The Concept of the Unmanned Surface Vehicle for the Observation-class ROV

A Yu Tolstonogov[1,2], A E Kozhushko[1], I A Chemezov[1], D A Skalskii[1], A Yu Kolomeitsev[1]

[1]Far Eastern Federal University, 8 Sukhanova Street, Vladivostok 690090, Russia
[2]Institute for Marine Technology Problems FEB RAS, 5a Sukhanova Street, Vladivostok 690091, Russia

E-mail: tolstonogov.anton@gmail.com

Abstract. Remotely operated underwater vehicles (ROVs) are widely used in underwater operations, from research and survey operations to complex underwater technical and rescue ones. But the connectedness of an ROV and a carrier vessel imposes restrictions on the ROV and vessel's joint motion. The article aims to present the concept design of an unmanned surface vehicle for an observation-class ROV. The surface vehicle allows breaking wired connections between the carrier vessel and the ROV by a wireless communication system based on Wi-Fi technology. The detailed design of the unmanned surface vehicle and its main systems are presented in the article.

1. Introduction

Remotely operated vehicles (ROVs) are widely used in various underwater operation [1-5], from research and survey operations to complex underwater technical and rescue ones in different conditions caused by the ocean or sea currents and waves.

Traditionally, the winch system installed on a vessel provides power supply and the data transfer between the supply vessel and the ROV. However, the wired connection between them leads to a problem of synchronizing the mutual position and movement parameters of the underwater vehicle and the supply vessel. Besides that, the communication tether between them is limited, and the ship is in continuous motion under the influence of wind and sea currents.

While performing essential tasks, the problem is solved using vessels with a dynamic positioning system [6-7]. This system allows the desired position of the ship to be achieved and held despite external factors. In case of a lack of a dynamic positioning system, the safety of the synchronous movement of the wired "vessel-tether-ROV" system can be ensured by a particular software system. For example, the paper [8] presents the software system that determines the vehicle's permissible operating areas based on its position related to its movement parameters.

The project aims to develop a concept of an unmanned surface vehicle that ensures the independence of maneuvering of the remotely operated underwater vehicle and the carrier vessel. The surface vehicle named "Aquila" was designed and developed to achieve this goal. The vehicle represents the wireless data gateway between the teleoperators' control station and the ROV "Millennium Falcon" developed before [9-10]. The surface vehicle is equipped with an automatic winch system and a propulsion system for a dynamic positioning over an underwater vehicle. The vehicle was inspired the paper [11] where the similar autonomous buoy system was developed. The vehicle presented there represents the buoy with the propulsion system for dynamic positioning. It implements a data gateway between AUV "Tuna-Sand" and the surface monitoring system.

2. Surface vehicle

The main task of the surface vehicle "Aquila" (Figure 1) is to eliminate the physical connection between the carrier vessel and the remotely operated underwater vehicle. The surface vehicle consists of two main parts: the winch system and the motion control system.

The winch system aims to maintain the optimal length of the connection cable between the control station and the ROV. This is the part of the communication system connecting them. The Wi-Fi interface achieves wireless communication between the surface vehicle and the control station.

The motion control system aims to manoeuvre on the water surface for keeping the target position above the area of ROV operation. The motion control system includes the propulsion system consisted of three rotatable thrusters. Additionally, the motion control system is equipped with a high-resolution digital camera to observe the ROV at shallow water visually.

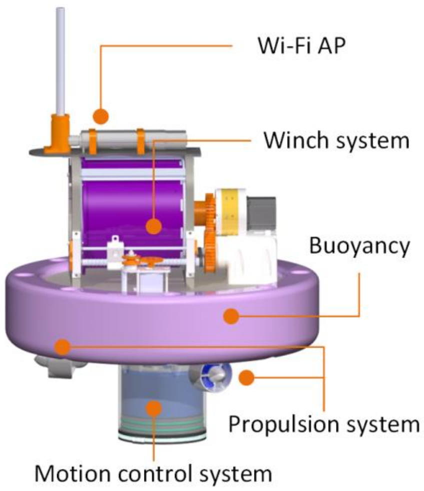
The autonomous power supply of the surface supply vehicle is implemented based on lithium-ion battery cells. Table 1 shows the main parameters of the "Aquila".

