IOP Conf. Series: Materials Science and Engineering **301** (2018) 012137 doi:10.1088/1757-899X/301/1/012137

The Design of an Autonomous Underwater Vehicle for Water Quality Monitoring

Yulong Li[1], Rong Liu[2] and Shujin Liu[2]

[1]Beijing National Day School, No. 66 Yuquan Road, Beijing 100039, China.
Email: xlfdly@sina.com
[2]School of Mechanical Engineering and Automation, Beijing University of Aeronautics and Astronautics, Beijing 100191, China.

Abstract. This paper describes the development of a civilian-used autonomous underwater vehicle (AUV) for water quality monitoring at reservoirs and watercourses that can obtain real-time visual and locational information. The mechanical design was completed with CAD software Solidworks. Four thrusters—two horizontal and two vertical—on board enable the vehicle to surge, heave, yaw, and pitch. A specialized water sample collection compartment is designed to perform water collection at target locations. The vehicle has a central controller—STM32—and a sub-coordinate controller—Arduino MEGA 2560—that coordinates multiple sensors including an inertial sensor, ultrasonic sensors, etc. Global Navigation Satellite System (GNSS) and the inertial sensor enable the vehicle's localization. Remote operators monitor and control the vehicle via a host computer system. Operators choose either semi-autonomous mode in which they set target locations or manual mode. The experimental results show that the vehicle is able to perform well in either mode.

1. Introduction

Through recent years, Unmanned Underwater Vehicles are proved to be efficient, cost-effective, and safe options to carry out maritime operations. UUVs reduce human losses in high-risk operations and decrease operational costs, and are therefore adopted by militaries and firms to perform tasks including oceanographic researches, environment monitoring, resource exploitation, maritime search and rescue, etc.

UUVs can be classified as Remotely Operated Vehicles (ROV) and Autonomous Underwater Vehicles (AUV). ROVs require tether connections for power supply and human operators at a remote base. Unlike ROVs, AUVs have power supply, propellant, and multiple sensors on board that enable them to operate individually. Via fiber optics, microwave transmission, communication satellites, and other communication media, remote controllers can supervise AUVs and give commands. Meanwhile, AUVs can operate individually according to given missions and send back data collected and processed by sensors and processors which reflect information about their surrounding environment and operation status. This work presents the development of an AUV used to monitor water quality at reservoirs and watercourses.

2. Vehicle Descriptions

2.1. Structure Design

The vehicle takes a streamlined configuration. It has a metal cover where a camera, a lightening device, antennas, and a switch locate. After all other components are fixed inside the vehicle, the cover is sealed with screws.

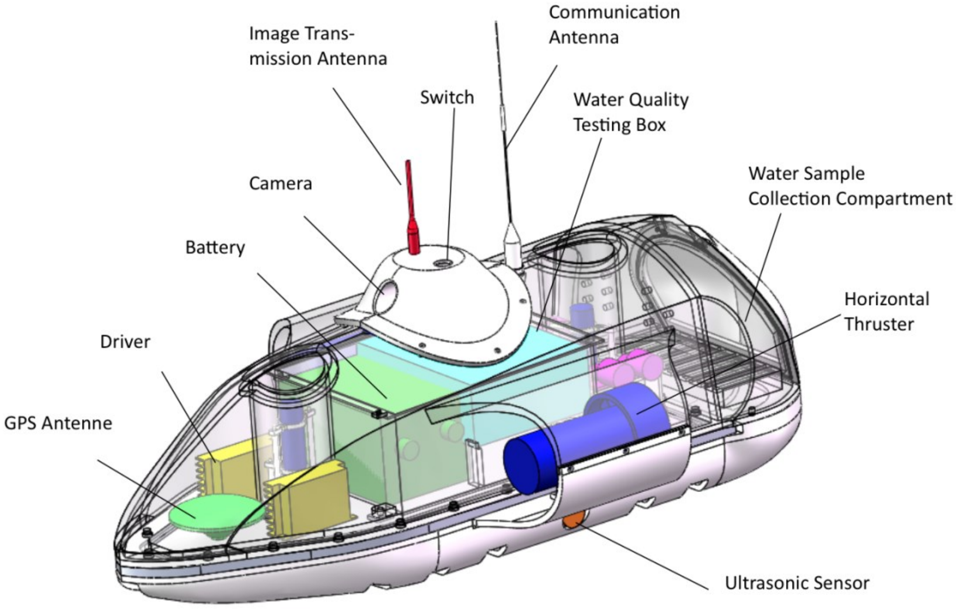

Figure 1. The overall design of the AUV.

