Stereovision Aided Navigation of an Autonomous Surface Vehicle

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***Abstract*- This paper presents a stereovision system to aid in navigating an Autonomous Surface Vehicle (ASV). The ASV is guided to follow a path mainly by GPS, while the stereovision system is designed for assisting it to avoid obstacles or follow a target floating on water surface. After calibration, the stereovision system can estimate the positions of floating objects founded simultaneously by both cameras, which can be used to plan the path such that the ASV can reach the target fast and avoid collision with other objects around. In fine sea state, when an obstacle is large enough and its color is different from the water surface obviously, the stereovision system can navigate the ASV to avoid it successfully. If the obstacle is small or difficult for the ASV to distinguish from the background, the operator in front of the console of the base station on a mother ship or on the shore can intervene in and guide the ASV remotely according to the couples of images from the two cameras.**

I. INTRODUCTION

Operating on water surface, an Autonomous Surface Vehicles (ASV) can be used for various missions that would be dangerous for humans to perform [1-2]. In order to carry out such missions, ASVs are often equipped with navigation system sensing both its position and surrounding objects. An ASV can find its position through GPS, which is accurate enough to guide it reach or pass through anticipated waypoints. However, avoidance of obstacles on the way is a critical problem to keep the ASV run safely. On the other hand, target following is also an important aspect of navigation. Because GPS cannot provide information of obstacles or target, other assistant methods for finding floating objects are necessary.

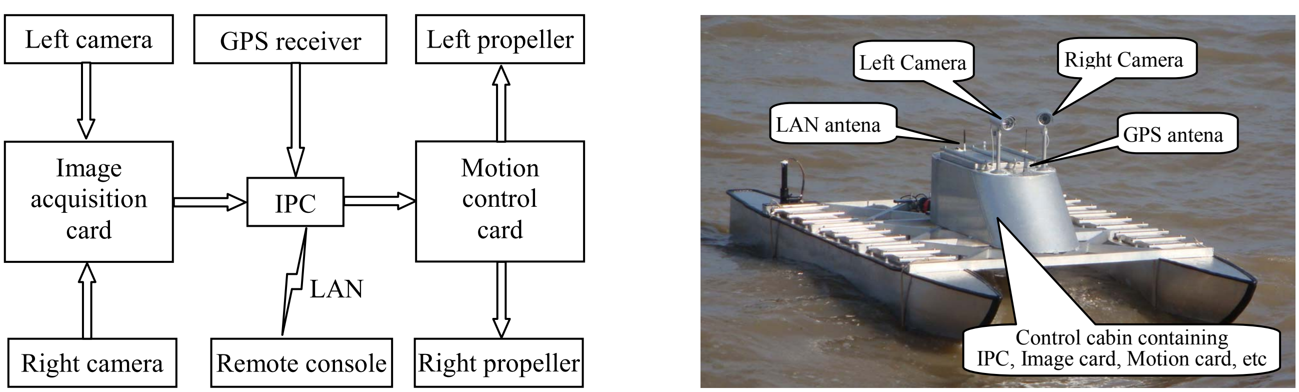
Vision is the primary sense for human to find objects around. Inspired by human vision, researchers have been trying to use vision-based method to navigate robots, including Unmanned Ground Vehicles (UGV), Unmanned Aerial Vehicles (UAV), and Unmanned Underwater Vehicles (UUV), and some successful applications have been reported [3-8]. Compared with UGV, UAV and UUV, ASV attracts fewer researchers, and it is only in the 1990s that a large proliferation of projects on ASV researches appears. Some researchers tried to apply vision technology of UGV to ASV [9-12], and encounter some difficulties due to special environment of water surface, especially reflection and wave.

Supported by Science and Technology Commission of Shanghai Municipality, an ASV is developed to satisfy requirement for multi-mission applications. In order to enable the ASV avoid obstacles, a stereovision aided navigation system is developed, which will be addressed in the following, including its hardware architecture, software flow chart and experiment results.