Table 1. The main parameters of the surface vehicle "Aquila".

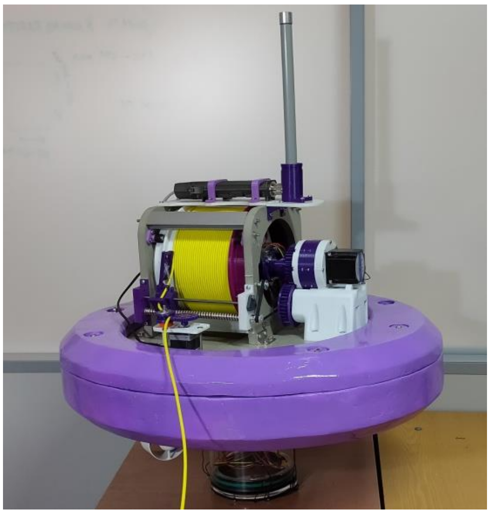
Height, m	0.782
Diameter, m	0.568
Dry weight, kg	17.6
Battery capacity, Ah	15
Velocity, m/s	0.6

2.1. Vehicle design

Figure 1 illustrates the overall design of the surface vehicle "Aquila". As it mentioned above, it consists of the winch system (it's attached above the base plate made of a polypropylene sheet) and the motion control system (it's attached under the base plate).



a)



b)

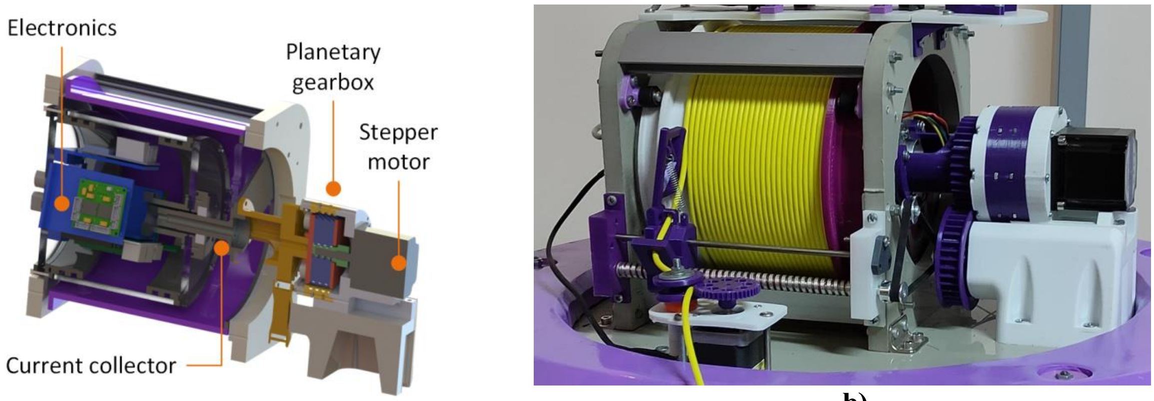
Figure 1. The overall render (a) and actual (b) view of the surface vehicle "Aquila".

2.2. Winch system

The winch system is a tether winch equipped with an automatic cable laying system. Two stepper motors drive it. The first is designed to adjust the cable tension in the auto-laying unit. Through a planetary gearbox, the second rotates the cable winch drum and by a belt-drive moves the auto-laying unit along with the drum. The drum itself is located between two polypropylene frame plates and is held by roller bearings. Figure 2 shows the render and actual view of the winch system.

The systems' electronics are located inside the sealed part of the drum. The tether to the ROV outlet is made through a current collector. Using the current collector is justified by the necessity of the electronics to be fixed during the cable drum rotation.

