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A Critical Analysis of Design Flaws in the Death Star

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Report submitted in partial fulfilment of the requirements of the module Project (E) 448 for the degree Baccalaureus in Engineering in the Department of Electrical and Electronic Engineering at Stellenbosch University.

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Abstract

English

The English abstract.

Contents

List of Figures

List of Tables

Nomenclature

Acronyms and abbreviations

USV	Unmanned Sailing Vessel.
GPS	Global Positioning System.
RC	Radio Controlled
CAD	Computer Aided Design

Chapter 1

Introduction

1.1. Background

The ocean covers 71% of the earths surface and 80% of it remains unmapped, unobserved, and unexplored. The ocean produces over half of the air we breathe and absorbs 50 times more carbon dioxide than our atmosphere currently does. It regulates our climate and the weather patterns by transporting heat from the equator to the poles. It provides sustenance to millions of people around the world. Many medicinal products that help to fight cancer, arthritis and heart disease come from the ocean. Marine transportation makes up a huge portion of global trade, which supports the economies of the world. Without the ocean, life as we know it would not be possible and the planet would become uninhabitable.

The rapidly growing global population and consequent resource consumption is impacting the local and global environment negatively through physical and chemical pollution. The release of carbon dioxide into the atmosphere contributes to climate change, ocean warming, ocean acidification and the rise in sea levels. When released into the ocean, chemical wastes such agricultural fertilizers result in ocean deoxygenation. Many other forms of pollution such as untreated waste water and micro and macro plastics have an environmental impact that as of yet is only partially known.

Ocean research has led to our current understanding of the huge role the oceans play in supporting life on this planet. The continuing research and exploration of our oceans will aid in assessing the growing negative impact human activity has on the oceans, and by better understanding this impact, more effective solutions can be developed. Ocean research requires large amounts of funding and human resources to support it. As of 2015 the United States had 4000 ocean science researchers, roughly 50 nationally maintained ocean research vessels and in 2013 had an annual national ocean science expenditure of $12.5 trillion [?]. These ocean research vessel cost from $10000 to $40000 a day to operate, with the crew itsef being one of the biggest expenses [?].These expenses can increase greatly when research missions to remote areas of the globe are conducted, many of these areas being hard or even impossible to access via research vessels.

Advancements in robotics and the development of unmanned vehicles can help bring down the cost and complexity associated with ocean research missions as well as increase the quality of research done. Unmanned sailing vessels(USV) will be able to travel long distances over the ocean, for long periods of time, to remote and inaccesable locations and with little power consumption. USV's can be equipped with various high quality sensors such as hydrophones that are used in marine research. The integration of solar panels with USV's can further increase the range and duration they are capable of.

1.2. Problem Statement

To design and develop the navigational and control systems for an unmanned sailing vessel that will enable it to sail along a predetermined route with a relative degree of accuracy. The route to be travelled is defined by a set of GPS coordinates.

1.3. Objectives

This section will state the objectives that need to be achieved in order to address the problem statement.

In order for the navigational systems to work the following objectives need to be achieved. The USV should receive the current GPS coordinates with the standard degree of accuracy associated with the GPS, which is 2.5m. The USV should also be capable of logging the current GPS location as it travels along the route, this is needed to verify successful operation of the USV. Additionally the USV needs to calculate distance between two GPS cordinates accurately in order to determine when it has reached its target location. The USV should be able to calculate bearing given two GPS locations - its current GPS location and its target GPS location.

In order for the control systems to be work the following needs to be achieved. The USV needs to be capable of measuring its current bearing to a relative degree of accuracy, this is a requirement for designing the rudder control system. The USV must be capable of determining wind direction relative to itself and adjust the sail position accordingly. The USV must be able to sail between two predetermined GPS coordinates with minimal deviation between its bearing and the bearing between the two coordinates. The Vessel should be able to tack into the wind in order to reach a target location. Given that these two objectives have been achieved, the vessel should be able to travel between three GPS coordinates such that the travelled path is a triangle.

