The Image Recognition System implemented in Aquaculture Stewardship

Lin, Chih-Yuan cylin@mail.tfrin.gov.tw
Fisheries Research Institute
of the Council of Agriculture
Taiwan

Wei, Chun-Sheng jenson@itri.org.tw
Smart Sensing and Systems Technology Center of Industrial
Technology Research Institute
Taiwan

Chen, Chao-Chien mark@smartagri.com.tw
Department of Communications Management
of Shih Hsin University
Taiwan

Corresponding Author: Chen, Chao-Chien

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Abstract

Clams are the primary shellfish farmed in Taiwan. From stocking seed clams to harvesting, it takes about 10-15 months. Farmers must be attentive to the water temperature, salinity, pH and dissolved oxygen. When required, perform daily measures to provide good water quality for growth. Additionally, due to the high stocking density in Taiwan, as the clams grow to a certain size, their growth will be affected by the gradual deterioration of the living environment or the decrease in the growing space. Therefore, if the slowing down of the growth of clams can be noticed immediately, effective approaches can then be performed. For instance, to dig the bottom of the pond and get rid of excessive suspended organic matter, to maintain the growth of the clams. Through developing the monitoring application technology of Autonomous Underwater Vehicle (AUV), in conjunction with the underwater image monitoring, images of the clam cultivation pond bottom of the clam demonstration site have been obtained through remote control and camera by this study. From the images, abnormal changes of the cultivation environment can be noted, allowing the farmers to take corresponding measures to the noted abnormalities during the farming period, so as to lower losses and decrease manpower consumed in keeping watch over the clam farms.

Keywords: Autonomous Underwater Vehicle (AUV), Image recognition, Aquaculture, Clam farming.

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1. INTRODUCTION

Clams (Meretrix lusoria) belong to the class Axopodidae, commonly known as clams. The shell is slightly triangular in shape, with the belly being blunt and round and a mainly yellowish brown color. Due to its delicious taste, it is the primary shellfish farmed in Taiwan. (Liu, Fu-Kuang, Ho, Yun-Ta, Kuo, Jen-Chieh, Liao, Yi-Chiu, 2002) [1]. The clam farming area in year 2021 was within 8,983.6 hectares, the annual output was 52,980 metric tons, and the output value was 3,969,283,000 dollars (Fisheries Agency, 2022) [2], which came first in farmed shellfish. Farmers mostly stock seed clams in March every year and the cultivation time is 13 ~ 15 months; for this reason, the quantity of clams to be harvested in July and August every year is small, making the selling price to peak during this time of the year. Generally, the survival rate of the farmer-stocked seed clams is about 80 ~ 90%. The ratio of clams reaching a size above medium (sieve, mesh 9.3 cm × 1.8 cm) is about 50 ~ 90% (Chou, Yu-Han, 2017) [3].

A balance between production and requirement has been maintained, in general, by the clam farming of the nation, and the origin price in most cases just shows seasonal fluctuations, which is within the expectations of the farmers. Overall, the survival rate must be higher than 30% for the farmers to be profitable (Huang, Chen-Ting, Chen, Yu-Chia, Liu, Ping-Chung, Lin, Cheng-Hui, Hsiao, Yao-Jen, Chen, Shih-Chang, Chuang, Ching-Ta, 2018) [4]. From stocking seed clams to harvesting, it takes about 10-15 months. Farmers must be attentive to the water temperature, salinity, pH and dissolved oxygen. When required, perform daily measures to provide good water quality for growth (Fisheries Research Institute, 2017) [5]. Additionally, due to the high stocking density in Taiwan, as the clams grow to a certain size, their growth will be affected by the gradual deterioration of the living environment or the decrease in the growing space. Therefore, if the slowing down of the growth of clams can be noticed immediately, effective approaches can then be performed. For instance, to dig the bottom of the pond and get rid of excessive suspended organic matter, to maintain the growth of the clams. Additionally, enhancing the flow of pool water and the frequency of water level changes can also improve the growth environment of the clams (Liu, Fu-Kuang et al., 2002) [1]. Over recent years, the increasing seriousness of slow clam growth and mass death has been reported quite frequently by the clam farmers, which is causing their revenue to scale down critically.(Chou, Yu-Han, 2017) [3].

