Energy Optimization in Marine Planning by implementing Autonomy

Rakshan V P

June 2023

Abstract:

- The topic of energy-optimized path planning using pseudospectral optimal control is considered
- An optimal control problem (OCP) is formulated to produce an energy-optimized path between two points among static obstacles
- The ship model is also affected by external disturbances such as ocean currents which is also considered in order to get a feasible and energy optimised path
- Our main area of interest is more likely on the simulated results rather than mathematical aspects of simulation.

Introduction:

- A nonlinear, underactuated 3-degree-of-freedom ship model affected by external disturbances in the form of ocean currents is used in both planning and simulation
- The planner finds an optimized path using an energy-based cost function, which is then used by a guidance controller.
- The optimization is performed on the three pose states, namely north and east position and heading, and on three velocity states, namely surge, sway and yaw rate.

Motion Control Architecture:

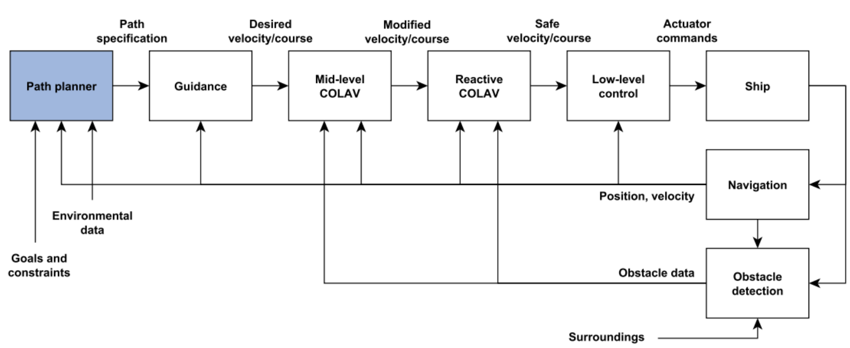

Figure 1: Block diagram of motion control architecture

- COLAV is the task of avoiding collisions with static and moving obstacles.
- The task may be split into three levels: High-level global path planning, mid-level protocol based COLAV, and low-level reactive COLAV.
- Low-level COLAV is responsible for avoiding immediate collision
- Mid-level COLAV is intended to prevent collisions by following a set of rules
- The high level planner relies on static information about the area, such as a map.

SHIP MODELING AND CONTROL:

Modeling:

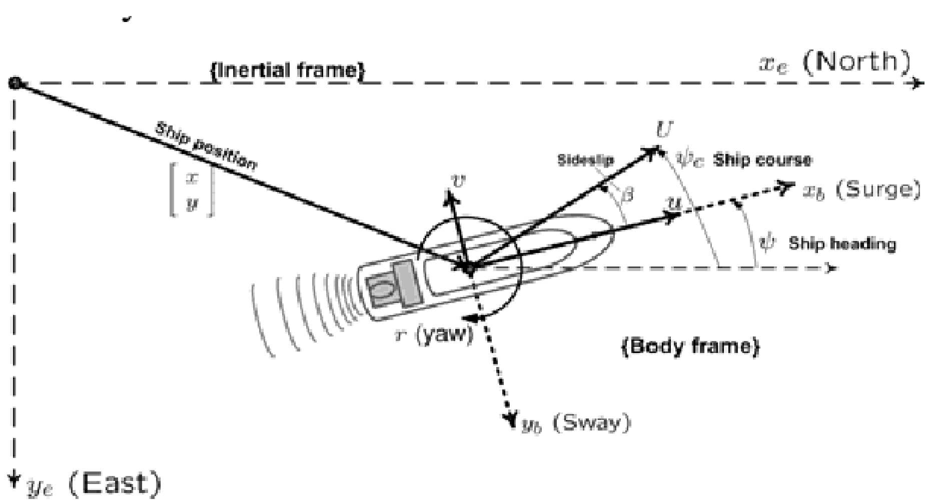

Figure 2: Cybership 2

*The mathematics of cost function and the motion of boat are given in detail in the research paper

Guidance Controller:

The main objective of this method is to make the axis of the boat parallel to axis of the particle at the brim of the obstacle at every instant so that the boat manages to travel a minimum distance in order to reach the target position within given time interval.

