Navigation and Control of an Unmanned Surface Vessel

Mechatronics Project 488

Project Proposal

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Executive Summary

|  |
| --- |
| **Title of Project** |
| Navigation and Control of an Unmanned Surface Vessel. |
| **Objectives** |
| The development of an independent navigation and control system that can be implemented on an unmanned surface vessel that uses electrical thrusters for propulsion and steering. |
| **What is new in this project?** |
| A new control system is going to be created to control the power to the thrusters and thereby steer the vessel. Building on this a navigation system will be created so that the vessel can navigate to a designated point autonomously. |
| **If the project is successful, how will it make a difference?** |
| With a successful navigation and control system, the system could be moved to vessels with better range and seafaring ability and these unmanned vessels can be used for research data collection, patrolling and search and rescue. |
| **What contributions have/will other students made/make?** |
| N/A |
| **Which aspects of the project will carry on after completion and why?** |
| For the vessel to be completely autonomous, a further project should add an obstacle avoidance system. This will be beneficial to avoid other sea vessels as well as fixed obstacles such as rocks and shore. |
| **What arrangements have been/will be made to expedite continuation?** |
| All the research and project documents will be archived with the university. |

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# Introduction

## Background

As technology has improved over the years, processes and systems have become more automated. Initially factories were replacing manual labour with automated machines but recently companies have been investigating self-driving cars and trucks. All over industries tasks are being automated or done remotely with fewer human involvement.

The ocean is the perfect area for unmanned surface vessels (USV) to be used as many of the issues faced with autonomous land vehicles such as self-driving cars are mitigated by open water. On the open water one gets a 360° of the surroundings of the vehicle and although there can still be high volumes of traffic in certain areas such as commercial shipping lanes, due to the expanse of the ocean these high traffic areas are avoidable. Finally, and probably the most desirable mitigating factor is that where a surface vehicle would need to look where the road surface is to follow it, an ocean vessel can move directly from point to point on any piece of water.

In South Africa there is a growing need to USVs with regards to ocean research and conservation. There has been a growing use of acoustic sensory systems to track dolphins and whales around the world. By combining this with the technology of USVs, a far larger area can be surveyed.

## Objectives

This project will focus on the navigation and propulsion control of the USV. This is the building block of the USV upon which a future project can build by adding an obstacle avoidance system or renewable power sources to keep the USV operational for longer. This project will have the following objectives:

1. Design and manufacture an electric surface vessel.
2. Designing and manufacturing the control system that will give a pilot manual control over the electric surface vessel.
3. Building on the manual control and implementing navigation control so that the electric surface vessel.

## Motivation

Currently the marine community is using these acoustic systems as stationary systems. By using the USV in conjunction with the USV the area that is studied can be greatly increased with fewer acoustic platforms as have been used in passed projects. Furthermore, the technology can be adapted for use in other industries such sonar surveying, defence and search and rescue. The use of USVs is becoming more prominent as a USV can be cheaper to operate and therefore organisations can either save costs in the case of sonar and acoustic research or in the case or marine patrols and search and rescue, USVs can be used to fill up the ranks of vessels and close the possible.

The tasks previously mentioned are often time consuming and the crew of the assigned vessel need time to rest whereas a fully autonomous USV can operate constantly, stopping only to replenish its energy source and with further developments such as solar charging, USVs could begin to operate indefinitely, having to only come in for services or if there is a problem with the system.

# Planned Activities

## Review Literature

Review the literature around navigation and control systems as well as those around global positioning satellites (GPS) and compare existing navigation and control systems of marine, land, and air vehicles.

## Review Similar Projects

Research and review projects that are like this project as well as projects that may have similarities on land or in the air.

## Design the Algorithm Flow Diagram

Design the algorithm required to navigate and control the system and draw the flow diagrams for this algorithm.

## Design the Control System Hardware

Design what hardware is needed to implement the designed algorithm and how it will interface with the vessel.

## Design the Mechanical Mountings

Design the mechanical mountings that will be mounted to the back of the vessel and will hold the propulsion. These mountings are required to lift up so that the propulsion can be lifted out of the water if required.

## Create Parts List

Using the concept design create a parts list for parts to be ordered. This must be done as soon as possible to allow time for the parts to arrive.

## Order Parts

Order the required parts, else source the required parts through the university.

## Manufacture Mechanical Mountings

The outboard mount of the thrusters must be manufactured with the help of the Mechanical Workshop and mounted onto the vessel.

## Manufacture the Control System Hardware

The control hardware such as the microcontroller, etc. needs to be assembled and be ready to integrate with the vessel.

## Program the Control System Algorithm

The software for the control algorithm needs to be implemented and debugged to a sufficient level ready for testing.

## Fix all System Elements

All the systems elements must be fixed together onto the vessel so that it is ready for testing.

## Test USV in Manual Control

Run a couple of tests using the manual control to test that the USV propulsion and steering is operating as required.

## Test USV in Self-navigating Control

Finally run the USV in self-navigating control tests where its ability and proficiency will be recorded and reported on.

## Compile Final Report

Compile the initial research and literature review with the initial concept design and any subsequent design changes together with the results from the tests into the final report.

# Project Risk Assessment

This project consists mostly of the control software and the electronic hardware needed to implement this software, however there is still a small mechanical hardware element with the vessel and how the propulsion is mounted onto the vessel. In this section of the report, I will detail the possible risks that could be encountered in the project and what precautions are being taken to limit the effect these risks might have.