Therefore, as a means to increase the efficiency of clam production management and lessen problems as long clam cultivation time, low growth rate and production decline, Autonomous Underwater Vehicle (AUV) and image recognition technology will be introduced by this study, in an attempt to make use of information technology to observe the growth status of the clams, so that the growth situation of the clams can be noted in real time, for instant adjustment of farming methods for increasing the production capacity of the clams.

2. LITERATURE REVIEW

2.1 Clam Farming Management

Clams are eurythermic and eurysalinic. Their survival temperature is 3 ~ 39°C, suitable salinity is 10-45ppt and the most suitable sand content of the habitat is at 60%-80%. The nature of the habitat ground has a certain impact on the growth and survival rate of the clams. For instance, hardening of the ground, insufficient ground fertilizer and pollution of the ground etc. may all contribute to the slowing down in the growth of the clams (Huang, Hsin-Yu, 2013) [6]. Ho, Yun-Ta(1995) [7] also pointed out that mass death of clams is likely to be caused by seasonal changes, especially in March, June and September of the lunar calendar. Moreover, high water temperature leads to slow growth and massive death to hard clams. Although hard clams are highly tolerant to low dissolved oxygen, long-term hypoxia eventually affects its growth and even resulted in death. Thus, the operation of waterwheels and amount of oxygen in the pond should be regularly monitored to ensure that there is sufficient oxygen for microbes to break down organic matters. (Chou, Yu-Han, 2017) [3]. It can be learned from the previous tests that the growth rate of hard clams at the early stage is proportional to the amount of feeds. However, a high density of farming and high amount of feed may lead to massive death of hard clams. Moreover, it is hard to know the condition of clams by just looking. The hard clam farmers have always given feeds depending on the color of the water, often resulting in overfeeding. (Liu, Fu-Kuang, 2001) [8]. Therefore, information technology may help us monitor the hard clam conditions and make earlier adjustments accordingly to reduce hard clam mortality.

2.2 Application of Unmanned Aerial Vehicles (UAV) in Agriculture

The rise of unmanned aerial vehicles triggers a revolution in several industries. In the agricultural industry, aging population and rural flight urge many farmers to use unmanned aerial vehicles to do pesticide/fertilizer spraying, crop analysis, disease prevention and hazard assessment of animals and the planet. (Peng, Kang-Chieh, 2018) [9]. In the oil palm plantations of Malaysia, unmanned ground vehicles are used together with other sensors to precisely sprinkle and spray fertilizers and pesticides in different areas to reduce production costs and materials wastage. (Wu, Hung-Chien, 2021) [10]. Some local governments or agricultural departments pervasively utilize UAV in pest and disease control and post-disaster agricultural loss assessment to bring more agri-benefits. [11] (Chiang, Yen-Cheng, 2019).

Autonomous underwater vehicles (AUV) carry sensors to monitor the environment, locate themselves and find directions, use motors for propelling fins and changing speed and change the propelling direction by using the rudder and servo control to make turns. It is also helpful in ocean science research, such as specimen collection, underwater positioning, side scan and videoing. [12] (Li, Min-Fan, Yang, Li-Jong and Kung, Wei-I, 2018) Since unmanned vehicles can be applied in diversified ways, the AUV is used in the Study to acquire the information about hard clam growth.