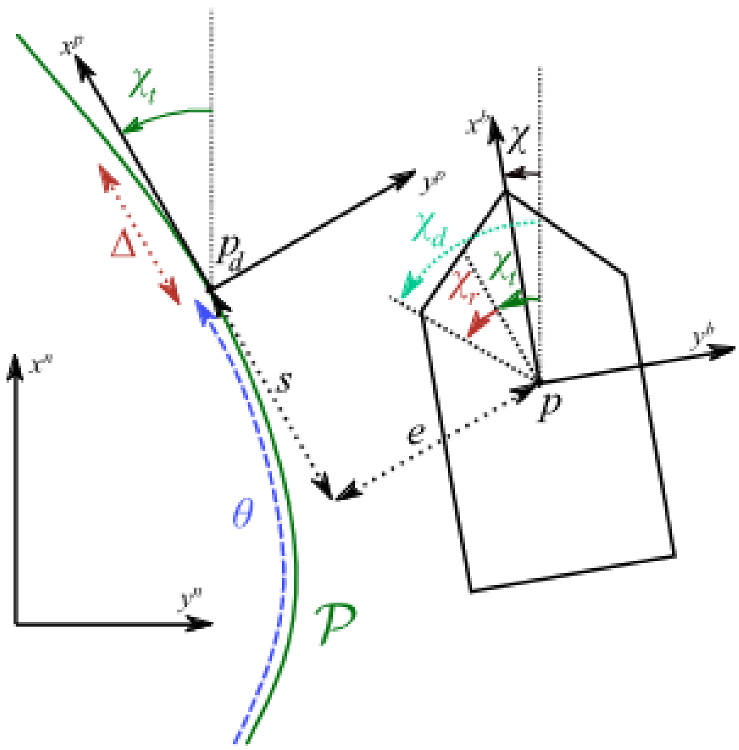

Figure 3: Geometric variables used in guidance

PLANNING AND SIMULATION RESULTS

Two different scenarios are explored in the results:
Scenario 1: (S1) Path planned using no current information.
Scenario 2: (S2) Path planned using correct current information

path:

After planning, both scenarios are simulated using a south-to-north current: Vx= 0.1ms1 and Vy = 0, equivalent to 0.84 m s1 for the full-scale ship. The ocean current magnitude is a significant perturbation to the ship, and the direction is selected to be perpendicular to the main direction of travel. This is to demonstrate that using ocean current information in planning reduces the energy spent in transit. The results from planning are labeled PL, while the closed-loop simulation results are labeled CL.

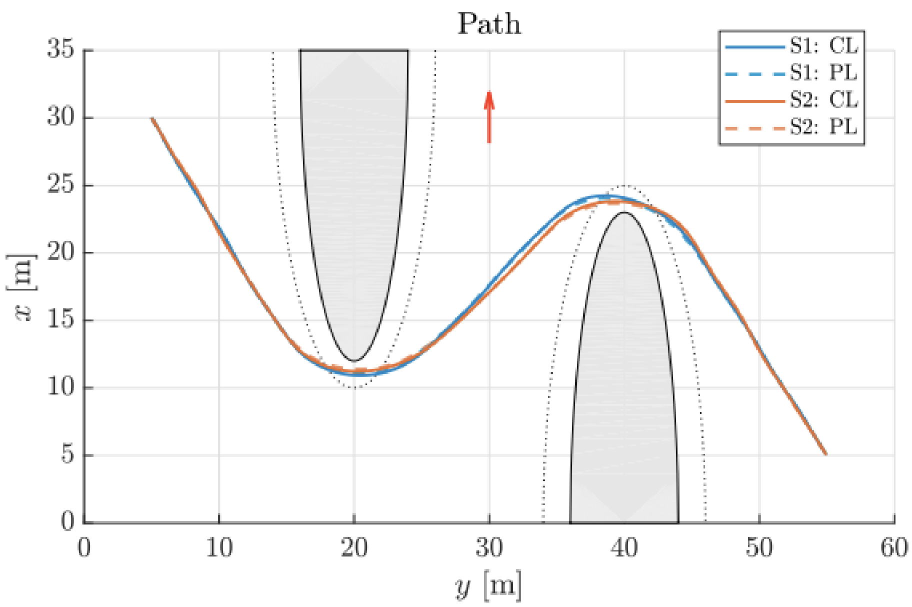

Figure 4: simulated path of both scenarios

speed difference and energy consumed:

