Adaptive Stability of Unmanned Surface Vehicle

M. Arun Magesh[1]
[1]*Department of Electrical and Electronic Engineering*
Arunai College of engineering
Tamilnadu, India

Abstract: *The goal of this project is to implement an algorithm to maintain the stability of the Unmanned Surface Vehicle (USV) during rough sea condition. The system consists of several sensor which acts as feedback to the propeller. The system runs on Proportional integral controller, and also consist of a Graphic interface to provide an interactive environment between the user and the system, enabling the user to track the path of the boat, GPS (global positioning system) location and to display real time data obtained from the sensors, path, speed of the boat and the battery life of the system.*

Keywords- *Proportional integral controller, propeller, sensors, unmanned surface vehicle.*

I. INTRODUCTION

Unmanned surface vehicles (USV) or autonomous surface vehicles (ASV) are vehicles that operate on the surface of the water without a crew. Autonomous unmanned surface vehicles have its applications in the research as well as the commercial fields. USVs are valuable in oceanography but cheaper than the equivalent weather ships and research vessels. They can go to places where it may be impossible for humans to reach. In most cases damage due to bad weather results in loss in precious data and cost. They are used in marine research for specimen and water sample collection. They can be used for object detection and tracking both above and below the surface of water, guiding ships to dock safely at harbors, assisting the border patrol to watch on the borders and also to analyze sea animal research.

They are available in different size which are capable of working from very shallow water to deep water operation. They are equipped with different payloads with various resolution for imagery and bathymetric survey. Military application of USV include powered seaborne targets.

The Space and Naval Warfare Systems Center, San Diego (SSC San Diego) has been developing the technologies for autonomy on unmanned surface vehicles (USVs) with the purpose of providing more autonomous functionality and reducing the reliance upon operator oversight [1]. SSC San Diego has been involved in the development of autonomous vehicles for over 25 years. SSC San Diego has worked with the NASA Jet Propulsion Laboratory (JPL) on stereo vision-based perception for the USV. JPL has used stereo vision on the Mars Rovers and SSC San Diego has transitioned some of that technology to their unmanned ground vehicle (UGV) programs [2].

The base USV would be required to perform basic tele-operation functions and waypoint navigation with an on-board observer. The Small Robot Technology (SMART) software architecture was developed for the URBOT UGV in October 1999 [3]. Development of Unmanned Ground Vehicles (UGVs) has been ongoing for decades. Much of the technology developed for UGVs can be applied directly to Unmanned Surface Vehicles (USVs) with little or no modification [4].

The technologies ported from the UGV to the USV include: the software architecture and protocol, teleoperation, a Kalman filter for state estimates, waypoint navigation, the Operator Control Unit (OCU), miniature processors, Ethernet switches and a video CODEC board. The URBOT is a Man Portable Robotic System (MPRS) developed for the Office of the Secretary of Defense (OSD) Joint Robotics Program (JRP) to provide a small ground vehicle with remote sensing capability [5].

The Protector unmanned surface vehicle was developed by the Israeli Rafael Advanced Defense Systems in response to emerging terrorist threats against maritime assets such as the USS Cole bombing, and is the first operational combat USV in service. By 2005, it was being first deployed by the Republic of Singapore Navy, then in support of coalition forces in the Persian Gulf and later in anti-piracy duties in the Gulf of Aden [6]. USV is tested for various applications including harbor surveillance, water quality sampling, hydrologic survey, maritime search etc.

