POTENTIALS OF USING UNDERWATER ROBOTICS FOR FISHING AND FISH FARMING

Bruno BOROVIĆ[1], Antonio VASILIJEVIĆ[1], Ognjen KULJAČA[2]
[1]Faculty of Electrical Engineering and Computing, Laboratory for Underwater Systems and Technologies, Unska 3, Zagreb, 10000, Croatia
[2]Brodarski Institute, Control Engineering Department, Av. V. Holjevca 20, Zagreb, 10020, Croatia

Abstract

The use of robotics finds more and more space among applications in marine environment. Once restricted to military and oil drilling applications, the today's underwater robotics covers more disciplines. It became a cheap, reliable and affordable platform that can be used in various surveys, mapping and other underwater activities by both research communities as well as various types of industry. It finds applications in marine biology, archeology and ecology. The general aim, purpose and the reason for using the underwater robots is gathering better knowledge about marine environment and consequently perform better management of underwater resources. This paper presents the applications of underwater technology in fishing and fish farming. Along these lines several potential applications, addressing both fishing and fish farming, will be addressed, explained and discussed.

The use of underwater robots for cleaning the aquaculture nets is addressed in the first part of the paper. Fish farming suffers from biofouling which can hurt fish, increase mortality and consequently reduce production. It is necessary to clean the nets in order to sustain the flow of oxygen-rich water through the cage. The conventional methods of cleaning, primarily manual cleaning, is quite time-consuming requiring extensive men-hours. The overview of several new systems, based on high pressure cleaning, that hit the market recently, is given.. They rely on heavy equipment making these systems unusable for small producers. The novel approach and methods in cleaning are needed. The discussion on strategy and economy on introducing ultrasonic underwater robot in cleaning and prevention of biofouling build-up is given in detail.

The second part of the paper deals with surveying and monitoring potentially protected marine areas in order to manage them more efficiently. Regular and frequent monitoring of marine environment results in estimating the amount of biomass in it as well as the water conditions. Regular monitoring may result in determining the amount of protected areas reserved for spawning of fish. It would allow determine when certain spices of fish spawn. Gathered knowledge helps in better management of the underwater resources and may determine the length of the period when fishing is to be allowed as well as amount of total biomass of the fish that is to be fished out from the sea. Monitoring also allows determining the impact of fishing and fish farms to environment.

Keywords

Marine robots, fishing, aquaculture

Introduction

Both fishing and fish aquaculture are important sources of food. The worldwide catch seems to have reached the limit at about 80 million tons due to overexploitation [1]. On the other hand aquaculture production yielded 47.3 million tons in 2008 and it can be said that today the half the seafood consumed around the world comes from farms. And, it is only in the past 50 years that aquaculture has become a true industry. In order to illustrate the utilization of marine robotics in fishing and fish farming, mutual aspects of marine robotics and three methodologies related to fishing and fish farming are discussed - aquaculture net cleaning, potential assistance in research on bottom trawling as well as potential in habitat and biomass monitoring.

First, net cleaning for fish farming. Biofouling builds up on aquaculture nets and is detrimental to the growth and well being of fish stocks. More biofouling occurs closer to the surface due to the sun activity. Biofouling reduces flow of water through the nets and causes a drop of oxygen concentration in the fish farming cage thereby causing a decrease in feeding activity and an associated reduction in the number of aquaculture fishes in the cage. It represents favorable condition for proliferation of parasites and may cause disease. It can cause physical harm to aquaculture fishes by adhering shellfish. Finally, it can cause weight increase of farming net that can cause sinking and damage of farming net cages. Therefore, one of the main issues with fish farming is to keep nets clean from biofouling. The cleaning can be done in many different ways [2] and the most interesting one for us is mechanical cleaning performed by marine robots equipped with right set of tools.

Second addressed issue is the fishing method - bottom trawling. The bottom trawling raises environmental concerns such as a perceived lack of selectivity and the physical damage which the trawl does to the seabed. Trawls are non-selective, sweeping up both marketable and undesirable fish as well as fish of both legal and illegal size, i.e. by-catch. Bottom trawling causes large scale destruction on the sea bottom. It steers up sediment, destroys sea grass, reduces bio-diversity and results in ecological changes towards more opportunistic organisms. Active research is done to improve both of these negative aspects of trawling and this paper will address the potential use of marine robotics that can be helpful here.

Finally, the last methodology discussed in the paper is governing, surveying and monitoring of marine areas in order to manage them better and more efficiently. Regular and frequent monitoring of marine environment results in estimating the amount of biomass within fish habitats. Regular monitoring also provides information and trends in quality of water and other environmental conditions. Consequently, it helps in determining the location and size of protected areas and estimating the amount of certain species of fish that is to be taken out from the sea.

