Soft Robotic Fish for Underwater Exploration using Marine Bio Mimetics

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Abstract—The world's oceans and aquatic ecosystems face multiple environmental challenges, including pollution, habitat degradation, and the impact of climate change. One promising solution is the development of underwater robotic surveillance fish, autonomous aquatic vehicles designed to mimic the behaviour and appearance of real fish while carrying out a variety of surveillance and data collection tasks. Underwater communication presents several unique challenges and difficulties due to the properties of water as a medium. Few of the existing problems are limited visibility, bio-fouling and communication delays. Robotic Fish is attracting attention due to their highly efficient performance, also it has low negative impact on the environment. This project aims to develop a novel underwater soft robotic fish capable of mimicking the movements and behaviour of real fish species. Which provides a various application in the marine exploration, environmental monitoring and underwater surveillance. These robotic fish help us navigate underwater complex environments and also to monitor and to detect the coral reefs. The project is mainly developed to perform operations such as object detection and monitoring, it is also very useful to measure the temperature in different areas of water and also provides a video capturing facility which is helpful for monitoring the water bodies. Underwater robotic fish provides a highly manoeuvrable and energy efficient solution for navigating the challenging under water environment. It also represents a significant step towards the advancement of autonomous underwater robotics for both scientific and practical purpose.

Keywords: Bio-mimetic robot, Hydrodynamic modeling, Smart material, Swimming mechanism.

1. INTRODUCTION

SoRoFAAM-1, a Soft Robotic Fish, demonstrated practical success with a 2 Hz actuation frequency, 60% heat dissipation improvement, and achieved a maximum cruising velocity of 87 mm/s at 1.5 Hz, along with a yawing velocity of 18°/s. The robotic fish surpassed expectations in bionic fidelity, meeting manoeuvrability standards with a factor of 0.15, head swing factor of 0.38, and a Strouhal number of 0.61, outperforming previous soft robotic fish designs[1]. The paper highlights practical goals: enhancing fish-inspired robots' speed and manoeuvrability, implementing efficient depth control mechanisms, and advancing energy-efficient, compliant structures. It emphasizes the importance of soft materials, autonomy, and innovative manufacturing for applications in defence, industrial inspections, deep-sea exploration, and environmental monitoring[2]. It provides information of fish swimming methods for aquatic motility. It explores various swimming techniques and their implications, contributing to the understanding of underwater mobility and determines the factors influencing fish movement and present insights into the hydrodynamics of swimming. And addressed the complexities of hydrodynamics related to different fish species[3]. The paper surveys fish swimming mechanisms, categorizing them as Body Caudal Fin (BCF) or Median Paired Fin (MPF) propulsion. It discusses swimming modes, kinematics, and analytical approaches, highlighting biomimicry potential in underwater robotics. The analysis underscores challenges, such as compromises in fish locomotion forvarious activities, and proposes employing flexible actuators like the "elephant's trunk" for robust implementation in artificial systems, with practical results from an ongoing testbed to be detailed in future publications[4]. It demonstrated an understanding of fin interactions in locomotion using a Biomimetic fish model. It likely targeted insights into the biomechanics of fish movement, aiming to contribute to the development of more effective biomimetic designs for underwater propulsion and focused on biomechanics and aims to understand the dynamics of fin and fluid interactions[5]. It used a soft robotic model that was pneumatically operated to investigate fish-like water propulsion. The accomplishment most likely entails using the soft-robotic model to study the biomechanics of aquatic propulsion and to gain insight into fish-like mobility. These parameters are then used to study how these parameters affect the generation of locomotor force and the development of soft robotics and bioinspired technologies for underwater applications [6]. Fast-moving soft electronic fish" introduced a novel soft robotic fish capable of rapid locomotion. The research achieved significant advancements in soft robotics by developing a fish-inspired device with quick and agile movements. The innovation holds promise for applications in underwater exploration and surveillance, The design and functionality of this fast-moving soft electronic fish, contributing to the field of bio-inspired robotics. [7]. It focuses on the development and application of this innovative actuator system. The modular design enhances the flexibility and adaptability of AUVs, showcasing advancements in actuation technology for underwater robotics. The work addresses challenges in driving miniature AUVs, offering a promising solution for improving the manoeuvrability and efficiency of such vehicles. [8]. The development of a underwater robot by generating body waves for propulsion. Published in Soft Robotics, the research contributes to bio-inspired robotics by demonstrating the effectiveness of a flexible actuator array in mimicking eel-like movements. It showcases advancements in soft robotics for underwater applications and provides insights into the design principles for achieving biomimetic locomotion in aquatic environments [9]. The design and implementation of a fish-inspired robot capable of fluidic and agile movements by demonstrating the potential of fluidic elastomer actuators in achieving biomimetic locomotion. The autonomous capabilities of the soft robotic fish mark a significant step forward in the development of agile and adaptable soft robots for various applications [10]. Itpresents a microrobot fish featuring a flexible biomimetic fin actuated by embedded shape memory alloy (SMA) wire. The embedded SMA wire serves as a key actuation component for the fish's flexible fin, allowing biomimetic underwater locomotion, emphasizing the integration of SMA technology for enhanced maneuverability [11]. It focuses on a shape memory alloy-based caudal fin for a robotic fish. The study encompasses the design, fabrication, control, and characterization of the robotic fish's tail, providing insights into the innovative use of shape memory alloys in enhancing robotic fish locomotion. The work contributes to the field by demonstrating advancements in tail design and control mechanisms for underwater robotic applications[12]. It offers a comprehensive exploration of the mechanical behaviour, mathematical modelling, and engineering applications of these unique materials. The content covers theoretical aspects and real-world applications, contributing to the broader understanding of these materials[13].