II. MECHANICAL DESIGN

The mechanical design for this project is a mixture of two standard designs:

- Airboat design

• Catamaran design

This type of design is called a **tri-maran** design. Fig 1 shows the Mechanical structure of the Tri-Maran Boat. The basic idea is to have a central Hull carrying all the systems and two other hulls that are attached on each side to enhance buoyancy. Instead of using mechanical sail, the boat is propelled by an electric motor. The propulsion and direction control mechanism are controlled by the controller connected to it

1. THRUSH REQUIRED

Thrust required is calculated by dividing the total required power by the velocity of the boat. This provides us with the available thrust the motor can provide to the boat calculated as follows

Force=Power/Velocity, (eg) 80W/2.2m/s=37.03N

2. ALGORITHM

The stability of the unmanned water surface vehicle is based on **proportional-integral-derivative controller** (**PID controller**) algorithm. The PID controller algorithm involves three separate constant parameters, called three-term control: the proportional, the integral and derivative values, denoted P, I, and D.

Basic working of this algorithm is that it consist of an accelerometer which will determine the saw and yaw movement of the boat as per the feedback. Side rudder motor begins to rotate causing it to float in steady position even in rough sea condition as shown in the Fig. 2.

3. SYSTEM UNIT

Basic working part of this project is the microcontroller, ultrasonic sensors, magnetometer, accerometer and GPS for navigation, Prototype consist of two main unit.

They are

i. Boat block

ii.Control block

3.1 BOAT BLOCK

Boat is the main working system. It consisit of an arduino, which takes care of the algorithm operation. This system is powered by a lipo battery. Propeller are drived by a driver kit and the system, is fitted with ultrasonic sensor for obstrucle avoidance, and accelerometer to detect the tilt and yaw movement. Magnetometer will act as a compass for navigation. It has GPS (Global positioning system) module for getting geographical location of the boat.

All the system is managed by raspberry pi which is fitted with camera and in turn to a wireless network where all the information can be accessed by a web server as shown in Fig. 3.

3.2 CONTROL UNIT

Using the Control Unit, the user can control the system both manually and autonomously and consist of a wifi master hub which manages all boats present on the network. Data from the boat was retrieved, logged and simulated to get its real time details of it as shown in Fig. 4 and the camera can acts as vision for the boat.

III. SOFTWARE DEVELOPMENT

1. Embedded Software

Python and Arduino based C language is used for the embedded processor and controller.

2. Communication

I2C (intercommunication bus) and Serial communication were used. I2C was used by inertial sensors whereas GPS module and raspberry pi is connected by serial communication at 9600 baud rate.

3. Analog to digital convertor

Analog to Digital convertor of the Atmega reads the anolog data using accelerometer which is used to senses the movement of the boat. Ultrasonic sensor is connected to a digital pin using PWM technique (pulse width modulation).

4. End User interface

Python is used to retrieve the value from several sensors and display it in a web page with a camera image displayed on it

IV. PROTOTYPE

The prototype is an inexpensive one which made of several water cans or metallic tins. Cans can act as a two hulls and both the hulls are connected by means of a small plastic extension for extensive support. The hulls are connected with a two DC motor which is connected to a propeller, and a motor control driver.

Central hub carries the microcontroller and sensor which is the brain for the whole unit. It is connected with a camera which in turn is connected to a web server that can be accessed by the end user. End user can able to view data related to the boat dynamics, path or direction of the boat. Fig 5 shows the user terminal of the GUI of the boat.