Marine Robots and Trends in Marine Robotics

In general, there are two types of unmanned underwater vehicles. The first one is Autonomous Underwater Vehicle (AUV) and the second one is so called Remotely Operated Vehicle (ROV). They are both shown in Fig.1. Main difference between two concepts is that ROV can be manually operated while AUV has to be either preprogrammed to perform a mission, or has to have some sort of intelligence to readjust the mission during its execution.

Typical low-cost AUV configuration comprises a torpedo-like hull equipped with adequate propulsion, batteries and a set of sensors. AUV mission is programmed upfront, before the mission starts, and is executed without human intervention. Hence, the AUV does not have tether or umbilical. The robot, when underwater, cannot rely on GPS for positioning so it has to be equipped with either good dead-reckoning navigation or have some means of acoustic localization.

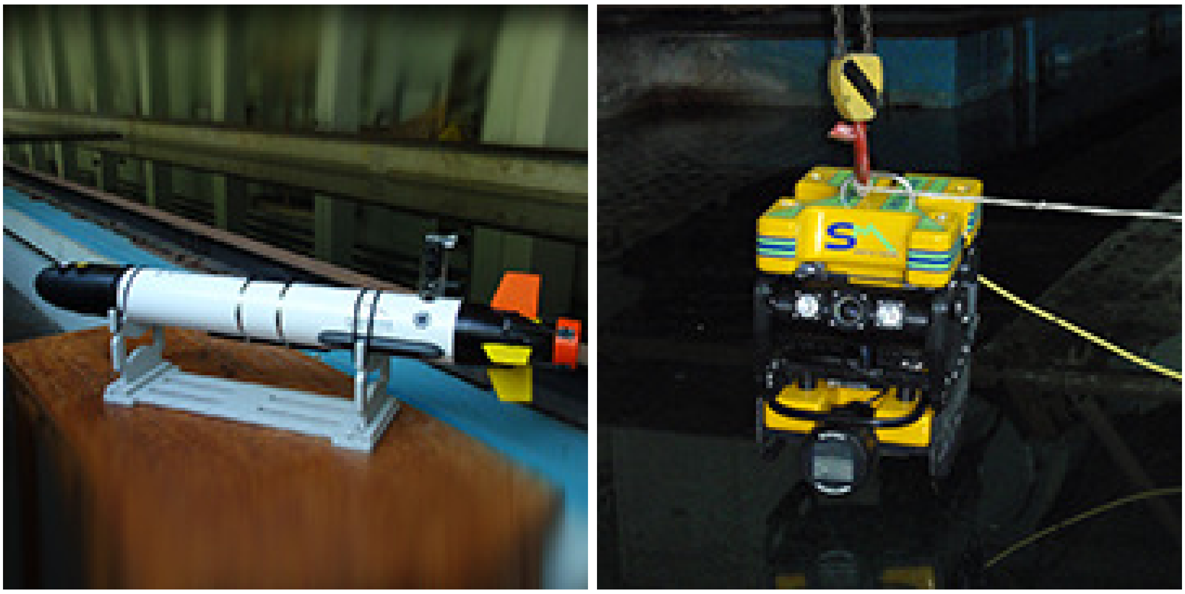

Figure 1

Typical AUV (left) and the typical ROV (right). ROV is under permanent control of the operator while AUV is not.

The AUVs are intended to survey larger areas of sea. Typical application is area survey by executing a set of maneuvers resembling a set of parallel lines - lawnmower pattern. Side scan sonar is used to scan the bottom and subsequent analysis of gathered acoustic images reveals potential targets, i.e. objects of interest. Accurate geo-referencing of the identified targets depends on accuracy of navigation which ranges, depending on situation and mission strategy, from few meters all the way up to several tenths of meters. Typical speed for small size AUV is 2 knots and can go up to 4 knots.

Recent trend in marine robotics are unmanned cooperative platforms. The acoustic communication of some type links and helps to coordinate two or more movable marine platforms, e.g. AUVs, ROVs or ships. The link between two has to be acoustic as electromagnetic waves do not propagate through sea water. The simplest example of coordinated platforms is when one platform follows the motion of the other one. In the cooperative scenario, the AUV retains its autonomy but, with built-in intelligent algorithms, changes mission in-run so the mission is not completely pre-determined. For example, the AUV can have a mission to follow a ship at certain distance and depth. The ship is equipped with simple acoustic beacons visible to the AUV. This way, the AUV can be essentially steered by maneuvering the ship.

