COLREGS COMPATIBLE MOTION PLANNING FOR ASVs

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Introduction

With an increase in the level of autonomy of surface vessels, comes an increase in necessary safety measures. Assuring that autonomous surface vessels (ASVs) are able to avoid obstacles, both dynamic and static, is therefore of crucial importance. The ocean presents a dynamic and uncertain environment, enabling a need for robust collision avoidance and path planning methods. Further, as ASVs are launched, they will be operating in an environment with other manned vessels. This calls for another dimension of the path planning problem, in that the autonomous vessel must behave in a manner that the manned vessel can interpret and predict. For this reason, adhering to the International Regulations for Preventing Collisions at Sea (COLREGS) is a factor ASVs must consider.

Objective and Scope

This thesis aims to investigate how the *Path-of-Probability* (POP) algorithm can be included in a motion planner such that the ASV can plan ahead in a static *and* dynamic environment. With dynamic obstacles, such as other moving vessels, emphasis is placed on the path obeying the "marine rules of the road" - COLREGS.

Motion planning is a complex task, and is regarded as a multi-objective optimization problem. It has therefore been simplified for the sake of this thesis, where the objectives considered are (1) feasibility, (2) safety and (3) obeying COLREGS. A global path planner, for static obstacles; and a local path planner, for dynamic obstacles, are implemented.

Methods and Modelling

The two following methods are combined to provide the motion planner:

1. **POP:**
   The POP algorithm uses stochastic differential equations (SDEs) to find a set of waypoints that are *most-likely* to reach the target.
2. **A* search:**
   Using a discretization of the surrounding environment of the ASV, called a network, the A* search uses a cost function, $f(n) = g(n) + h(n)$, to determine a set of waypoints that ultimately lead to the target with minimal cost. Further, in order to ensure a feasible path, a *T-neighbourhood* (from [1]) is used to define the set of reachable nodes in the A* search.

These two methods are merged by including the probability of reaching the target into the cost calculation $f(n)$ of each node.

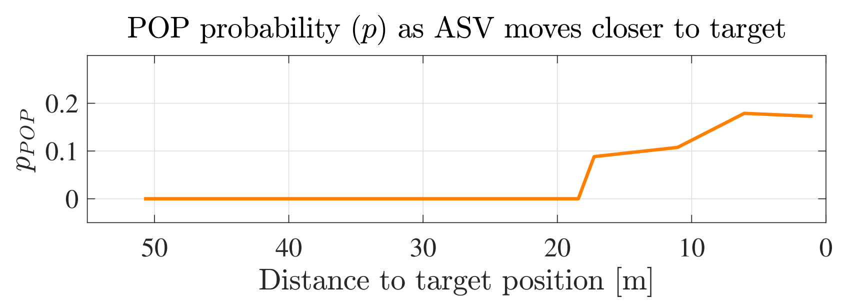
Simulations and Discussion

A variety of designs for the total cost function $f(n)$ are tested in a global path planner, where two of the resulting paths are shown in figure (1) and (2) to the right. Their respective cost functions used are:

(1) $f(n) = e_g + e_h + (p_{RAD} + p_{POP})e_h$
(2) $f(n) = e_g + e_h + p_{POP}e_h$

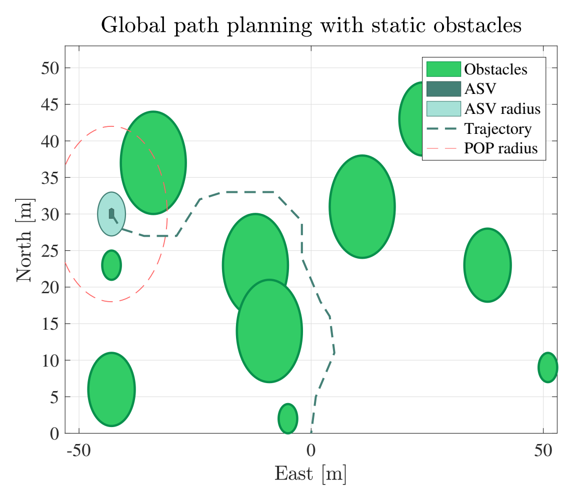
where e_g and e_h refer to the Euclidean distance from the current node n to the start node and target node respectively. The two extra contributions from p_{RAD} and p_{POP} are penalty factors that increase the cost of a node if it violates the ASV's safety radius or has a low probability of reaching the target.

Examining the trajectory in figure (2) reveals how the path starts to turn towards the target point too soon causing the path to move too close to the obstacle. This then forces the detour around the obstacles in figure (2). With this in mind, it can be speculated that the fault in the POP algorithm lies in how it handles obstacles. The method is collected from [2], which is based on a *single* static obstacle. In more complex scenarios, like the one presented here, the nodes are often given a zero probability of reaching the target. This is especially true when the distance to target position is large, as seen by the figure below. When $p = 0$, the POP algorithm is ineffective and does not aid the A* search. Based on the figure below, this occurs regularly.

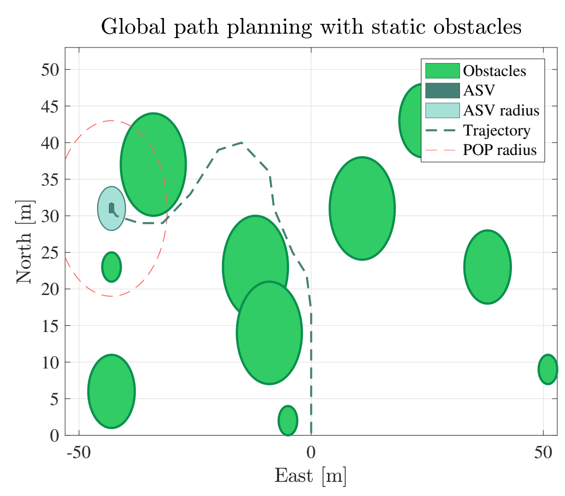


Global Path Planning

(1) Using POP and Safety Margin around ASV:



(2) Using only POP:



Conclusion

It is clear from the results in the global path planner, as shown in figure (2) above, that POP is ineffective over longer distances and multiple obstacles. Nevertheless, it remains to be soon how it measures up in a collision avoidance scenario; where the motion planning is completed over shorter distances. Further analysis of local path planning using POP and A* search in a collision avoidance scenario is provided in the final thesis report.

Even though the algorithm has its flaws, its stochastic approach is still considered as one of its strengths. This, as the working environment for all ASVs is stochastic by nature. It is therefore vital to incorporate the uncertainties into the motion planner.

References

[1] Michael Blaich et al. "Fast grid based collision avoidance for vessels using $A*$ search algorithm". In: *Methods and Models in Automation and Robotics (MMAR), 2012 17th International Conference on.* IEEE. 2012, pp. 385–390.

[2] Jaeyeon Lee and Wooram Park. "Design and path planning for a spherical rolling robot". In: *ASME 2013 International Mechanical Engineering Congress and Exposition.* American Society of Mechanical Engineers. 2013.