Aqua-Vision (An underwater panoramic camera with computer vision and analytics)

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Abstract. In the present social media-bound lifestyle, capturing memories and keeping them accessible is gaining a significant demand globally. For this purpose, a robust, portable camera system for recreational or commercial purposes can be of substantial advantage to society. Aqua-Vision intends to bring an affordable underwater camera system with various innovative features to the hands of consumers. The smart module consists of a waterproof gimbal camera that can be used underwater, providing a hassle-free and reliable user experience and offers rotary motion along two axes. The camera features various general modes like panorama, burst shot, and smart modes using inbuilt computer vision algorithms. The gimbal camera setup can be controlled and switched remotely between all possible modes using a mobile application. All the above features will allow the user to capture photos/videos in any possible setup and use the camera module for various applications. The advent of such innovative, convenient, and robust modules will help cater to the market demands effectively.

Keywords: Camera, Gimbal, Computer Vision, Underwater, Photography, Object Tracking, Remote control, Multipurpose camera.

1 Introduction

In the post-pandemic social lifestyle, a vast multitude of people believe in exploring all parts of the world and visiting offbeat locations to spend some downtime. In such situations, underwater cameras are convenient for recreational photography and videography, fish-spotting, monitoring, and many more creative requirements [1]. Industrially, the camera can monitor underwater machinery, perform maintenance operations, and get visuals in places where it is not easy for humans to access [2]. These applications motivated the design of Aqua-Vision, an underwater camera with many features to aid users in getting underwater photos, videos and monitoring the underwater environment. The gimbal camera uses two servo motors that allow 2-degree of freedom motion. The two servo motors can be controlled remotely using a simple mobile application. An onboard Wi-Fi module facilitates the communication between the camera module and the mobile application. The connections between the camera and Wi-Fi modules are sealed in a waterproof casing, making it robust and multipurpose. The consumers can also use the extendable stick to take pictures/videos at a certain depth from the ground level. The 2-axis gimbal setup is detachable, and thus users can fix it up in any location based on the requirement.
The camera system has multiple functioning modes. The first one being the Panorama mode wherein, once the user initiates the mode by clicking a button on the mobile application, the servo motor along the X-Y plane rotates 180 degrees to capture the image. The camera setup can take multiple pictures at once with very high shutter speed in the burst mode. The camera's video mode allows live camera relay of the underwater environment to the user's mobile application. The onboard LED light enables the user to capture photos and videos in low-light environments too. Overall, the multi-functional underwater smart gimbal camera can be vital in many applications and has an immense potential of scaling to multiple domains.

2 Literature Review

Underwater photography and monitoring are domains that attract a wide variety of consumers for various applications [3]. Although underwater cameras are available commercially, they are usually expensive and typically designed for professional photographers, fishers, and scuba divers [4]. Hence, less economically viable options are available for average consumers to take underwater pictures/videos for recreational purposes. Most of the commercial cameras also do not have integrated computer-vision-enabled smart features for monitoring and object detection. Besides the commercial underwater cameras already available, there isn't much active research on affordable day-to-day underwater cameras. Aqua-Vision aims to provide a frictionless experience to the user along with a wide variety of functionalities at an affordable price. It also includes a live feed relay of the underwater environment and proximity analysis for critical applications where a static camera feed would be cumbersome for the user. The camera mounted on the two-axis gimbal can be controlled remotely using a mobile app. For the prototype, the servo motors in the gimbal setup are controlled using the BLYNK app [5]. Added features of panoramic view and burst mode can also be controlled using the mobile app. Thus, the camera can be used to view underwater environment which is not very easily accessible [6]. This feature gives the underwater camera module the potential to scale to multiple domains. The extendable stick enables the camera to have a large depth range. Further, the onboard Wi-Fi module relays live feed to the cloud and can be accessed from any device [7]. Commercially available cameras are usually static, and manual controlled, making it difficult to be used in all types of locations. Thus, the Aqua-Vision smart underwater camera provides the user with highly convenient and valuable features mounted on a robust structure to make it completely strong and versatile.

3 Proposed Methodology

3.1 System Architecture

The Aqua-Vision can be broadly structured into a 3-level architecture, as shown in Fig.1. These levels are integrated to give the user a frictionless experience while using the camera. The three levels can be briefly described as follows:

1. Control Level: The user selects what function the camera must perform, for example, taking a panorama image. The control is achieved by using a mobile application that is wirelessly connected with the help of an onboard Wi-Fi-enabled microcomputer. The control for various modes of the camera is also initiated at this level.
2. Data Abstraction Level: The data abstraction level describes the media abstracted with the help of the 2-axis gimbal underwater camera. The user input controls the camera and further executes the function. The data abstraction level is the most crucial segment for the underwater module and defines the image quality of the feed.
3. Communication: Media from the camera is then transmitted wirelessly to the cloud interface using an onboard Wi-Fi-enabled microcomputer. This cloud data is then made accessible to the user through the mobile application.
3.2. Structure and Schematic

The structure of the underwater smart camera system has an extendable stick on which the 2-axis gimbal camera is mounted. As the smart stick should be completely waterproof, the camera can be placed inside a casing with a transparent front so that it does not hinder the vision of the camera, and to waterproof the servo motors, the back casing should be removed, and the servo motor should be filled with a non-conducting incompressible liquid like oil. It would not let any other conducting liquid like water enter the casing of the servo and damage the electronics. The servo motor on the base that facilitates motion along the X-Y axis should have a greater torque than the one on the top. The panoramic mode is implemented by the 2-axis servo gimbal when one of the servo motors moves 180 degrees once the button on the application is pressed [8]. Overall, the whole structure has robust and versatile characteristics to make sure it fits an extensive range of applications. The onboard microcomputer is placed at the top to reduce risks of failure due to water seepage. The camera and extendable stick module can be covered with thin waterproof acrylic sheets to allow 180-degree rotation and have compact waterproofing of the whole system [9]. The prototype of the smart stick module is as shown in Fig 2.