On the other hand, a typical low-cost ROV configuration comprises a ROV itself, a tether, a control console and a power supply. The ROV is typically equipped with camera with adequate lights and some navigational equipment on board. Typical examples are magnetic compass and, in some cases, Doppler velocity log (DVL), a sensor that measures the speed of the vehicle. Another useful tool is Ultra-Short BaseLine (USBL) which acoustically measures the position of the ROV relative to the platform, e.g. ship. The ROV is essentially a moveable camera with sensors that tells the operator where the ROV exactly is.

Unlike AUV, the ROV is intended for point search which assumes that ROV is deployed from a platform, which is typically small ship, and dives down towards the previously geo-referenced target for detailed inspection. The approximate target position is known within a couple of tenths of meters. Multi-beam or some other type of sonar, acting as underwater radar, can be used to precisely localize the target. The ROV can also be used for types of missions such as following a pipe, rope or a net at the bottom of the sea. Typical speed ranges from is 0 to maximally 2 knots.

Besides pure ROVs and AUVs, the marine robots can be of so called hybrid type. Hybrid underwater vehicles actually put together some advantages of ROV and some advantages of AUVs and are typically designed and used to perform some specialized tasks.

Ultrasonic Aquaculture Cleaning

Marine growth build-up on aquaculture nets is one of the major issues in aquaculture industry. Biofouling is fought by regular mechanical cleaning, antifouling paints, chemicals and development of new net materials which are less susceptible to biofouling. The simplest mechanical cleaning techniques are mostly based on taking the nets out of the sea and cleaning them with high pressure nozzle. This methodology requires a lot of men hours and turns out to be quite expensive, and even impossible when dealing with large nets. As a result, several cleaning solutions based on marine robots have been introduced during the last several years. Majority of these solutions are based on high pressure or vacuum systems. Examples of companies producing such systems are YANMAR, Hughes Pumps Ltd., Aqua Group and Micmarine.

Typical high pressure or vacuum cleaning system is a ROV with wheels or sledges for moving at the net. There are several disadvantages related to such systems. The robot has to be connected to the ship by an umbilical that provides power and communication with operator. Furthermore, when the robot moves over the net the ROV need something that will press it against the net - for example a strong perpendicular thruster. Also, the robot has a high pressure hose for cleaning and a vacuum hose for removing the remnants of the bio-waste. All these adds to the system complexity, weight, i.e. 150-250kg for robot itself, and cost, i.e. ~EUR 150,000. The cleaning requires a ship with several workers hence resulting in high cost of operation. Finally, due to its size, high pressure and vacuum systems are impractical for cleaning the smaller size cages.

Here, a small autonomous underwater vehicle with cleaning capacity less than 1 square meter per minute can significantly reduce the price of cleaning. The vehicle should be light so that one person can deploy and recover it. Cleaning should be done with ultrasonic head mounted on the AUV. The AUV is programmed to circle within the cage, and is separated from the net by few centimeters, enough for ultrasound to be effective. With each circle, the depth increases a little. It is possible to mount a camera above the cage so the operator can check on the AUV from time to time. Essentially, besides initial cost, and one operator who is even not 100% engaged in cleaning there are no other operational expenses. The system is shown in Fig. 2.

The umbilical can be removed completely as there is no need for operator. Also, there is no need for a system which will keep the robot attached to the net because, unlike high pressure system, the ultrasonic cleaning does not produce reactive force. Lack of reactive force also makes design of dynamic positioning system, used to keep the robot at the proximity to the net, easier. The easy deployment and low-cost operation allows for more frequent use of the robot therefore reducing the amount of bio-waste per cleaning consequently eliminating the need for a disposing vacuum hose.

