

Design and Realization of USV Experiment Platform

Jing-hui WANG, Xiong-shan BI, Tao ZHANG and Wei GUAN*

Navigation College of Dalian Maritime University, Dalian, Liaoning 116026, China

*Corresponding author

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Abstract. An unmanned surface vessel (USV) platform that could realize the ship course-keeping^[1] experiment is proposed in this paper. Integrated the high-precision Global Positioning System (GPS) into the USV platform, the high accuracy position and USV dynamics data could be obtained. Then a steering controller for course-keeping control based on the Proportional-Derivative (PD)^[2] control strategy is tried to control the USV platform on the given course. Finally, the course-keeping experiment results illustrate that the proposed USV could be utilized as a platform for USV intelligent collision avoidance and other advanced USV controller experiments.

Introduction

In recent years, the research of Unmanned Surface Vessel (USV)^[3] has attracted a lot of scholars attention, because it contains a huge amount of potential in various practical engineering applications. The USV is a complicated system, and it is divided into hardware module and software module. In terms of hardware module, what is most important is how to obtain the attitude and position data from the sensors that installed on the vessel. This paper uses the high precision Global Positioning System (GPS) module as the attitude sensor to get USV real-time attitude data, and then storage the data into the database that established by SQL Server. On the other hand, if the computer deployed on the shore has connected to the internet, anyone who has the account and password could access the USV attitude data at any place where there is a network. While the vessel is being tested on the sea, it is very convenient for us to monitor the vessel, and collect the navigation data at the same time. The course-keeping is the fundamental function of USV and it can be used in various field of the USV motion control engineering. Especially in the constrained water areas, the more precise ship course-keeping performance is, the more safety the USV can embrace. In this study, steering controller^[4] based on proportional-derivative (PD) strategy was adopted as a tool to control the smart USV on the given course. The smart USV is equipped with a very high precision GPS receiver and wireless radio communication system to identify its positions.

The Introduction of the USV Experiment Platform

The platform includes two parts, hardware module and software module. The overview of the USV is shown in Fig. 1.



Figure 1. The overview of the USV

The architecture of the USV is shown in Fig.2. The control system consists of the real time USV yaw angles, speed, position and other USV dynamic data through gyroscope and GPS. The steering controller based on the PD control is designed and the tuning parameters of the controller reasonably adjusted to ensure the USV could achieve the given course according to the command. The remote control receiver is mainly utilized to receive the commands from the remote controller, and is responsible for switching control between manual and automatic modes. The main function of the data transmission station is to transmit the USV navigation status and other control commands up-down-link to the shore based control center. Under the coordination and cooperation of various systems, the real-time monitoring of the USV status and the course-keeping control results during the navigation process can be realized and achieved.

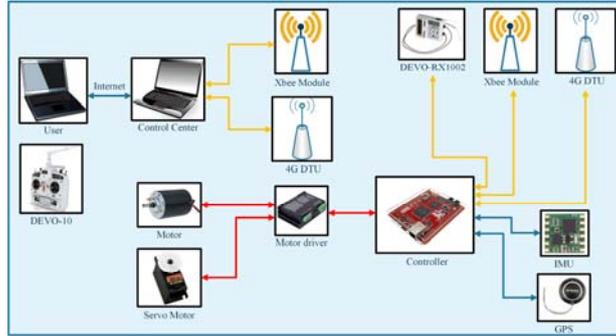


Figure 2. The architecture of USV

The software module uses VC++ programming in the Visual Studio 2013 developing platform, and its function is mainly responsible for collecting and retrieving the USV dynamics information from GPS, steering controller and other sensors to realize the function of course-keeping. The structure of the software module is shown in Fig 3.

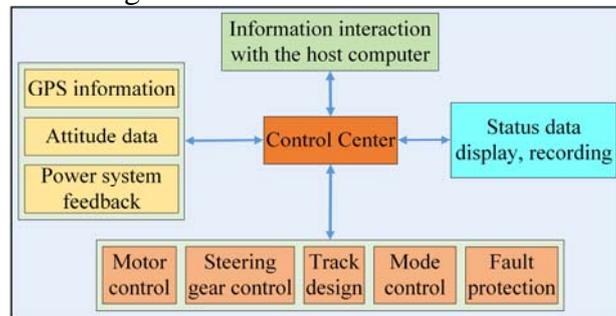


Figure 3. The architecture of the software

The PD Steering Controller Design for Course-keeping

The PD controller is proportional derivative control, and it can be represented as,

$$P = K_p e_p(t) + K_p K_D \frac{de_p(t)}{dt} + P(0). \quad (1)$$

Where P is PD steering controller target status, K_p , K_D are proportional, derivative gain, and $e_p(t)$ is deviation between the desired course-keeping value and the measured course value, $P(0)$ is controller initial status.

