OE5005: MARINE AUTONOMOUS VEHICLES

Course content:

Overview of autonomy: Autonomy levels for marine vehicles - Technology Readiness Levels, Regulatory concerns, IMO Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) Kinematics and dynamics: Reference frames, coordinate transformations, Euler angles, quaternions, Newton-Euler equations of motion of marine vehicles, Coriolis forces and moments, Hydrostatic forces, Added mass, Dissipative forces, Wind, wave and current forces Traditional Guidance: Line of Sight (LOS) guidance law, Lyapunov stability, Vector field guidance law, Proportional LOS, Integral LOS Modern Guidance: Probabilistic Road Maps (PRM), Obstacle avoidance - Artificial potential fields (APF), Fuzzy logic based COLREGs Navigation: Sensors overview - GPS, IMU, Cameras, LiDAR, RADAR, Wave and Noise filtering, Fixed gain observer, Luenberger observer, Kalman Filter, Extended Kalman filter (EKF), Sensor fusion Traditional Control: PID Control, successive loop closure autopilot, Pole placement for SISO and MIMO systems, Control law stability Modern Control: Deep Reinforcement Learning - Markov decision process, Utility function, Bellman equations, Q-value iteration, Deep Q network (DQN), Deep Deterministic Policy Gradient (DDPG), Proximal Policy Optimization (PPO), Collision avoidance strategies Practical: The practicals will focus on implementation of the autonomy algorithms developed in Robot Operating System 2 framework and deployment on an autonomous surface vessel. This will involve coding exercises on IoT devices (Raspberry Pi and Arduino boards) and working with various sensors such as GPS, IMU and other sensors. Learning Objectives: After completing this course, the students should be able to: Recognize the different levels of autonomy and recollect the current regulations governing autonomy of marine vehicles Differentiate between traditional and modern methods of guidance, navigation and control Understand a simulation environment of a marine vehicle incorporating the kinematics and dynamics Implement guidance, navigation and control algorithms in a simulated environment Use ROS2 to interface with the sensors and actuators in a marine vehicle Design parameters of an Extended Kalman Filter (EKF) to fuse the data from multiple sensors Implement guidance, navigation and control algorithms in ROS2 and test them on real marine vehicles

Text Books:

1. T.I.Fossen (2021). Handbook on Marine Craft Hydrodynamics and Motion Control. John Wiley and Sons. Brunton, S. L., & Kutz, J. N. (2019). Data-driven science and engineering: Machine learning, dynamical systems, and control. Cambridge University Press. (Supplementary Material: http://www.databookuw.com/)

Reference Books:

1. T.I.Fossen, "Guidance and Control of Marine Vehicles", John Wiley & Sons, 1994. Lewis,E.U, Principles of Naval Architecture, SNAME, New Jersey, U.S.A, 2010. Goodfellow, I., Bengio, Y., Courville, A., & Bengio, Y. (2016). Deep learning. Cambridge: MIT press.

Prerequisite:

Programming