1.4. Summary of Work

1.5. Scope

Chapter 2

Literature

2.1. Sail Theory

2.2. Related Work

2.2.1. Unmanned Sailing Vessel by Philip van Schalkwyk

Philip is a mechatronics graduate who designed and developed an unmanned sailing vessel for his final year project at Stellenbosch University [**?**].

Objectives

To design and develop an USV that is capable of autonomous sailing - uses navigational and control systems to travel along a predetermined path consisting of GPS waypoints.

Method Used

A RC sailing vessel was retrofitted with micro-controller that would read data from sensors and adjust the rudder and sail position in order to sail along a desired path. The system consisted of a micro-controller, GPS receiver, a micro-SD card, an electronic compass, wind direction sensor and two servo motors - one to control the sail and one to control the rudder angle. The micro-controller that was used was a Espress ESP-WROOM-32 micro-controller which is relatively low cost and has a 240 MHz clock speed. The electronic compass was used to determine the current bearing of the vessel, it was designed and developed using a magnetometer, accelerometer, gyroscope and tilt compensation algorithms. The MPU9250-6500 9-axis sensor module was used for the electronic compass as it consists of a magnetometer, accelerometer and a gyroscope. A mechanical wind vain was designed with CAD software and printed with a 3D printer. The wind vain was fitted with a magnetometer - also the MPU9250-6500- which was used to determine the bearing of the wind vane and therefore the wind direction. The GPS receiver that was used for the navigational system was a Neo M8N GPS, it would log positional data to the micro-SD card.

A proportional controller was used to control the rudder position. The desired heading/bearing was calculated using the current GPS coordinates obtained from the GPS receiver and the target GPS coordinates. A sample would then be taken from the electronic compass which would give the current bearing of the vessel, the difference the current bearing and the desired bearing is the error signal. The proportional controller would then determine the rudder angle given this error signal, and the servo motor controlling the rudder would be adjusted accordingly.

The main sail position was determined by the samples taken from the wind direction sensor and the current bearing. Only three point of sail classifications were used for the sail positions : close-hauled, beam-reach and Run. This was done to give more time to navigational and rudder control systems. If it was determined that angle of attack was less than 45 deg the vessel would tack into the wind. This was achieved by calculating the bearing to either side of the no-sail zone, the vessel would then sail with one of these bearings for 50 meters and then change to the other bearing. The vessel would alternate along these bearings until the target destination was reached.

Results

The e-compass was tested against a magnetic compass and the results showed the average error in bearing to be 5.84 deg, the e-compass did however produce a consistent spike at 180 deg across multiple tests. Tests that were done with the GPS receiver showed that the positional accuracy of the GPS receiver was sufficient for the navigational system and data-logging. The Wind sensor that was developed was unable to provide wind direction data consistently, a possible explanation for this is that the length of the I^2C was to long and therefore the capacitance in the lines caused a low pass filter effect on the signal. The final tests that where done to verify the workings of the USV, the point of sail classification was set to run initially and sail adjustments were not taken throughout the duration of the test - due to the wind sensor not working. The results of the final test showed that the rudder control system was capable of keeping the vessel on a near constant heading, with a maximum absolute error of 6 deg. This test was conducted between two GPS coordinates and the vessel therefore sailed on a fixed bearing between them. Fig **??** shows the results of this final test.

Remaining challenges

The rudder control system designed by Phillip was capable of accurately tracking a desired bearing during tests. Proportional integral control could not be implemented due to the consistent error that occurred during the e-compass testing. The USV that was developed does not however have the ability to dynamically adjust the sail position according to the relative wind direction, and is therefore unable to achieve the desired performance if wind direction changes from its initial direction. Tests where also not conducted to verify the tacking capabilities of USV.

and the sail position was set accordingly depending on readings from the wind direction sensor.

Chapter 3

Summary and Conclusion

Appendix A

Project Planning Schedule

This is an appendix.

Appendix B

Outcomes Compliance

This is another appendix.