ECE 445/ME 470 Senior Design ZJUI

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Project Proposal

Submarine Model

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1. Introduction

1.1 Problem

The problem at the core of our project is how to build a fully functional submarine model. Building submarine models can help drive scientific and technological innovation, enhance military capabilities, enhance training and education, and support environmental research and rescue operations. The combined effect of these aspects makes submarine models of great value in many fields.

1.2 Solution

Our proposed solution includes the development of a complex and versatile submarine model that integrates cutting-edge technology to address key challenges in underwater operations. At a high level, the model is designed to simulate all aspects of a submarine's performance, including propulsion, navigation, and communication capabilities. The main goal is to create an integrated tool that can serve a variety of purposes, such as performance testing and tactical simulation, to promote the advancement of submarine technology. In order to realize our solution, we will utilize simulation technology. The model will be designed to replicate the complex dynamics of submarine movement, taking into account factors such as buoyancy, fluid dynamics and propulsion systems. Advanced algorithms will be used to simulate the complex interactions between the submarine and its environment, combined with realistic physical models. The communication system will be precisely modeled to simulate the challenges of underwater data transmission. The implementation will be modular, allowing for future updates and integration of emerging technologies. By combining these elements, our solution aims to provide a holistic, adaptable submarine model that contributes to the continuous advancement of underwater technology.

1.3 Visual aid

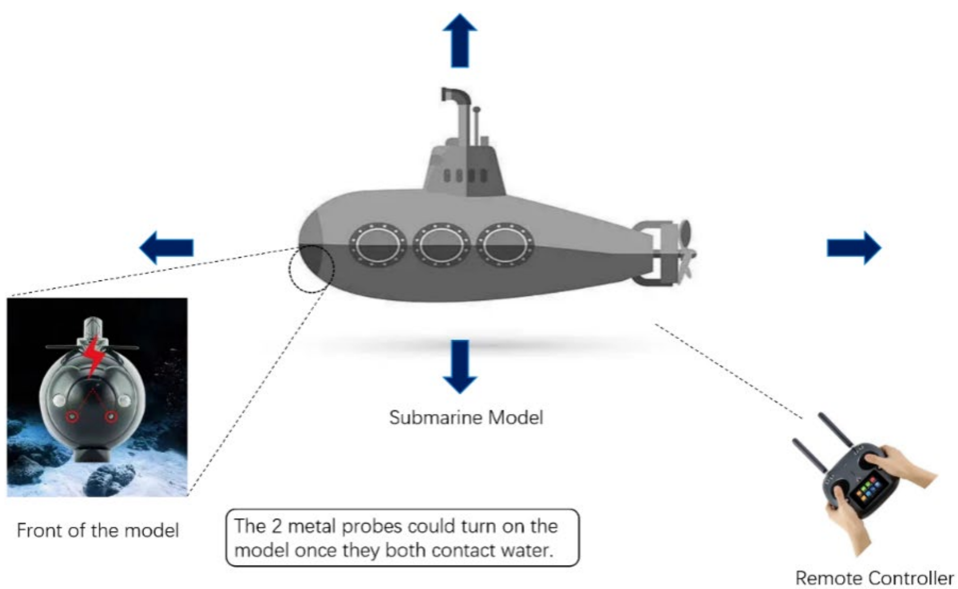

Figure 1 Visual Aid for Submarine Model [1][2][3]

1.4 High-level requirements

- The submarine model can operate successfully in the water with a 1-meter height.
- The submarine model can float at a certain height stably.
- The submarine model can move according to the commands from a remote controller.