![Figure 1. System Architecture. (Architecture designed by respective authors)](image)

3.3. Practical Development

To make the project easily comprehensible, the design of Aqua-Vision is very fundamental, as visualized in the block diagram in Figure 3.

- The user has control over the camera using a mobile application connected to the microcomputer on-board. The wires to the microcomputer are enclosed inside a waterproof case to ensure that the system is robust and does not fail due to the underwater environment.
• The microcomputer sends and receives data from the camera and hence the camera acts as the actuator in the process. The user gives inputs remotely to the camera with the help of a mobile application. The mobile application relays the given input to the microcomputer wirelessly with the help of the onboard Wi-Fi module. The microcomputer is also connected to the servo motors to help change the camera's orientation based on given inputs.

• The data collected by the camera then gets conveyed to the user either via a cloud platform or directly using the mobile application and Wi-Fi. The cloud services allow further scaling towards computer vision analytics and image recognition with the help of an extensive database.

![Diagram](image.png)

**Figure 3.** Practical Development (Diagram designed by respective authors)

4 Results and Discussion

4.1 Circuit Realization

![Circuit Diagram](image.png)

**Figure 4.** Circuit Realization (Circuit designed by respective authors)
Figure 4. Shows how the camera is connected to the main microcomputer, the Raspberry Pi 3b+ (could be replaced with any microcomputer in the Pi series that includes a 3.5mm jack) in the prototype. The camera's video output is connected to the Raspberry Pi through its 3.5mm headphone jack with a suitable RCA to 3.5mm converter. This feed from the Raspberry Pi can be relayed for global access through Wi-Fi connectivity provided with the Raspberry Pi. A 12V power supply powers the camera. The 2-axis gimbal is made up of 2 servo motors, responsible for the X and Y-axis of motion. They are controlled by PWM signals generated from the GPIO pins of the Raspberry Pi. The duty cycle of these signals can vary from 0% to 100%, which corresponds to 0 to 180 degrees of the servo motor. The duty cycle depends on the input given by the user or based on the calculations of the computer vision algorithms.

4.2. Underwater Feed

To get the underwater feed from the camera to the laptop an RCA to USB connector was used. The real-time underwater feed is as shown in Fig.5.

The Raspberry Pi can use this feed to run computer vision algorithms or relay it to the cloud so that the user can view the feed and store the images on the cloud. The camera gives information about the proximity to a specific object in focus, which can further draw insights into the underwater environment.

4.3. Conclusion

The research and development of Aqua-Vision give insight into the possibilities and opportunities in the field of underwater cameras. The smart underwater camera brings a wide range of features to the hands of ordinary customers who can utilize it for multiple purposes. Aqua-Vision goes beyond an underwater camera for specific applications by involving onboard Wi-Fi modules along with smart modes to control the system remotely. After analysis the development of Aqua-Vision and testing its capabilities, it can be observed that the module is affordable and very robust with the characteristics like waterproofing and multiple functionalities. Currently, the pandemic has thrown the entire world into an economic
crisis, and therefore there is a growing demand for affordable technologies and alternatives to current solutions in the market [10]. Currently, in the market, an industrial camera can cost around Rs.10000, while manufacturing the Aqua-Vision module takes close to Rs. 8500. Therefore, this innovation can solve a variety of industrial problems at a fraction of the cost of current commercially available solutions [11]. The cost structure of the module is given in Fig. 6.

![AquaVision - Bill of Materials](Picture taken by respective authors)

**Figure 6.** The cost structure of Aqua-Vision (Picture taken by respective authors)

Compared to standard industrial cameras like Basler cameras, Aqua-Vision comes with onboard processing capabilities and an extendable stick to adjust the camera's position, making it comparatively very easy to deploy and integrate with existing technology. Aqua-Vision has applications in domains ranging from consumer technologies to helping access places not normally accessible, thus reducing risks. For instance, A public sewage cleaner can use Aqua-Vision to check for clogs - without entering the sewages themselves. Overall, the simplistic, multi-functional module can be stretched in many different directions and be beneficial for various use cases.

5 Future Work

Aqua-Vision has excellent potential for compatibility with various applications because of its modularity and ability to be scaled. The camera can be further enabled with computer vision processing for applications like taking a census of fish population in a pond or monitoring a specific aquatic organism to observe its behavior and use the insights for further study. An automation task can be linked to the Aqua-Vision through an IoT network grid and further enhanced using local edge computing [12]. Further, the actuators on the Aqua-Vision are modular and can be changed as per the requirement, making it a multi-functional device. For instance, in ships, it could be mounted with ultrasonic sensors and check for cracks within the metal. Or it could be mounted with thermal IR sensors and used to check the temperature of ocean floors [13]. Similarly, Aqua-Vision can be extended to include a display to reduce the required configuration and setting and make it even easier to deploy and use by workers.

This model could also be scaled up, and a group of Aqua-Visions can be used for applications like farming of fishes [14]. Built with capable and reliable technologies, Aqua-Vision will meet consumer and industrial demand and provide reliable data to the customers and help them work better and more efficiently [15]. Hence, Aqua-Vision delivers an affordable, modular, and dependable solution to the market, and its scalability makes it suitable for long-term investment.
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