II. GENERAL STRUCTURE

A. Hardware architecture

The hardware architecture is shown in Figure 1. The ASV is mainly guided by waypoints given by the Industrial Personal Computer (IPC) and real-time position data from the GPS receiver. The left camera and right camera take images of field in front of the ASV real timely. Images are digitized through



(a) (b)

Figure 1. Hardware architecture
(a) Function module; (b) Installation on the ASV.

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acquisition card and then input into IPC for stereovision computation, obtaining the position of an obstacle or target with respect to the ASV. The position data of obstacles or targets are used for path planning together with GPS data.

At the same time, the digital images and other data are transmitted back to console of the base station on a mother ship or on the shore through wireless LAN. An operator in front of the console always monitors the real-time images from the ASV. When a dangerous obstacle occurs and the stereovision system cannot find it, or when disturbs from wave and wind is too heavy for the controller to guide the ASV to avoid danger, the operator can interfere in and send commands to guide the ASV remotely, ensuring the ASV from danger.

B. Software flow chart

Software flow chart of the stereovision system is shown in Figure 2. Inputs of the system are images taken by the left and right cameras, GPS data, anticipated waypoints and camera parameters obtained from calibration. Outputs are control voltages to the left and right propellers. The main modules of the stereovision are image process and stereo computation.

The left and right images are input to image processing module, where histogram equalization and filtering are first carried out to improve quality of the images, and then edges are detected, followed by sky-water line removing. As the result of image processing, contour images of obstacles are obtained, i.e. features of obstacles. As an example, the process is demonstrated in Figure 3, where (a) and (b) are the original images from the left and right cameras, (c) and (d) being results of edge extraction, (e) and (f) being contour images after removing the sky-water line.

Matching of the left and right features produces disparity, which is used to stereo computation together with camera parameters. Position and size of an obstacle can be found through the stereo process. Then the path planning module decides the heading direction and speed of the ASV, which are input to the control module, where control voltages to left and right propellers are output. The interface of the software is shown in Figure 4, where some other parameters besides stereovision are displayed.

III. Experiment results

Some static experiments have been conducted on the ASV with the stereovision system. The ASV runs in remotely control mode, with the stereovision system processing images and outputting result of stereo computation, but not inputting into the path-planning module. The images in Figure 3 and Figure 4 are from an experiment at Fengxian bay of Shanghai in August 2009, when the scene of the experiment was recorded as shown in Figure 5.

Results of static experiments show that the stereovision system can find some large obstacles such as boat, shallow shoal with flourishing reeds when the sea state is fine, which indicates that the hardware of the stereovision system can satisfy requirement for aiding in navigating an ASV to avoid obstacles, and the software also realizes its function correctly. However, performance of the stereovision system is not stable when the reflection of light and wave of water surface is somewhat complicated.

We also had some try to test if the stereovision system can guide the ASV to avoid some large obstacles, but only in a few lucky cases, it behaved correctly. In order to avoid obstacles, the operator in front of the console on the base station has to monitor the couples of images from the two cameras, and guides the ASV remotely through wireless LAN.

IV. Conclusion

The hardware of the stereovision system can satisfy requirement for aiding in navigating an ASV to avoid obstacles. The software also realizes its function. In fine sea state, when an obstacle is large enough and its color is different from the water surface obviously, the stereovision system can estimate its position, and guide the ASV to avoid it.

However, performance of the stereovision system is not stable and robust enough to be put to use. Complicated environmental conditions on the water surface, such as reflection of light, wave and so on, are the main factors affecting the stereovision system. If these factors can be compensated, the stereovision system is promising to guide the ASV to avoid obstacles.

