MCTE 4362 ROBOTIC HARDWARE SYSTEMS

Unmanned Surface Vessel (USV)

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Introduction

- Unmanned Surface Vehicles (USVs) are autonomous or remotely controlled vessels that operate on the water's surface without an onboard crew.
- USVs are equipped with navigation, communication, and propulsion systems, allowing them to perform a wide range of missions in marine environments.
- They can carry various sensors and payloads, such as cameras, sonar, and environmental sensors, for data collection, mapping, and monitoring.
- Real-life applications of USVs include oceanographic research, environmental monitoring, offshore inspection, search and rescue operations, and military surveillance, making them invaluable for tasks that are hazardous or challenging for human crews.

6 Main Components of USV

1. Hull Design
2. Propulsion System
3. Navigation System & Control
4. Data Collection
5. Data Transmission
6. Power Management

Hull Design

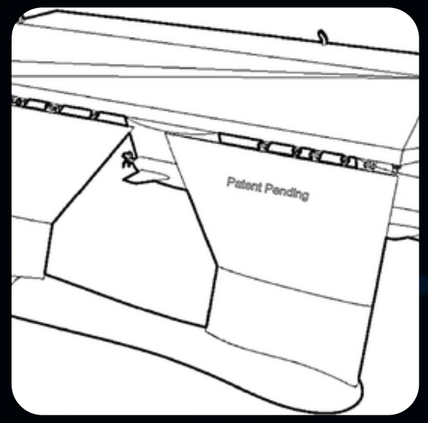
- Refers to the skeleton of the USV which acts as a frame and support for all the components.
- Hull design depends on the USV mission and objectives and the environment that it's going to be operated in.

Monohull (Single Hull)

- Efficient on high speeds and long distance
- Stable in calm waters but less stable in rough seas

Catamaran (Twin Hull)

- High stability making it well-suited for survey and research missions in moderate to rough waters.
- Reduced drag
- High payload capacity.



Small waterplane area twin hull (SWATH)

- Twin hulls with submerged torpedo like hulls connected by narrow thin struts.
- Enhanced stability but hgh drag, thus requiring more power

Trimaran (Three Hull)

- One main hull with two smaller outriggers on each side.
- High speed, stability, and a larger deck area
- Ideal for high-speed operations and heavy payloads.

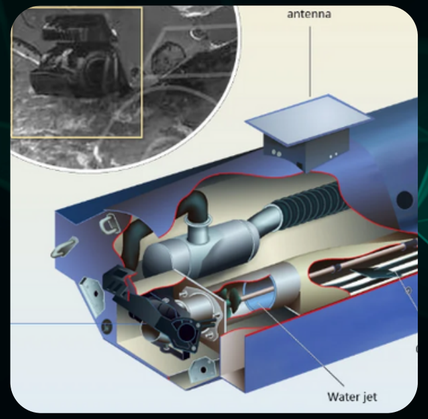
Planing Hull

- Low drag at high speeds
- Designed to skim the water surface at high speeds
- Less stable in rough seas

Propulsion Systems

Includes motors, propellers, and ESCs (Electronic Speed Controllers). This is the system that moves the USV. The motors will drive the propellers, generating thrust for lift and maneuvering, while ESCs regulate motor speed.

USV‘s may used a combination of propulsion systems to suit its mission and capabilities.



Water Jets

- Ejects water at high velocity
- Easy to maneuver
- Not prone to damages as it is quite small.

Airboats

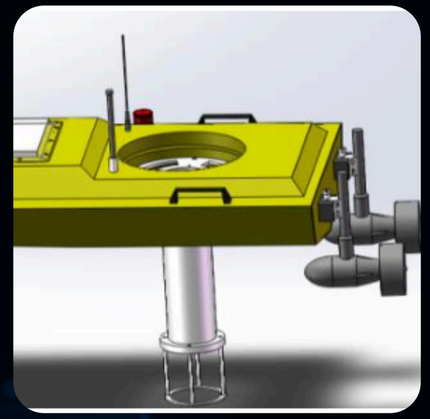
- Suitable for shallow waters or debris-laden waters as the system is on the boat and not exposed to water

Diesel Engines

- Used for missions that requires long range and high endurance.
- The diesel engines would provide power to the propellers.

Electric motors & Wave Driven

- Powered by solar energy and wave motion.
- A submerged glider with fins that convert wave motion into thrust.
- Energy-efficient, ideal for long-duration, low-speed missions like ocean monitoring.



Propeller

- Efficient for medium to high-speed operations
- Suitable for a a variety of mission types

Sail-Driven

- Uses wind energy to travel long distances autonomously.
- Eco-friendly and efficient for oceanographic data collection.

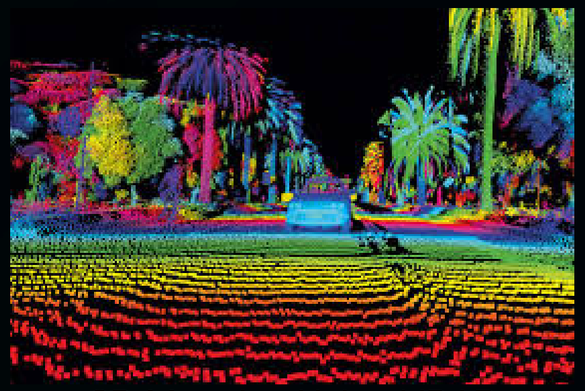
Navigation System & Control

The navigation and control systems of a USV are critical for achieving autonomous or remotely operated missions with high precision.

