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DEPARTMENT OF COMPUTER ENGINEERING

MODULAR SELF-NAVIGATING UNMANNED SURFACE DRONE FOR MARINE APPLICATIONS

A Research Paper
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ABSTRACT

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The project is motivated by the desire to explore the potential benefits of modularity coupled with autonomy. Developing a water surface drone leveraging an ESP-32 microcontroller and incorporating autonomous navigation powered by GPS and magnetometer sensors to create an easy to use and modular system by minimizing complexities, ensuring smooth operation and simplified troubleshooting. Testing procedures will evaluate the drone's accuracy in reaching designated target positions, providing quantitative insights into its navigational reliability. This project includes information on how to create said drone allowing anyone to reproduce it and use the drone as they see fit as it is modular by nature, some parts can be replaced or swapped out or even add new components to fit users intended use. Given the correct components, mapping lakes and rivers or monitoring ocean conditions for scientific research becomes a much easier task.

Contents

Chapter 1

Introduction

This chapter has seven parts: (1) Background of the Study, (2) Statements of the Problem, (3) Theoratical Framework, (4) Conceptual Framework, (5) Scope and Limitations, (6) Significance of the Study, and (7) Definition of Terms.

Part one, Background of the Study, gives an overview as to which the research problem was anchored.

Part two, Statement of the Problem, identifies the main problem and enumerates the specific problems which the study hoped to answer.

Part three, Theoretical Framework, discussed the relevance of the variables in the identified theory, concept or principle to the research problem.

Part four, Conceptual Framework, presents the paradigm of the study.

Part five, Scope and Limitations, specifies the scope and coverage of the study in terms of purpose, research design, research instruments and statistical tools employed in the study.

Part six, Significance of the Study, presents the possible contributions and the specific application of knowledge that might be gained from the result of the study.

Part seven, Definition of Terms, contains the conceptual and operational definitions of key terms used in the study.

Background of the Study

As the ocean covers over 70% of the Earth's surface, presenting a vast and complex environment ripe for exploration and study. Sea surface drones offer a valuable tool for navigating water bodies, collecting data, and conducting research across various disciplines. Unmanned surface vehicles (USVs) equipped with autonomous navigation capabilities have become pivotal in various applications, particularly in water environments.

Early USVs were also called ASC; Autonomous Surface Craft (ASCs)which were first developed at the MIT Sea Grant College Program in 1993 and were designed for various missions. Aptly named ARTEMIS,the vessel was a scale replica of a fishing trawler used as a platform capable of testing the navigation and control systems required by an ASC. Later on a new ASC ACES(Autonomous Coastal Exploration System) was developed during 1996 and 1997(Justin E. Manley 2008)

Further adaptation of USV in the early 20th century saw the development of remotely controlled USVs used for mine detection and target practice. World War II further spurred advancements, with nations utilizing USVs for reconnaissance and explosive delivery. Post-war, oceanographic research embraced USVs for data collection and underwater exploration. Notably, the bathyscaphe Trieste, equipped with a rudimentary autopilot, famously reached the deepest point in the Earth's oceans in 1960(National Museum of the U.S. Navy)

The 1990s witnessed a surge in commercial applications, with USVs employed for offshore oil and gas exploration, pipeline inspections, and aquaculture monitoring. The 21st century has seen a continued proliferation of USVs, with advancements in sensor technology, autonomous navigation systems, and communication capabilities propelling their capabilities further.

However, while traditional methods for marine data collection involve time-consuming, expensive, and potentially risky manual operations, unmanned surface vehicles (USVs) offer a compelling alternative. These vehicles promise efficient, cost-effective, and safe data collection across vast areas. However, current USV technology faces three key hurdles: high cost due to complex hardware and software, limited accessibility due to user interfaces and maintenance requirements, and navigation challenges in dynamic aquatic environments. This study aims to address these limitations by developing a modular unmanned surface drone with a focus on simplified maintenance, affordability, and interchangeable components that can be easily switched.

Empirical testing conducted as part of this research, quantifying the water surface drone's ability to reach predefined target positions, serves as a critical quantitative assessment of the system's accuracy. The results obtained will offer data ensuring the navigational reliability of the drone.

The drones modular design enables adaptation on sea applications based on specific needs, seamlessly integrating communication modules, lifesaving equipment, or various sensors as required. This adaptability ensures tailored responses to emergency situations and varied data collection demands.

Statement of the Problem

How accurate is the Modular Self-Navigating unmanned surface drone when moving from point of origin to the user inputted coordinates?

Hypothesis

Drone accuracy will be high and can effectively navigate to the user supplied coordinates.

Theoratical Framework

From a control systems perspective, the Drone leverages feedback mechanisms and advanced algorithms to achieve autonomous navigation and mission execution. This dictates the drone's ability to gather environmental data, make real-time decisions, and dynamically adjust its actions based on sensor readings and mission parameters. Furthermore, the modular design aligns with the principles of modular robotics, emphasizing the benefits of independent, interchangeable components. This enables tailored configurations for diverse tasks, offering adaptability to various environments and operational needs. Additionally, the drone can be understood through the distributed systems theory, which emphasizes the coordination of multiple agents towards a common goal. In this context, the modular components act as individual agents collaborating to make the sea surface drone function. This theory guides the design of communication protocols and inter-module coordination algorithms, essential for seamless collaboration and collective task execution. By integrating these theories, drone development can benefit from established principles in control, modularity, and distributed systems, leading to a robust, adaptable, and efficient platform for maritime operations.

