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Net Cage with "Nervous System" for Offshore Aquaculture

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We propose the embedding of extra-fine metal multistranded wires in traditional fishing nets as the "nervous system" of a transmission network. When the newly developed net cage detects poaching or vandalism, it can automatically issue a warning signal in the same way that a human knows where pain is occurring and remedies it promptly. With this newly designed net cage, fish loss can be greatly reduced.

1. Introduction

Taiwan, a small island, has a coastline of 1566 km but its water resources are inadequate. Since marine capture fishery and inland fishery resources are declining year after year, the country has to scale its aquaculture production to meet the increasing demand for marine products. In the past few years, the government has vigorously promoted the concept of Taiwan as a marine country. Taiwan has the advantage of being surrounded by ocean, and many net cages to breed a variety of fish have been built, particularly in Penghu, Pingtung, and Liouciou. Fishery farmers use net cages to nurture fish species with a high unit price (such as cobia and grouper) to greatly increase their economic value.

Although cultivation with net cages can save large areas of land and water resources, it faces the stringent tests of climate and currents and the risk of losses due to typhoons, marine pollution, and other factors.(1) In addition, caged fish can be an easy target for thieves because of their high economic value. Thieves may steal fish on dark nights, also damaging the net. Theft and vandalism have been cited as major problems by cage tilapia producers in the Philippines. As shown in Fig. 1, cages must be placed where access can be controlled and poaching risks reduced. Operators are increasingly employing electronic security methods as additional protection.(2) Other problems experienced by the fish farmers include damage during storms, theft, and vandalism.

Poaching and vandalism of cage fish farms usually occur on dark nights. Monitoring net cages with lights and guards is effective but requires a large amount of labor and power and has a high cost. While sonar can be used to identify the sound of a boat's motor, farmers still need to

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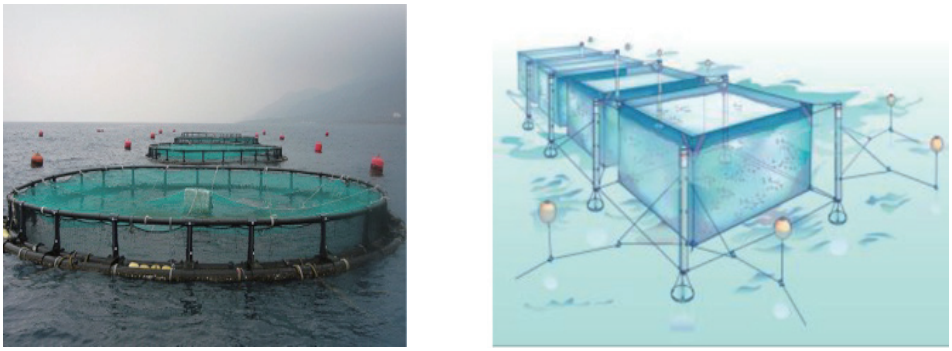


(a) (b)

Fig. 1. (Color online) (a) Offshore fish cages and (b) close-up of structure.

exclude ambient noise.[3] In addition, visual surveillance technology can also be used, but it requires a large amount of electricity, computing time, and hardware.[4] To overcome some of these problems, we have designed a net cage with a "nervous system" similar to that of humans, which can detect damage to nets to reduce economic loss. This active type of nervous sensing system immediately sends a warning message to a manager's mobile device by a solar-powered wireless network.

2. System Design

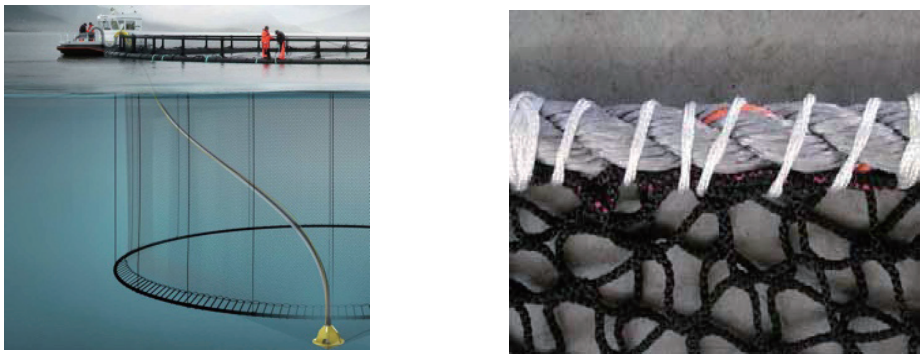
Net cages are composed of a cross-weave rope. Many materials can be used to fabricate net cages, the most common of which are nylon and high-density polyethylene, as shown in Fig. 2.