2.3 Application of Image recognition in Agriculture

Hyperspectral image (HSI) classification is a non-destructive testing technique which is widely used in many fields, such as precision agriculture, crop management and produce quality tests in the agricultural industry. For example, the water potential of tomato leaves can be intuitively judged through clear and understandable visualization. [13] (Tung, Kuo-Chih, Yen, Ping-Lang, Tsai, Chao-Yin, Lin Sheng Yung and Chen, Shih-Ming, 2021) The advanced fruit maturity detection technique is applied to find out whether or not fruits ripen through camera images, opening a new chapter for agriculture 4.0. (Chen, Yu-Hsiang, Tsao, Hui-Hua, Chen, Shih-Wei, Liu, Chun-Yu and Yeh, Ling-Yun, 2018) [14]. Even more, the varroa destructor is the most damaging pest and not easily identified by the naked eyes. Therefore, Pai, Ping-Chuan, Chen, Po-Hsun and Hsu, Pei-Hsiu (2022) [15] apply bee and varroa mites image recognition technique to build an auto-monitoring system which lays a foundation for integrated pest control. In some river ecology researches, the image processing technique is used to develop an automatic bed quality measuring system. Meanwhile, an underwater object detection scheme which is built by using the background subtraction method and underwater cameras is proposed to help ecologists understand the behavior of fish. (Chung, Chang-Han, 2012) [16].

3. RESEARCH QUESTIONS

3.1 Application of AUV in Hard clam Observation

The selected AUV are adjusted and integrated with the system in order to be remotely controlled in the wireless way. With the cameras mounted on the vehicles, the AUV can be used to video the condition of breeding ponds. The AUV which can either be wired or wireless controlled. The real-time images can be transmitted to the ground station via the 4G network to create a navigation map for the AUV to explore the ponds.

The AUV can run for 1 hour. The system is composed of communication software, hardware and a ground station. The structure is shown in FIGURE 1. The structure of the AUV is described in the following sections.

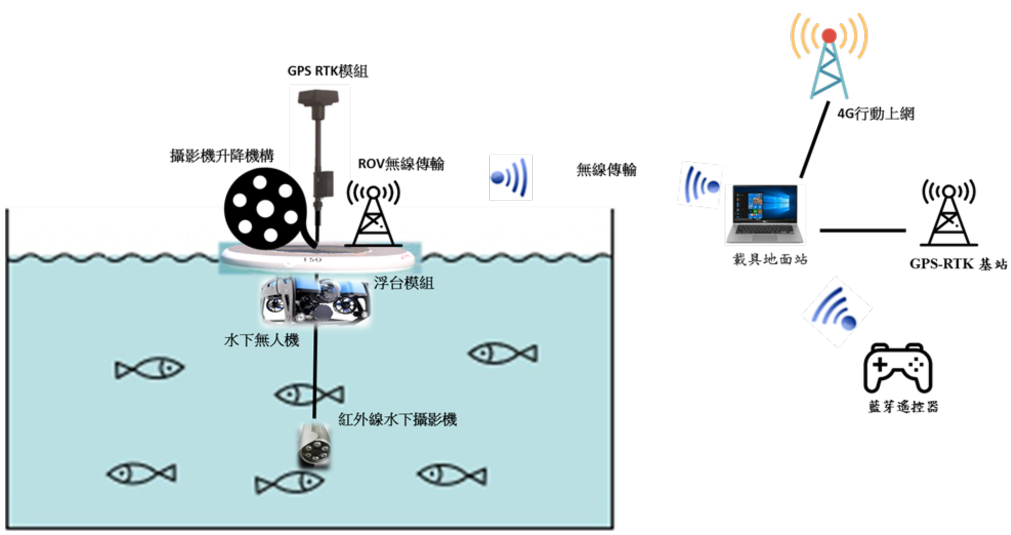

Figure 1: AUV structure (created for the Study)

3.1.1 Communication software

The AUV communication system includes 3 software, as shown in FIGURE 2.

1. ArduSub: The ArduSub is an autonomous driving software and is responsible for coordinating input and AUV control, like the brain of the AUV.
2. QGroundControl: The QGroundControl is the user interface which displays the map and real-time underwater images and supports the video recording.
3. Raspberry Pi: The Raspberry Pi is the microcontroller unit and is responsible for the communication between the automated driving system and the QGroundControl via Ethernet and sending images to the QGroundControl.

