STL).**

I. INTRODUCTION

Traditionally, the kinodynamic motion planning problem is defined as: Given a dynamical system, an environment, an initial state and a goal state, find a sequence of control inputs so as to drive the system from the initial state to the goal state while fulfilling some constraint dictated by the environment, e.g., avoiding obstacles. But as robotic systems become more complex, it opens up new advanced applications. We need algorithms which can handle more constraints automatically rather than breaking down the problem to simpler task. Timed constraints is similar constraints, this can be helpful in situations where you have applications which are time critical such as surgical robots, cobots and manufacturing applications. If we are able to achieve this we can solve problem along the lines of "Pick up object bottle in 10 seconds, pour the liquid in a glass for 5 seconds and keep the bottle down, do this entire task in 30 seconds".

In this project we try to extend the constraints that a motion planning algorithm can handle. We will use Signal Temporal logic (STL) specifications as it consists of both spatial and temporal constraints on continuous signals. A key benefit of STL is its quantitative semantics – robustness - which provides a score indicating to what extent a signal satisfies or violates a given specification.

II. RELATED WORK

Most of current approaches solve the problem using RRT*, they modifying the cost function using STL formulation to maximize the STL Robustness [1], [2] and [3]. Closest of what we want to achieve is showcased in [3] where they solve the problem using a modified biased sampling and a guided steering for the RRT* algorithm. The Major Flaw in the current approaches, according to our understanding is that all of them revolve around RRT* and RRT - which can become limiting in higher dimensional spaces and the algorithm itself is very complicated due to inclusion of STL semantics. There is a large pool literature on this topic, but for this project we limit our scope as this is a initial stage of bigger project.

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III. PROPOSED METHODS

We start by solving the motion planning problem for multiple goal task or which can be shown as a Linear Temporal Logic Specification. Then we move one to include time constraints for a given system using some sort of cost function as proposed by previous works but here we will try to keep it as simple as possible because previous works have several modifications leading to complex algorithm. Meanwhile, we will investigate how to combine a more complex state-of-the-art of motion planning algorithm like Syclop[4] or KPIECE[5] with Signal Temporal Logic (STL).

IV. CURRENT PROGRESS

We divide our project into three sub-goals given by

1) Literature Review, programming and understanding Signal Temporal Logic (STL) Specifications.
2) Multi-goal RRT* Implementation: Simple Modification to RRT* where we can find path to multiple goals in order dictated by LTL Specification (We pass the start-goal pair to RRT* as dictated by the specification - modifications required).
3) Combine STL with RRT* : (Expected) Design RRT* Algorithm and use information from the STL Semantics - robustness and/or Boolean Satisfaction.

V. PLATFORM & EVALUATION

To design and evaluate this project we will majorly use Python. If needed we will use the Open Motion Planning Library (OMPL) to test and implement more complex algorithms.

VI. LIMITATIONS OF THE PROJECT

Due to strict timeline for the class project, currently our end goal is the develop a motion planning algorithm which can handle time constraints for at-least one goal if not multiple goals. This will help us focus on design a algorithm that is simple enough, as STL semantics for multiple goals will have several mathematical complexities which need to be taken care of.

VII. CONTRIBUTIONS OF TEAM MEMBERS

- Jeel Chatrola - Literature Review and Design
- Dev Soni - Implementation
- Combined Effort - Evaluation and Documentation

VIII. CONCLUSIONS

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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