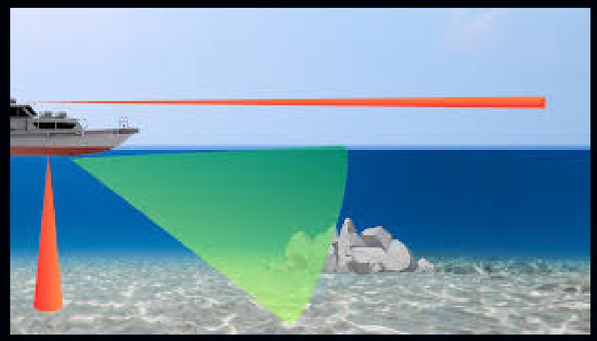
The navigation system allows the USV to determine its position, orientation, and path with respect to the environment while the control system processes input from the navigation system and makes adjustments to the USV's propulsion and steering to stay on course, avoid obstacles, and achieve mission goals

The navigation system of a USV may includes several technologies that would help the missions such as:

1. GPS (Global positioning System) : Uses a network of satellites the to provides real-time location and orientation of the USV to the user.
2. LiDAR: Provides precise 3D mapping and object detection by emitting pulses of light and measures how long it takes for the reflected light to return to the sensor. The distance between the sensor and the object is calculated using the velocity of light. Super helpful in obstacle avoidance and environmental mapping.
3. Sonar: Using sound waves to detect and map underwater or submerged objects like sea life, debris or submarines to plot the correct course.
4. Radar: Used for detecting and avoiding obstacles in real-time, particularly valuable in adverse weather conditions or high-traffic areas.



3D Mapping Using LiDAR



Obstacle Detection Using Sonar

Radar

Data Collection

- Since the missions of USV is to collect data where it may prove to be unsuitable for human exploration, the technologies used for said task should be suitable for their specific missions. Data collection is an integral part of the USV especially in applications like environmental monitoring, oceanography, and defense
- As USV's gather specialised data for their missions, they may used specialised sensors similar to those used for navigation system, such as the GPS, LiDAR, radar and camera.

Location of Sensors	Component	Function	Application
Top	LiDAR	Creates high-resolution 3D maps above water	Coastal Mapping, Obstacle Detection
	Cameras and Visual Systems	Captures optical/infrared images, video	Surveillance, Inspection
	Meteorological Sensors	Measures wind speed, humidity, and air pressure	Weather Forecasting, Environmental Monitoring

Data Collection

Location of Sensors	Component	Function	Application
Bottom	Sonar Sensors	Maps underwater topography, detects objects/marine life	Maps underwater topography, detects objects/marine life
	Environmental Sensors	Measures water quality parameters like temperature, salinity, etc.	Oceanography, Environmental Monitoring

- All the data that has been received from the sensors would require the help of a post-processing software to analyse the data obtained. Each software supports a variety of marine survey applications that require accurate georeferencing, mapping, and multi-sensor integration.

- Examples of post processing software includes HYPACK, POSPAC MMS, and QINSy, which is the most common post-processing software used in handling data collected by USV's.

Data Collection

Software	Purpose	Main Features	Applications
HYPACK	Hydrographic and Navigation Software	- Data acquisition, processing, and analysis for hydrographic surveys - Compatible with a range of sensors, including sonar, LiDAR, and GPS.	Used for hydrographic surveys, dredging, environmental mapping, and coastal monitoring.
POSPAC MMS	GNSS and Inertial Post-Processing Software	- GNSS and IMU data processing for high-precision positioning - Real-time or post-processed kinematic (RTK/PPK) solutions - Used with POS MV and other Applanix sensors.	Essential for precise georeferencing in marine surveys, especially in GNSS-denied environments.
QINSy	Integrated Survey and Navigation Software	- Real-time data acquisition, processing, and visualization - Supports multi-sensor integration (sonar, LiDAR, GPS) - Tools for bathymetry, dredging, and sub-bottom profiling	Suitable for offshore construction, dredging, and underwater inspections requiring multiple data sources.

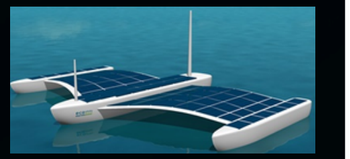
Data Transmission

- Data transmission refers to the hardware that transmit the collected data to operators or data ceners in real-time or stored ofr later.
- It allows for communication between the operators and the USV to perform a variety of tasks such as autonomous tasks, collecting data and transmitting the real time data to the user.

Component	Function	Application
Satellite Communication	Long-range data transmission when USV is far offshore.	Real-Time Data Transfer in Remote Areas
Radio Frequency (RF)	Short-range, line-of-sight transmission	Near-Shore Operations, Low-Latency Transfer
Cellular Networks (4G/5G)	High-speed transmission near shore	Video Streaming, Near-Shore Monitoring
Wi-Fi	High-speed data transfer within close range	Data Download When Docked at the Pier

Power Management

Power management refers to ensuring a right power source are chosen with respect to the mission duration to optimise energy consumption and implementing energy storage solutions. The power source chosen must be able to handle the USV's mission, range and endurance.

Power Source	Advantages	Disadvantages
Batteries (Li-ion, LiPo) 	• High energy density, lightweight • Rechargeable • Quiet and emissions-free, ideal for eco-sensitive operations	• Limited operational duration without recharging • Requires effective battery management to prevent overcharging/deep discharge • Longer recharging time compared to fuel
Fuel Cells (Hydrogen)	• High energy density • Quiet and low emissions • Suitable for extended missions	• Expensive and complex fuel storage (e.g., hydrogen) • Limited availability of refueling infrastructure • Lower power output for high-speed needs
Solar Panels 	• Renewable and sustainable • Low maintenance • Can continuously recharge batteries, extending mission duration	• Dependent on sunlight availability • Limited power output, often insufficient for high-power applications
Diesel	• High power output • Used for long range, high payload capacity USV	• High noise emission

Thank You