Communication and Control for Remotely Operated Underwater Vehicles

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Abstract. This paper presents a research and development on communication and control for Remotely Operated Underwater Vehicles (ROV). Todays, ROVs are popular used in oceanic research for purposes, such as current and temperature measurement, ocean floor mapping and hydrothermal vent detection. ROVs utilize seafloor mapping, bathymetry, digital cameras, magnetic sensors, and ultrasonic imaging. In this work, a ROV is designed with a torpedo-shaped. The ROV is driven by flexible steering system, including a couple of blade ruder in the horizontal direction and a couple of steering thrusters in the vertical direction. For communication and control the ROV from a Ground Control Station (GCS) on a mothership or on land, a lightweight messaging protocol for communicating with ROV based on developing MAVLink has been used. Communication and control system of the ROV from a GCS are including two steps. The first step, communication between the ROV and a float is conducted via electrical cable technology. The float is used as a wireless access point. The companion computer is designed based on Linux operating system to communicate and transport MAVLink protocol between the main control system of ROV and the float. The second step, communication between the float and a GCS on mothership or on land is conducted via wireless technology. The GCS is setup wireless interface with static IP address, and same router's gateway with the companion computer.

Keywords: Communication · Control · ROV · GCS · Mothership · MAVLink

1 Introduction

Underwater vehicles like Removed Operated Underwater Vehicle (ROV) and Autonomous Underwater Vehicles (AUV) have risen consistently since they were introduced in the 1960s and found their most frequent scientific research use and data collection. Since the 1980s, the offshore oil industry has used ROVs to assist in offshore development, especially as waters became too deep for human divers to go. Underwater vehicle systems face more difficulties in operating in unstructured environments than ground robots, subject to the impact of noise and sensor limitations, leading to difficulty

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in control and operation. ROV is a semi-automatic device with human intervention. Thanks to this feature, the vehicles are monitored and controlled to minimize the risk of unexpected incidents. Furthermore, it ensures flexible and stable control in different operating environments. However, communication underwater is limited due to the limitations of electromagnetic radiation in water. Therefore, the research of communication and control system plays an important role in ROV system. Recently, studies are investigating the communication and control for ROV and AUV.

Traditionally, communication is fed through a tether or cable using metallic conductors or fiber optics to transmit and receive data with a single channel RS-232 [1]. It is a practical and low-cost, but low data rate. Due to cable length or cable entanglement limitations, wireless methods have also been investigated to improve ROV mobility. They are based on acoustic and optical communication [2]. However, underwater acoustic communication has many problems such as low data transmission, short-range, and costly [3]. Underwater optical communication has an advanced technology improving the data rate, long-range, but difficult to maintain and costly [4, 5]. This study develops an inexpensive communication and control system using tether and wireless to transmit and receive data between ROV and mothership. The wire communication between ROV and a float is improved using ethernet, which supports local networks, long-distance, and high rate data. The wireless communication between a float and mothership is implemented to increase the long-distance control and ground control system's mobility. Communication and control for system are developed based on MAVLink protocol.

2 Hull Form of the Remotely Operated Underwater Vehicles

The hull form of the Removed Operated Underwater Vehicle in this study is a torpedo-shaped ROV. It is including three main parts and make from steel and aluminum. The fore and the rear of the AUV hull are parabolic shapes, the middle of the AUV hull is a pipe shape. Total length of the ROV hull is 3.2 m, the diameter of the ROV is 0.3 m. The ROV has a camera with LED light system in its fore for recording video under water [6]. Figure 1 shows the main hull form of the ROV.

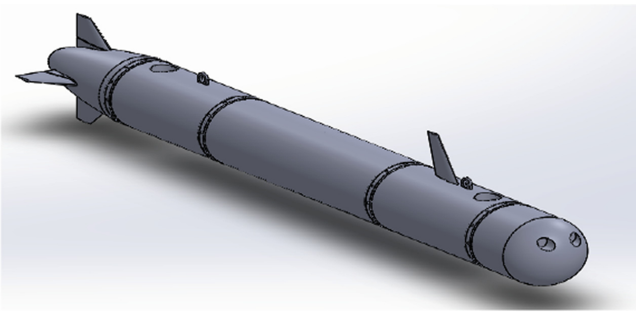


Fig. 1. Hull form of the ROV

3 Propulsive and Steering System

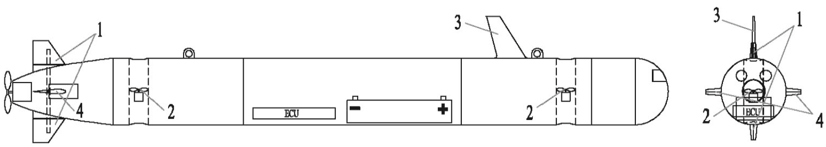
3.1 Propulsive

The Removed Operated Underwater Vehicle uses a main propeller for creating propulsive force for moving forward and backward. It is a fix pitch propeller with four blades. The propeller is made by aluminum. Figure 2 shows the main propulsive propeller of the ROV.

Fig. 2. Propulsive propeller of the ROV

3.2 Steering System

The Removed Operated Underwater Vehicle uses a flexible steering system by combination of blade rudders and thrusters. For horizontal steering, the ROV is driven by a couple of blade rudders that have aerodynamic profiles and located at above and below of the rear of the ROV. Those two blade rudders use the same steering shaft. The steering shaft is located at the symmetrical plane of the ROV. The steering shaft of the blade rudders connect to the ROV hull by ball bearings. The blades rudders are rotated and controlled via steering shaft by a servo motor. The flexible steering system of the ROV is shown in Fig. 3.