To control the winch system, a Raspberry Pi 3B + computer and a stepper motor driver based on the L6470 controller, which was developed specifically for this vehicle, are used. The SPI interface is used for communication between them. The power supply to the topside is carried out using the underwater part of the surface vehicle's battery module. Figure 3 shows the principal scheme of the winch system.



a) b)

Figure 2. The render (a) and actual (b) view of the winch system.

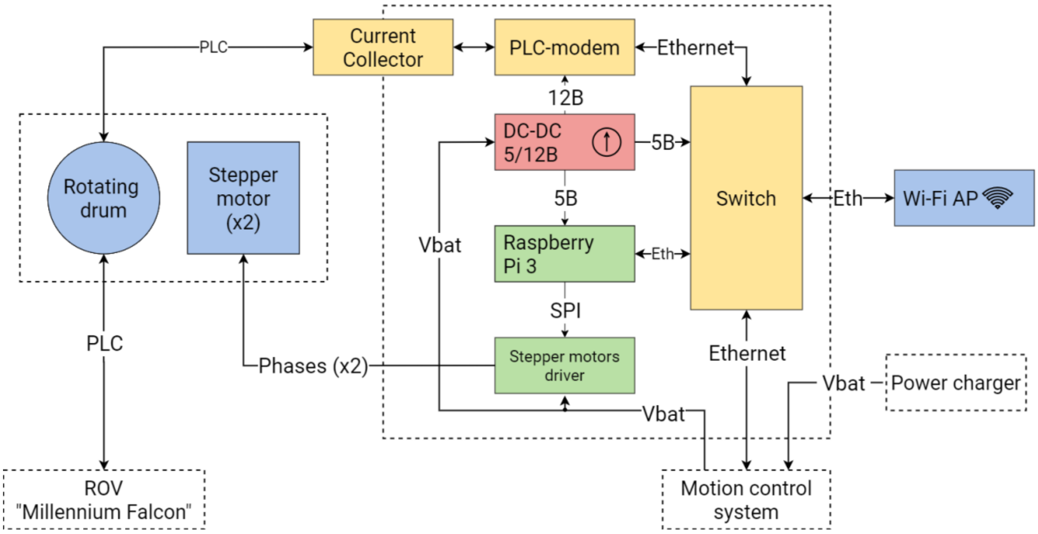
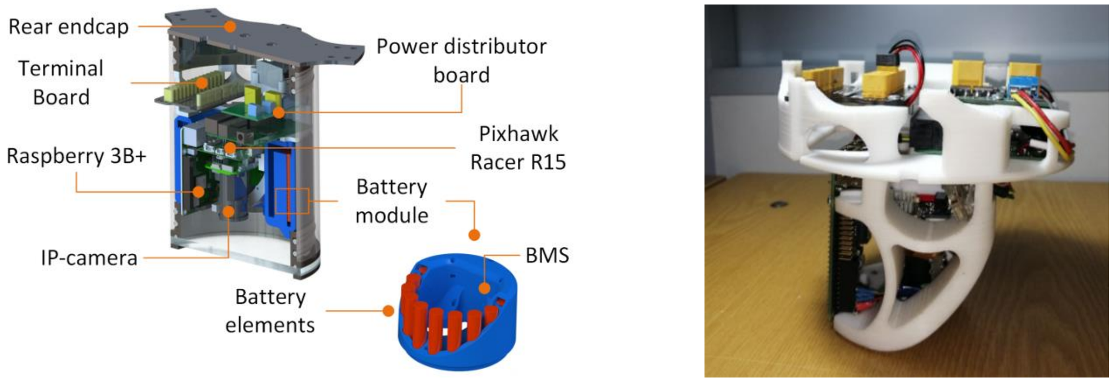


Figure 3. The principal scheme of the winch system.

The winch driver developed in C++ using the QT library is used to control the cable feed. The winch driver calculates angular velocities with synchronizing both stepper motors, based on the cable's linear feed rate, ensures safety during cable unwinding, reeling, and critical situations, and can calibrate maximum and minimum lengths.

