1. Introduction

Problem:

Fish have a special ability to sense vibrations in water using their lateral line system. This ability helps them detect obstacles, prey, and predators. The problem of our research is to build a bionic device that copies this natural skill. The device will sense vibration signals to find underwater objects. Such a tool can be very useful in ocean exploration, marine research, and safety applications. Many researchers support the idea of mimicking nature to solve engineering problems. Our work is important because it can lead to better underwater sensors and help us understand marine environments more clearly.

Solution:

Our solution includes both hardware and software solutions. For hardware solutions, we will construct a complete device that can mimic the vibration of underwater objects. We will also implement several sensors that can detect and collect the vibration of water and store them into computer. For the software solutions, we will build several modules to process the data collected by the sensors. Then, we will use the data to train an AI framework that can precisely predict the location of objects based on the vibration signal from the sensors.

2. Design Requirements

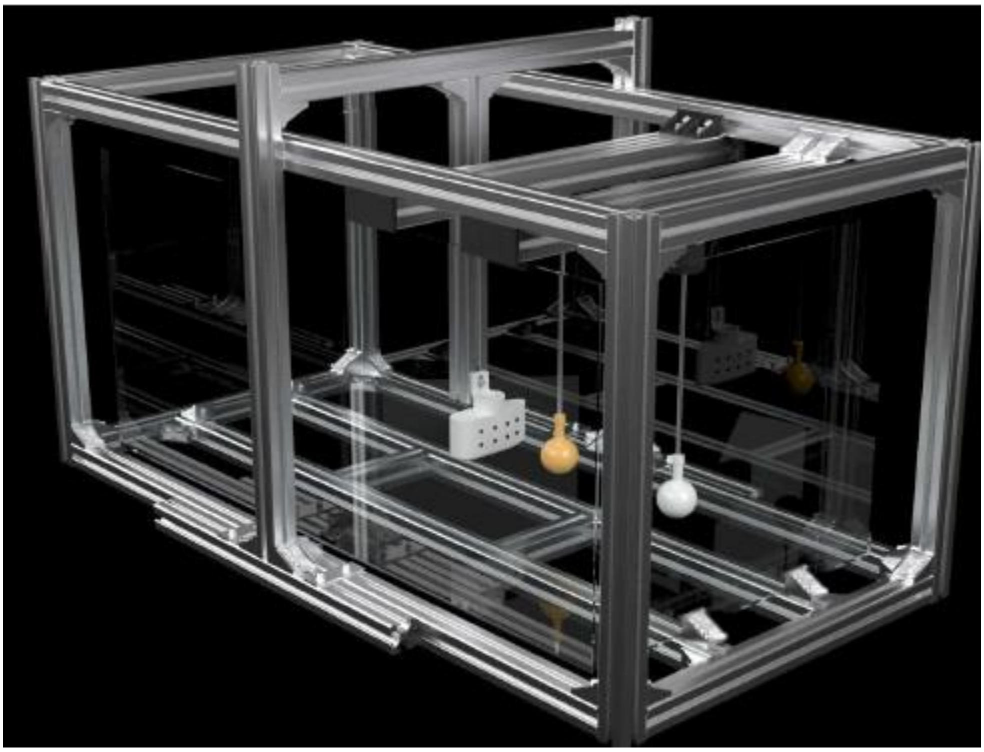


Figure1 Experiment Platform

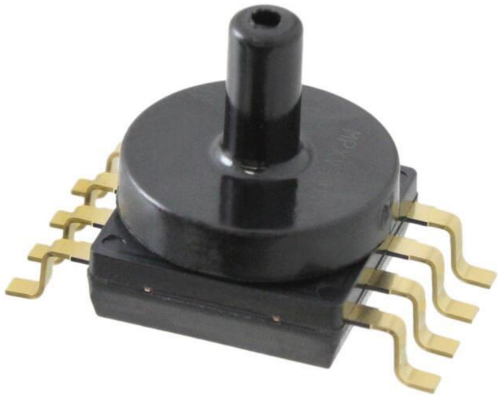
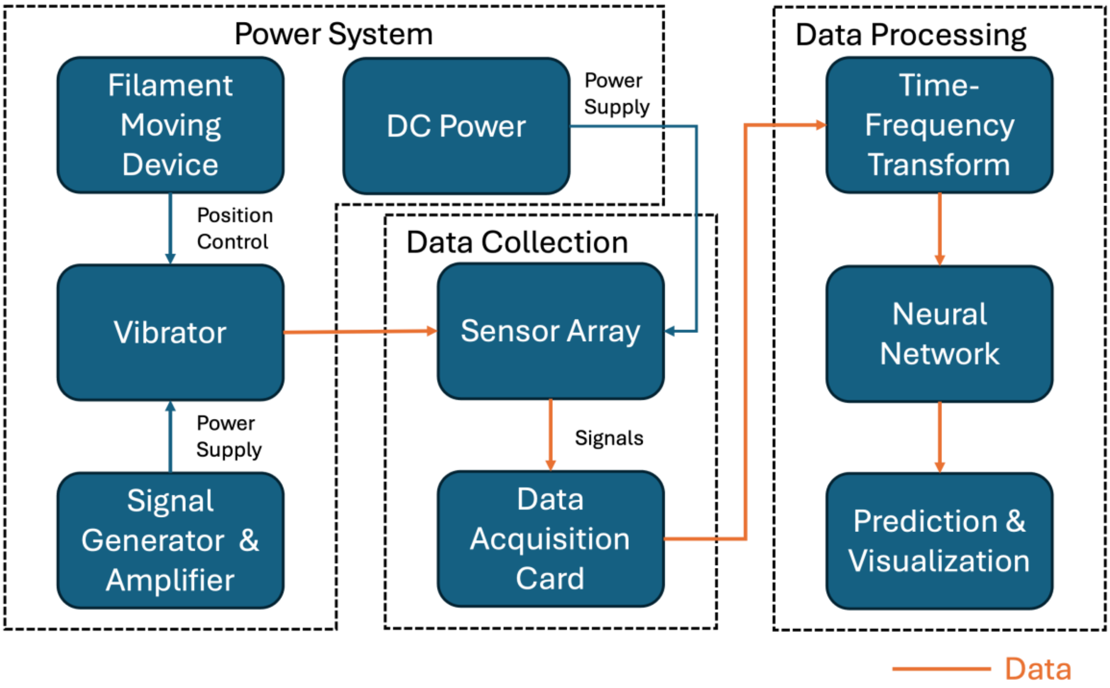