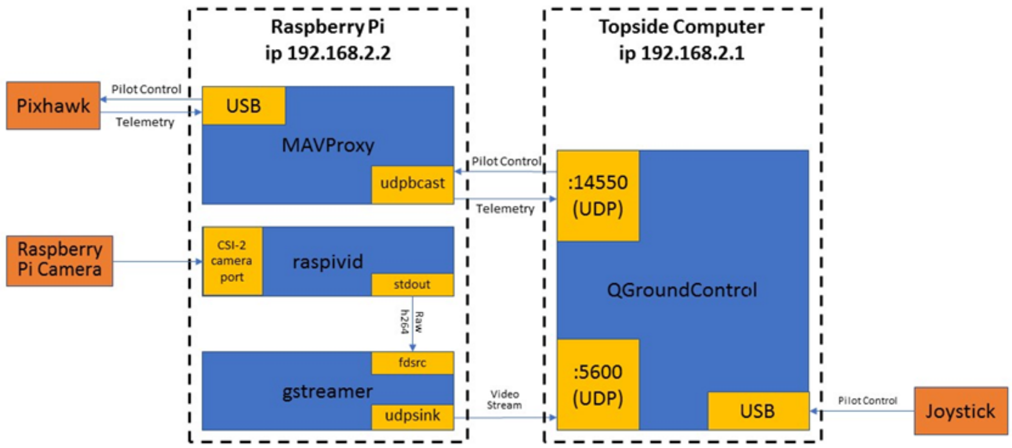

Figure 2: AUV communication software structure (created for the Study)

3.1.2 Hardware Structure

1. Image system: 2 cameras are equipped, i.e. one built-in camera which can be used to make full HD 1920x1080 videos with the angle of 110° and one HD 1080P infrared camera which provides clear views in low light with the angle downwards.
2. Positioning system: 72-channel u-blox M8 engine. Maximum update speed: up to 10Hz. Planar positioning precision: RTK 0.025m + 1ppm CEP. It supports the RTK GPS to increase positioning precision.
3. Lighting system: 2 1,500 lm LED lights are installed on both sides of the AUV to brighten dark areas. They are 2 or 4 x 1,500 lumens and adjustable. The beam angle is 135° and can be adjusted.
4. Power system: The AUV is equipped with 6 rotor propellers which allow it to move upwards, downwards and forwards or make turns. It can go as deep as 100m under water at the maximum speed of 1 m.

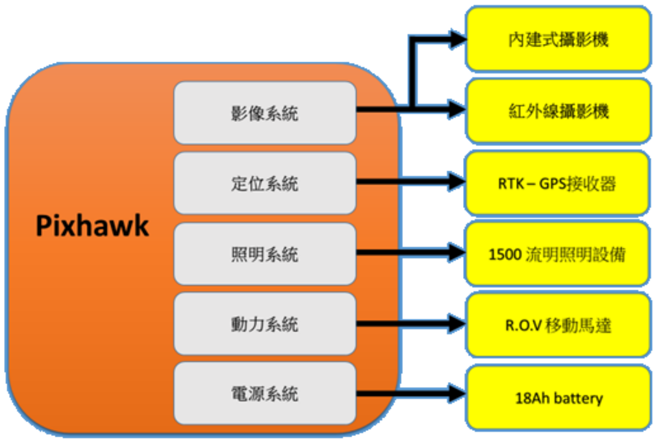

Figure 3: AUV hardware structure (created for the Study)

3.1.3 Ground station

The AUV is controlled by the PC at the ground station via Ethernet. The Pixhawk hardware is installed in the control panel and is compatible with QGroundControl which shows real-time images, coordinates and sensor information to help drivers operate safely. The Xbox controller is used to make the AUV move.