2. LITERATURE REVIEW

Berlinger et al demonstrates modular dielectric elastomer actuator to drive miniature autonomous underwater vehicles which discusses about the soft material used for the soft movement with proper elasticity with no aid control and demonstrates the elastomer soft material used [7]. Feng et a introduces the development of an eel-inspired underwater propulsion system through the use of a fiber reinforced soft fluidic elastomer actuator array. This research contributes to the field of soft robotics by investigating body wave generation for anguilliform locomotion, mimicking the undulating movement of eels. By leveraging fluidic elastomer actuators, the authors aim to create a biomimetic propulsion mechanism capable of efficient underwater locomotion [8]. Marchese et al present a significant contribution to the field of soft robotics with their study on the development of an autonomous soft robotic fish equipped with fluidic elastomer actuators capable of executing escape maneuvers and remarkable flexibility and agility in the robotic fish's movement, enabling it to perform complex maneuvers akin to those observed in natural fish [9]. It offers a comprehensive exploration of the mechanical behavior, mathematical modeling, and engineering applications of these unique materials. The content covers theoretical aspects and real-world applications, contributing to the broader understanding of these materials and it demonstrates the various aspects of the underwater exploration and its characteristics determining the features of the underwater robotic fish and the parameters that are determined by the soft robot and also the features it implements to perform the underwater navigation and other defense applications [13]Rao, A., Srinivasa et al described about the phase transformations, hysteresis behaviour, and constitutive modelling incorporating aspects such as material selection, geometric configurations, and actuation strategies to achieve desired performance characteristics like actuation force, speed, and energy efficiency and advancements in computational techniques, such as finite element analysis and multi-physics simulation, have enabled more accurate modelling and prediction of SMA actuator behaviour under different loading conditions and environments[14].Shintake et al introduced about the significant contribution to the field of soft robotics with their work on a biomimetic fish robot constructed using dielectric elastomer actuators (DEA's). The study builds upon existing research in soft robotics, particularly focusing on the use of DEAs for actuation, which offer advantages such as lightweight, flexibility, and compliance. The paper likely discusses the design and fabrication of the fish robot, exploring aspects such as locomotion mechanisms inspired by biological counterparts and the integration of DEAs for propulsion and maneuverability[15].Jin et al contributes to the literature on soft robotics by presenting advancements in the design and fabrication of a soft robotic gripper with tuneable stiffness properties. The paperemphasizes the importance of compliance and adaptability for effective grasping and manipulation tasks. Their work likely explores novel approaches for achieving tuneable stiffness in soft actuators, potentially incorporating materials with variable mechanical properties or innovative design configurations[16]. Ye et al introduces a significant contribution to the field of bio-inspired robotics, focusing on the development of a 2D maneuverable robotic fish propelled by multiple ionic polymer-metal composite (IPMC) artificial fins and highlight the challenges associated with achieving effective maneuverability and control in underwater environments and the potential advantages of employing multiple IPMC fins[17]. Hubbard et al proposed on the development and application of advanced control methodologies in the field of robotics, particularly focusing on robotic manipulation and automation and described about the focusing on aspects such as trajectory planning, motion control, or force regulation. The surface electrode pattern on the IPMC is created using a simple surface machining process[18]. Zhang et al describes about the the formation control of soft robotic swarm remains challenging mainly due to the limitation in relatively low precision and slow response of the soft actuators. In this work, a soft robotic fish swarm system with global vision positioning was the formation control of soft robotic swarm remains challenging mainly due to the limitation in relatively low precision and slow response of the soft actuators, the formation control of soft robotic swarm remains challenging mainly due to the limitation in relatively low precision and slow response of the soft actuators[19]. Li et al presents the development and characterization of a novel soft electronic fish prototype capable of rapid locomotion and discusses the fabrication process and materials used construct the soft robotic fish, emphasizing the importance of flexibility and compliance for efficient swimming motion and also demonstrate the performance of the robotic fish in terms of speed, agility, and responsiveness, showcasing its potential for applications such as underwater exploration, environmental monitoring, or biomimetic research[20].

III PROPOSED MODEL

3.Block Diagram of our work

The block diagram consists of camera module which is used for visual inspection of the data and a USB to TTL converter is used for the purpose of transferring and receiving of the data and a Servo motor is initialized for the movement of the robot, a waterproof ultrasonic sensor is used to utilized for distance measurement, obstacle detection, proximity sensing, flow measurement, level monitoring, weather monitoring, and marine applications. servo motors are used for precise control of angular position. These contribute for mapping and for underwater exploration and for marine applications.

