Path Planning for Underwater Gliders with the CTS-A* Algorithm

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1 Introduction

Underwater gliders are a technology still in active development, which has proven very promising in Ocean Research [2]. They modify the buoyancy describing a very efficient, in terms of power consumption, saw-tooth profile. However, due to the low surge speed induced, they are far more affected by ocean currents than other vehicles, hence the importance of path planning for glider navigation.

We propose a path planning algorithm named Constant-Time Surfacing A* (CTS-A*). It bases on A*, already adapted to the problem at hand by some authors [1]. A* discretizes the search space with an uniform grid, and so the bearings. The time between consecutive surfacings is non-constant then. On the contrary, we have engineered our path planner to obtain constant time surfacings. It takes a set of bearings and integrates the glider trajectory, so being consistent with the glider behavior the resulting paths are more realistic and informed.

2 Constant-Time Surfacing A*

In the field of path planning for gliders there exists a number of authors that have adapted the A* algorithm to the problem at hand minimizing a temporal cost based on the glider speed and the distance between a pair of locations $\mathbf{x}_i$ and $\mathbf{x}_j$. Since the currents might not permit the vehicle to move in a particular direction, we are facing a slightly different problem than the original one which A* was designed for. In A*, the successors of a node n_i are the 8-neighbors n_{i+1} around it, in an uniform grid. CTS-A* operates differently, with a notable modification to the original A* centered on the generation of successors (see Fig. 1). For each surfacing location $\mathbf{x}_i$ the glider trajectory is integrated for the surfacing time t_s for several bearing angles θ_{g_j}. This process is repeated with the new surfacing locations, sorted according to $f^*(n)$. These locations are not discretized, since they are saved in the Nearest Neighbor node $n_{i+1}^{\theta_{g_j}}$ of a grid that tessellates the search space. In the next iteration, the glider trajectory is computed starting at the location $\mathbf{x}_{i+1}^{\theta_{g_j}}$.

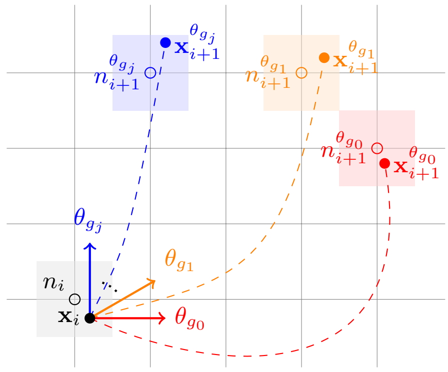

Fig. 1. Successors generation in CTS-A*. Starting at a node n_i several trajectories are integrated for a surfacing time t_s considering different bearings θ_{g_i} from location $\mathbf{x}_i$.

We intend to evaluate the path cost and the CPU time for our CTS-A* approach, compared with a Direct-to-Goal (DtG) strategy and A*. For this purpose, we have built 21 test cases using ocean currents. The results show that CTS-A* finds paths of lower cost than both A* and DtG. Our approach performs better than other path planning techniques in those cases where there are obstacles or strong currents between the departure and target locations.

To sum up, we have introduced the CTS-A* path planning algorithm, which have been designed for underwater gliders in mind. It searches the best path to reach the goal computing the vehicle trajectory. Unlike A*, our proposal offers more realistic and informed results thanks to its mode of operation. And in most cases, the paths found have lower cost than both the DtG strategy and A*.

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