2.2. The Propulsion System

The propulsion system of the vehicle consists of four thrusters. Two horizontal thrusters enable the vehicle to surge and yaw; two vertical thrusters enable the vehicle to heave and pitch. An appropriate yaw angle can prevent the vehicle from swaying. Because the vehicle operates at reservoirs and inland rivers where winds and waves are weak, the vehicle rolls insignificantly.

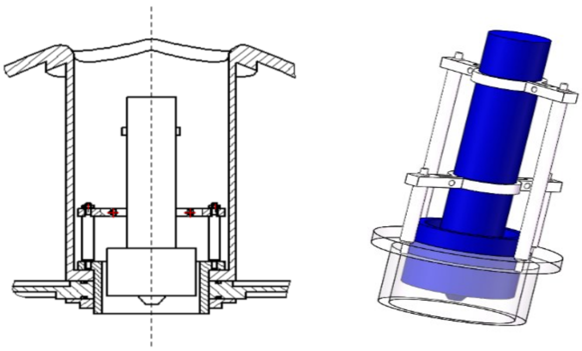

Figure 2. The design of vertical thrusters.

2.3. The Water Sample Collection Compartment

Figure 3 displays the structure of water sample collection compartment which is composed of a pump compartment and sample bottle compartment. The seal of the pump compartment is strictly the same as that of the control system. The sample bottle compartment is sealed by a hinge and a locking pin. The pumps, sample bottles, and the outside water environment are connected by high pressure water pipes. The water bottles can be locked through rotation into the holders.

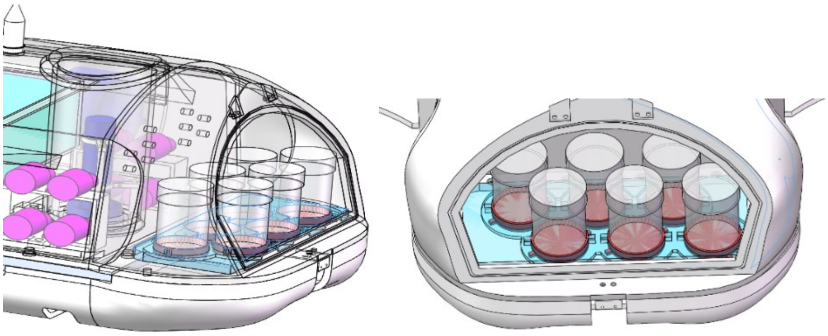

Figure 3. The water sample collection compartment.

3. The Power System

The vehicle uses 24V ferric phosphate battery. Comparing with traditional lead-acid batteries, ferric phosphate battery is environmental friendly with greater energy density and better high temperature performance.

The horizontal thrusters require power sources of 24V 30A DC, vertical thrusters require power sources of 12V 40A DC, communication device requires a 12V power source, and the control module requires 5V power source. The ferric phosphate battery directly powers the horizontal thrusters. Power is supplied to vertical thrusters through a 24V to 12V converter. Because the thrusters require large currents, instead of the switch directly controlling the thrusters, the switch controls the thrusters through a relay.

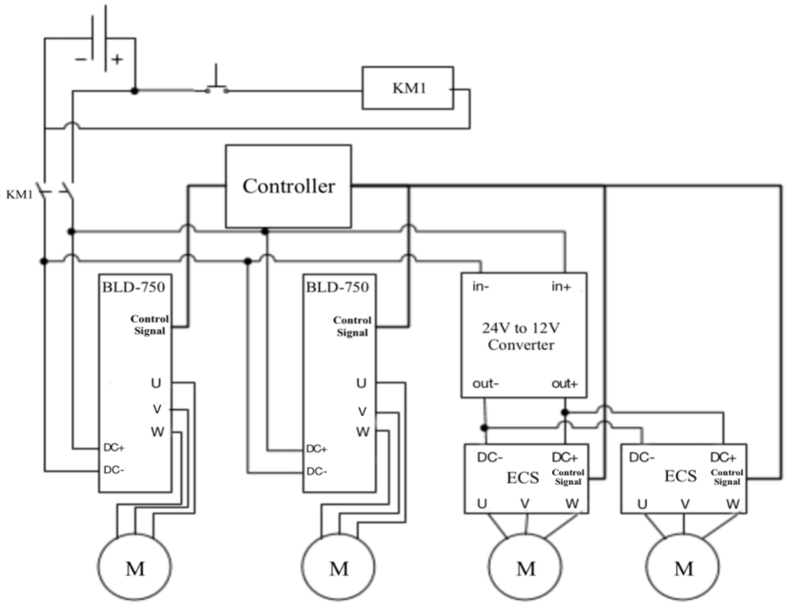

Figure 4. The circuit diagram.