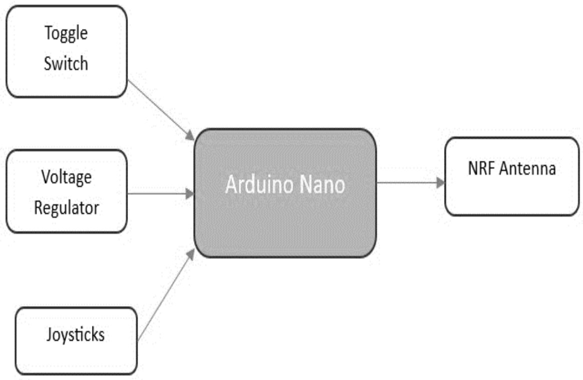

Figure1.Transmitter side.

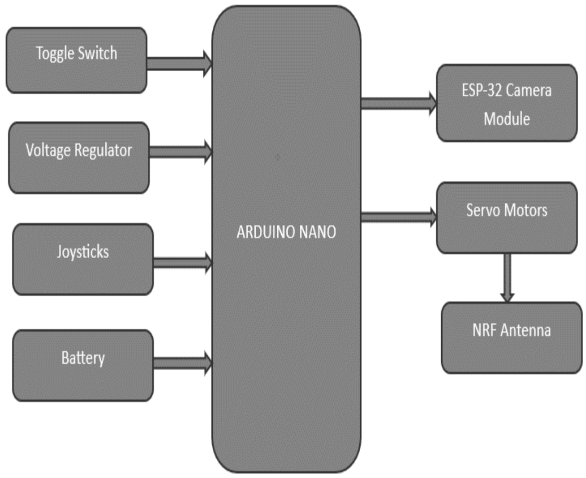

Figure2.Block diagram of Soft Robotic Fish

The block diagram consists of camera module which is used for visual inspection of the data and a USB to TTL converter is used for the purpose of transferring and receiving of the data and a Servo motor is initialized for the movement of the robot, a waterproof ultrasonic sensor is used to utilized for distance measurement, obstacle detection, proximity sensing, flow measurement, level monitoring, weather monitoring, and marine applications. a battery is used to provide with the necessary electrical energy to operate autonomously or as a backup power source in combination with other power systems. a 3-axis accelerometer sensor is utilized across numerous industries and applications to measure acceleration in three dimensions: Xaxisforward or backward, Yaxis ,left or right, and Zaxis, up or down. servo motors are used for precise control of angular position. These contribute for mapping and for underwater exploration and for marine applications. The Block diagram gives the detailed description about the project and briefs the features and functionality of the Underwater soft robotic fish project.

4. DesignandMethods

4.1 Design and Integration of the Camera module:

A ESP-32 camera module is interfaced to the robotic fish for the visual inspection. By using the camera module exploration of underwater will be performed in a easier way. The camera module is is a low-cost ESP32 development board with an onboard camera. Wifi and low-power battery low power are integrated on the board, as well as two high-performance 32bit CPU. In the conceptualization of our soft robotic fish, we have ingeniously incorporated a dual-controller system, diverging from the economically impractical use of the Raspberry Pi. Instead, we opted for the utilization of distinct components, namely the Arduino Nano and ESP32 CAM. The ESP32 CAM, tethered to a power supply, requires meticulous code loading facilitated by a USB to TTL converter for operational readiness and code into the ESP32 CAM module, an assigned IP address manifests, affording us the privilege to access a browser interface. This interface grants control over the camera's settings and provides a live feed, permitting the storage of video frames as images. Conversely, the Arduino Nano orchestrates the integration of diverse sensors, servo motors (SG90), and the buoyancy control unit. Among the sensors incorporated in our robotic fish are the Waterproof Ultrasonic Sensor (JSN-SR04T) for obstacle detection, and the 3-Axis Accelerometer and Gyro Sensor (MPU6050) forascertaining both speed and orientation. This amalgamation of sophisticated components ensures a comprehensive and finely-tuned control system for our innovative creation. The ESP 32 camera module is a low cost modulewith an ESP 32 development board with an onboard camera. Its frequency adjusts from 80Mhz to 240Mhz and an inbuilt flash in it. The transmitting and receiving power of the camera is high as it provides a clearimage.Integrating the ESP 32 camera module involves several steps to ensure correct functionality and performance. The waterproofing material is important and crucial to ensure better functionality and performance. So that the components which are integrated will be safe. This can be ensured by using a ESP32 camera and its associated circuitry in waterproof enclosures or potting them in epoxy resin. Next, power management is essential to ensure uninterrupted operation underwater. This might involve using waterproof batteries or power sources suitable for underwateruse. Additionally, ensuring reliable wireless communication between the ESP32-CAM and a surface control station is necessary.