Figure2 Pressure Sensor



Power Subsystem

- **Subsystem Overview:** Oscillator Subsystem is used to imitate the movement of underwater entity. The system consists of signal generator, power amplifier, DC power, movable platform, fish tank, filament moving device and vibrator.
- **Subsystem Requirements:** The signal generator must output a 5V sinusoidal signal at approximately 10Hz, serving as the input to the power amplifier. The power amplifier should then generate a 5V sine wave with higher power to drive the vibrator. When we need to move the vibrator horizontally, the filament moving device is connected to vibrator to

control its position. The vibrator is placed in the fish tank, and the movable device allows its position to be adjusted. DC power is set to 5V DC to supply power to the sensor array.

- **Tolerance Analysis:** The system must be capable of generating vibrations of varying intensity and location to enhance data diversity, which benefits model training and improves model robustness.

Data Collection Subsystem

- **Subsystem Overview:** The system consists of a sensor array containing multiple pressure sensors, which are placed underwater in the middle of the fish tank. These sensors are responsible for collecting raw pressure data caused by vibrations. To record the data, the system has a data acquisition card connecting with a PC. The data acquisition card will connect directly to the sensor system through bread board. The collected data will transfer to data processing subsystem to predict the location of the object.
- **Subsystem Requirements:** The system must successfully collect valid and meaningful data. Specifically, if the power amplifier generates a sinusoidal waveform, the collected data should exhibit a similar sinusoidal pattern—rising to **Value_max**, falling to **Value_min**, and then rising again to **Value_max**, following the characteristics of a sine function. Additionally, as the amplitude and frequency of the input sinusoidal wave vary, the measured pressure should correspondingly change. Otherwise, the collected data would be of low quality and indistinguishable. The data acquisition card must connect every sensor in the sensor system through bread board and electric wire. In the training phase, we plan to collect 100 sets of data from 20 different locations and use the data to train the model.
- **Tolerance Analysis:** The sensors will be submerged in kerosene for an extended period, which may lead to malfunctions and pose a risk to the success of the project. Therefore, it is essential to ensure that the sensors can operate stably under these conditions over the long term. Wire break poses a risk to successful of the project. We need to solder to sensor with the data acquisition card to ensure connection.

Data Processing Subsystem

- **Subsystem Overview:** The system is entirely software system which is used to analysis the data form data collector system and calculate the result. The system consists of signal processing stage and deep learning model. We will use s-transform to transfer time domain data to frequency domain data. In the demo phase, the system will connect directly to the sensor system to analysis the real time signal and predict the location.
- **Subsystem Requirements:** The system should achieve a minimum accuracy threshold (e.g., above 90% prediction accuracy, to be refined after testing). If accuracy falls below the threshold, retraining with additional data augmentation should be considered.
- **Tolerance Analysis:** The system must handle variations in signal quality due to environmental factors like temperature, humidity, and interference. The deep learning model should be robust to slight deviations in collected data.

3. Ethics and safety

Ethic Issues:

Fairness and accessibility: The functionality of the system may depend on a particular infrastructure, which may prevent some users or regions from enjoying the technology, creating unfairness.

Environment Impact： In the experiment, we used silicone oil to simulate water, and its discharge may have an impact on soil and water. The degradation of silicone oil is slow, and it is easy to destroy the balance of the ecosystem.

Safety Issues:

Silicone oil long-term contact with the human body may cause allergic reactions, may lead to local skin resistance decline. We will wear gloves and masks to protect ourselves during the experiment.

Some sensors may stop working under pressure, causing the system to be unable to collect data and respond to the pressure. We will design redundant systems and emergency braking features to ensure safe stopping and replacement of sensors in the event of a system failure.

The oscillator may stop working due to overload, in which case the oscillator may overheat and cause a fire. We will design the temperature detection mechanism.

4. Reference:

[1] Pu, Y.; Zhu, C.; Yang, K.; Hu, H.; and Yang, Q. 2023. A Novel AMSS-FFN for Underwater Multi-Source Localiza- tion Using Artificial Lateral Line. IEEE Transactions on Instrumentation and Measurement, 72: 1–14.

[2] Pu, Y.; Hang, Z.; Wang, G.; Hu, H. Bionic Artificial Lateral Line Underwater Localization Based on the Neural Network Method. Appl. Sci. 2022, 12, 7241. https://doi.org/10.3390/app12147241