2 Design

2.1 Block Diagram

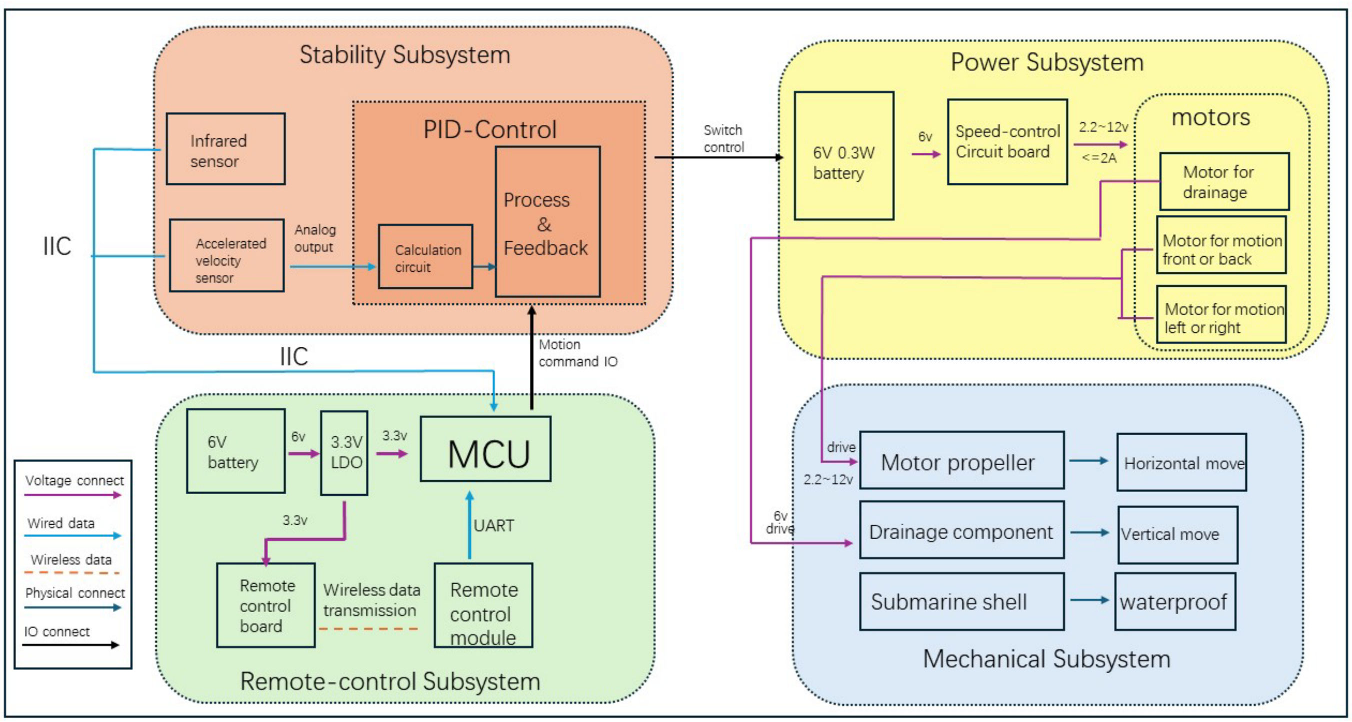

Figure 2 Block Diagram for Submarine Model

2.2 Subsystem Overview

2.2.1 Mechanical subsystem

The Mechanical subsystem serves as the submarine model's foundational component, functioning as the outer shell and providing waterproof capabilities. The drainage component of the mechanical part is closely linked to the Stability subsystem, which is responsible for the submarine's vertical movement. Additionally, the mechanical part's propellers are closely interconnected with the Power subsystem, which handles the propulsion of the submarine.

2.2.2 Remote-control subsystem

The Control subsystem serves as the central hub that connects and coordinates the operation of all other subsystems. It plays a crucial role in managing the functioning of various modules and receiving remote commands. Once the Microcontroller Unit (MCU) receives control instructions, the Control subsystem can command the directional movement of the Power subsystem and ensure the stability of the submarine by calculating and controlling the Stability subsystem.

2.2.3 Power subsystem

Stability control is paramount for submarines, directly influencing the balance and maneuverability of the submarine underwater. Achieving buoyancy aims to ensure that the submarine can maintain a specific depth in the water and stabilize its floating when required. Effective control of the buoyancy adjustment system is crucial to maintaining the submarine's balance in the water, allowing it to descend to the desired depth while maintaining a suspended state. We also need to ensure that the submarine can descend rapidly and in a controlled manner when necessary. By adjusting the ballast tank and other systems, the submarine can achieve descent to the desired depth. [2]

2.2.4 Stability subsystem

The Stability subsystem is a crucial component designed to ensure the stable navigation of the submarine underwater. It plays a key role in facilitating the submarine's buoyancy, descent, and maintaining a stable hover at a specific horizontal plane. By processing data obtained from various sensors through the control system, the Stability subsystem collaborates with the power unit to achieve stable vertical movement of the submarine.

2.3 Subsystem Requirements

2.3.1 Mechanical subsystem

1. Hull Structure: The hull material must be corrosion-resistant to simulate prolonged underwater exposure realistically. The shape and dimensions of the hull must adhere to common submarine design principles.

2. Control Surfaces (Fins and Rudders): Control surfaces must be adjustable within specified angles to simulate realistic steering. Materials used in control surfaces must be durable and resistant to water-induced degradation.

3. Propulsion Mechanism: The propulsion system must accurately simulate the power output and efficiency of common submarine propulsion methods. Adjustable thrust settings to mimic varying speeds and power usage.

4. Ballast System: The ballast tanks must fill and release water in a controlled manner to mimic buoyancy adjustments. Accurate representation of the impact of ballast adjustments on the submarine's depth.

