Hybrid Collision Avoidance with Moving Obstacles for ASV

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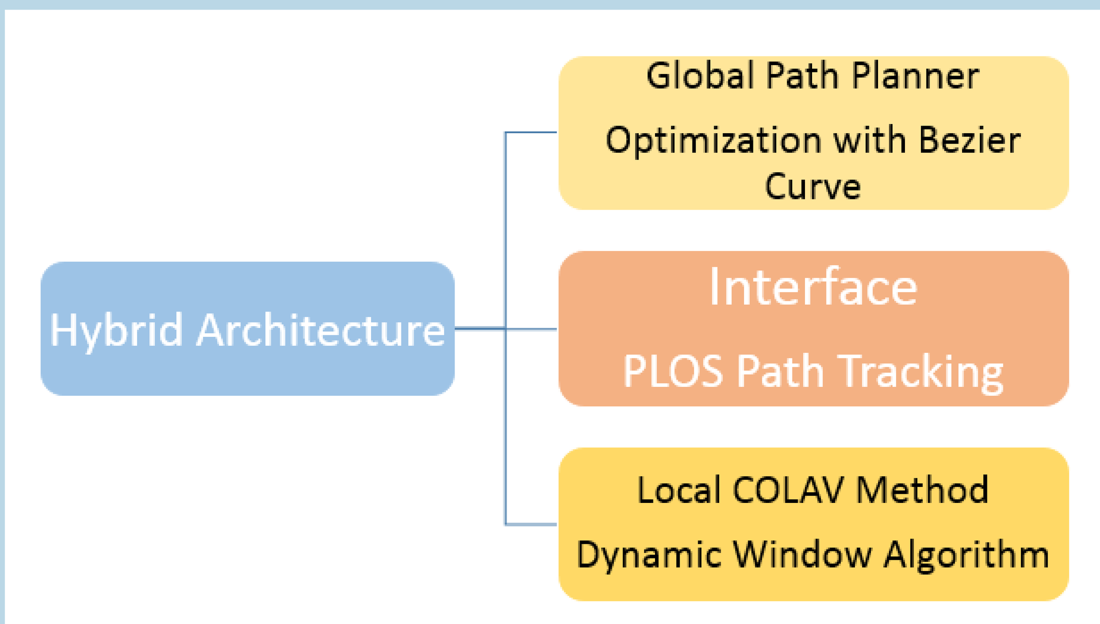
Problem

Over the past few decades, the field of autonomous vehicles has witnessed an ever increasing interest in motion planning. We propose a hybrid collision avoidance (COLAV) approach for Autonomous Surface Vehicle (ASV), based on the integration of a global path planning algorithm and a reactive collision avoidance approach to address the COLAV issue with the presence of the moving obstacles.

Introduction

A considerable amount of work has been done in the field of autonomous vehicles and collision avoidance (COLAV) over the past few decades. The hybrid COLAV architecture proposed here, decomposes the task into global path planning and local collision avoidance issue. ASV is required to make real-time response while navigating in the unknown cluttered environment. Hence, a reactive COLAV method that receives data and information of immediate environment from sensors, significant contributes to local collision avoidance in the presence of both static and dynamic obstacles. Reactive COLAV methods are widely used due to low demand for computing capabilities, while it still suffers the risk of being trapped in a local minima, which motivates the introduction of a deliberate path planning method. The global path planning is carried out using a new generation of path planning that incorporates in its formulation the dynamics of the vehicles and extra data made available by on board sensors about obstacles and other vehicles in vicinity.



References

[1] Hassani, Vahid and Lande, Simen V: *Path planning for marine vehicles using Bezier curves*, IFAC-PapersOnLine (2018)

[2] Fox, Dieter and Burgard, Wolfram and Thrun, Sebastian: *The dynamic window approach to collision avoidance*, IEEE Robotics & Automation Magazine (IEEE 1997)

[3] Eriksen, Bjørn-Olav H and Breivik, Morten and Pettersen, Kristin Y and Wiig, Martin S: *A modified dynamic window algorithm for horizontal collision avoidance for AUVs*. IEEE Conference on Control Applications (CCA 2016)