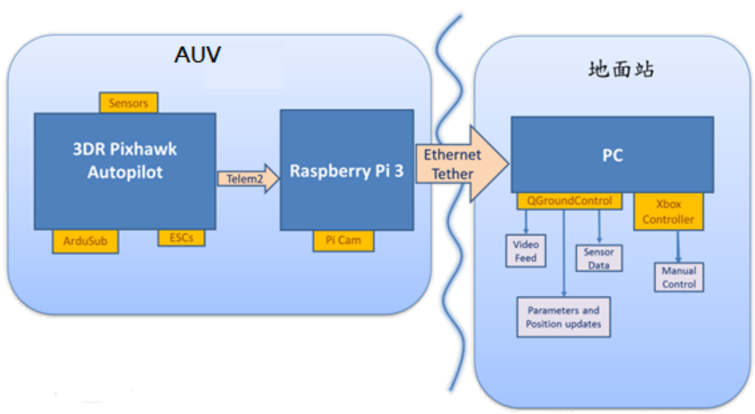

Figure 4: Ground station (created for the Study)

s(p) = avg($p_{i,j}$), where $0 \leq i, j \leq n, n$ is block size

3.2 Application of Image Recognition Technology in Hard clam Observation

3.2.1 Pond bed Image Processing

The photo of the hard clam ponds taken with the underwater camera cannot be directly used for image recognition and should be processed properly to make them clearer for later recognition. The images processing steps are smoothing, binarization and re-smoothing.

1. Smoothing: Digital images have discontinuity of color levels. In order to make adjacent pixel values more continuous, improve the image quality and reduce minor noises, digital masking is used to increase the continuity of color levels and reduce noises. The pixel value of the midpoint is multiplied by the brightness value of adjacent pixels and the weights of related locations, as shown in FIGURE 5. The original images are smoothed to improve the quality for the following clam area determination.

$$R = \frac{w_1 \cdot P_1 + w_2 P_2 + \cdot w_3 \cdot P_3 + \cdots\cdots + w_9 \cdot P_9}{w_1 + w_2 + w_3 + \cdots\cdots w_9}$$

Figure 5: Image smoothing formula

2. Binarization: The aim of binarization is to remove the pixels of non-hard clam areas in gray-scale images and enhance the pixel values of possible hard clam areas. For example, the gray scale of the original image is [0, 255] and BinTh is the binarization threshold. There will be 2 images generated, i.e., a highly similar one and a lowly similar one. The digital images after binarization is produced. The formula is shown in FIGURE 6.

$$p(x, y) = \begin{cases} 255 \ if \ p(x, y) > BinTh \\ 0 \ otherwise \end{cases}$$

Figure 6: Image binarization formula

3. Re-smoothing: The hard clam images of high similarity is obtained after binarization. However, external factors such as light or waves may cause minor noises in binarized images. Thus, additional smoothing is necessary to reduce noises generated during image acquisition in order to improve the accuracy of the following hard clam area determination. To increase the calculating speed and reduce noises, re-smoothing is calculated based on block averages. The formula is shown in FIGURE 7.

Figure 7: Resmoothing formula

3.2.2 Hard clam Area Estimation

After the binarized images are smoothed, the hard clam area can be defined based on the edge of the blocks in the images.

Edge detection is a technique for identifying boundaries of objects and backgrounds. Because of sharp changes in gray scales between the object edges and background, the edge can be determined based on the first derivatives and the second derivatives. To detect the image edge, the derivative operator is used as a mask in convolution to obtain the derivative value of each point. Then, the threshold T is calculated by using the derivative value. If the derivative value of the image point is greater than T, it is considered as an edge point.

Among various derivative operators, the Sobel operator is selected to calculate derivative values. The Sobel operator is less sensitive to noises and has the features of derivative algorithm and image equalization. There are 2 corresponding masks, i.e., Sx in the X direction and Sy in the Y direction, as shown in FIGURE 8.

