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Original Article

Low cost submarine robot

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Abstracts

A submarine robot is a semi-autonomous submarine robot used mainly for marine environmental research. We aim to develop a low cost, semi-autonomous submarine robot which is able to travel underwater. The robot's structure was designed and patented using a novel idea of the diving system employing a volume adjustment mechanism to vary the robot's density. A light weight, flexibility and small structure provided by PVC can be used to construct the torpedo-liked shape robot. Hydraulic seal and O-ring rubbers are used to prevent water leaking. This robot is controlled by a wired communication system.

Keywords: submarine robot, volume adjustment, underwater, novel design

1. Introduction

Robots have been used in a variety of fields i.e. industry, agricultural, military, space, medicine, human rescue, and science. Submarine robots are one of the widely applied robots, which are used in submarine exploration and marine environmental research. Submarine robots have been developed by many scientists; for example, Keller *et al.* (1976) constructed a submarine robot, which has an ability to dive to 61 meters depth using a ballast system. This robot can be used to collect oceanographic data and is controlled by computer. However, this robot is impractical for many applications because of its size (2.13 meters long; 0.37 meters diameter) and weight (110 kilograms). The ballast system is commonly used in the submarine robot (McDuff *et al.*, 2000; Bokser *et al.*, 2003). McDuff *et al.* (2000) constructed a low cost submarine robot using PIC16F877 as a processing unit containing a variety of sensors such as ultrasonic sensor, light sensor and pressure sensor. This robot can be moved up and down by controlling air pressure in its ballast, while in the study of Bokser *et al.* (2003) the movements of the robot were controlled by adjusting air pressure using water ballast. This robot communicated with a computer using radio waves. The communication system between robot and computer is crucial. Hernando and Hambao (2003) suggested that the delayed communication could reduce damage from an inaccuracy in the communication system. Yoshida (2003) suggested that the underwater robot should be designed using three communication systems, autonomous, semi-autonomous, and a human-control system using radio and sound waves. Radio and sound waves were also used in an underwater cable-investigated robot (Asakawa *et al.*, 1996). In Thailand, Chatchanayuenyong *et al.* (2004) developed an underwater robot named "Chalawan" which is used for exploring ocean beds. The robot was constructed by an aluminum tube, positioned by a gyroscope and moved by

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blades. However, a problem in submarine robot development is that they are too expensive (Withcomb, 2000) for researchers in developing countries. Furthermore, they are not portable and difficult to be fixed by the researchers themselves.

Consequently, the aim of this study was to design and develop a low cost small submarine robot structure for marine environmental research. The robot can be easily used underwater controlled by wired communication.

2. Hardware design

The main criteria in the development of this robot were: 1. light weight, 2. small size, 3. easy to be constructed, used, and fixed. Therefore, poly vinyl choride (PVC; Thai Pipe Co., Ltd., Thailand) was chosen to construct the torpedo shape robot because of following qualifications: 1) high corrosion resistance, 2) outstanding durability, 3) light weight, 4) excellent mechanical strength, 5) non-flammable, 6) high electric insulation, 7) low heat conductivity, and 8) easy installation and maintenance (Thai Pipe Co., Ltd., 2008). Figure 1 shows the diagram of the robot's hardware. The physical system is shown in Figure 2. The low cost submarine robot is a small size robot with 81-116 centimeters in length, and 10.16 centimeters in diameter. The maximum weight of the robot is about 10 kg. Most of electronic devices, motor, and batteries are in the hull, which is watertight. O-ring rubbers were used to make a watertight system. Figure 3 shows the inner parts of the submarine robot, which consists

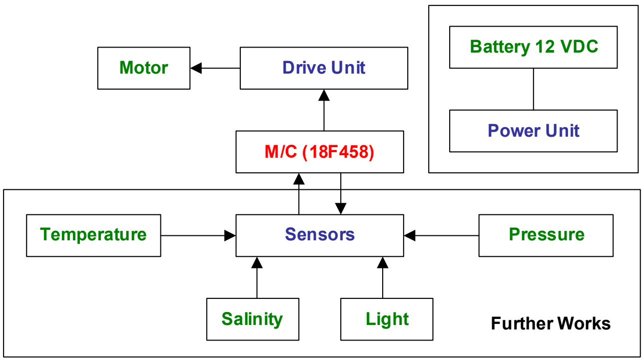

Figure 1. Conceptual diagram of robot's hardware.

Figure 2. Physical system of the low cost submarine robot. For scale see Figure 3.

of the system units, with processing unit, power unit, drive unit, and others.