2.3. Motion control system

The motion control system of the surface vehicle “Aquila” (Figure 4) consists of a software subsystem and a hardware subsystem (Figure 5 illustrates its principal scheme), including the sensors and the propulsion system. Figure shows the shows render and actual view of the motion control system.



a) **b)**

Figure 4. The motion control system of the surface vehicle (without the propulsion system), **a)** is the render, **b)** is the actual view.

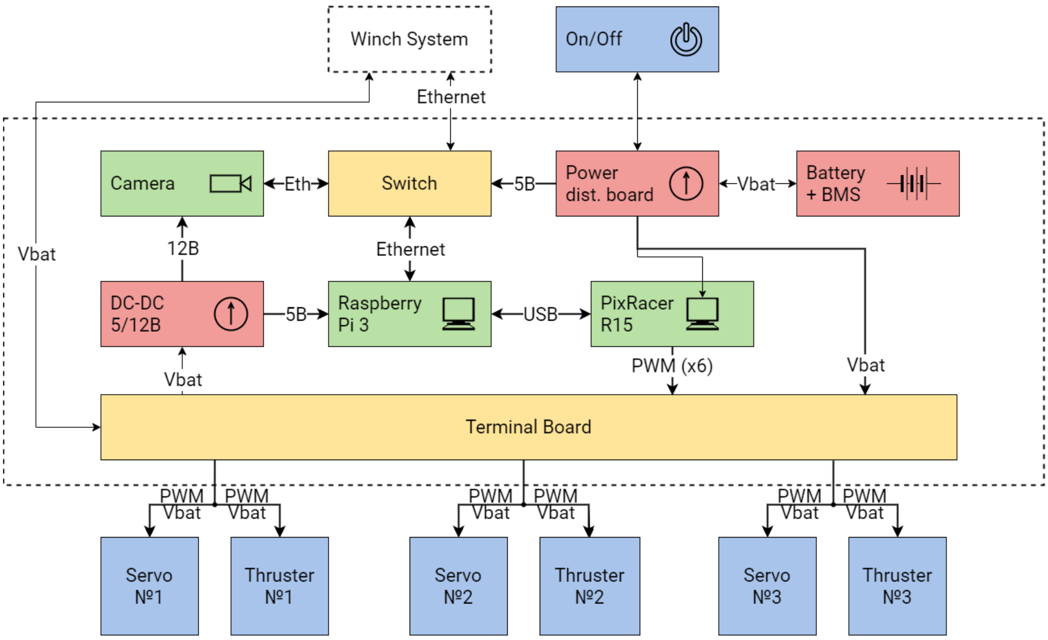


Figure 5. The principal scheme of the motion control system.

The hardware subsystem is housed in a sealed acrylic tube. The bottom endcup of the tube is a round plate made of transparent acrylic. The top endcup is an aluminum plate with sealed connectors. All PCBs are mounted on a solid frame made of 3D plastic inside the tube. Under the frame is a battery module consisting of 18650 Li-Ion cells and a BMS board.

A combination of a Raspberry Pi 3B + single board computer and a PixRacer R15 flight controller is used to control the motors and servos. Motors and servos are connected to power supplies and PWM sources through a connector board. The IP-camera is located at the bottom of the compartment and is surrounded by a battery pack. The signals from the camera and the single board computer go through the switch board to a sealed compartment inside the drum. Two DC-DC converters are used to power the electronics.

The software subsystem aims to implement control algorithms and allow movement of the vehicle to be controlled by an operator in manual mode or by software algorithms in automatic mode. It represents a set of functionally separated nodes with the propulsion system. Each node is the standalone application written in high-level language C++. For inter-process communication between nodes, the particular library developed by the Institute of Marine Technology Problems FEB RAS was used [12]. The software was developed within the Qt Creator environment with the qmake compiler. Figure 6 presents the principal software architecture of the control system.