2.3.2 Remote-control subsystem

The control part mainly consists of MCU process and remote control. As for remote control, we need to use remote control module to give the order of motion to submarine. We need to control distance at least 50 meters to realize remote control. And the control signal will be delivered to the MCU control part. As for the requirement of MCU part, we need to use 3.3V battery to drive the chip and we need use low power mode to provide continuous work. The MCU needs to have enough ability to process the signal from remote control module and generate control signal to drive the motion of motors. MCU control is also required to process the data of velocity and accelerated velocity to realize the function of stability. What's more, if we add the function of camera, the MCU is required to capture the frame and transmit picture to the server to display the frame.

2.3.3 Power subsystem

The power part is to power the whole model to move properly. It includes a battery (0.3W, 6V), speed control circuit board (2.2V-12V, <=2A), at least 3 motors (9-88 rpm) to move front or back, left or right and enable the tank to pump in or out water respectively and corresponding propellers to motivate the model to move. Besides, it also contains a protection switch to ensure the system is on only when the model is inside the water. To achieve this, 2metal probes act as the switch. When the model sinks into the water, the water between the probes serves as a conductor and thus the circuit is on. [2]

2.3.4 Stability subsystem

Stability control is paramount for submarines, directly influencing the balance and maneuverability of the submarine underwater. Achieving buoyancy aims to ensure that the submarine can maintain a specific depth in the water and stabilize its floating when required. Effective control of the buoyancy adjustment system is crucial to maintaining the submarine's balance in the water, allowing it to descend to the desired depth while maintaining a suspended state. We also need to ensure that the submarine can descend rapidly and in a controlled manner when necessary. By adjusting the ballast tank and other systems, the submarine can achieve descent to the desired depth.

2.4 Tolerance Analysis

2.4.1 Waterproofing and Submarine Appearance Tolerance Analysis

Conducting tolerance analysis for the waterproofing of the submarine is crucial. The dimensions and connections of key components must be tightly controlled to ensure that the hull does not leak during underwater operations. If waterproofing cannot be ensured, the submarine's internal electronic facilities will be severely affected or destroyed. Ingress of water may lead to circuit short-circuits, equipment damage, or complete failure. Tolerance analysis of submarine appearance involves the shape and surface treatment of components such as the hull, rudders, and sensors. These factors directly affect the hydrodynamic performance and attitude stability of the submarine.

2.4.2 Submarine Motor Tolerance Analysis

Tolerance analysis of submarine motors is crucial as they provide the propulsion for the submarine, directly affecting its hydrodynamic performance and attitude stability. Key components such as motor rotors, bearings, and electrical connections must undergo strict dimensional and performance control.

The goal of tolerance analysis is to ensure that each component of the submarine motor maintains consistent dimensions and performance characteristics during manufacturing, thereby guaranteeing the motor can provide effective and balanced propulsion. If there are dimensional deviations or performance instabilities during manufacturing, it may lead to reduced hydrodynamic performance or instability in the submarine's attitude, even resulting in serious consequences such as capsizing. Therefore, careful tolerance analysis and control of submarine motors are essential to ensure the submarine's safety and reliability. So, we need to ensure that the power provided by each motor is essentially the same and understand the precision of motor rotation.

2.4.3 Suspension Stability Tolerance Analysis

Tolerance analysis for suspension stability involves using accelerometer sensors to measure the translational acceleration of the submarine. By analyzing the acceleration data using mathematical formulas, the suspension stability of the submarine can be assessed:

Assume the submarine mass is m, the acceleration due to gravity is g, the depth of the submarine is h, the density of water is ρ, the volume of the submarine excluding the tanks is V_0, and the volume of the tanks is $S \times x$, where S is the cross-sectional area of the tank and x is the drainage height of the tank. We control the value of x through the motor. Thus, we can have:

$$\rho g(V_0 + S \times x) = mg - m\ddot{h}$$

Assume $\dot{y} = \frac{\ddot{h}}{g}$, $y(t = 0) = 0$, which means that the submarine's initial vertical velocity is 0. Thus, we can have $y(t = +\infty) = 0$. By control the value of x, we can achieve this.

3. Ethics and Safety

Analyzing the ethics and safety aspects of the project is crucial. According to the IEEE Code of Ethics [4], we should ensure that the project design, manufacturing, and testing processes adhere to the highest safety standards to protect the safety and health of project participants. In addition, we need to ensure that any collection, storage, and processing of personal data involved in the project adhere to strict privacy protection requirements to safeguard users' personal privacy rights. Submarines must avoid contaminating water quality during operations, and we will strictly control all emissions and waste to ensure environmental protection and preservation. At the same time, we will ensure that our project objectives are legal and comply with all relevant laws, regulations, and requirements to ensure that our activities do not violate any legal requirements or provoke unnecessary controversies.

In terms of safety, we will ensure the safety of circuits to prevent short circuits or electric shocks. We will take appropriate measures such as proper insulation and protective measures to ensure the stability and safety of the circuits. Additionally, we will take measures to ensure that equipment such as motors does not pose a risk of injury to classmates' bodies, such as installing safety covers or implementing safe operating procedures.

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