Conceptual Framework

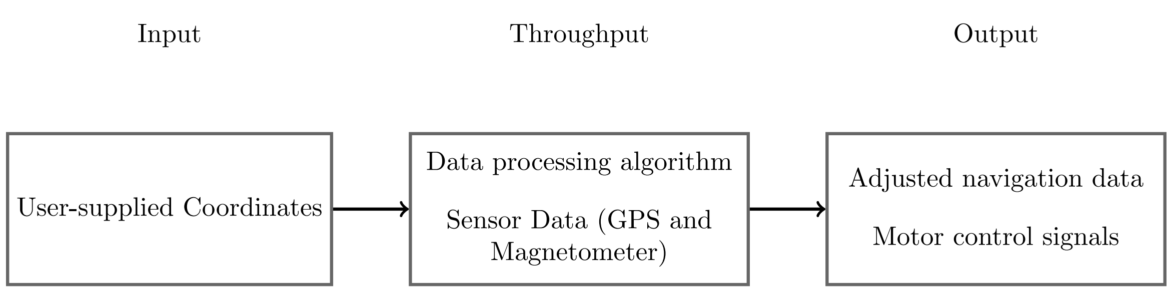

Figure 1.1: Conceptual Framework

Figure 1.1 shows the conceptual framework on how the drone functions. To discuss briefly; user provides geographical coordinates or destination data to the ESP-32 onboard the sea surface drone. Magnetometer and GPS sensors collect real-time data regarding the drone's current position, orientation, and the magnetic field. The ESP-32 employs a navigation algorithm that processes user input and sensor data from gps and magnetometer.

Continuous feedback loop adjusts the drone's path in real-time based on the latest sensor data, ensuring adaptability to various sea disturbances.

Objectives:

General Objectives:

– To design an ESP-32 based water surface drone with autonomous navigation capabilities using GPS and Magnetometer

Specific Objectives:

– To construct an easy to use and maintainable water surface drone system

– To test the accuracy of the sea surface drone to reach the target

Significance of the Study

Developing a modular water surface drone equipped with autonomous navigation capabilities holds significant value. The widespread adoption of such drones requires accessible construction and upkeep, making them viable tools for various users. Evaluating the drone's accuracy in reaching target positions offers crucial empirical data, validating its reliability and paving the way for more practical applications. This project contributes to the progress of sea surface drone technology, potentially impacting research initiatives in oceanography, environmental monitoring, and more. Furthermore, being easy to reproduce fosters broader use, democratizing access to this technology.

Scope and Limitations of the Study

The research concentrates on assessing the accuracy of the drone's navigation, particularly in reaching user-provided coordinates, with a focus on real-time adjustments and adaptability to various water disturbances. The drone is limited to a navigation algorithm that checks and corrects for its navigational pathing on loop. Said algorithm is only designed for relatively small distances as it doesn't take into account the curvature of the earth and the distance measured by the algorithm is assuming a straight line and not a part of the Great Circle.

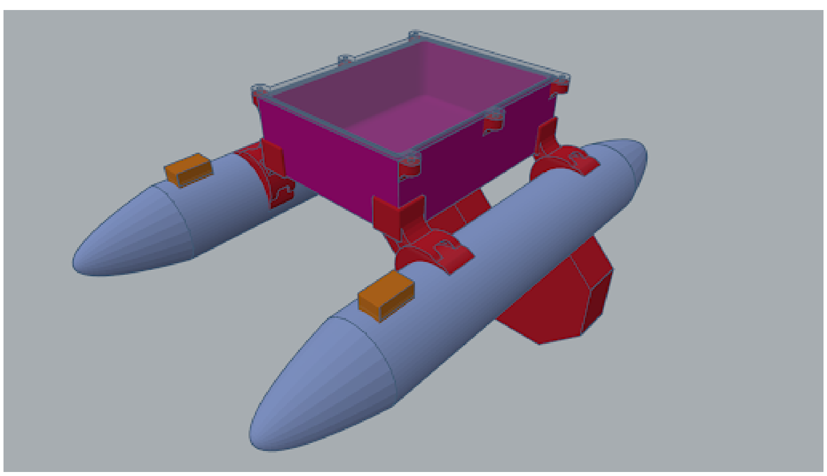

Figure 1.2: CAD Model

The study does not consider the potential challenges posed by capsizing due to strong tidal waves or encountering large obstructing objects in the ocean. Furthermore, the research does not extensively explore the intricate legal and regulatory frameworks governing unmanned surface drones, instead prioritizing an in-depth examination of the technical aspects related to navigation.

While the study's primary focus is on navigation accuracy, the drone is inherently modular(Figure 1.2). This modular design enables the replacement of various components to meet the specific requirements of future users, enhancing its versatility and adaptability in different scenarios.

Definition of Terms

- ESP32 – low-cost, low-power system-on-chip (SoC) microcontrollers designed by Espressif Systems. Widely used in various applications such as IoT (Internet of Things), home automation, wearables, and industrial automation due to its versatility, low cost, and built-in Wi-Fi and Bluetooth connectivity. It is commonly programmed using the Arduino IDE or the Espressif IDF (IoT Development Framework).
- Shroud – refers to 3d printed components that covers and protects the propeller from marine debris. Secures brushless motor in place.
- Pontoon – refers to 3d printed components; Provides the drone with enough buoyancy to keep afloat on water.
- Enclosure – refers to 3d printed waterproof containers housing electronic components.
- Bracket – refers to 3d printed components; Design includes 6 pieces connecting the shroud to the pontoon and the pontoon to the enclosure.