Three-Dimensional Time-Optimal Path Planning in Dynamic and Realistic Environments

by

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B.Tech, Indian Institute of Technology Bombay (2015)

Submitted to the Department of Mechanical Engineering
in partial fulfillment of the requirements for the degree of

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Abstract

Autonomous underwater vehicles (AUVs) are a valuable resource in several oceanic applications such as security, surveillance and data collection for ocean prediction. These vehicles typically travel at speeds comparable to ocean currents, and their movement is significantly affected by these dynamic currents. Further, the speed of currents may vary greatly with depth. Hence, path planning to generate safe and fast vehicle trajectories in such a three-dimensional environment becomes crucial for the successful operation of these vehicles. In addition, many marine vehicles can only move in specific directions and with a speed that is dependent on the direction of travel. Such constraints must be respected in order to plan safe and optimal paths.

Thus, our motivation in this thesis is to study path planning for vehicles with and without motion constraints in three-dimensional dynamic flow-fields. We utilize the time-optimal path planning methodology given by Lolla et al. (2012) for this purpose.

In this thesis, we first review some existing path planning methods (both in two and three-dimensional settings). Then, we discuss the theoretical basis of the rigorous partial differential equation based methodology that is utilized in order to plan safe and optimal paths. This is followed by an elaborate discussion about the application of this methodology to the various types of marine vehicles. We then look at the robust and accurate numerical methods developed in order to solve the governing equations for the path planning methodology with high accuracy in real ocean domains. We illustrate the working and capabilities of our path planning algorithm by means of a number of applications. First we study some benchmark examples with known analytical solutions. Second, we look at more complex flow-fields that analytically model different oceanic flows. Finally, we look at the path planning for different types of marine vehicles in a realistic ocean domain to illustrate the capabilities of the path planning methodology and the developed numerical framework.

Thesis Supervisor: Pierre F.J. Lermusiaux
Title: Professor

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