Volume adjustment of the hull is used to control density, as the hardware is shown in Figure 4. The density (r) of any substance is defined as its mass per unit volume:

$$\rho \equiv \frac{m}{V} \quad (1)$$

where: m is mass, and V is volume. In this case, the density of seawater at the standard conditions (0°C and atmospheric pressure) is around $1.03x10^3$ kg/m^3 (Serway, 2004). Motor, ball screw, spindle, and superlene nylon are used for a volume adjustment. When the motor is driven, the spindle is moved so that the robot top side will be moved in and out in the same way as a cylinder liner, which is connected to a hydraulic seal. This PVC has ability as a piston and the piston ring is used as water tight. Two micro switches are used to control the limitation in adjusting robot volume.

The time used in maximum extended distance (4 cm) is 29.22 s so that the volume adjustment rate is 10.76 cm^3 s^{-1} (Figure 5). At 1 m depth, the robot can sink and float in 21.12 and 43.28 s which means that the sink and float rate is 4.73 cm s^{-1} and 2.31 cm s^{-1} (Figure 6a and b).

2.1 Processing unit

The processing unit is the main unit controlling the functions of the robot. The main component of this processing unit is a PIC18F458 microcontroller (Microchip Technology Inc., U.S.A.), which controls a motor driver, a volume adjustment unit and two micro switches and receives commands and sends data between the robot and user.

2.2 Power unit

The microcontroller and the motor of the submarine robot are driven by a sealed lead acid battery (12 V 2.3 mAh) or a Nickel Cadmium Battery (12 V 1000 mAh) depending on the maximum loading weight of the robot. A sealed lead acid battery is used when the loading weight is high while nickel cadmium battery is used when the loading weight is low. An external power can be used to drive the robot as well.

2.3 Drive unit

The microcontroller sends a signal to the motor driver to control its function. The motor driver is used for controlling the volume adjustment and movement system, such as, up and down, forward and backward, turn right and turn left. Figure 7 shows a circuit diagram of the robot's hardware.

3. Software design

The software design consists of a robot controlling software and a computer controlling software (Figure 8). The