The architecture of the proposed "nervous system" for cage fish farming is shown in Fig. 3. It has three main parts: (1) the sensing circuit, responsible for the detection of damage to the net cage, (2) the power source, responsible for converting solar energy into alternating current, and (3) the wireless signal transmission network, responsible for sending a warning message to a manager.

Sensing circuit: The main difference between the newly proposed net cage and general net cages is the composition of the net material used. Extra-fine metal multistranded wires are embedded in traditional twine as the nervous system of the transmission network. The net webbing is shown in Fig. 4.

Power supply: Net cages are placed in the ocean. In practice, cables cannot be used to provide electricity due to climate constraints. Hence, solar power is the best choice for the power supply.

Wireless signal transmission network: A wireless 3G/4G network is adopted to send a warning signal to the server and mobile devices. When the net cage is in good condition (no damage), the launch circuit intermittently sends information to the server on the shore and to mobile devices simultaneously. When the net cage is damaged, the system stops transmitting a signal.[7]



(a) (b)

Fig. 2. (Color online) (a) Structure of general fish cage and (b) close-up of fish cage.[5,6]

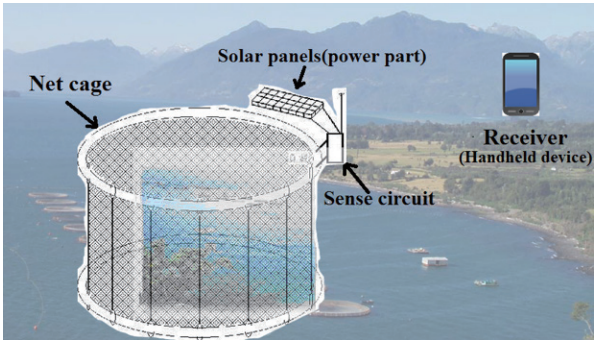
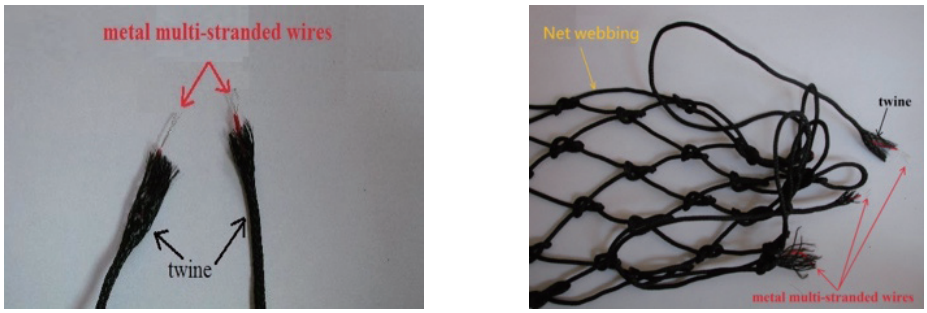


Fig. 3. (Color online) Overall architecture of remote monitoring system.



(a) (b)

Fig. 4. (Color online) Proposed braided (a) netting twine and (b) net webbing.

3. Proposed Cage Structure

The structure of the novel net cage is shown in Fig. 5. At present, net cages commonly have a diameter of 8 to 12 m. If a net cage is damaged, a fish farmer often needs to consult divers to search the entire net cage to find the damaged region, which is time-consuming and laborious. The novel net cage is expected to simplify the inspection and maintenance work. The net cage is constructed in several sections, each equipped with two high-brightness LEDs. When the LEDs of a section light up, it means that the section has been damaged.[8]

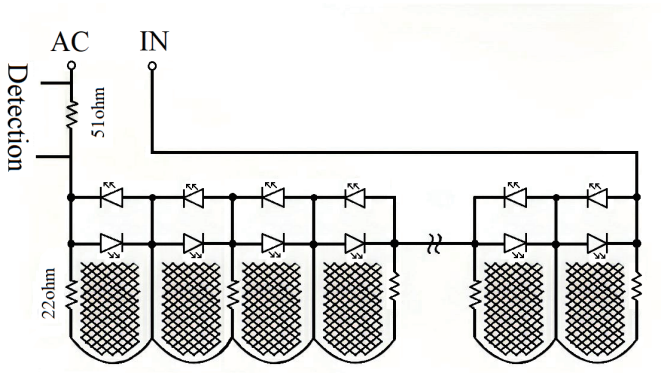


Fig. 5. Structure of net cage with nervous system.