This can be achieved by using waterproof antennas and establishing a robust communication protocol. Mounting the ESP32-CAM securely within the robotic fish to provide optimal viewing angles is vital for capturing clear underwater footage. Calibration and testing are essential to ensure that the robotic fish operates effectively in an underwater environment, accounting for factors such as buoyancy, stability, and maneuverability. Finally, implementing appropriate image processing algorithms on the ESP32-CAM to analyze underwater scenes or detect objects enhances the capabilities of the robotic fish for various applications such as underwater usage.Additionally, ensuring reliable wireless communication between the ESP32-CAM and a surface control station is necessary. This can be achieved by using waterproof antennas and establishing a robust communication protocol. Mounting the ESP32-CAM securely within the robotic fish to provide optimal viewing angles is vital for capturing clear underwater footage. Calibration and testing are essential to ensure that the robotic fish operates effectively in an underwater environment, accounting for factors such as buoyancy, stability, and image processing algorithms.

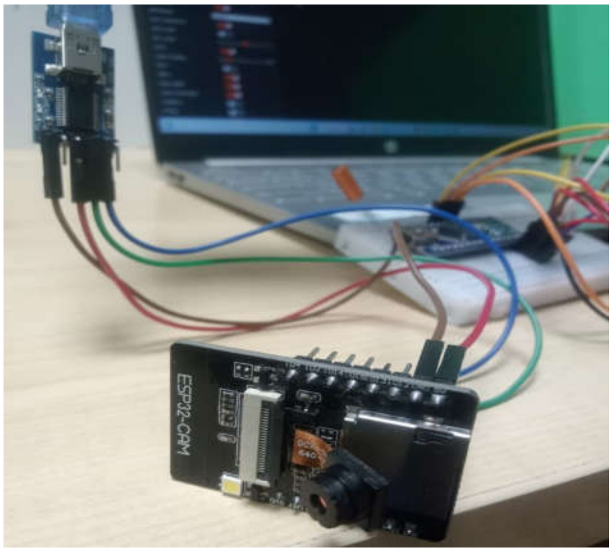

Figure 3. Design and integration of a camera module which involves the simulation part which is integrated to other component.

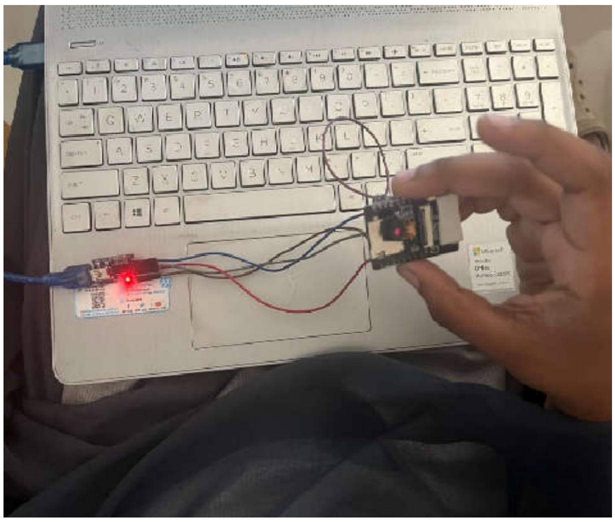

Figure 4. Initializing thewi-fi and after that by connecting the camera module to the web server and then a image will be captured and the results are attached so visualize the image captured by ESP 32 camera module.

4.2 Design and Integration of USB to TTL Converter.

A USB to TTL converter is used for the purpose of transferring and receiving of the data. It is actually a USB port to logic level serial port converter. It has two ends a USB connector and four wires connector that are made to attach to the terminal ports so that it provides the connection between USB and serial UART interface. When a USB to TTL converter is interfaced with the camera module an IP address will be obtained for accessing the data. After that the camera module with the web server to capture the image. The data is transferred over the wi-fi. By connecting the USB to TTL converter the images captured will be in high resolution. The pixels of the image can be adjusted.

4.3Interfacing of the Servo Motor.

A Servo motor is initialized for the movement of the robot, The SG90 servo motor stands out for its compact yet highly functional design, featuring dimensions of approximately 22.0 x 11.5 x 27 mm (0.86 x 0.45 x 1.0 inch) and a lightweight build weighing about 9 grams. Operating with a stall torque of 16.7 oz/in (1.2 kg/cm) at 4.8 volts, this servo motor demonstrates its versatility across a voltage range of 4.0 to 7.2 volts. With an impressive operating speed of 0.12 sec/60 degrees at 4.8 volts and no load, the SG90 offers precise control for applications demanding accurate rotation. Its rotation range spans approximately 180 degrees, allowing for a 90-degree movement in each direction. Utilizing plastic gears, this servo motor responds to pulse width modulation signals as the control input. Renowned for its efficiency, the SG90 has become a popular choice for hobbyist and DIY projects, finding applications in small-scale robotics, model control, and scenarios that require meticulous rotational control. Facilitating the integration of the SG90 servo motor with an Arduino Nano involves a systematic wiring connection process. The VCC, the red wire is connected to the 5V pin on the Arduino, while the SIG (yellow/orange) wire is linked to digital pin D8, a PWM-enabled pin. Completing the circuit, the GND (Black/Brown) wire connects to the GND pin on the arduino. the GND (Black/Brown) wire connects to the GND pin on the Arduino. Digital pin D8, a PWM-enabled pin. Completing the circuit, the GND (Black/Brown) wire connects to the GND pin on the Arduino. The utilization of servo motors plays a important role in emulating the natural locomotion of aquatic creatures like fish. These servo motors, acting as the muscle-like components of the soft robot, are integral to its design and functionality. Unlike traditional rigid robots, soft robotic fish are made of flexible materials that allow for organic movement, closely resembling the fluid motions of their biological counterparts. Thus servo motors contribute to the movement of the fish, so that the robotic fish can move according to the real time situations in the underwater and according to the underwater environment.

