THE CUSTOMIZED GRIPPER DESIGN FOR EXPLORATORY-PURPOSE ROBOTS: A PROTOTYPE OF THE REMOTELY OPERATED UNDERWATER VEHICLE (ROV) FOR POLLUTION CANALS

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ABSTRACT - Robotics has not only been recognized as one of the disruptive technology, but it is also one of the phenomena of convergence of digital technology. It is the most demanded technology, particularly in developing countries such as Thailand, which is in the stage of development through Industry 4.0. Mostly, development projects on robotics in Thailand are for working in the operation line in factories; whereas, a handful of studies regards to apply it for an environmental solution. This research's main objective is to propose a gripped robot design as an option for exploratory underwater objects. In this study, we utilized knowledge from the robotics field, the internet of things, and digital technology for building a unique prototype of an underwater exploration robot with a customized design of a gripper. The prototyping design was mainly developed operational tests for a physical location in the canal. In the design part, the core component is called Remotely Operated Vehicle (ROV), which was driven with a direct DC motor and controlled directions and movement with a controller board. The gripper had been navigated the direction in the vertical- and horizontal-axis, as well as the arm releasing and catching, which were set by an onboard switch. This customized gripper design prototype would be productive and reusable for exploratory-purpose robots that work well underwater within pollution constraints.

Keywords: Exploratory underwater robots; Gripper design; Robotics; IoT.

1. INTRODUCTION

Environments such as water, air, soil are essential for human life. Humans need to utilize many of these natural resources. But using it regardless of the impact it will cause pollution in the environment. Water pollution is one of the most critical environmental problems in Thailand. Compared to other pollution problems, water pollution is more common in big cities, making it impossible to take full advantage of various water sources. One of the causes of water pollution is plastic waste and waste in water resources. Plastic waste in the environment is not the only problem in the country, but also a global problem. There are many different types of plastics being used around the world. In 2014, there were about 322 million tons of marine waste. Now, that number is growing incredibly fast [1].

Many scientists are being used robotics as a tool to collect basic information. They allow for new perspectives and a better understanding of the world and its environmental processes. Now, robots have explored our oceans and the state of pollution [2,3]. Underwater exploration robots are essential nowadays. The need for robots to work under the sea is increasing, especially in the petroleum industry. It is used to find petroleum in shallow waters or in areas where it is more difficult for people to manage but for rivers. The water source in the community has not received much attention due to the high cost of underwater robotics and the cost-effectiveness of the investment. Therefore, we have the initiative to create underwater robots to explore rivers and canals. The water resources in the community are regular cloudy and dirty. It is challenging to send humans down to investigate the cause of polluted water or garbage underwater, and the constant flow of ships makes diving difficult to explore. In addition, ROV must take the health and safety of the surveyors into account. In comparison, underwater exploration robots have much higher exploration capabilities and durability than humans. For example, humans need oxygen to breathe underwater, but underwater robots do not. It only uses energy to make the robot work.

The robot industry was originally developed to aid or replace humans for dirty or dangerous tasks used in various applications. Robot arms are used in automated assembly lines, observation, radiation zones, surgery, space exploration, and modern industry with an efficient load capacity of 1000 kg [4]. But there has not addressed much research into the testing of robot arms or grippers in water.

To design a robot that aims to solve a specific problem with limited materials and equipment conditions, the usage issues are different, including working on the varied landscape. Especially in the competitions, the well-working underwater and diving mode are core features for robots. Another critical component is the gripper, which holds things up underwater. Most underwater grippers do not have an electronic circuit board to control the motor. This project's objective is to study the initial experiment of the robot's grip pattern picking things up in everyday life Weight not more than 450 grams. The IoT controller is chosen Arduino to use in programming to control the robotic arm.

2. LITERATURE REVIEW

Gripper's world is as expansive as imaginable. And before starting the design, it is essential to know more about the types available and what they used to choose the right type for use with underwater garbage collection robots.