In this work, we study how to construct the cage with the nervous system. While weaving the cage, its circumference is divided into 15 sections; for a cage with a diameter of 10 m, the circumference is 10 m × 3.14 ≈ 30 m and the length of each section is about 2 m.

4. Circuit Design

A block diagram of the circuit design of the system is shown in Fig. 6. The system requires electricity from a solar panel with a DC 12 V battery. The main circuit board of the system has an LED, which flashes when the circuit is working properly. When the net is damaged, the electric current will flow through the sea, and the use of DC would cause the electrolysis of sea water. Therefore, low-voltage AC is used, which will not be harmful to humans or fish. The system network comprises the entire net cage and the two LEDs of each section. When the net cage is in the normal state, the LEDs are off,[9] but when any section of the cage is damaged, the LEDs of the broken section are lit. In this way, the damaged section can even be distinguished on a dark night. The signal detection and control circuit is responsible for sensing the status of the fishing net. After amplifying the detected small signal through the precision rectifier circuit, the window comparator is used to interpret the status of the fishing net. When the network is undamaged, an intermittent pulse signal is output to trigger the Raspberry Pi 3 computer to transmit the signal to the server and mobile devices. When the fishing net is damaged, the output pulse signal is no longer emitted. Therefore, the mobile devices do not receive a signal, indicating that the cage is damaged.

5. Remote Monitoring

Single-board computers with multiple functions, such as thin and full- featured handheld devices, have been developed. Because most people now have at least one handheld device, the proposed system is designed to send information to a manager with a handheld device. The manager can thus monitor the fish cage in real time.

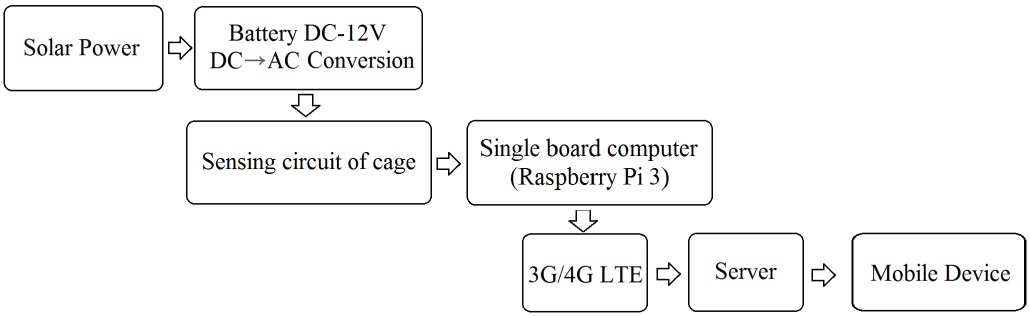


Fig. 6. Block diagram of circuit design.

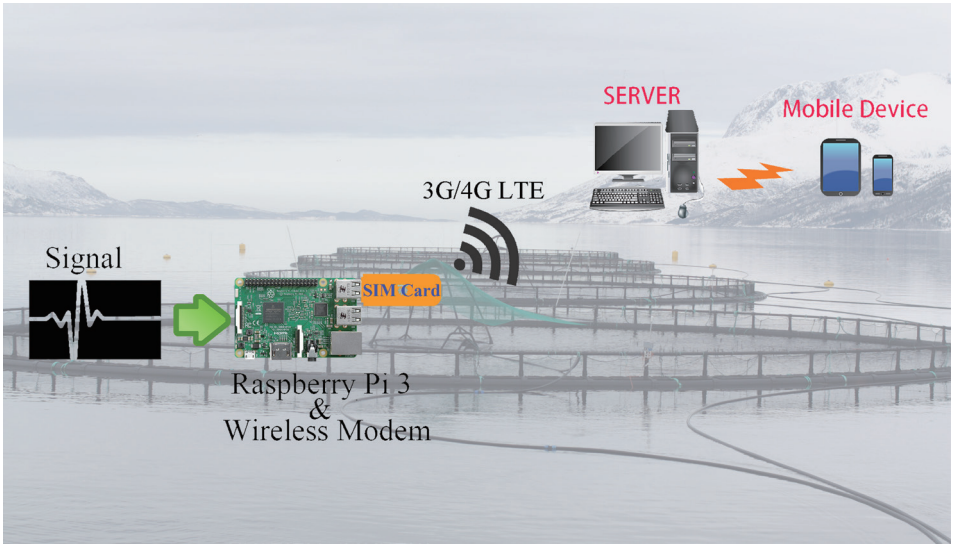


Fig. 7. (Color online) Block diagram of wireless signal transmission.