4. The Control System

The control system consists of three modules: a propulsion module, a sensor module, and a central control module.

The propulsion module consists of four thrusters and their corresponding drivers. Thrusters in the horizontal direction use induction brushless motors and thrusters in the vertical direction use synchronous brushless motors.

Water quality sensor, water logging sensor, and underwater ultrasonic sensor are controlled by a subordinate controller (using Arduino MEGA 2560). The sensors and the controller constitute the sensor module.

Radio station, Global Navigation Satellite System (GNSS) and inertial sensor, and the central controller (using STM32) constitute the central control module. The central control module is responsible for receiving the instructions from the host computer system and, according to the instructions and data from sensor module, performing vehicle routing and task allocation.

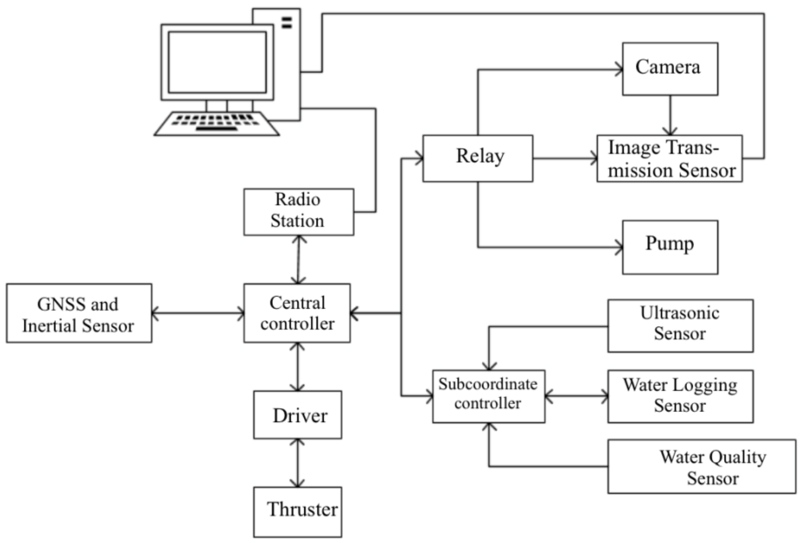

Figure 5. The diagram of the control system.

5. The Host Computer System

5.1. The Login Interface

The host computer system allows a user to control the vehicle and read sensors' data after login. The system enables both manual control and autonomous control.

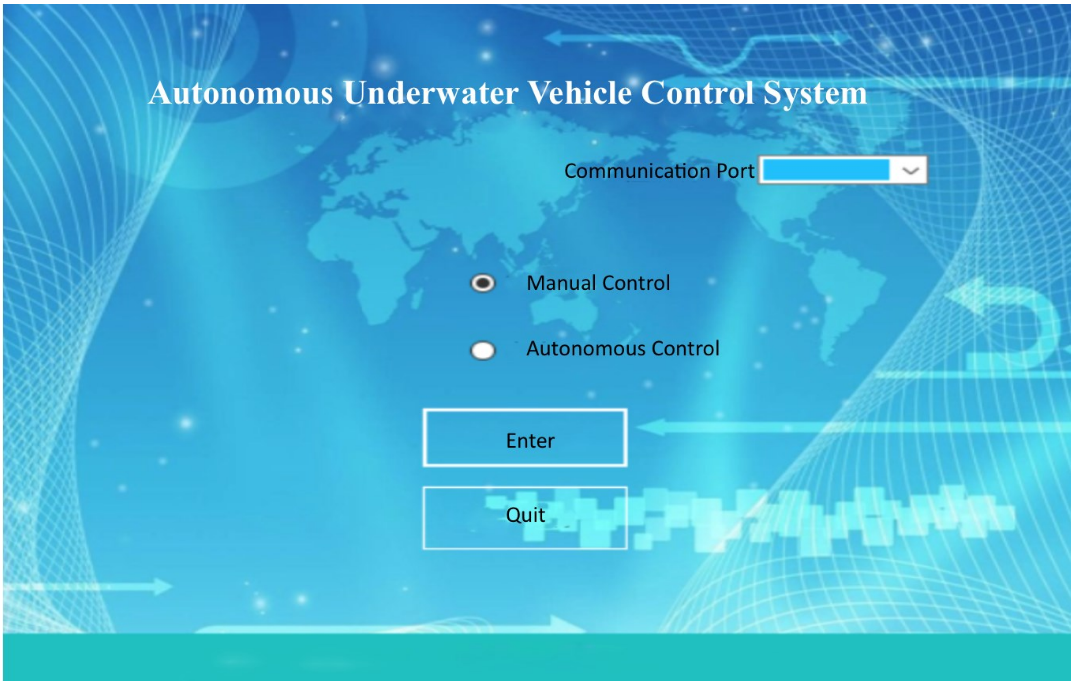

Figure 6. The login interface.