2.1. Robotic and environment

Research in India has built a pond cleaning robot, "Pond Cleaning Robot," to eliminate water pollution in the Godavari River at Nashik. Due to the increase in water pollution in the form of solid waste. Equipment related to removing debris from the water surface and safely disposing of it from the water source. The pool cleaning robot Works on Bluetooth to separate wastewater, plastic, and waste from the Godavari River at Nashik [2]. The researcher invented the tiny water boatman robot, "Row-bot," for eats waste and reducing pollution. It can be self-recharged without any helping human operator required [3]. The study related that IoT was developed as a garbage monitoring system with notice via a mobile application that helps pollution less environment in a smart city. In addition, it prevents the overflowing of garbage in dustbins, reduces cost, and saves time using an algorithm to find the best route in collecting [5,6].

2.2. ROV and Gripper Design

According to previous research, some researchers have proposed the functions of underwater robots should have as follows: (1) a camera and sensors for the acquisition of images and environmental data. (2) robotic hands for collecting objects and other necessary things. The recommended idea was easily removable and separated mechanical and electrical systems [7].

When designing the gripper, a rotational part of the motor has been considered for symmetrical movement for the two fingers. The design will be made focusing on the simplicity of the mechanism to ensure that it can grasp any object. And torque is directly transmitted to the jaws. However, we should also take the material used to build the gripper into account.

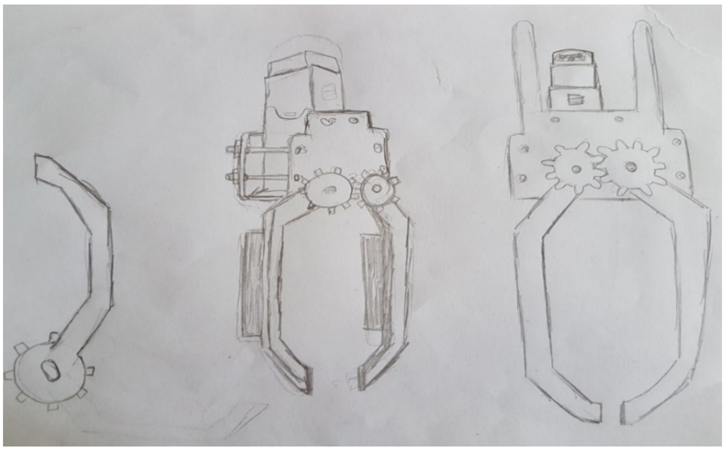

Figure 1. Gripper design

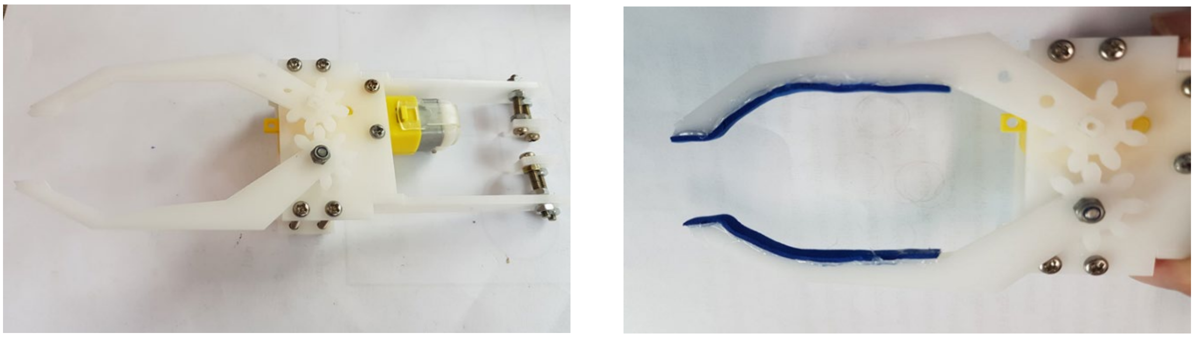

Figure 2. Gripper prototype (left) and gripper prototype adding texture (right)

For quantifying the construct difficulty, it is necessary to consider the number of pieces that are needed. On the one hand, the number of plastic pieces is laser-cut, and the number of screws and bolts used to fix it all together. And, the time required to assemble the prototype from all the separate pieces is also crucial when determining its building complexity.