This paper applies the PD steering controller to carry out USV course-keeping experiment [5]. The USV consists of a very high precision GPS receiver so that the ship position and other related information are regularly provided to the control system. Fig. 4 shows the general flow of control system, which GPS signal provides the system with yaw angle. Comparing the real-time heading with the desired course, then the steering control command can be calculated, and the USV heading can achieve the desired course precisely.

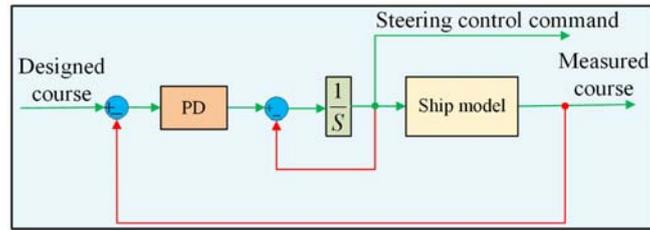


Figure 4. Block diagram of the close-loop control system

Experimental Result

To illustrate the validity of the proposed USV course-keeping control platform, a series of the USV experiment should be carried out. Fig.5 shows the experiment scene. Firstly, the desired headings and turning point^[6] for USV course-keeping control experiment have been defined as Table 1. We choose a calm lake as the experiment area, ignoring the effects of obstacles, fishes, ships, etc., and we just design a simple course-keeping experiment to verify the effectiveness of the PD steering control.

Table 1. Desired headings and turning points

Number	Heading(°)	Turning point(°)
1	56.54	[38.936033, 121.437404]
2	300.15	[38.936211, 121.437011]
3	270.44	[38.936215, 121.436635]



Figure 5. The experimental scene

The results of the experiment are shown in figure 6-10. The latitude and longitude position of starting point is (38.9358455, 121.4370534). In Fig. 6, red straight line is designed tracking course, and the blue dotted line is the USV trajectory.

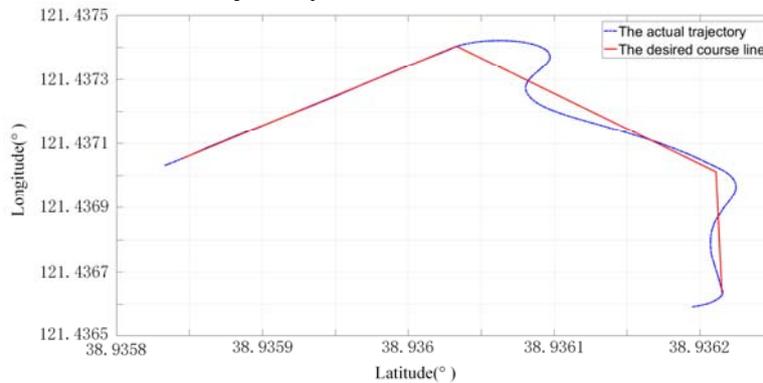


Figure 6. The USV's trajectory

When the experiment was carried out at the Tang-li Lake, where GPS signal is very strong, and the average depth of the water reservoir is about 5 meters. The temperature was 17 °C and wind direction of the experiment day was southwest, and the velocity of the wind varied from 1.7 to 2.2 m/s. The

maximum wave height was about 0.2 meters. It seems that the weather condition on that day is very suitable for steering course-keeping control experiment. But these factors still have impacts on the navigation control of the USV, especially when the steering angle changed a lot, the impact becomes greater.