1: Horizontal rudders 2: Vertical steering thrusters 3: Bigger fixed fin 4: Small fixed fins

Fig. 3. Steering system of the ROV

For vertical steering, the ROV use two thrusters. To enhance the ability to generate thrust and torque for steering the ROV, the thrusters are set inside ducts. The thrusters are driven by specialized brushless motors that could be operated normally underwater environment.

In addition, for increasing the stability for the ROV, a set of three fixed fins is designed. They are including a bigger fin with hydrodynamic profile of NACA 0025 is placed on the back of the ROV, two smaller fins placed on left and right at the rear of the ROV.

4 Communication and Control

For communication and control the Removed Operated Underwater Vehicle from a GCS on a mothership or on land, authors have used a lightweight messaging protocol for communicating with ROV based on developing MAVLink.

MAVLink is a transmission protocol developed to communicate between the unmanned systems and mother ship or ground control stations. It supports both point-to-point with retransmission and multicast. It is also equipped with a double checksum to ensure reliability and message integrity. Both the transmitter and the receiver use binary serialization in MAVLink for communication. The transmitter transformed the message into a byte sequence and transmitted them through the network, the receiver deserialization to get the original message. It gains a significant advantage of reducing the size of the message compared to other messages' type [7]. It has two types of protocol headers, which are version 1 and version 2. The significant improvement of version 2 compared to version 1 is a signature at the last of protocol header. It develops the communication security of ensuring that the link is tamper-proof. Figure 4 shows the structure of MAVLink 2 header, which consists of flags, system IDs, components, checksum codes and payload data. The data frames can be from 0 to 255 bytes depends the message type [8].

Fig. 4. MAVLink 2 header

The ROV uses both wire and wireless technologies for communication and controlling. The ROV and a float that pulled by the ROV are communicated together via a cable. The float and a GCS on a mothership or on land are communicated via wireless technology. In order to communicate and transport protocols between ROV, the float and the GCS, the network interface is implemented. Figure 5 shows the communication system for the ROV.

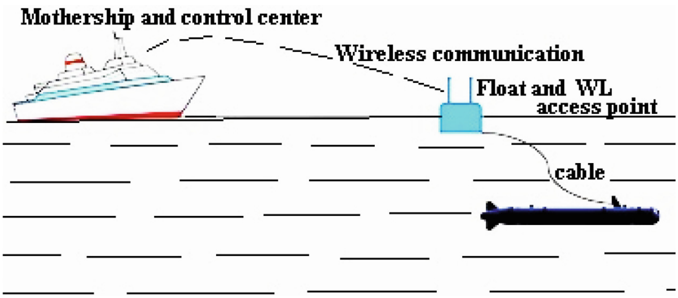


Fig. 5. Communication system

4.1 ROV and Float Communication

The communication between the ROV and the float is conducted via electrical cable technology. It is a cable with 30 m in length. The float is used as a wireless access point. The companion computer is designed based on Linux operating system to communicate and transport MAVLink protocol between the main control system of ROV and the float. The companion computer is functional to forwarding the messages and configure the IP network interface. The companion computer is setup with static IP address.

4.2 Float and Mothership Communication

The communication between the float and the GCS is conducted via wireless technology. The maximum distance for communication between the GCS and the float is 500 m. The float is equipped with wireless router, which is set up with security protocol WPA2 for protection. The GCS on the mother ship or on land is setup wireless interface with static IP address, and same router's gateway with the companion computer.

4.3 Monitoring and Controlling ROV

GCS is developed on the open-source software platform QGroundControl to monitor the system state and control ROV from the GCS through MAVLink messages, as shown in Fig. 6. The main control system on ROV sends the state messages to the GCS. Those messages include information on sensor health, battery status, system status such as angles, velocities. The command messages are sent from GCS to ROV. Those commands are designed based on the system requirements, such as move left, right, forward, backward, or buoyancy control in an emergency. The specific function of command is implemented on the control system on ROV. The command message format is designed on the XML file and generated in C++, and embedded in both GCS, companion computer, and a microcontroller on ROV. On ROV, the ACK (command acknowledgment) is used to get the command results, such as success, failure, or still in progress. Based on this response from ROV, people on mothership can know whether or not ROV implemented that command.

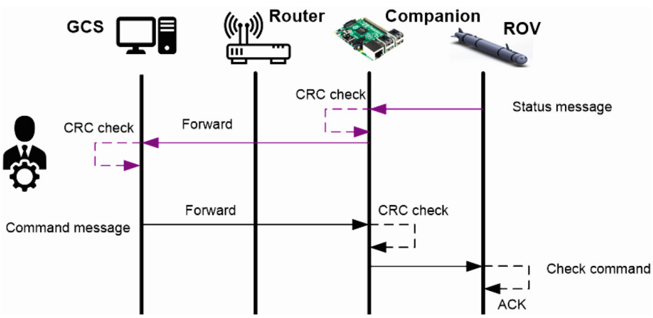


Fig. 6. Diagram of monitoring and controlling ROV

5 Conclusions

In this work, authors have developed a communication and control system for a ROV based on MAVLink. Communication and control system of the ROV from a GCS on a mothership or on land are including two ways. They are including communication from ROV to a float and communication from the float to a GCS. Communication between the ROV and a float is conducted via electrical cable technology. The float is used as a wireless access point. The companion computer is designed based on Linux operating system to communicate and transport MAVLink protocol between the main control system of ROV and the float. Communication between the float and the GCS on a mother ship or on land is conducted via wireless technology. The GCS is setup wireless interface with static IP address, and same router's gateway with the companion computer.

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