Firstly, I will look at the electronic side of the project. Due to the tight timeline of the project, the main risk to the project would be a delay in the delivery of the ordered components. The software can be developed independently to a point, beyond which the electronic components are needed to troubleshoot and ensure that the software is executing correctly and that there are no issues that need to be resolved. Having no control over the supply lines, the solution to mitigate this risk is to finalise the design concept and order the components as soon as possible. Therefore, if any delays in the delivery or development of the control system there will still be sufficient time to complete the project.

Secondly, with regards to the mechanical hardware, there is also a risk of delays in manufacturing of the hardware. However, because the manufacturing will be sourced to the universities mechanical workshop, the material will be bought from the workshop stock on hand, and all manufacturing will be ordered in the first half of the year1, there is a smaller chance of this risk occurring. It will still be prudent to, as with the electronics, have the design concept and technical drawings completed as soon as possible.

Thirdly, the last main risk to project schedule to consider is risks associated with the testing phase of the project. Due to the vessel needing a large body of water to test, testing days will need to be scheduled and planned out ahead of time. However, due to testing on a large body of water, any moderate to harsh weather conditions could negatively effect and possibly hinder testing. To mitigate these risks, in the planning of a test, the weather forecast will be regularly consulted and more than one day of testing can be scheduled so that the ideal testing conditions can be achieved.

When testing there is also the risk of the boat running off course when doing self-navigating tests. This would be problematic as it could run ashore or run into other vessels on the water. For this purpose, the vessel will always have a pilot who can override the boat and take manual control. There is also the risk of the boat having issues and taking on water or sinking. To mitigate this, all personal on the boat must have a lifejacket and at least one person must have a valid skippers license.

Finally, the risks to the budget must be considered. The risk of the project running over budget are high. There are several costly components required for the project which will push the project cost up. However, this is slightly mitigated by the fact that the university has already acquired a couple of the costliest components namely, the vessel, with a trailer for transport, the electric thrusters for propulsion and, the batteries for the power source. There are, however, further costs to the project which could push the project over budge. There will significant total cost for the transport required to and from the testing site. Fortunately, there is little cost expected to be accrued from any laboratory or equipment use through the university.

1 Most of the manufacturing done by other students is submitted in the second semester and so the workshop should not be overly full of orders in the first semester.

# Conclusions

The need for self-navigating unmanned surface vessels is clear as South Africa looks to do more acoustic research. The projects aim is to develop a control system for unmanned surface vessels that will incorporate self-navigation. This control system could then be used further in commercial, defence or fishing industries.

The project team are sufficiently equipped to complete this project and have the required facilities. The project has been estimated to have a total cost of R306 475, of which R45 700 is capital expense to procure the vessel, with a trailer, the thrusters required for propulsion, and the batteries. The project deadline is 4 months to completion. There are some risks to the timeline and the project overall that have previously been mentioned and all mitigating factors have been put in place.

# References

Beam, S., Hydrographic, E. and Boat, S. (no date) ‘Z-Boat 1250 ®’.

Caruso, F. *et al.* (2020) ‘Monitoring of a Nearshore Small Dolphin Species Using Passive Acoustic Platforms and Supervised Machine Learning Techniques’, *Frontiers in Marine Science*, 7(April). doi: 10.3389/fmars.2020.00267.

Wiggins, S. M., McDonald, M. A. and Hildebrand, J. A. (2012) ‘Beaked whale and dolphin tracking using a multichannel autonomous acoustic recorder’, *The Journal of the Acoustical Society of America*, 131(1), pp. 156–163. doi: 10.1121/1.3662076.

Planning Details

This appendix breaks down the planning with regards to the budget with an estimated cost to complete the project in Table A.1 and a Gantt chart which outlines the planned timeline for the activities in Figure A.2

Budget Planning

Table A.1: Estimate Cost per Activity

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Activity** | **Engineering Time** | | **Running Costs** | **Facility Use** | **Capital Costs** | **MMW** | | **MMW** | **Total** |
|  | | | | | | **Labour** | | **Material** |  |
|  | **hr** | **R** | **R** | **R** | **R** | **hr** | **R** | **R** | **R** |
| Review Literature | 25 | 11250 | 150 |  |  |  |  |  | 11425 |
| Review Similar Projects | 20 | 9000 |  |  |  |  |  |  | 9020 |
| Design the Algorithm Flow Diagram | 15 | 6750 |  |  |  |  |  |  | 6765 |
| Design the Control System Hardware | 10 | 4500 |  |  |  |  |  |  | 4510 |
| Design the Mechanical Mountings | 10 | 4500 |  |  |  |  |  |  | 4510 |
| Create Parts List | 5 | 2250 |  |  |  |  |  |  | 2255 |
| Order Parts List | 5 | 2250 | 3000 |  | 45700 |  |  |  | 50955 |
| Manufacture Mechanical Mountings | 20 | 9000 |  |  |  | 45 | 13500 | 1500 | 24065 |
| Manufacture the Control System Hardware | 25 | 11250 | 250 |  |  |  |  |  | 11525 |
| Program the Control System Algorithm | 35 | 15750 |  |  |  |  |  |  | 15785 |
| Fix all System Elements | 20 | 9000 | 300 |  |  |  |  |  | 9320 |
| Test USV in Manual Mode | 90 | 40500 | 1500 |  |  |  |  |  | 42090 |
| Test USV in Self-navigating Control | 150 | 67500 | 1500 |  |  |  |  |  | 69150 |
| Compile Final Report | 100 | 45000 |  |  |  |  |  |  | 45100 |
| **Total** | **530** | **238500** | **6700** | **0** | **45700** | **45** | **13500** | **1500** | 306475 |

****Timeline Planning

Figure A.2: Gantt Chart of Project Timeline