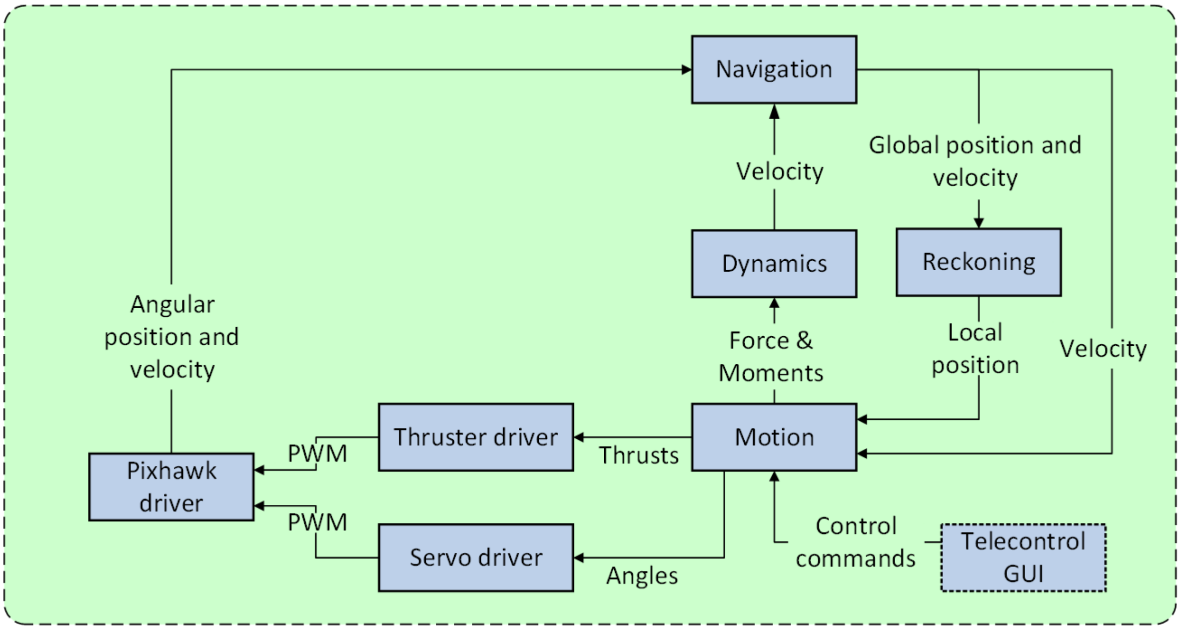


Figure 6. The principal software architecture of the control system.

The propulsion system of the surface vehicle (Figure 7) aims to control the vehicle and implement the dynamic positioning algorithm. It consists of three thrusters placed in the angles of an equilateral triangle. Each thruster is attached to a sealed servo, which allows the thruster to rotate in the angles' range of -60/+60 degrees relative to the primary position.

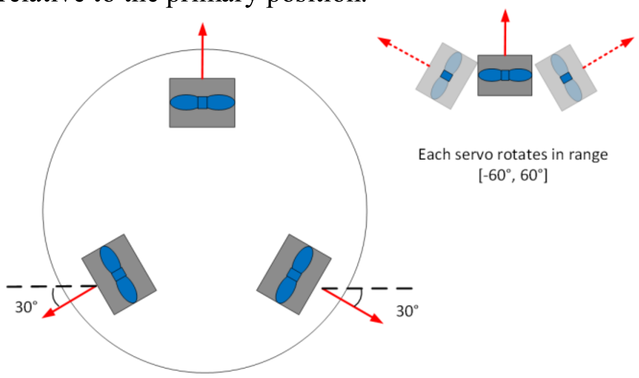


Figure 7. Propulsion scheme of the surface vehicle.

3. Conclusion

In the paper, the concept of the unmanned surface vehicle for the observation-class ROV with autonomous power supply was presented. The surface vehicle can automatically track an ROV vehicle and automatically adjust the length of the communication tether by the winch system. The detailed design of the proposed system was described.

The vehicle was tested in the water pool with ROV “Millennium Falcon” developed earlier.

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