-1	0	1
-2	0	2
-1	0	1

x方向

-1	-2	-1
0	0	0
1	2	1

y方向

Figure 8: Sobel operator mask

The Sobel operator after X direction and Y direction combined:

$$M = \sqrt{S_x^2 + S_y^2}$$

Images convolution is performed with Sx and Sy to obtain the values which are used to calculate the M value of all dots which are used to calculate the edge threshold T. When the M value is greater than the T value, the dot is considered as the edge dot. The potential hard clam areas obtained through edge detection cross-referenced to the outline obtained through integrating information from edge detection help define the outline of potential hard clam areas, as shown in FIGURE 9.

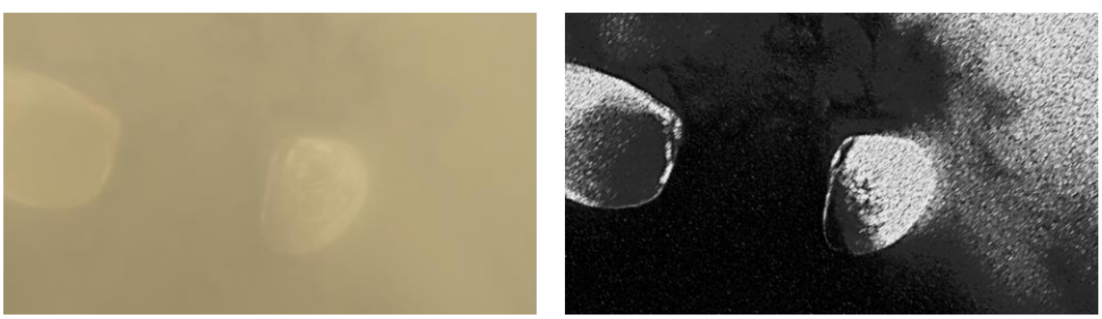

Figure 9: Hard clam outline of binarized images (findings of the Study)

3.3 System Features Integration Test and Adjustment

3.3.1 AUV (autonomous underwater vehicle) Features Integration Test

The pre-launch checklist for AUV:

1. Whether or not the AUV is properly connected to the QGroundControl.
2. Whether or not the vent plug is installed.
3. Whether or not every propeller works properly, push the forward/backward levers to check whether or not the vector propeller works functionally, and push the up/down levers to check the vertical propeller.
4. Check the camera to ensure that the oblique photography and indicators work properly.
5. Set AUV in the auto mode to see if it can patrol rightly.

3.3.2 Underwater Camera and Camera Motion Control Integration Test

The camera motion control can lower the infrared underwater camera beneath the water to probe the underwater environment. The mechanism is designed to go up and down automatically and the infrared underwater camera can be brought beneath the water in a wireless way until it touches the bed.

3.3.3 RTK-GPS Application Test

The RTK-GPS (Real Time Kinematic, RTK) has 2 GPS (Global Positioning System) receivers. One receiver is fixed in a clearly-known position as a reference station and the other is mounted on the AUV as the moving station. Both receivers continue to communicate with GPS satellites and send real-time information to the moving station end via radio transmitters. The moving station continues to receive signals from GPS satellites and the data from the reference station via radio transmitters. Then, we can obtain the carrier phase difference based on the 2 sets of data to reduce errors in the data of the reference station and find out the highly precise 3D real-time position of the moving station.

3.3.4 System Integration Test

The system integration test is the key to know whether or not the AUV can work properly. The checklist is shown below:

1. Does the ground station communicate with the AUV in a wireless way in order to obtain AUV information, such as power capacity and connection status?

2. Is the AUV controlled by the ground station with remote controls wirelessly?
3. Can the images in front of the AUV and the infrared images of the underwater camera be clearly seen in the ground station in the wireless way?
4. Can the current location of the AUV be shown in the ground station?
5. Can multiple coordinates be shown in the ground station for auto navigation?
6. Can the RTK-GPS status be shown in the ground station?
7. Can the infrared underwater camera go deep in the water?