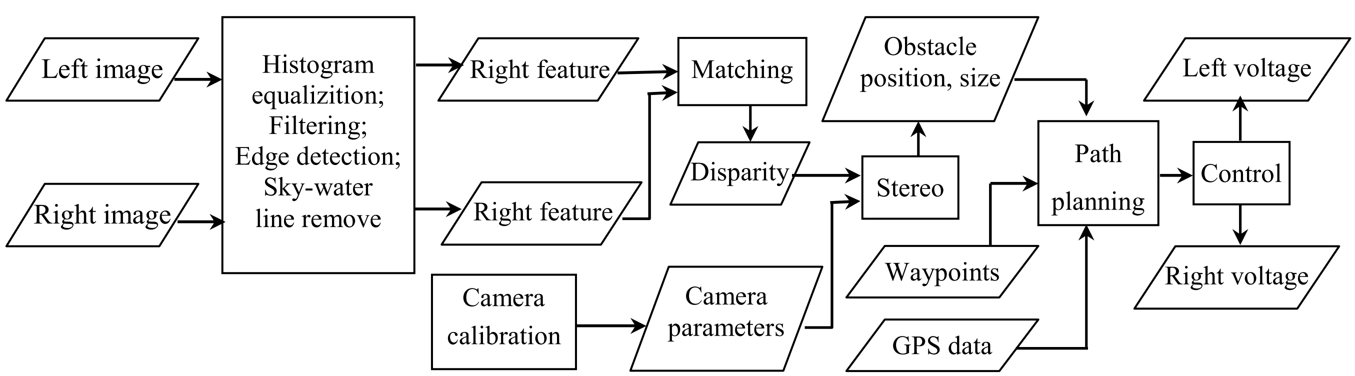
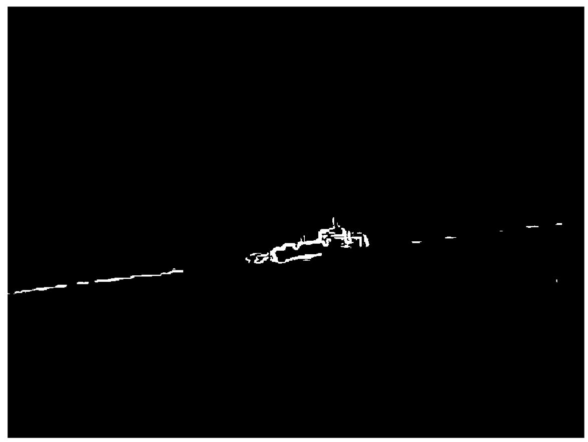


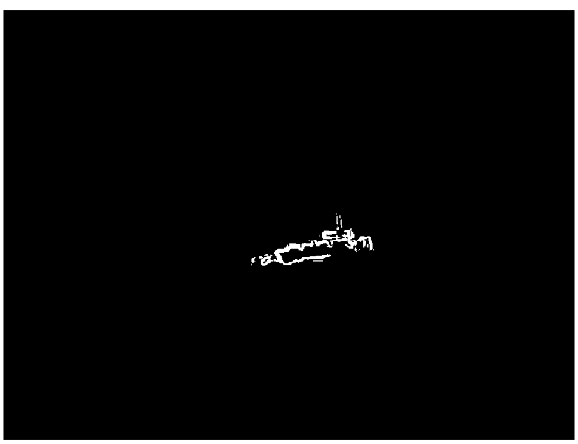
Figure 2. Software flow chart


(a)


(b)


(c)


(d)


(e)

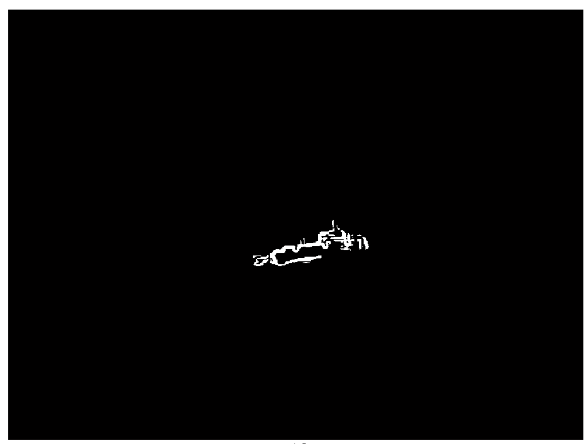

(f)

Figure 3. Image processing steps

(a) Left image; (b) Right image; (c) Left edge; (d) Right edge; (e) Left feature; (f) Right feature.

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Figure 4. Software interface of the stereovision system

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Figure 5. The scene of experiment

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