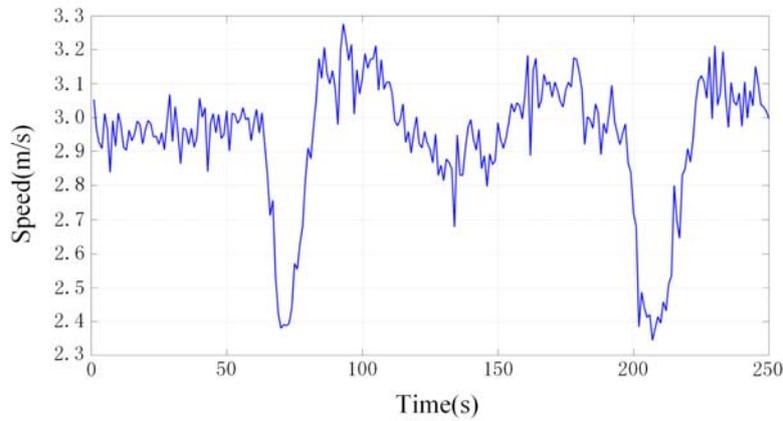


Figure 7. Time history of speed

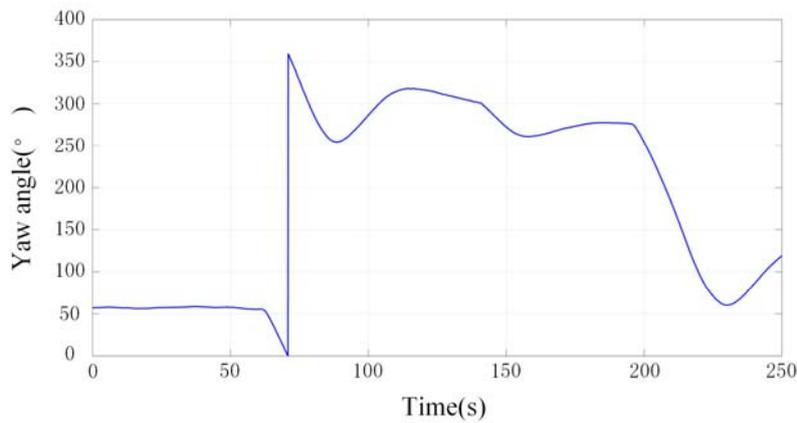


Figure 8. Time history of headings

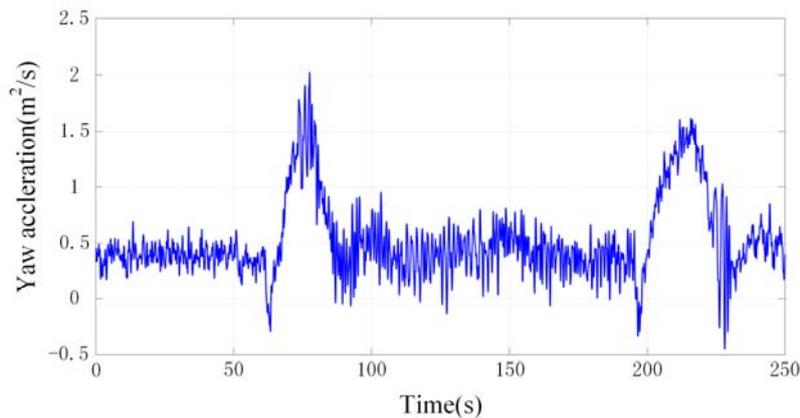


Figure 9. Time history of acceleration

Fig. 7 shows the time history of the USV speed during the experiment. Fig. 8 and Fig. 9 indicate the yaw angle and yaw acceleration of the USV, and Fig. 10 shows the steering control signal retrieved from PD steering controller to servo motor. On the one hand, the steering signal is not obviously mutations, which helps to protect the actuator. On the other hand, it means that the PD controller shows the good performance of USV course-keeping.

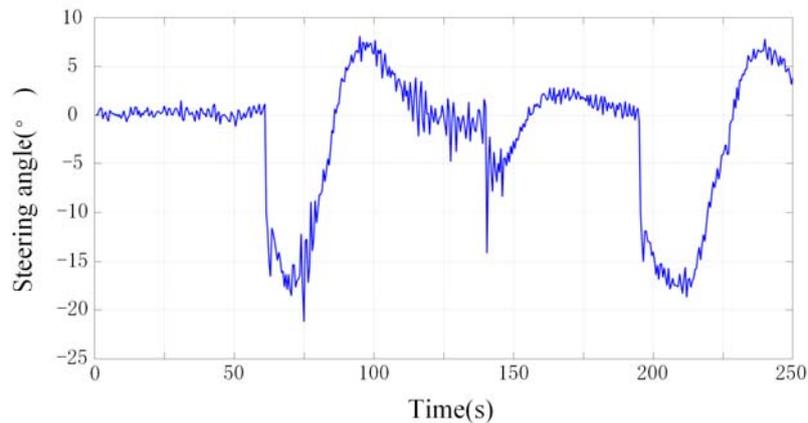


Figure 10. Time history of steering angle

Conclusions

The conclusion of this study can be summarized as follows.

- The main architecture of the USV experiment platform is introduced.
- The design and realized of steering PD controller for USV course-keeping are described.
- The USV platform course-keeping experiment was carried out, and the effectiveness of PD controller has been proved.

However, the USV platform still has a great of limitations, and a lot of functions for USV platform are not implemented, such as track-keeping, collision avoidance, real-time monitoring, etc. So, there are many works and experiments need be carried out in the future.

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