V. FIGURES

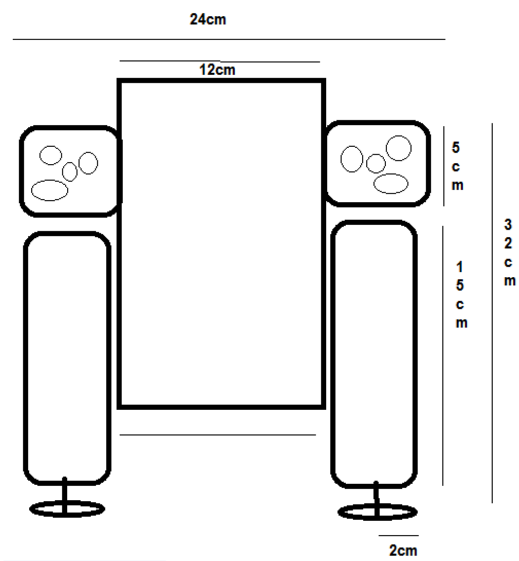

Figure 1: This shows the Mechanical structure of a Tri-Maran Boat

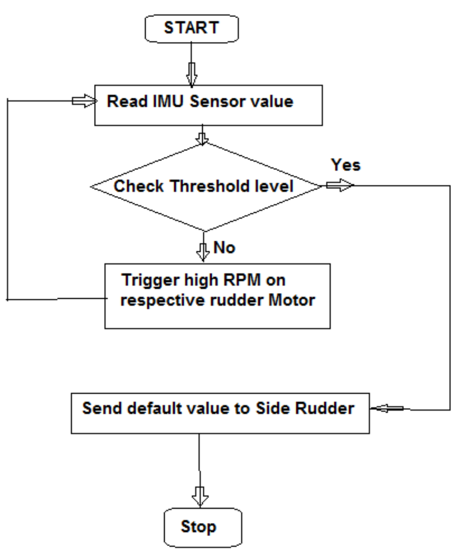

Figure 2: Shows the flowchart depicting the stability of the boat

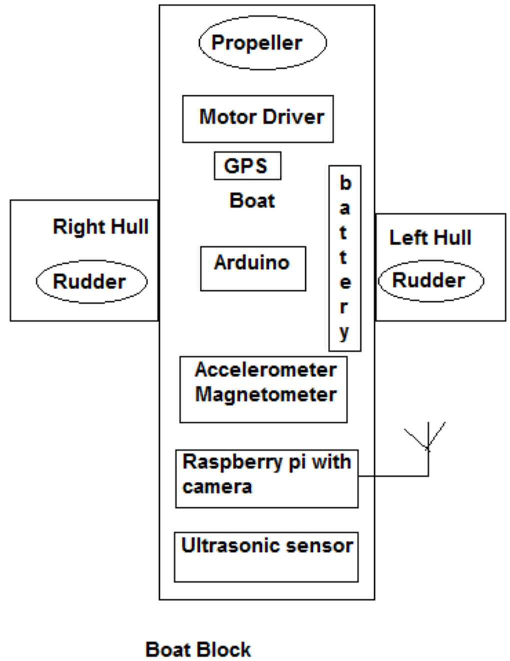

Figure 3: Shows the block diagram of the unmanned surface vehicle

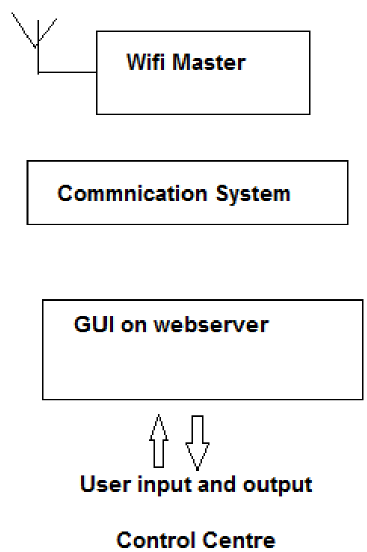

Figure 4: Shows the block diagram of the Control section

Figure 5: Shows the User terminal of the GUI of the boat

VI. CONCLUSION

By adopting a well-developed architecture and adapting software and hardware created for Unmanned Ground vehicles, a significant reduction in construction and integration resources are achieved. Recent advances in processor performance and vision algorithms have made near real time detection possible. The testing of the project was conducted at small water pool. Multiple tests were conducted to ensure the error free working of the system. The data obtained from the sensors was processed and the algorithm is applied for the stability of the boat under rough water condition. The real time simulation of the obtained data was retrieved and plotted from distant server which controls the boat both autonomously and manually.

VII. FUTURE DEVELOPMENT

The next step in the project would be the development of a Sonar based detector. For this, surface analyzing kinetic sensor can be used and the relevant processing done on it to get a view on the path. It can also be made as submarine for under water analysis

VIII. ACKNOWLEDGMENT

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