2.3. Prototype Remotely Operated Vehicle Design

This project designs and constructs control systems for underwater exploration robots using a control-driven mechanism with wireless and manual joysticks. The operator can be visible via a video camera underwater environment from the monitor. This project has been designed and developed a gripper installed in underwater exploration robots (ROV). A DC motor had driven this ROV project; moreover, we controlled the gripper with a three-way toggle switch. The gripper could manipulate moving in the vertical and horizontal axes, grip objects, and release objects. The advantage of all equipment, it can proceed to install on the other robots. A prototype built based on the design specification in this section is introduced in the subsections as follows.

1. Motors and cameras are stored within a water-resistant vessel and prevent external torque are affects these electronic devices.
2. The underwater robot communicates semi-control with wire and wirelessly. Electricity is supplied through a cable.
3. A camera is attached to the manipulator. Images from the camera are able to be watched by the monitor on the control box.

The experiment is divided into two parts. The first part, an experiment, is the ability of grippers, which can able to grip some trash in day life (e.g., balls, cans, shoes, egg, and Marker). Second, testing operated in water; it can grasp objects in the water and moving up to the surface. From the result of grippers in each type, we found that different types of grippers had various forces to grab. The plastic gripper cannot hold any object, such as a bottle, because the shape and friction at the tip affected grasping the objects.

Figure 3. ROV prototype

3. METHODS

In order to measure up the goodness of each mode, some tests will be passed. We will evaluate the number of picking 8 objects in the types of grasping. Each test consists of four types of grasping: normal grasping, normal grasping with rotation, grasping in water, and grasping in water with rotation. In each test, the results will be accepted if the mission passes, and then it collects 1 point, whereas if it fails the task, it gets 0 points.

- Normal grasping (NG): Keeping the gripper installed on the front part of ROV and open. Each item approaches the gripper from the top with the axis (red line) placed vertically to the floor. Once the object has been grasped, it must be held for three seconds and then open and drop the object.
- Normal grasping with rotation (NR): It consists of the same procedure as the normal grasping. When object has succeeded the normal grasping then the gripper is rotated 90º to each side. It will check if it is stable enough to persist grasped and held object during three seconds
- Grasping in water (GW): The same procedure as normal grasping but the axis (red line) is placed vertical in the water. If it can hold three seconds will get a pass.
- Grasping in water with rotation (GWR): The procedure is similar to normal grasping with rotation, but the test occurred underwater.

This ensures that the gripper can grasp objects precisely in the same way. Before starting the experiment, we defined the centerline of the object by the red line in the vertical axis in Figure 4.