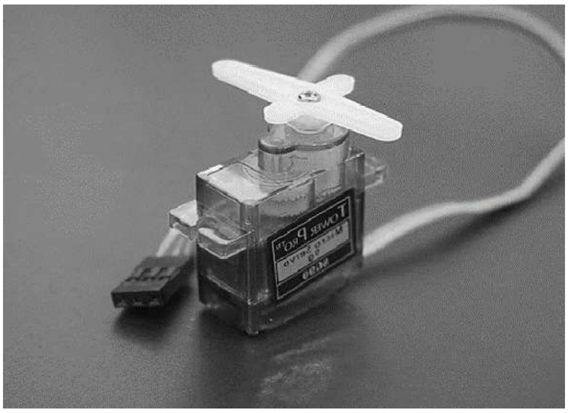

Figure 5. Servo motor (SG-90)

4.4 DesignandIntegration of the servo motor:

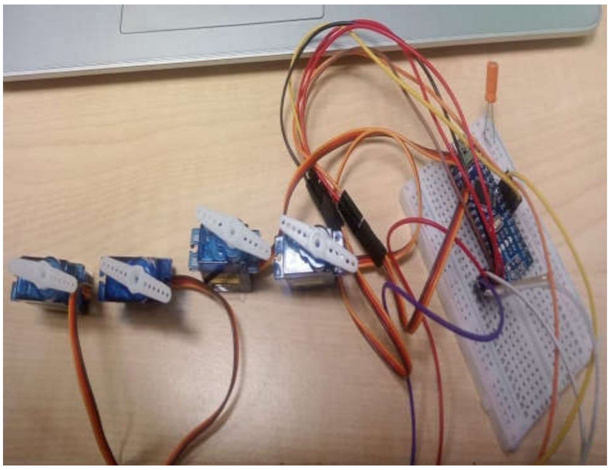

Figure6. Designandintegration of the servo motor to the Arduino nano. The obtained results are attached along with the connections which provides the movement of the robotic’s

4.5 Interfacing of the 15 pin and 2x4 pin Header.

A 15pin header and 2x4 header are connected on the printed circuit board at the transmitter side to interface for connecting various electronic components, facilitating communication, power distribution, and expansion. The 15-pin header typically consists of multiple pins, each with its specific function. For instance, some pins may be designated for sensor inputs, allowing the robot to gather data about its environment such as water depth, temperature, or pressure. Other pins may be allocated for communication purposes, enabling the robot to exchange data with external devices or systems, such as controllers on the water's surface. Additionally, certain pins may be used for power distribution, providing a centralized connection point for supplying power to different components of the robotic fish, such as servo it can be utilized for connecting and interfacing with different electronic components such as sensors, actuators, communication modules, or power sources. Each pin in the header can be assigned to a specific function or connection, allowing for organized and modular integration of various subsystems within the robotic fish. For instance, certain pins may be dedicated to sensor inputs, enabling the collection of data about the underwater environment, including parameters like water temperature, pressure, or pH levels. Other pins may be allocated for motor control, allowing precise manipulation of the fish's fins or tail for propulsion and maneuverability. Additionally, pins can be designated for power distribution, supplying electricity to the various components of the robot. motors, sensors, or communication modules.

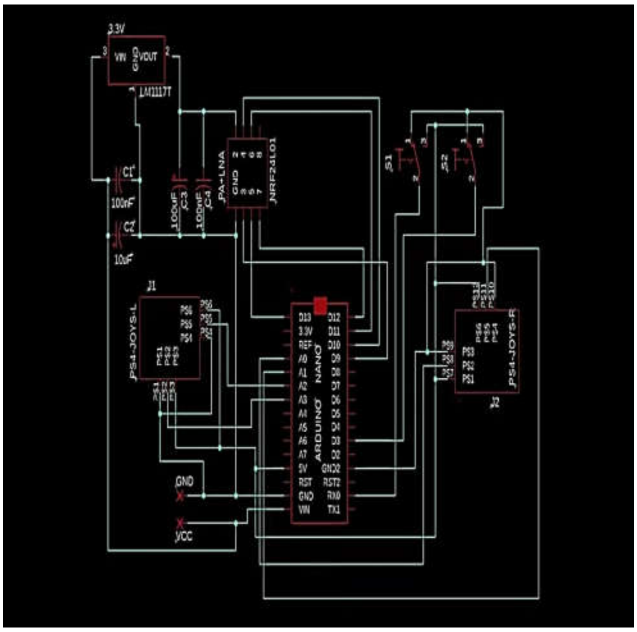

Figure 7. Systematic representation of the components connection.