Hybrid COLAV Architecture

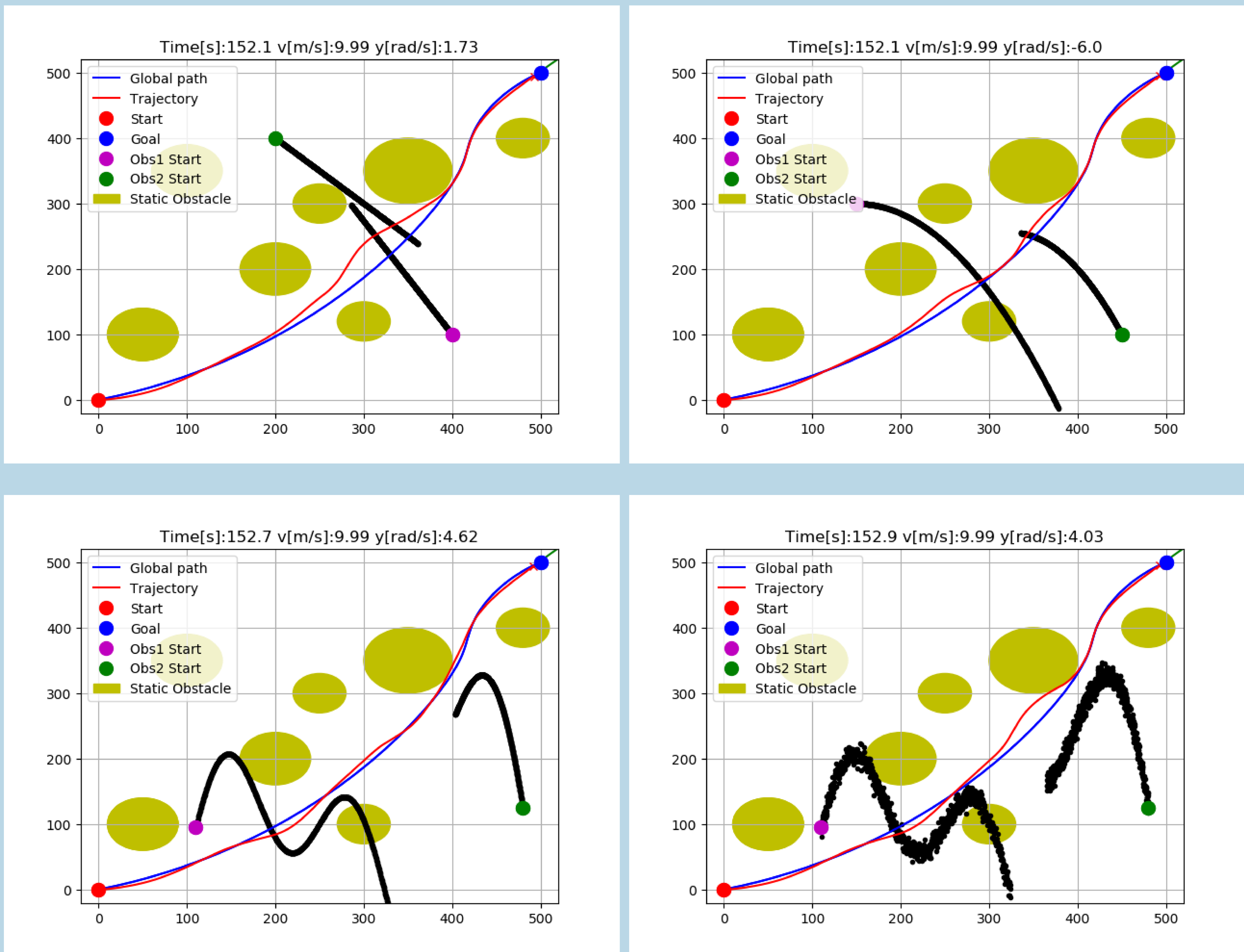
The hybrid architecture can be formulated as a hierarchy, decomposed into three layers: global path planner, interface including path tracking algorithm and local COLAV method. Specifically, global path is generated within the framework of optimization, based on Bézier curves [1], and dynamic window approach [2] is employed as a reactive COLAV method taking the moving obstacles into account. Based on previous work [3], a modified DW algorithm is adapted and tested for ASV with second-order nonholonomic constraints. While path tracking algorithm (PLOS) is utilized to convert the global path into desired trajectory, functioning as a guidance for DWA, such that the interface between global and local layer is developed, aiming diminishing the distance from current position to the desired trajectory at each time step.

Bézier Curves are used as the basis for generating a rich set of paths that determines spatial and temporal profile of the vehicles. Using differential flatness property of the vehicle, we are able to reconstruct all the states of the vehicles during the maneuver. The calculated states are then used to assign a cost function to each path that reflects the dynamic capabilities of the vehicle on that path. As a reactive COLAV method, dynamic window searches for commands implemented in the space of velocities, and optimal velocity pair is determined to maximize the objective function, in which a path alignment term is incorporated to bond with global path.

$$G(u,r) = \alpha \cdot goal(u,r) + \beta \cdot dist(u,r) + \gamma \cdot vel(u,r) - \delta \cdot align(p_d, p_p) \qquad s.t.(u,r) \in V_r,$$

Simulation and Results

Several simulation results regarding different situations of moving obstacles are presented, verifying the feasibility and robustness of the hybrid COLAV algorithm, which is capable of generating collision-free trajectory with the guidance of global path. It is remarkable that collision avoidance always takes precedence over path alignment to guarantee the safety of ASV.



As depicted in the simulation results, the ASV is able to perfectly follow the global path without threats of moving obstacles, while it deviates from the path when dynamic obstacle occurs in vicinity. To evaluate the robustness, random obstacles involving gaussian noise with different standard deviation is taken into account.

Conclusion and Future Work

A hybrid COLAV method based on Bézier curves and dynamic window algorithm is introduced. Pure pursuit guidance is exploited to track the global path and extensively contribute to developing the interface between deliberate and reactive COLAV method. Furthermore, the feasibility and robustness of the algorithm is analysed regarding different scenarios through numerical simulations. The future work will include collaboration with the International Regulations for Preventing Collisions At Sea (COLREG).