Technical methods of cleaning shipwrecks from ghost nets

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Abstract. **Ghost nets are fishing gear lost and left in bodies of water that continue to be fished. Most of the fishing gear that is lost is made of synthetic materials that break down very slowly or not at all in nature and continue to work long after the net is lost. A ghost net drifts in the sea until it catches on an object, most often a shipwreck. This harms both nature and people's economic interests. Currently, the release of shipwrecks and other sunken objects from fragments of lost nets is mainly done by human hands, resp. divers dive to the wreck and use hand tools to free the wreck from fragments of fishing gear. There are innovative robotic systems in the world that can partially replace the work of divers.**

Keywords: gostnets, blue economy, underwater robots, sustainable.

I. Introduction

Ghost nets in the sea: Today, it is the durable and cheap use of plastic in fishing that has caused a serious problem in marine ecosystems. These abandoned fishing nets continue to 'fish' and kill the creatures living in the waters in an uncontrolled manner, causing serious damage to both nature and people, often also ships. Plastic waste does not decompose in nature, so ghost nets remain in the oceans and seas for a long time, causing long-term pollution. Studies show that these ghost nets are responsible for significant threats to marine life species and can also cause hazards to ship navigation. Solutions to this problem include improved management, nets labeling and a shift to greener materials in fisheries, as well as active de-littering and cleaning from the sea. The aim is to preserve the marine environment and its biodiversity by reducing the impact of ghost nets.

The aim of the given scientific research is to review the innovative robotic methods of freeing ghost nets and to provide solutions that could improve this process.

The methods used in the research are based on the analysis of scientific articles, the analysis of the technical possibilities of technologies and the search for innovative solutions that could improve the marine environment and have a positive impact on the processes of the blue economy. Theoretical and methodological basis of the study. When developing the study, research by Pedersen, S., Liniger, J., Sørensen, F.F., von Benzon, M., Fernandez, J. J., were used.

II. General Regulations

At present, human hands are used to free shipwrecks and other sunken objects from fragments of lost nets. divers dive to the wreck and use hand tools to free the wreck from fragments of fishing gear. Fragments of fishing gear above the release, they are lifted into the water with winches or inflatable buoys. The use of manual labor to free wrecks from lost fishing gear is a laborious and slow process influenced by a number of factors. Primarily, it is the time spent underwater, which is limited by the diver's air reserves and nitrogen, which is formed due to the diver's blood pressure while working underwater, depending on the depth and time spent underwater.

The authors of this article organized an expedition in August 2023 and freed the shipwreck near Engure (Latvia) from ghost nets. The total time for the divers to free this shipwreck from the ghost nets with the preparation time took 4 days, a total of about 20h. The shipwreck was at a depth of 20m, which limited the work of divers and the time to get out of the water. Floats were used to highlight the gost nets. In total, about half a ton of nets were brought out. Highlighting and analyzing the structure of the nets, it was found that mostly those kapron nets, therefore lost around the 60s-90s of the last century.

Practically, this means, regardless of air reserves, depending on the depth of immersion, the divers' total time under water is strictly limited. For example, when performing a no-compression dive in the Baltic Sea at a

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depth of 30 meters, taking into account the water temperature, the useful working time spent at depth is approximately 15 to 18 minutes. When performing a decompression regime immersion, this time can be extended, but it is inseparably connected with the involvement of vessels specially adapted for underwater work, which are equipped with barocameras, to carry out the work. In the case of Latvia, such equipment is only at the disposal of military structures, and renting it from foreign private structures would increase the cost of carrying out work in a geometric progression.

Fig.1. Cleanup of a shipwreck near the port of Engure, August, 2023. Baltic Sea (Latvian territorial waters) [photo from the authors' archive]

It is clear that the Baltic Sea, which is at the top of the list of the world's most polluted seas, is not a good home for its inhabitants. There are many shipwrecks in the Baltic Sea (including Latvian waters), most of which have not been identified and surveyed. A large amount of lost fishing gear - "ghost nets" have been found on all surveyed shipwrecks, which continue to act as passive fishing gear and cause significant damage to the marine environment - aquaculture, as well as technically affect ships that practically do not degrade or degrade over a long period. Currently, only direct visual inspection of wrecks and sunken objects is carried out by diving, which is significantly limited by air reserves and the permissible time spent at depth.

