Title

Toward Precise Control of a Robotic Boat

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CENS **Center for Embedded Networked Sensing**

Toward Precise Control of a Robotic Boat

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Need for Precise Control

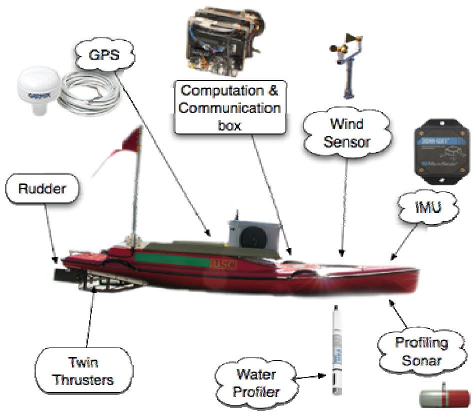
Introduction

Unmanned surface vehicles (USVs)

- Subjected to external forces
  - wind
  - water currents
  - waves
  - **challenging control problem**.
- Typical problems in USV control
  - navigation
  - trajectory tracking
  - station keeping.

Task	Requirements
Vertical profiling which involves dwell time and sampling rate at multiple depths.	Hold position for ~10mins in the presence of drift.
Efficient ***bathymetry*** with profiling sonar.	• Heading control for efficient scanning. • Regular and dense scan patterns involve planning of trajectory in position and velocity.☐
Docking to recharge for long term deployments.	Docking maneuver.
Collaborative missions involving multiple boats.	Multi-robot missions and formations.

Platform and Methodology



System Dynamics

$$M\dot{\nu} + C(\nu)\nu + D(\nu)\nu + g(\eta) = \begin{bmatrix}\tau \\ 0\end{bmatrix}$$

$$\dot{\eta} = J(\eta)\nu$$

M = inertia matrix
C = coriolis and centripetal matrix
D = hydrodynamic damping matrix
G = gravitation and buoyancy vector
ν = velocity vector in body frame
η = velocity vector in global frame
J = kinematic tranformation matrix

System Identification

- Identify the dynamics of the boat
- Empirically determine unknown parameters by observing response of the system to specific inputs.

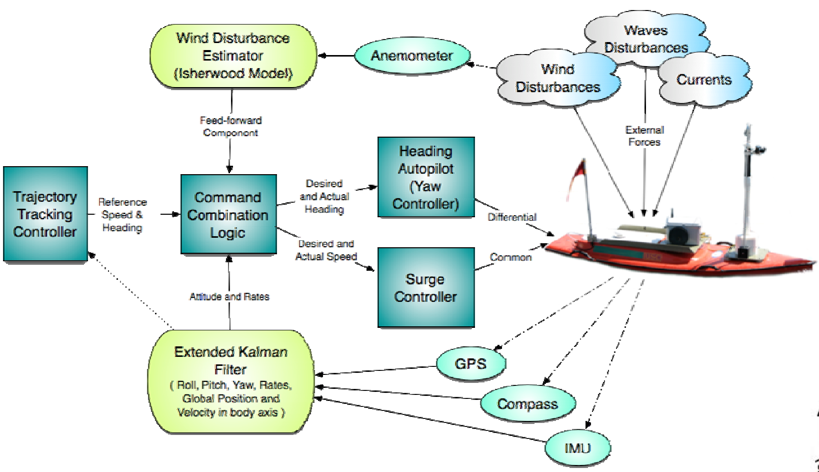
State Estimator

Sensors are noisy. A good state estimator (location and orientation) is essential for precise control. We use an Extended Kalman filter.

Controller Design

- Feedback controllers for heading and speed.
- Feedforward controller for correcting the effect of wind.

Design Details and Preliminary Results



Station Keeping

Problem - Wind results in position drift.

Proposed solution

- Monitor wind direction and speed using an anemometer.
- Estimate effect of wind on the boat using a wind model
- Align boat to the wind direction.
- Compensate for wind using Feedforward control.
  - adjust heading and speed to hold position.
- Learn set of gains for robust position regulation.

Simulation Results

A - initial position of the boat oriented at 0°.
B - align with the wind.
C - Minimize error to the target while maintaining alignment.