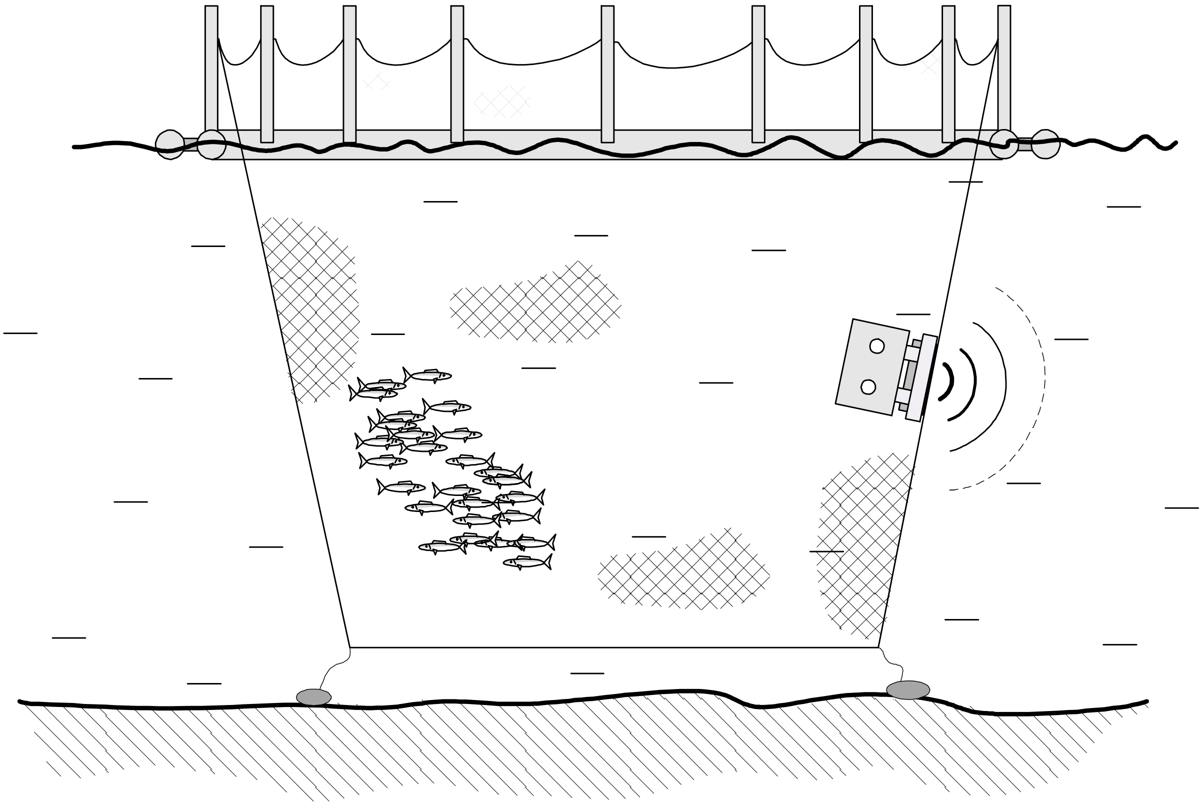

Figure 2
The underwater robotic system for ultrasonic cleaning of nets. The system is easy deployable and requires one person to operate the vehicle.

However, the issue related to ultrasonic cleaning is its influence on fish. Prolonged exposure to the high intensity ultrasound may cause undesirable health consequences. To the authors knowledge, this issue has not been addressed adequately yet. On the other hand, the intensity of sound drops with the distance from the source and attenuation level depends of sound frequency. The sound with higher frequency gets absorbed in water better than the low frequency sound. If relatively high frequency of sound was used it would provide high intensity sound at the net surface, i.e. few centimeters from the ultrasonic head, but significantly lower intensity just a few meters away where the fish is. Therefore, in order to have good cleaning results, the distance from the ultrasonic head to the net should be small.

Trawl Net and Environmental Effects

One of the methods of observing the trawl net is filming its mouth [3]. The trawler drags the net at 2.5-4 knot speed along the predetermined line. The diver awaits for the trawl net, hovering at one point on the line above the anticipated height of the mouth of the net. Diver, equipped with camera, films the passing net. It is a quite dangerous procedure for diver and results in relative small amount of useful material, i.e. film. In order to achieve good coverage, it would be desirable for diver to follow the mouth of the net at a trawling speed. It is rather impossible task for the diver and provides a reason good enough for introduction of the AUV into the methodology.

Utilization of the AUV for monitoring the trawler nets can eliminate the danger for the diver and allow following the mouth of the trawl net at close distance. The net is trawled at 2-3 knots, same as a cruising speed for small-size AUV. Several acoustic beacons can be fitted on the net and advanced localization algorithm are used to maintain the AUV at the appropriate position above the mouth of the trawl net. The AUV, equipped with camera moves along with the net and has continuous view of the mouth. The proposed technique is illustrated in Fig 3.