Collecting seafood animals (such as sea cucumbers, sea echini, scallops, etc.) cultivated in shallow water (water depth: ~30 m) is a profitable and an emerging field that requires robotics for replacing human divers. Soft robotics have several promising features (e.g., safe contact with the objects, lightweight, etc.) for performing such a task. In this paper, we implement a soft manipulator with an opposite-bending-and-extension structure. A simple and rapid inverse kinematics method is proposed to control the spatial location and trajectory of the underwater soft manipulator's end effector. We introduce the actuation hardware of the prototype, and then characterize the trajectory and workspace. We find that the prototype can well track fundamental trajectories such as a line and an arc. Finally, we construct a small underwater robot and demonstrate that the underwater soft manipulator successfully collects multiple irregular shaped seafood animals of different sizes and stiffness at the bottom of the natural oceanic environment (water depth: ~10 m). [1]

This type of underwater robot, equipped with manipulators, would also be useful for other underwater work, such as cleaning shipwrecks from ghost nets.

Previously, the rigid robotic arms used for underwater manipulation have several challenging issues such as delicate grasping fragile and squishy seafood animals. Meanwhile, the traditional rigid hydraulic arms usually have large mass. The huge inertia caused by the rigid arm during locomotion would induce significant vibration for the small underwater vehicle. [2]

Introduction highlighting the challenges in precisely controlling underwater robotic arms due to environmental fluctuations and limitations of traditional control algorithms. It emphasizes the importance of remotely operated vehicles (ROVs) and robotic manipulators for complex underwater tasks.

The ROV, or Remotely Operated Vehicle, is a purpose-built underwater apparatus equipped with propellers, cameras, and a manipulator arm. The ROV's body is constructed from a specialized aluminum alloy designed to be both lightweight and durable for marine environments. Its propellers provide omnidirectional mobility, enabling the ROV to move freely in all directions. The manipulator arms of the ROV are highly articulated, often exceeding 1 m in length, and can be fitted with various specialized tools such as welding, cutting, gripping, and holding devices, depending on the specific task requirements. [3]

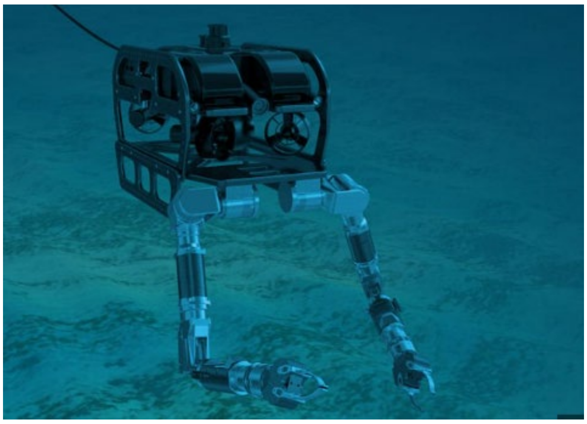

Fig.2. The simple structured robotic manipulator of the ROV [3]

The area of remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) has rapidly developed, with several decades of experience, both in research (see, for example, the study described in [4]) and industrial applications of increasing complexity, both in terms of missions and levels of automation (see for example [5] on cooperative navigation). Regarding the latter, many control algorithms have been proposed, both for simulated and actual vehicles. However, it is generally not immediate to compare control algorithms between them. Indeed, while some articles comparing newly-proposed control laws for ROV stabilization to previous algorithms can easily be found [6, 7, 8, 9, 10, 11], it is primarily based on simulation models for which the actual physical replica is not easily accessible or affordable, thereby limiting the comparability between control algorithms and the extent of the benchmarking attempt. [12]

More recently, the industry has also evolved towards more affordable products meant for researchers, students, or hobbyists, several of which are proposed under the open-source paradigm (see, for example, OpenROV, OpenROV Trident, BlueROV2) [13]. The advantages of open software and hardware solutions lie in their cost-effectiveness compared to conventional solutions and that they allow increasingly faster development, modifications, and improvements. Among these solutions, the widely-popular BlueROV2 [14] combines an open-source architecture with components of sufficiently good quality, allowing relatively advanced missions (see, for example, [15,16,17]).