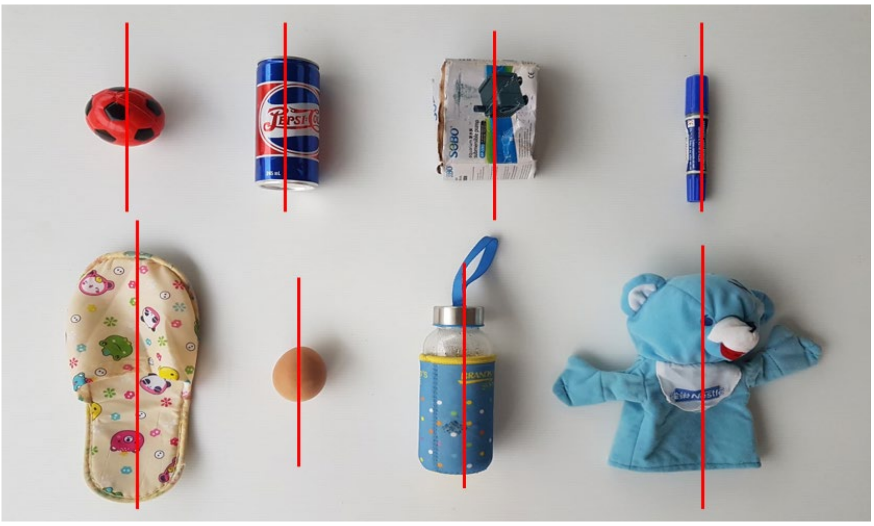

Figure 4. Objects with vertical axis in red

The objects used in the experiment differ in shape, material, and weight. The weight of the smallest object is 30 grams, and the greatest weight is 450 grams, as shown in the table below.

Table 1. Table of weights of objects used in the experiment

Objects	Weight (g)
1. Plastic ball	30
2. Beverage can	250
3. Egg	100
4. Shoe	140
5. Box	150
6. Glass bottle	450
7. Marker	90
8. Teddy	300

The experimentation will go through the four tests as follows. In the results table of each test, there are the four replicas' activities. We had calculated the total average of each object from the sum of them provides a grade from 0 to 4 of how successful the test was in the average of every grasping type.

This sequence is repeated with the eight objects. Then objects are grasped in their fixed order, and the results are written down in the table. Then the eight objects are grasped again in a normal grasping manner in the same order and then a third time. Finally, the average of the three tests is calculated.

4. RESULTS

In order to establish, explore the effect of the design of the gripper was conducted to compare the gripper types in four activities. We use the average success in each object to drawing a graph.

4.1. Results of the gripper prototype

From the experiment, it was found that the normal grasping cannot pick up a glass bottle. Whether it is a normal capture stationary, including clamping and turning, it was found that the glass bottle could not be clamped. Because the glass bottle is slippery and heavier than other objects, it cannot be lifted and rotate.

The results from the experiment of normal grasping in water with a normal gripper, it can be clamped to 7 different objects except for the glass bottle experiment (refers to Table 1.). Because the glass bottle is slippery and the clamping motor has not enough torque. It is unable to lift the glass bottle up to the surface of the water. Even the buoyant force of the water keeps the object floating but still unable to clamp the glass vial.

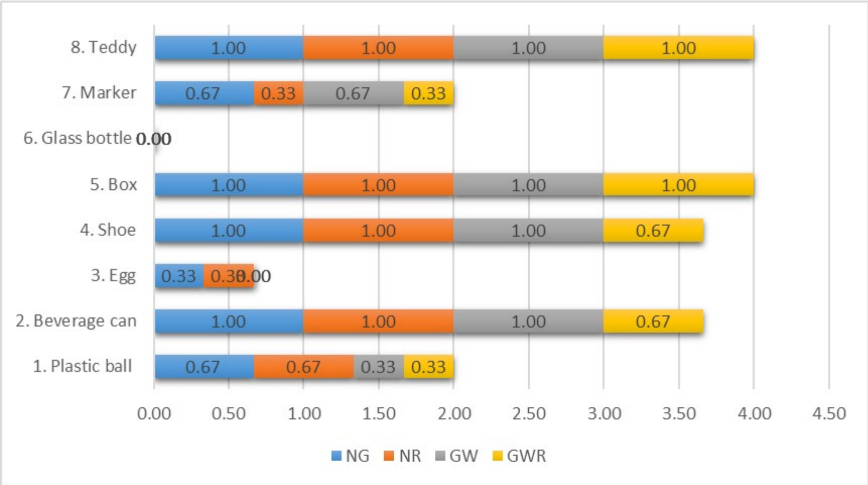

Figure 5. Average success of normal gripper.