5.2. The Manual Control Mode Interface

The manual control mode interface displays the vehicle's position, the monitor of the camera, and the vehicle operation status. Via the interface, a user controls the vehicle's movements, starts water sample collection, and captures images from the camera. Due to errors in the simulation, the system enables modification of the vehicle's parameters in the real environment. A user can modify the control parameters of three active disturbance rejection control (ADRC) channels, each for surging, pitching, and yawing.

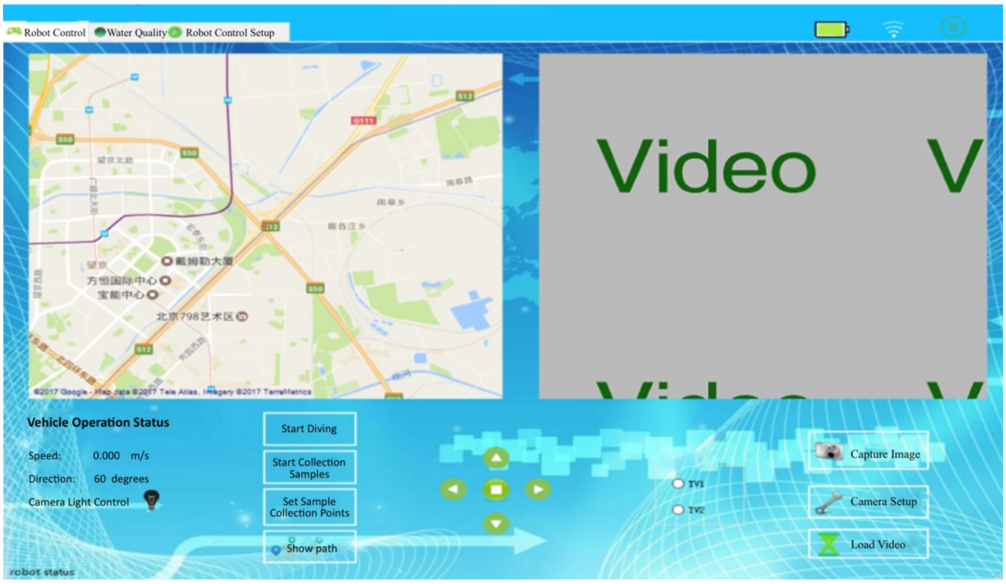

Figure 7. The manual control mode interface.

IOP Conf. Series: Materials Science and Engineering **301** (2018) 012137 doi:10.1088/1757-899X/301/1/012137

5.3. The Autonomous Control Mode Interface

The autonomous control mode interface (Figure 8) asks a user to set target locations on the vehicle will perform tasks accordingly without manual control. The interface allows a user to capture images from the camera. A user can also switch to the manual control mode.

6. Design Specifications

The vehicle has following specifications:

Table 1. Design specifications of the vehicle.

Dimension (mm^3)	Weight (kg)	Rated Load (kg)	Operation Depth (m)	Operation Range (km)
1100×400×320	70	7	20	2

Mobility	Maximum Speed (m s^{-1})	Positioning Accuracy (m)	Image Resolution	Control Mode
Surge, Heave, Yaw, and Pitch	1	±1	Standard Definition	Manual and Autonomous