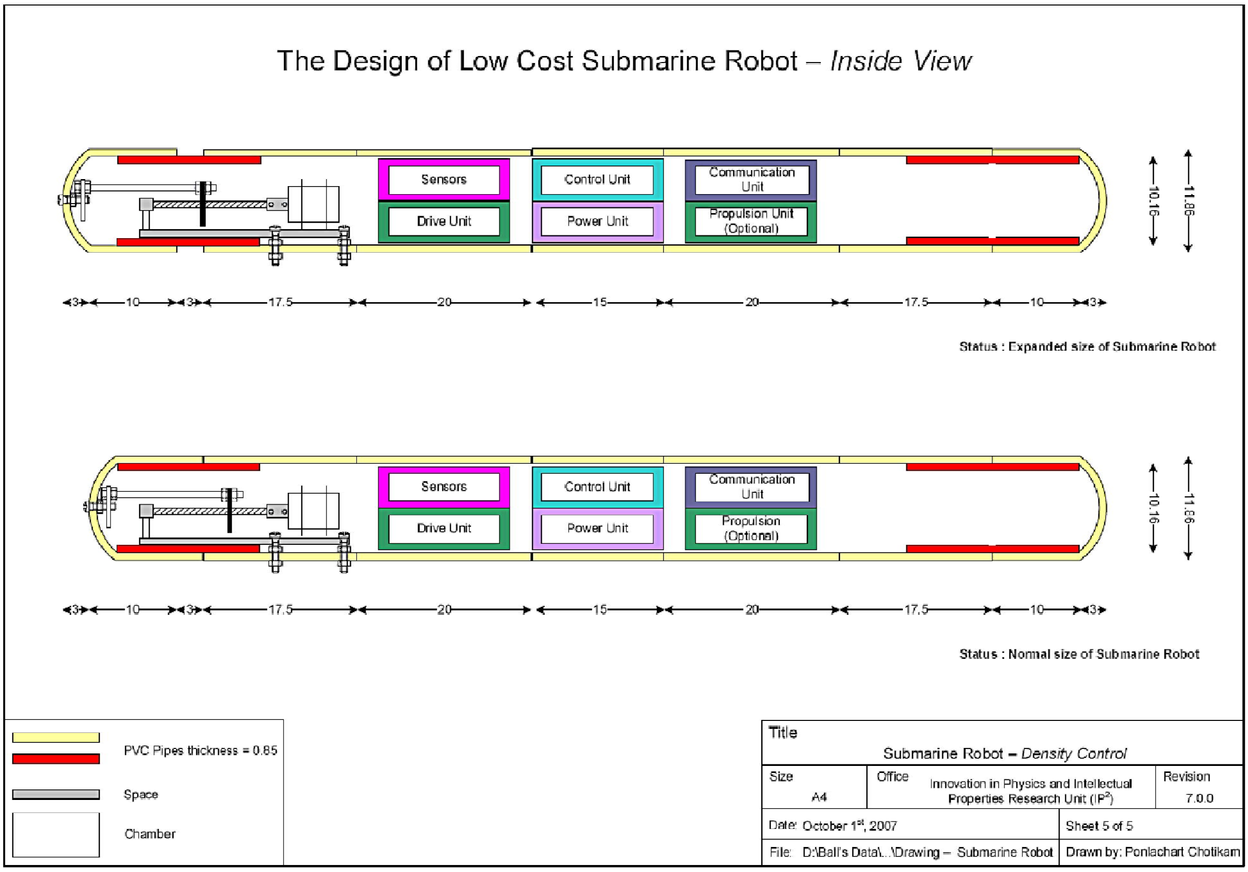

Figure 3. Inside view of the submarine robot consisted of the system units, processing unit, power unit, drive unit and others.

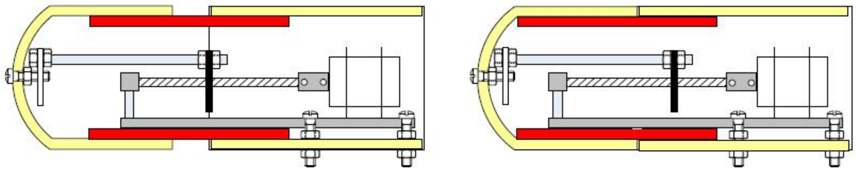

Figure 4. Diagram of volume adjustment of the hull.

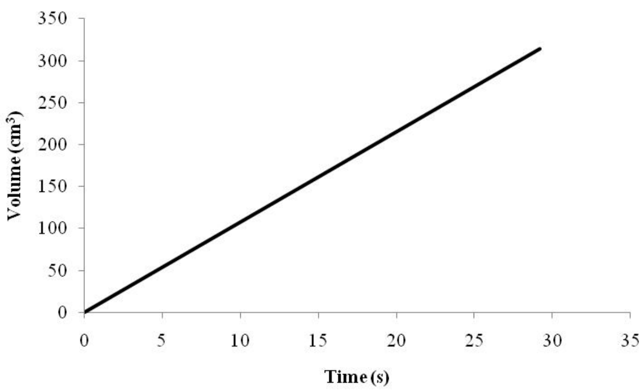

Figure 5. Chart showing the volume adjustment rate of the submarine robot.

robot controlling software sends a command to a robot components (i.e. moving up and down, forward and backward, turn right and turn left) and displays a function process on a computer. The computer controlling software is used to display the data sent from the robot. In semi-autonomous mode, the software will allow the user to control the robot itself. The command and data are sent between the robot and the computer using an RS-232 Serial Communication. This software is developed on a PIC18F458 microcontroller (Microchip Technology Inc., U.S.A.).

4. Application

The communication between robot and computer is a wire-system using RS232 serial communication. However, we have tested the wireless communication using a very

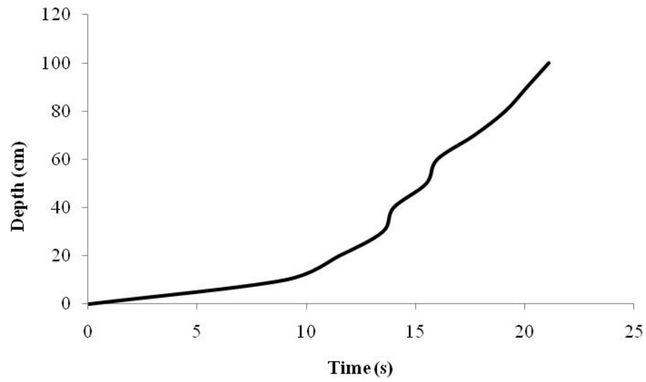

Figure 6a. Chart showing the submarine robot's sink rate.