4.2. Results of the gripper adding texture

The result of the gripper with added texture is the same as the normal grasping; that is the glass bottle cannot be clamped. However, it can clamp oval objects better than normal grasping. Although the gripper's touch surface is enlarged, it is still slippery when touching the bottle's surface. And the weight of the bottle is a cause of failure to incomplete the mission. Therefore, the glass bottle cannot be clamped. Another factor may be that because the motor used in the clamping test has relatively low torque, it is not sufficient for clamping the glass vial. The other object clamping can squeeze normally.

In testing the gripper with added texture in water, it can be clamped objects as if adding texture on land for both normal and rotary clamping because it contributes to increasing the contact surface, resulting in more firmly gripping objects. In addition, the buoyant force in the water makes the object lighter. But still cannot catch the glass bottle.

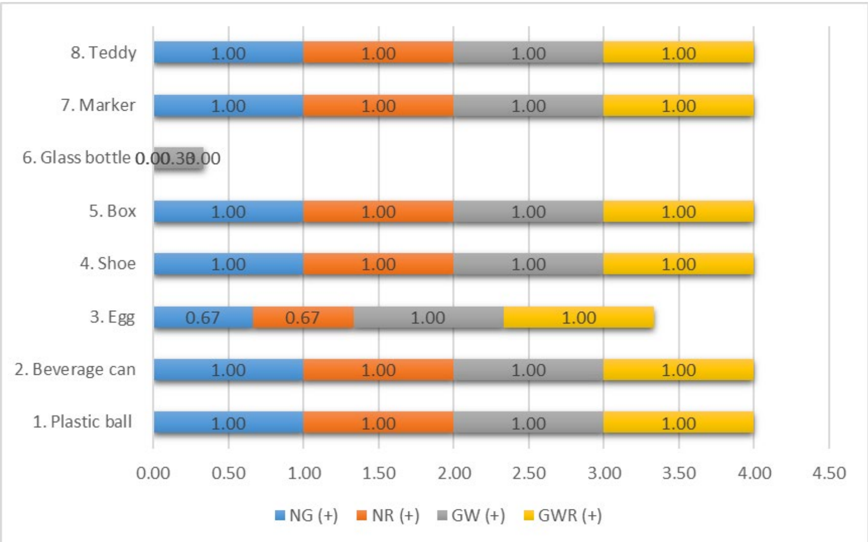

Figure 6. Average success of gripper adding texture.

4.3. Results of Comparison of the gripper in the water

Compared with the test results of both types in the water, we found that the gripper adding texture had a higher average number of times than the conventional gripper. The result of the gripper in the water when rotate is similar to a normal grip; the gripper adding texture can hold objects better than conventional ones.

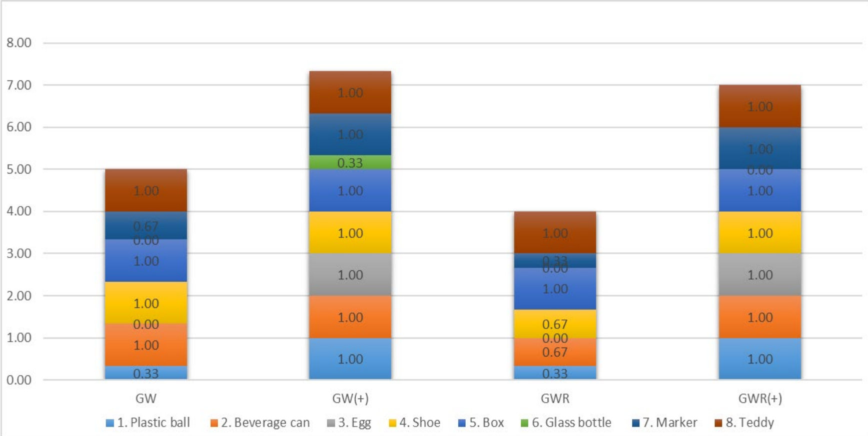

Figure 7. Comparison of gripper between types in the water.