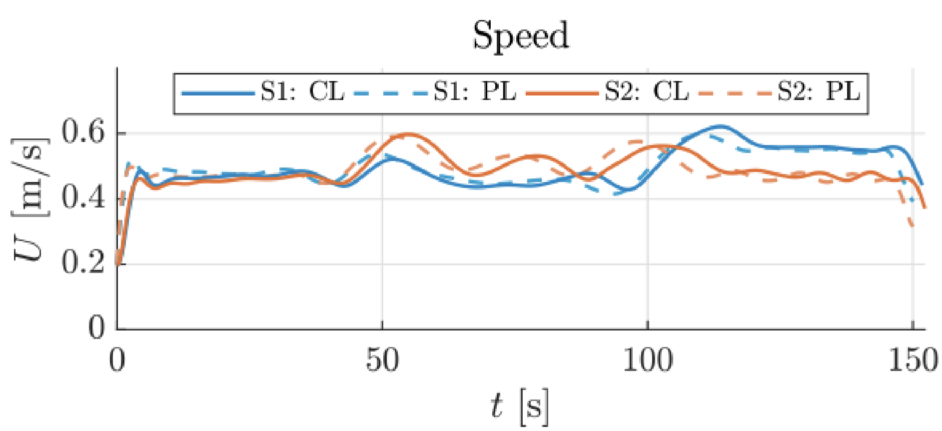

Figure 5: speed difference in two scenarios

The planned paths are quite similar, however,especially when the ship ma-

Table 1. Scenario results.

		Scenario 1		Scenario 2	
PL	J	124	J	153	J
CL	J	164	J	**151**	**J**
PL	t_f	150	s	150	s
CL	t_f	152	s	152	s

Figure 6: energy consumed

neuvers along the current direction, the path differs. This is also evident from figure below,which shows significant speed differences between the scenarios after 50 s. These differences lead to significant changes in energy consumption between the two scenarios.An 8% reduction of consumed energy is seen in Table 1,with the same time to completion tf .

performance metrics:

The cross-track error**(e[m])**stays within 0.2 m for both scenarios, which is satisfactory and corresponds to 1.7 m for a full-scale ship. The simulated energy consumption in S1 surpasses the planned consumption, however, since this scenario is planned with no current information, the discrepancy is to be expected. In S2, the simulated energy consumption stays close to the planned consumption, and is significantly lower than in S1

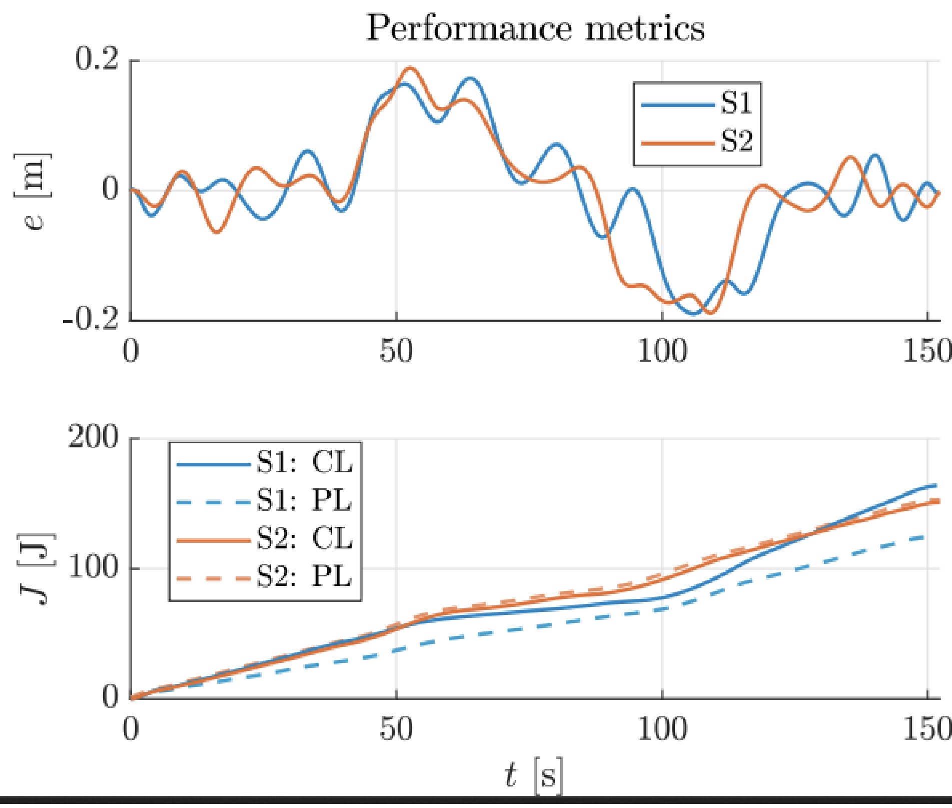

Figure 7: performance metrics