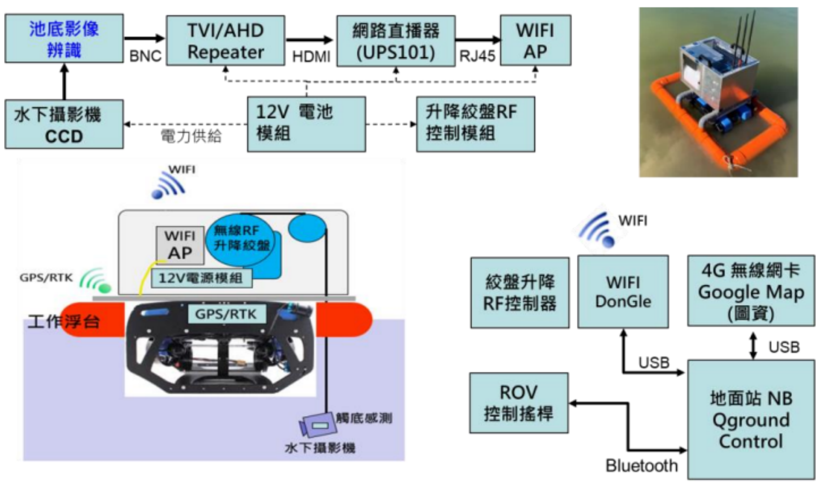

Figure 10: Application of the AUV and image recognition system in hard clam management system (created for the Study)

4. DISCUSSION

In the Study, the AUV is integrated with the systems and equipped with the RTK-GPS positioning feature for auto navigation. With the infrared underwater camera and QGroundControl, the real-time condition of pond beds can be seen from the ground station for monitoring and recording and images can be transmitted by using wireless signals. It provides an effective solution for integrating the hatchery parametric analysis of smart hatchery ponds in the future.

The AUV system which is developed for auto probe has not been applied in other ways mainly because the AUV is manually operated to perform underwater tasks but it cannot receive satellite signals beneath water. The auto navigation feature allows the AUV to perform tasks automatically. It receives satellite signals for positioning while floating and the retractable rod allows the infrared camera to go deep to the pond for monitoring and recording.

We propose that the AUV should be equipped with a wireless transmitter so that the images and data in AUV can be exchanged with the base station on the ground. Due to its wireless nature, the

AUV can be free of the restrictions of cables which may be entwined with waterwheels. Thus, the AUV can perform tasks in clam ponds safely.

The QGroundControl software is installed in the ground station. The transmission of data and images with the AUV requires a wireless transmitter of the same network segment. Thus, the infrared underwater camera can output by using wired signals and send images on the wireless transmitter.

The AUV alone cannot carry overly heavy devices. To solve this problem, we propose mounting buoy modules on the AUV to increase its load capacity in order to carry wireless modules and motion control mechanisms. The buoys are made up of heat-resistant pipes. The heat-resistant nature allows buoys to stay longer in ponds and keeps buoys s from being damaged in the harsh environment.

Regarding image recognition, there are few issues as described below: 1. How many clams need to be identified? (Oyster Image Segmentation), 2. Where are they? (Object Localization) and 3. How to identify? (Oyster Image Classification.) The object detection technique provides a solution by using object positioning and image classification.

5. CONCLUSION

Through developing the monitoring application technology of Autonomous Underwater Vehicle (AUV), in conjunction with the underwater image monitoring, images of the clam cultivation pond bottom of the clam demonstration site have been obtained through remote control and camera by this study. From the images, abnormal changes of the cultivation environment can be noted, allowing the farmers to take corresponding measures to the noted abnormalities during the farming period, so as to lower losses and decrease manpower consumed in keeping watch over the clam farms.

The AUV proposed in the Study is a practical equipment which can automatically probe hatchery ponds. It is expected to see more sensing features on the AUV, such as robot arms for specimen collection or water quality examination. The AUV will become the water quality analyzer with multi-sensors and multi-functions. Furthermore, with the hatchery decision-making system and the parametric analysis of smart hatchery environment, the production efficiency can be greatly improved.

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