Several robot simulators have previously been developed, some of which are specific for underwater robots [18,19,20]. However, the simulators for underwater robots are generally based on a user-defined model, such as the UUV Simulator [18] package for Gazebo or the Simu2VITA [19] block for Simulink™, which makes it challenging to use as a benchmark for control algorithms. Furthermore, these simulators neglect the tether force many underwater robots use for top-site communications or power [21]. The present paper aims at bridging the gap between simulation for control systems and experimental testing by proposing a MATLAB™ and Simulink™ open-source package of the tethered BlueROV2 for the control community as a benchmark in simulation toward full deployment on the same well-known platform. MATLAB™ and Simulink™ have been chosen as they are well-known to the control community and offer various toolboxes to implement advanced control and missions. These missions could be measuring reefs [22], monitoring and removal of marine growth on offshore structures [6,23,24], water quality and ecology monitoring [25], detection of oil plumes [26], fish farm net monitoring [27], etc.

III. RESULTS AND DISCUSSION

The essential limiting factor in the use of human labor is directly trained, availability of trained and experienced divers. Taking into account the release of shipwrecks from the nets in the Baltic Sea objective working depths and conditions, respectively, limited visibility conditions (in the Baltic Sea approximately 0.5-1 m), low water temperature, currents, the specifics of the work are dangerous precisely because of the fishing gear, can be practically carried out only technical divers (Technical Divers) or professional divers (Commercial Divers), whose availability is limited and man-hour and equipment costs are high. Practically, this means that taking into account the time and resources that are consumed to free one wreck from lost fishing gear using human labor hands, this process is too slow to make a significant contribution to improving the ecological status of the Baltic Sea, because while one net is freed, another ten are lost. Significant improvements in the clearance of shipwrecks from lost fishing gear and thus improve the ecological situation of the Baltic Sea, can only be achieved by doing this cleaning more efficient from time and cost points. If the underwater robot was equipped not only with an ROV-type tentacle manipulator, but also with a disc cutter manipulator, then it could be replaced by the work of a diver. With such a solution, human manual work would be minimized and consumption would be reduced accordingly time and cost. Using shipwrecks for clearing lost fishing gear, with special underwater robot equipped with manipulators, the working time limit is solved primarily because the robot is being controlled from a cutter or ship. Practically, this means that shipwreck cleanup will be able to be carried out in a 24/7 mode, restrictive the factor will be only metrological conditions resp. wind speed and swell, which would limit to the same extent clean-up work if carried out by divers. The use of a robot equipped with special manipulators wrecks in purification, means extending the useful time for achieving the goal up to ten times or more. At the same time the number of technical divers involved in the wreck clearance works, whose labor costs would be significantly reduced due to specific skills and equipment, is one of the largest cost items. Of course, clearing the wreckage from for lost fishing gear, using an underwater robot equipped with special manipulators, in the process it will not be possible to completely abandon the involvement of technical divers, but their number and working hours will be significantly reduced, accordingly reducing costs in the position of hiring underwater personnel.

Fig.3. Gost nets near Engure port [photo from the authors' archive]

Objectively, it should be understood that only effective the use of financial and human resources can ensure a significant cleaning of the Baltic Sea from lost nets pace increase.

IV. CONCLUSIONS

Analyzing scientific publications, several science-based solutions for auxiliary equipment of underwater robots have been found, with the help of which shipwrecks can be freed from ghost nets, but all these solutions are based on ROV-type tentacle-type arms. These robots are not given the ability to spin and not get entangled in ghost webs. Therefore, it is important to create technologies that can help free shipwrecks from ghost nets with more modern methods, because nowadays they are not only cotton nets, but more often already various plastic elements, besides there are also shipwreck cables, metal parts, etc. (respectively nylon and other material nets, metal cables, chains, plastic floats, metal weights and other elements of trawls and nets), so it is important to develop a technological scheme for lifting the freed net fragments above the water for further collection and delivery to the shore. These manipulators should be designed to be equipped with cutters for cutting nylon and other material nets and rotating cutting discs for cutting metal cables, chains and other hard materials. The manipulator equipped with a cutting disc is also intended to be used for cutting off or dismantling elements on shipwrecks that interfere with the removal of nets.

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