4.6 Interfacing of the PS4 Analog Joystick:

Two PS4 analog joysticks are connected to the sides of the printed circuit board. It is used to control the control the direction and speed of movement. In such a project, the analog joystick serves as a human-machine interface, allowing operators to intuitively manipulate the robotic fish's behavior underwater. By connecting the joystick to the project's control system, which typically includes a microcontroller like an Arduino or Raspberry Pi, operators can input commands that translate into specific movements of the robotic fish's fins or tail. For example, tilting the joystick forward could instruct the fish to move forward, while tilting it to the left or right could trigger corresponding directional movements. The analog nature of the joystick provides precise control over the speed and intensity of these movements, enabling operators to navigate the underwater environment with accuracy and responsiveness. firstly disassemble the controller to access the joystick module and identify the pins for the X and Y analog signals. Connect these pins to analog input pins on a microcontroller like Arduino, ensuring proper power and ground connections. Then, develop code to read the analog signals from the joystick module using functions like analogRead(), mapping the readings to control the fish's movement along the X and Y axes. Test and calibrate the joystick control for smooth operation, integrating it into the overall control system of the robotic fish project for deployment in underwater environments, thus providing intuitive and precise control over the fish's movements.

4.7 Integration of LM1117.

An LM1117 voltage regulator of 3.3V is used as it provides stable and regulated power to various electronic components, ensuring their reliable operation in the challenging underwater environment. In such a project, the LM1117 voltage regulator can be used to regulate the voltage supplied by the main power source, such as batteries or solar panels, to a consistent level suitable for powering sensitive electronic devices like microcontrollers, sensors, servo motors, and communication modules. By providing a stable output voltage despite fluctuations in the input voltage or current, the LM1117 voltage regulator protects the electronic components from potential damage due to overvoltage or voltage spikes. Its compact size, efficiency, and an ability to handle moderate current loads make it an ideal choose for power regulation in underwater robotic fish projects by selecting the appropriate variant matching the voltage requirements of the project's components. Then, connect the input voltage source to the input pin (Vin) of the LM1117 and ground (GND) to the ground pin. Connect the output pin (Vout) to the positive terminal of the load, such as microcontrollers or sensors, and place capacitors between Vin and GND, as well as Vout and GND, to stabilize input and output voltages respectively. After soldering and testing the circuit for stability, integrate it into the overall electronics system, ensuring waterproofing measures are in place. And monitor the voltage output periodically to maintain stability and performance in the underwater environment. It has various benefits as it provides the regulated biased voltage which do not interrupts the robot and provides the stabilized voltage.

4.8 Connection of the Arduino nano:

The Arduino nano acts as the central control unit, facilitating the coordination and execution of various functions within the robotic system. Its compact size, versatility, and ease of programming make it an ideal choice for such applications. The Arduino Nano can be used as an interface with sensors, control actuators like servo motors or thrusters, process data, and communicate with external devices or systems. In an underwater robotic fish project, the Arduino Nano can gather data from sensors measuring parameters like depth, temperature, and pressure, use this data to make decisions about the fish's movements, and control the actuators to achieve desired swimming behaviours. Additionally, the Arduino Nano can facilitate communication with surface controllers or base stations for remote operation, data transmission, and monitoring of the robotic fish's performance. ensure compatibility of the power source with the Arduino Nano's voltage requirements, typically 5V or 3.3V, and connect it to the VIN or RAW pin along with the ground (GND) pin. Then, integrate sensors such as depth sensors or temperature sensors by connecting them to appropriate digital or analog pins. Connect actuators like servo motors to PWM pins for precise control of the fish's movement. If needed, integrate communication modules like the nRF24L01P to enable wireless communication with external devices, ensuring proper pin connections. Write and upload Arduino code to define the fish's behavior based on sensor inputs and user commands.

4.9Interfacing of nRF24L01P:

The nRF24L01P is a popular wireless communication module commonly used in various projects including robotics, IoT (Internet of Things), and sensor networks. It operates in the 2.4 GHz ISM (Industrial, Scientific, and Medical) band and employs the Enhanced protocol for efficient and reliable data transmission. This module provides a simple and cost-effective way to establish wireless communication between the devices over short to medium distances. It features low power consumption, which makes it suitable for battery oriented applications. With its built-in features such as auto-retransmit and automatic acknowledgment, the nRF24L01P ensures robust communication even in noisy environments.By enabling wireless communication between the fish and external devices, such as surface controllers or base stations. Its low power consumption, compact size, and reliable communication protocol make it an ideal choice for transmitting data over short to medium distances in underwater environments.Connect the nRF24L01P in an underwater robotic fish project, ensure the module is waterproofed and connect its SPI pins to corresponding SPI pins on the Arduino Nano, along with connecting CE and CSN pins to digital pins. Power the module with a stable 3.3V supply, connecting VCC to 3.3V and GND to ground. Optionally, connect an external antenna to the ANT pin for improved range. Write Arduino code using libraries like RF24 to configure the module and establish wireless communication. Test the setup in a controlled environment to ensure reliability, adjust antenna placement if needed, then integrate the modules into the fish's structure with waterproofing measures, and deploy in the underwater environment for real-world testing and operation.