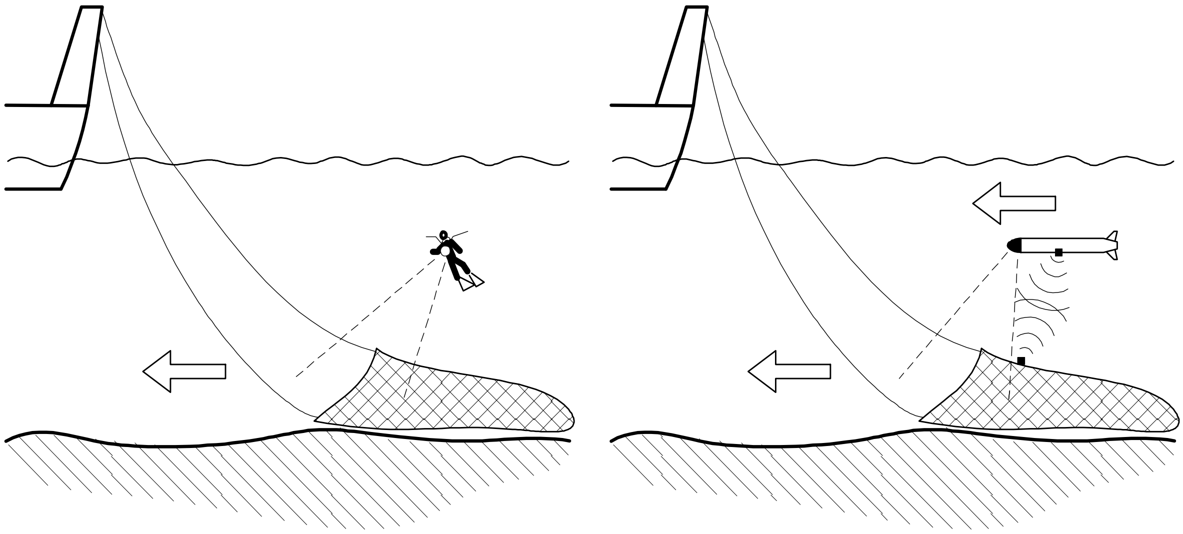

Figure 3

Trawl net mouth following by diver (left) and the AUV (right). Besides being dangerous for diver, the diver can film the trawl net mouth only for few seconds. On the other hand, the AUV moves along the net keeping relative position by acoustic positioning and can monitor happenings at the mouth of the trawl net.

Fish Habitat Monitoring

The other potential application of marine robotics in fishing is periodical monitoring of fish habitats. For example, the AUV may be used to determine the location of underwater reefs by using side scan sonar. It is possible to survey relatively large areas in a relatively short time. Typical appearance of the reef nearby the cape Pelegrin on island of Hvar on the side sonar image is shown at the left side in Fig. 4. The potential fish habitats are geo-referenced with the accuracy of 10-15m.

Figure 4
The side scan sonar image of an underwater reef, potential habitat for fish. This is typical situation found around the cape Pelegrin on island Hvar. Empty muddy bottom with occasional pile of rocks.

Next, the ROV can be used to visit the sites periodically and assess the situation on fish population. The ship equipped with the ROV can inspect >20 such sites during the day, assuming they are relatively close to each other. It is also possible to deploy a camera which will film a site for a few days and will be recovered by the ROV. The procedure can be repeated on several spots all around the year and will give the nice insight to the fish population in the inspected area.

Conclusions

Within the last ten years, the underwater robots have developed to become low-cost, reliable and affordable platforms for performing various underwater activities - from frontal work all the way to gathering knowledge about marine environment. It has consequently led to lower-cost of frontal work and better management of underwater resources in fishing as well as aquaculture industry, yielding a set of potential applications. Three of them are presented in this paper.

First one is the use of ultrasound for aquaculture net cleaning with an autonomous underwater vehicle. The existing systems are large, heavy and expensive to operate. Ultrasound cleaning systems have a potential of making the cleaning much simpler, literally without the operator, and consequently for lower cost. The successful cleaning system relies on advanced dynamic positioning algorithms rather than on of heavy equipment.

Second, the marine robot can significantly improve research on methodology for determining the environmental impact of bottom trawling. Deployment of the AUV instead of the diver can both reduce the risk for the diver and can improve amount and quality of collected material per time. The use of AUV to follow the trawling net by hovering relative to the moving net is a promising strategy for getting a more detailed picture of the impact of trawling net to the seabed and fish population.

Finally, underwater robotics enables simple monitoring of fish habitats. Regular and frequent monitoring of marine environment results in accurate estimate of the amount of biomass in the habitat as well as the changes in water conditions. Frequent monitoring yields better understanding and consequently more efficient management of such habitats.

References

1. Walsh B, The end of the line, TIME, July 18, 2011, pp 25-31.
2. Willemsen P.R., Biofouling in European Aquaculture: Is there an easy Solution, European Aquaculture 2005, Socviet Spe. Public. No. 35, pp. 82-87.
3. Soldo A., Cetinić P., Underwater observations of different trawl constructions in the Eastern Adriatic, Proceedings of the 5th International Workshop DEMAT '01, Vol.2, November 2001.