Animating Motion Planning Topics

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I. Introduction

Motion planning is a uniquely visual field of robotics whose fundamental ideas are inherently spatial and geometric in nature. Among these ideas are planning algorithms, a method used to find some path between a start and a goal in physical space, and the concept of a configuration space, a complete specification of a given robot's parameters which can be interpreted as a n-dimensional plot. I have taken on the challenge of both animating and explaining these two ideas in the form of a simplified *configuration space* as well as the *rapidly exploring random tree* planning algorithm as first developed by LaValle in 1998 [1]. These were chosen for their relative simplicity and visual structure.

Throughout this project, I make use of *Manim Community*, a powerful python library initially built by Grant Sanderson for simple mathematical animations. This gives a great deal of programmatic control and design uniformity throughout the project.

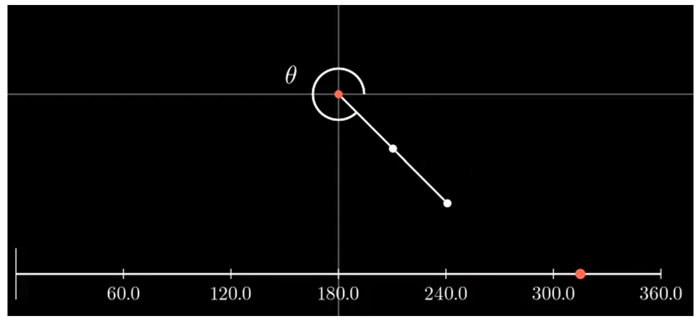

Fig. 1. "Unwrapping" joint 1.

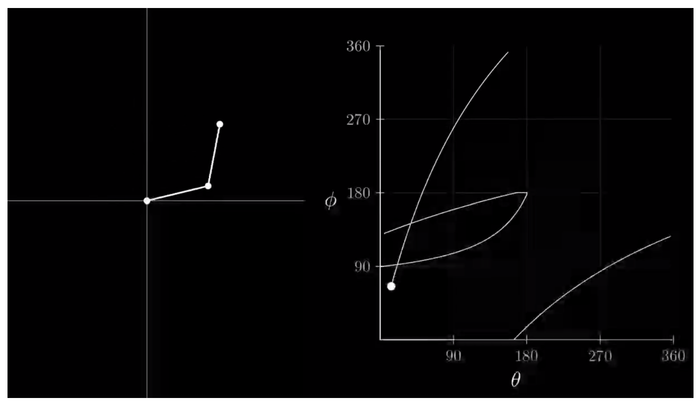

Fig. 2. Plotting a 2R robot with a 2D configuration space.

II. Lesson 1: Configuration Space

To introduce the concept of the configuration space, I first attempted to extract information about a simple 2R robot, and make simple connections to plot their configuration both in physical space, then in configuration space. To unite the physical space to the configuration space, I animated 'unwrapping' both θ and ϕ (the first and second angle of our 2R robot). This is achieved by transforming the circle formed by θ into a straight line, as seen in Figure 1. Do the same for ϕ, and you can form a two-dimensional plot as seen in the left of Figure 2. The white dot represents a pose of the robot: θ and ϕ. The line is simply a visual aid to track the path of the dot over time.

To make this more interesting, I have been able to implement different kinds of obstacles and robots into SE2EZ, a program written in C++ which has implemented many different kind of motion planning algorithms. It comes with a configuration space visualizer, plotting both the robot and its obstacles onto a 2D plane in real time. Creating obstacles in SE2EZ and pulling their visualiztions into my animation is a clear diretion to improve this explaination. More unique visualizations could include stacking 2d plots and creating a 3D volume which might represent a 3R robot's configuration space.

III. Lesson 2: Rapidly exploring random tree

The rapidly exploring random tree (RRT) algorithm is a particularly compelling sampling-based planner that 'grows' a tree from some start position to some goal position in an n-dimensional space, and is often included in introductory motion planning courses. Myself and my advisor, Prof. Constantinos, have developed a three-step plan to introduce RRT by incremental explaination.

1) Intuition: To ease our audience into an initial introduction to the topic, I animated a complete RRT growth based on a simple premise: "say you are a student at their home apartment, and you would like to find a path to your class." This grounds the otherwise ephemeral visual plot with white shapes representing obstacles to a tangible and relatable reality: a student going to class. With this premise, I grow a pre-planned RRT tree from the edge of the map to a building in the map, showing off RRT's capabilities to grab the audience's