5. DISCUSSION

The success of this study suggests that an experiment in this project has built a gripper to work with an underwater robot. In the investigation of the gripper, of robot have tried to pick up items that are found out in the canal. The prototype grippers made from acrylic are less robust, so they should improve the grippers joint. We should develop the width of the grippers to have a greater width than the old one.

For further study in terms of the design of the gripper and using a new material with different surface roughness for reducing the pressure between the contact surfaces and increase in friction may improve the adhesion of objects. Secondly, the subsequent study is the control of wireless robotic underwater how deep it can use. In the next version of the gripper prototype, AI technology will be implemented and replaced the manual control of the remote feature to grasp objects accurately.

Even if we build robots technology IoT to reduce pollution by collecting waste in the water, its structure consists of plastic structures, motors, and wires, which are not biodegradable. Therefore, it cannot be operating in the water all the time to prevent water pollution occurrence.

6. CONCLUSION

From the experiment and investigation, we obtained satisfactory results with some constraints. Firstly, two gripper types can clamp and lifting objects used in the experiment. Most of all types of the gripper are capable of clamping 7 items out of the 8 according to the weight of each object shown in Table 1, except for glass bottles. It cannot be grasped in the center of the bottle. Therefore, the clamping is incomplete. Additionally, with the glass bottle having a slippery surface and weight than 300g, the acrylic gripper cannot be incompletely clamped. Secondly, this prototype has an opportunity to develop product commercialization; therefore, the cost of the fabrication process, the price of components, and complexity optimization should be firmly considered for success in the market, together with the ultimate features of usability.

The final point, one of the problems encountered when the gripper was attached to the robot caused the robot's balance when in the water to change. Therefore, we plan to improve the balancing adjustment for the weight control in the next upgraded robot.

AUTHOR CONTRIBUTIONS

T.J. designed and performed experiments. A.W. contributed to experiment preparation. Both A.W. and T.K. authors contributed to the interpretation of the results and discussion. T.J. wrote the manuscript in consultation with A.W. and T.K.

REFERENCES

1. Rojas, J. (2018). Plastic waste is Exponentially filling our oceans, but Where are the robots? 2018 *IEEE Region 10 Humanitarian Technology Conference (R10-HTC)*. https://doi.org/10.1109/r10-htc.2018.8629805
2. Gornicki, K., Groves, K., Carrasco, J., & Lennox, B. (2018). The pond cleaning system. *2018 UKACC 12th International Conference on Control (CONTROL).* https://doi.org/10.1109/control.2018.8516738
3. Pooja Niturkar. (2021). Row-Bot eating pollution for environment clean-up. *JournalNX - A Multidisciplinary Peer Reviewed Journal*, 331–334.
4. Siciliano, B., Khatib, O., & Kröger Torsten. (2016). *Springer Handbook of robotics*. Springer.
5. Khoa, T., Phuc, C. H., Lam, P. D., Nhu, L. M., Trong, N. M., Phuong, N. T., Dung, N. V., Tan-Y, N., Nguyen, H. N., & Duc, D. N. (2020). Waste management system using IoT-based machine learning in university. *Wireless Communications and Mobile Computing*, 2020, 1–13. https://doi.org/10.1155/2020/6138637
6. Hassan, H., Saad, F., Fazlin, N., & Aziz, A. (2018). Waste monitoring system based on Internet-of-Thing (IoT). *2018 IEEE Conference on Systems, Process and Control (ICSPC).* https://doi.org/10.1109/spc.2018.8704142
7. Takemura, F., Shiroku, R. T., Kawabata, K., & Sagara, S. (2013). Development of easy-removable Underwater Manipulator unit with Built-in Controller. *Journal of Robotics and Mechatronics*, 25(5), 778–784. https://doi.org/10.20965/jrm.2013.p0778