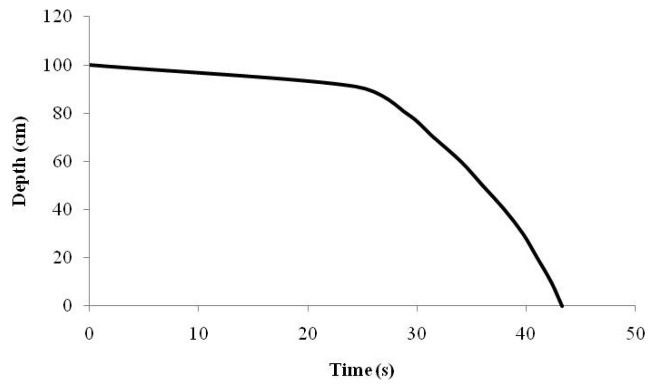

Figure 6b Chart showing the submarine robot's float rate.

high frequency (VHF) and an ultra high frequency (UHF). The 88 MHz is used in VHF wave. At 50 cm, the VHF receiver is able to receive a signal from a transmitter. However, the signal cannot be tranferred at 1 m distance (Figure 9). The UHF wave provided by a mobile phone service (DTAC, Thailand) is not able to transmit to the receiver as well. Thus, VHF and UHF are not used in the wireless communication system.

5. Discussion and Conclusions

The low cost submarine robot is a semi-autonomous submarine robot used for marine environmental research. We aim to develop a low cost, semi-autonomous submarine robot which is able to travel underwater. The robot's structure was designed and patented using the novel idea of the diving system employing a volume adjustment mechanism to vary the robot's density. When the robot volume decreases, the density increases, so that the robot can move downward and vice versa. In other studies, the density adjustment can be processed from the moving in and out of water in ballast (Keller *et al.*, 1976; McDuff *et al.*, 2000; Bokser *et al.*, 2003) using air pressure. The advantage of this ballast water density adjustment technique is its ease. However, the problem of this technique is its robot size because they need some space of the ballast. Moreover, it is needed to have a high pressure container to reserve an air for moving ballast water.

In this study, we use a volume adjustment technique to adjust the robot's density so that the ballast is unnecessary. Thus, the robot can be of a small size and travel under-

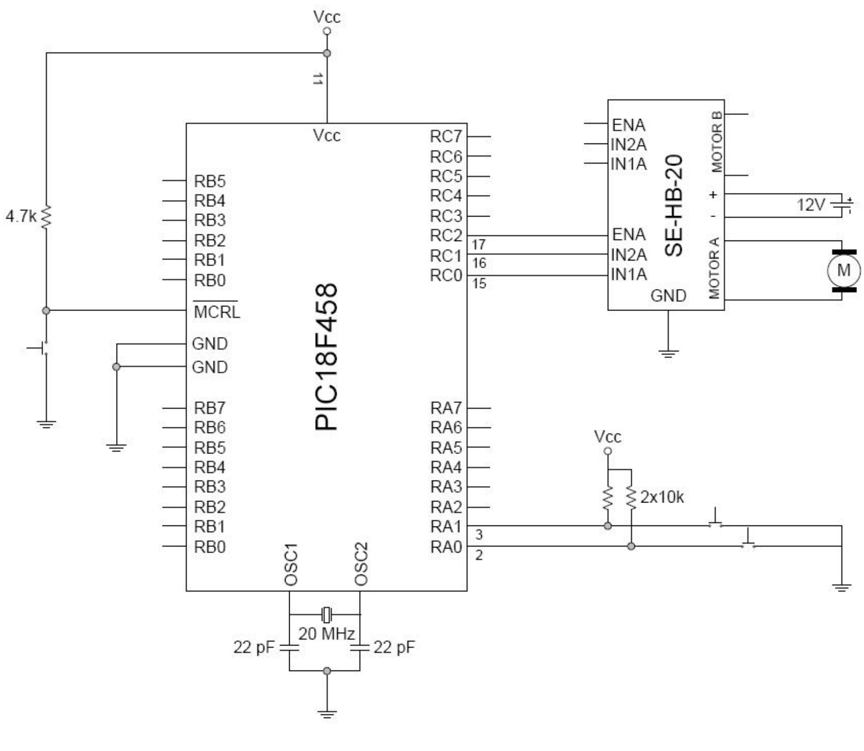

Figure 7. Circuit diagram of submarine robot's hardware.