The signal arriving from the sensing circuit on the net cage is transmitted by a single-board Raspberry Pi 3 computer and a USB mobile network card. The sensed information is stored in the server and then displayed on the manager's mobile device using an application (app).

As shown in Fig. 7, to assess the condition of the cage without cables, a Huawei E8372H 4G Wi-Fi mobile network shared USB telecommunication card is selected.[10] To transmit information by wireless internet, a 3G/4G SIM card is required for the telecommunication card. The Raspberry Pi 3 computer can send information to the cloud server via the 3G/4G network and the manager's handheld device.

6. Power Supply of Fish Cage

It is very difficult and expensive to set up and maintain power lines offshore. Thus, wind and solar energy were considered for the power supply system of the proposed fish cage. An offshore

wind power system has the disadvantages of being buffeted by waves and that it must be installed on a solid foundation, making it unsuitable for use on net cages. An offshore solar system uses batteries to store electricity because the sun provides a relatively constant amount of light to provide continuous power. A single silicon solar panel is used to generate electricity, which is stored in a battery.[11] DC power is supplied to the signal transmission circuit and is also converted to AC to provide electricity for the sensing circuit system. Although electronic equipment used at sea is vulnerable to erosion by sea water and the crystallization of salt, making it necessary to maintain the equipment, this is not expected to be a major problem because fish in cage farms require regular feeding, enabling the fish farmer to check and maintain the equipment regularly.

7. Comparison with Other Cage Systems with Anti-vandalism Measures

In this paper, with the aim of solving the problems in mesh cage damage detection, a mesh cage detection method and system are proposed. A centralized remote monitoring system was developed with a set of remote detecting nodes, a local monitor, and a control center to provide a timely alarm when the net is damaged or fish escape. One project proposed a visual surveillance system for cage aquaculture that automatically detects and tracks ships (intruders).[10] A master's thesis proposed the use of acoustic sensing in a net cage alarm system that included a sonobuoy and a monitoring station on land.[5] The sonobuoy is a passive sonar that collects the sounds near the cage and transmits suspicious signals to the monitoring station. A remote camera, or Cage Cam, has been installed on an aquaculture cage off the Persian Gulf, which was operated continuously from an adjacent Chevron gas platform. The camera allows constant monitoring of the cage, the sea, and the weather conditions. Another automated innovation is a satellite tracking system that notifies researchers if a cage moves outside the range within which it is supposed to be.

A sonar system can be set up to monitor illegal fishing boats entering the area around cages. However, the equipment is expensive, and it is not easy to distinguish between legitimate boats and those intent on illegal behavior from the detection results.[12–14]

Using submarine cameras to monitor the status of cages has the following shortcomings.

(1) Submarine cameras are not easy to fix and maintain stable in the ocean. Owing to the free movement of fish and the ocean current, the angle of the camera cannot be accurately controlled to monitor the entire cage.
(2) Camera lenses can easily be covered with plankton. Fish may also block camera lenses, making it difficult to identify the status of fish nets.
(3) Submarine cameras require a large amount of power, particularly when a remotely controlled submarine controls the camera. The required electronic equipment is also expensive and may itself be the target of thieves when unattended at night. Therefore, they are still difficult to use in practice.

8. Conclusion

In this paper, we studied the embedding of ultrafine metal multistranded wires in conventional fishing nets as the "nervous system" of the transmission network. When a newly developed centralized remote monitoring system detects poaching or vandalism, it can automatically send warning signals. With this newly designed cage, fish losses can be greatly reduced.

A comprehensive comparison of the proposed system and other anti-vandalism systems revealed the following advantages.

(1) The net structure is improved.
(2) The additional cost of installing the wires is small and the possibility of damage to the equipment is taken into account.
(3) The anti-vandalism measures are effective: a warning signal can be transmitted in real time.
(4) It can also be used to automatically detect damage to net cages caused by a storm or aging without human inspection.

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