

Homework Assignment

Problem 1

Autonomous underwater vehicles (AUVs) are becoming increasingly popular for deep-sea exploration. AUVs can operate in dangerous and remote environments without putting human lives at risk, especially where conditions can be harsh and unpredictable.

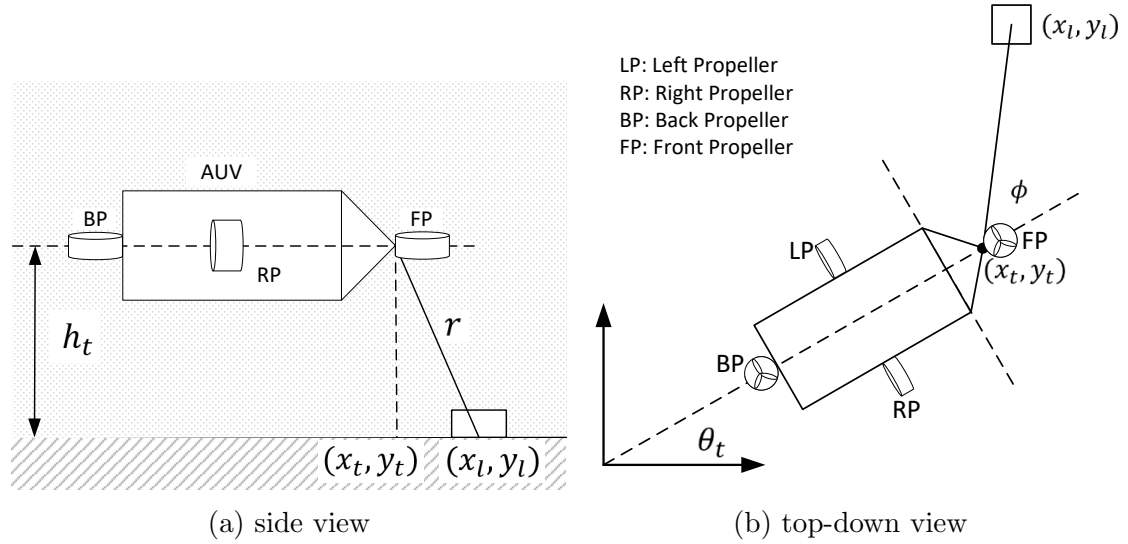


Figure 1: Autonomous underwater SLAM system

An AUV as depicted in Fig. 1 is to be utilized for the exploration of a certain shipwreck. The AUV achieves autonomous navigation using a semi 3D-SLAM system with a feature-based map. The state of the AUV is given by its 3D position (x_t, y_t, h_t) and its 2D orientation θ_t . Distinct rocks on flat seabed are considered to be landmarks in the map. The state of a landmark is given by its 2D coordinates (x_l, y_l) . Consider the following conditions for the motion model of the AUV:

- AUV receives a control input $u_t = [v_t \ \omega_t \ \gamma_t]^T$ at each time step. v_t is the horizontal translational velocity, ω_t is the horizontal rotational velocity, and γ_t is the vertical velocity.
- During each time step (Δt), the overall effect of u_t is such that the AUV, first, adjusts its height using γ_t for Δt_γ , and then rotates on the spot using ω_t for Δt_ω , and finally moves in a straight line using v_t for Δt_v ($\Delta t = \Delta t_\gamma + \Delta t_\omega + \Delta t_v$).

The perception system returns sonar range-bearing measurements (r, ϕ) as illustrated in Fig. 1.

- Explain how the AUV achieves different types of motion using its propellers (LP, RP, BP, and FP). [6 marks]
- Construct the motion model as a function of control input u_t and the AUV's previous state. [4 marks]
- Augment the motion model to the full SLAM state transition model for a single landmark situation. [3 marks]
- Derive the Jacobian matrix of the augmented state transition model with respect to the state variables of the augmented state. [4 marks]
- Formulate the measurement model of the system. [4 marks]
- Derive the Jacobian matrix of the measurement model with respect to the state variables of the augmented state. [4 marks]