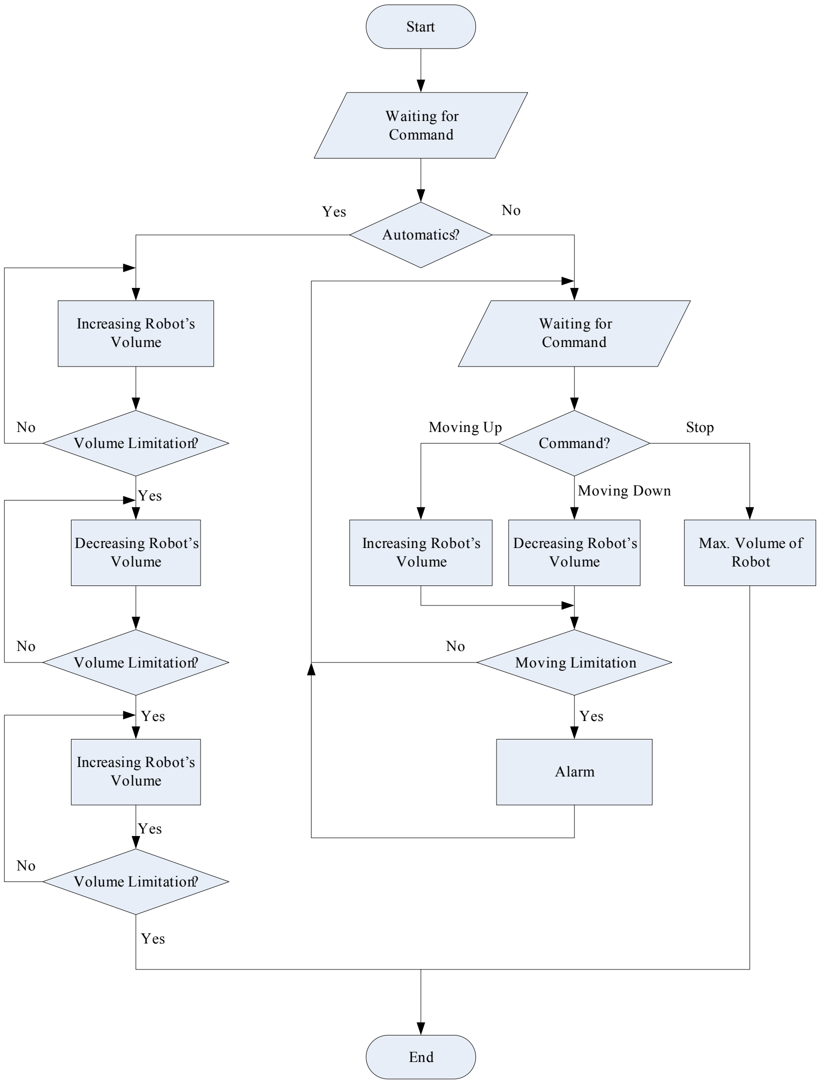

Figure 8. Flowchart of software function.

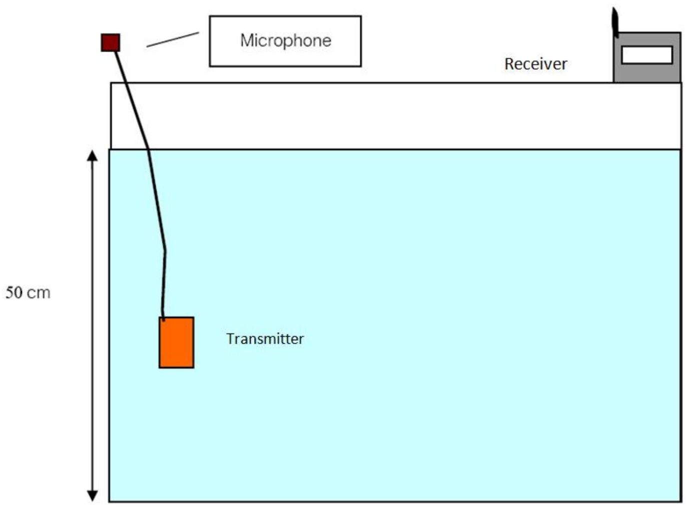

Figure 9. Schematic diagram of the VHF transmission test setup.

water over a longer period of time. Moreover, without moving upward to the water surface to collect an air, the robot can be moved upward and downward for many times.

However, the communication system of this low cost submarine robot needed to be improved for the wireless system. In underwater, the low frequency sound wave is needed. Extremely low frequency sound waves (3-30 Hz) and super low frequency sound wave (30-300 Hz) would be suitable to be used in the communication (Stojanovic, 2003). We suggested that the Global Positioning System (GPS) would be additional useful in positioning this low cost submarine robot. This work was patented under the Thai patent and petty patent system.

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