4.10Schematic Representation:

The schematic representation of Underwater Robotic fish is designed using Easy EDA software which is shown in Figure 3. The schematic diagram shows how the parts of the robotic system interface with one another. The Arduino Nano, a central control unit, sits at the heart of the system. The Arduino nano communicates with a various devices , including esp-32 cam module, servo motors, and voltage regulator for the implementation of the Soft Robotic Fish.

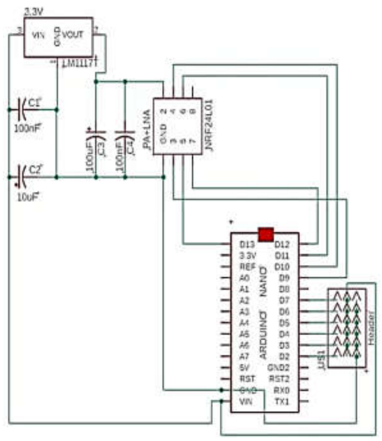

Figure 8. Schematic representation of the connections.

4.11 To upload data in Mobile Inventor app.

MIT Inventor app is used to control the robotic fish over Bluetooth. and it is used to store the captured images.

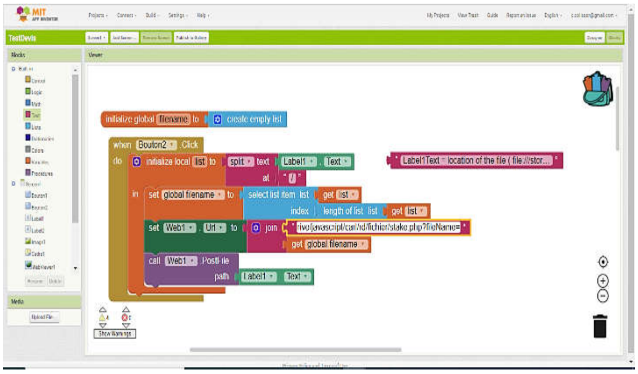

Figure9. Uploading of the data.

The "Mobile Innovator" application is a dynamic platform crafted to inspire users to generate and explore new ideas through mobile technology. Through this app, individuals can access a variety of tools and functionalities tailored to encourage creativity, problem-solving, and interactive learning experiences. Its intuitive interface, equipped with drag-and-drop functionality, enables users to effortlessly design and build mobile applications, even without extensive coding expertise. Moreover, the application may provide educational materials, pre-designed templates, and a wealth of resources to support users throughout the app development journey. Furthermore, it may include community forums and sharing features, fostering collaboration among users and allowing them to showcase their projects. In essence, the Mobile Innovator app serves as a valuable resource for those seeking to express their creativity and transform their mobile app concepts into reality.

Receiver side

At the receiver side, A 15 pin header and a 2x4 pin header are connected on the printed circuit board. The capacitors are connected to used for energy storage, voltage regulation, and noise filtering. An IC is connected for controlling movement, processing sensor data, and enabling communication. An Arduino nano with NRF24L01+ PA+ Wireless SMD is connected to utilized in underwater robotic fish projects to enable reliable wireless communication between the fish and external devices, such as controllers or base stations. Its enhanced power amplifier (PA) and signal amplification capabilities extend the range of communication, crucial for maintaining connectivity in challenging underwater environments.The one end of the Servo Motor is Connected to the channel 1, The second servo motor is connected to channel 2 likewise other two servo motors are connected to channel 3,channel 4, channel 5 and channel 6. A 7.4 lipo is connected to the printed circuit board. The batteries of servo motors are connected.

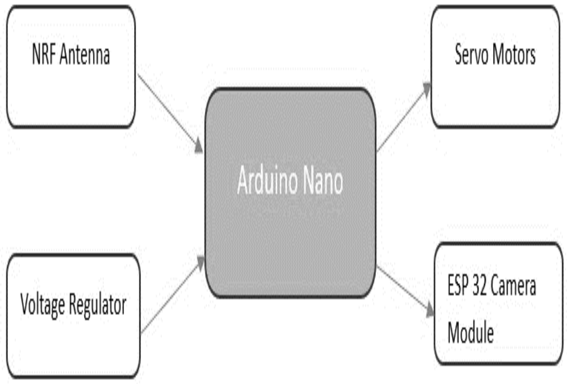

Figure10.Receiver side.

RESULT

The robot system implementation involves constructing the outer casing using 3D printing technology, ensuring a durable and customizable design that can withstand underwater conditions. Additionally, servo motors are integrated into the system to enable remote control of the robot's movements, allowing for precise navigation and exploration of underwater environments. This combination of 3D-printed outer casing and servo motors enhances the versatility and functionality of the underwater soft Robotic Fish, enabling effective monitoring of Underwater environment and exploration of aquatic habitats with ease. The proposed three-dimensional model design of underwater robotic fish.The proposed three-dimensional model design of underwater robot was illustrated in Figure 12.