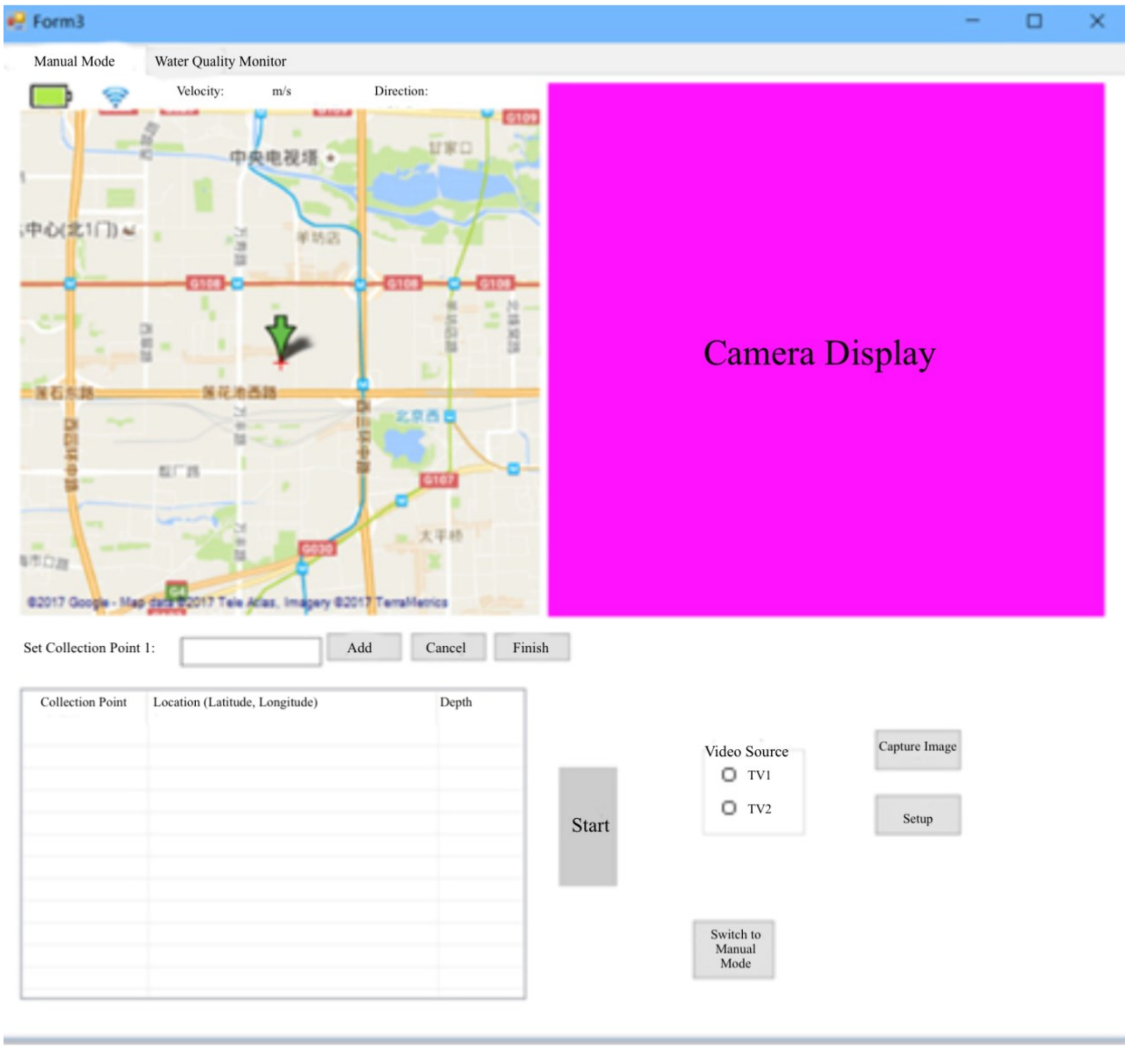

Figure 8. The autonomous control mode interface.

7. References

[1] Mcphail S. Autosub6000: A Deep Diving Long Range AUV [J]. Journal of Bionic Engineering. 2009, 6(1): 55-62.

[2] Kunz C, Murphy C, Camilli R, et al. Deep sea underwater robotic exploration in the ice-covered Arctic ocean with AUVs[C]. Nice: 2008.

[3] Purcell M, Gallo D, Packard G, et al. Use of REMUS 6000 AUVs in the search for the Air France Flight 447[C]. Waikoloa, HI: 2011.

[4] Rong-Jong W, You-Wei L. Adaptive Moving-Target Tracking Control of a Vision-Based Mobile Robot via a Dynamic Petri Recurrent Fuzzy Neural Network[J].Fuzzy Systems, IEEE Transactions on. 2013, 21(4): 688-701.

[5] Li J, Lee P. Design of an adaptive nonlinear controller for depth control of autonomous underwater vehicle [J], Ocean Engineering. 2005, 32(17-18): 2165-2181.

[6] Petrich J, Stilwell D J. Robust control for an autonomous underwater vehicle that suppresses pitch and yaw coupling [J]. Ocean Engineering. 2011, 38(1): 197-204.

[7] J W O. An introduction to inertial navigation [J]. University of Cambridge, Computer Laboratory, Tech. 2007: 696.

[8] Prestero, Timothy. Verification of a six-degree of freedom simulation model for the REMUS AUV. Master's thesis, Massachusetts Institute of Technology and the Woods Hole Oceanographic Institution.Departments of Ocean and Mechanical Engineering. 2001.