Fig 11. Hardware Setup.

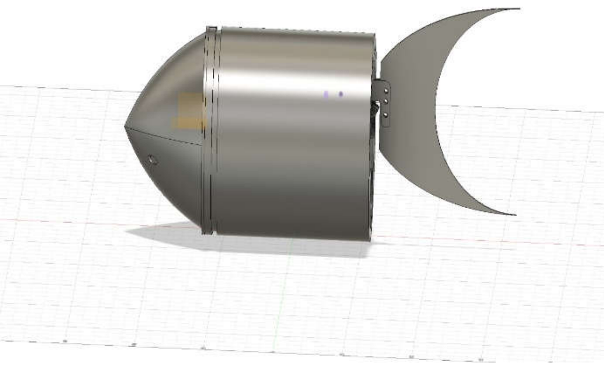

Fig 12. Software Result.

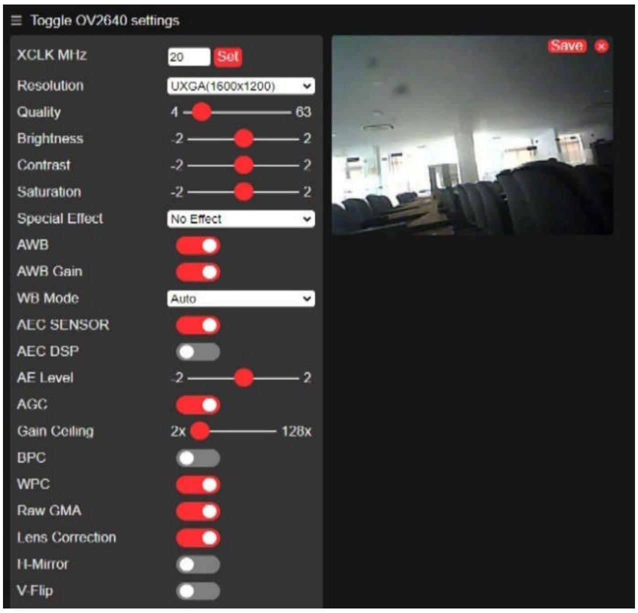

Fig 13. Result obtained by the Camera Module.

Fig 14. Result obtained by the Robotic Fish.

CONCLUSION

The underwater robotic fish project, designed for both exploration and defence applications, marks a significant advancement in underwater technology. Through meticulous design and integration of various components such as servo motors, sensors, and wireless communication modules like the NRF24L01+ PA+, these robotic fish offer unparalleled manoeuvrability, data collection capabilities, and remote control functionalities. Their potentialfor underwater exploration extends to marine research, environmental monitoring, and resource discovery, while also finding critical use in defence applications such as surveillance, reconnaissance, and protection of maritime assets. As versatile and efficient aquatic agents, these robotic fish represent a promising frontier in underwater technology with vast implications for both civilian and defense sectors.

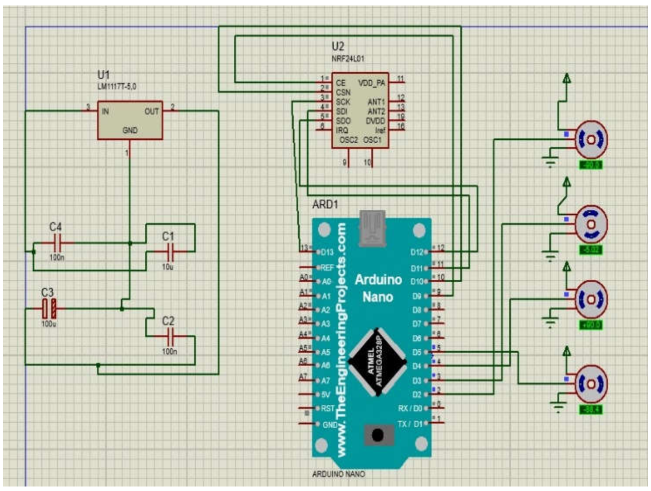

Fig.12: Program code.

The development and implementation of underwater robotic fish for exploration and defence applications represent a remarkable advancement in underwater technology. These robotic fish, equipped with sophisticated components such as servo motors for propulsion and manoeuvrability, sensors for environmental monitoring, and wireless communication modules like the NRF24L01+ PA+ for remote control and data transmission, offer unparalleled capabilities in underwater environments. In the realm of exploration, these robotic fish serve vital roles in marine research, underwater archaeology, and resource exploration, enabling scientists to access remote underwater locations and gather valuable data without human intervention.The underwater soft robotic fish project represents a significant milestone in biomimetic robotics, showcasing the potential of soft robotic systems to emulate and surpass the capabilities of biological organisms in underwater environments. Through meticulous design, experimentation, and integration of cutting-edge technologies, the project has demonstrated the feasibility and effectiveness of soft robotics in achieving autonomous underwater navigation and exploration, paving the way for future advancements in marine robotics and environmental monitoring.

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