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Deep Drainage Detection System for Inland Vessels Based on Machine Vision

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Abstract

In order to prevent inland ships from overdraft, it is necessary to detect the draft depth of inland ships to ensure the safety of navigation. To design a river ship draught depth detection system based on machine vision, it collects accurate and comprehensive visual images of ships through image acquisition module, and provides industrial computer with reasonable detection methods to detect the draft depth of ships. The detection results are stored in the database and displayed in real time. The detection module is composed of FPGA and DSP hardware to realize the system detection process, communication and transaction, and the effective control of the terminal. When the inland water body is clear, the system uses the edge detection based draft depth detection method to effectively detect the ship draft depth. When the inland water body is turbid, the system uses binocular stereo vision three-dimensional detection method to measure the ship draft depth. The test results show that when the inland water body is clear, the error of the intake depth of inland ships detected by the detection system is ±0.05 m, and when the inland water body is turbid, the error of the system is within ±0.07 m. This shows that the detection system can accurately detect the intake depth of inland water body in clear and turbid conditions, and the test results are comprehensive and accurate.

Keywords: : Machine Vision, Inland Ships, Draft Depth, Water Clarity, Edge Detection, Binocular Stereo Vision;

1. Introduction

At present, due to the decline of water level in many rivers and the transitional cargo loading of shippers, the phenomenon of overdraft of inland ships is becoming more and more common. The phenomenon of overdraft of inland ships refers to the maintenance depth of ships beyond the waters, and the abundant water depth is insufficient to support the normal loading and navigation of inland ships. Overdraft of inland ships is very harmful, which will damage the structure of the ship itself, and the heavy load will lead to the overdraft of inland ships. Grounding or anchoring of a ship poses a threat to the lives of people on board. The management of ship overdraft behavior has always been a difficulty that has a special focus of inland waterway administration (Baigvand et al. 2015). It is difficult to grasp the actual draft condition of a ship by checking the ship’s water gauge or measuring the actual draft in the cabin. This makes it difficult to manage the phenomenon of ship’s over-draft. It makes it difficult for the channel administrators to obtain evidence of ship’s over-draft. Owners usually argue and deny and refuse to compensate for the loss caused by the channel. How to design an effective ship draft depth detection system to detect and stop the phenomenon of ship over-draft in time is the problem that the waterway administrators need to solve. After the over-draft ship destroys the waterway, the waterway administrators can truly and accurately grasp the actual information of the ship draft and obtain the evidence of the ship over-draft (Prez et al. 2016).

Inland watercraft draft depth refers to the depth of inland watercraft immersed in water. It is a very important parameter in the field of ship survey. It reflects the buoyancy of inland watercraft in the course of navigation, and uses it to reflect the ship’s drainage and cargo carrying capacity. By measuring the intake depth of inland ships, we can know whether there is over-draft phenomenon in inland ships or not. It is convenient for the Inland Ship Administrators to control the phenomenon of over-draft, and it also ensures the personal safety of the staff on board. At present, the detection of intake depth of inland ships is mainly based on manual detection, which mainly draws the intake line on the hull surface to get the intake depth. According to the intake depth, it can be judged whether the ship has over-draft phenomenon or not. In the measurements, the ship needs to be ashore, and the relevant staffs are on board to observe the intake line. This way cannot be separated from manual operation. In order to detect, it is necessary for ships to go ashore, which affects the normal navigation of ships and reduces the efficiency of ships. At the same time, because the ship draft detection line is exposed to the outside, it is eroded by river water, and it becomes ambiguous, which affects the accuracy of manual detection. Moreover, the artificial detection method is greatly affected by weather, and often affects the detection results when the surface wind and waves are large. This method also has one of the biggest drawbacks, that is, the ship’s draught line can be modified artificially, which

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makes it difficult for the staff to judge whether the ship is in over draught state (Keenan et al. 2015). Therefore, a new detection system is needed to detect the draft depth of inland ships (Li et al. 2015; Bhatt & Pant 2015).

In recent years, with the rapid development and wide application of image processing technology, machine vision has been widely used. Because machine vision has the advantages of non-contact and high efficiency, most scholars adopt machine vision technology to detect the draft depth of inland ships, such as designing a system based on gradient amplitude extraction to detect the depth of the ship’s draft line, and tracking code based on color image segmentation. Some scholars use HIS spatial color gradient and heuristic edge extraction algorithm to design a system based on gradient amplitude to extract water lines. However, these systems have some defects. In the process of detection, the above systems select ideal high-definition images, and the scratches on the surface of the ship are small, not natural fields. The general model in this scenario is only suitable for theoretical research under laboratory conditions, but lacks a practical ship draft line detection system (Qureshi & Payne 2016). Chen et al. proposed a draft detection system for inland water vessels based on multi-beam sonar sounding system. Based on sonar ranging technology, the design draft for inland river ships in testing system, complete test system software architecture design and communication protocols, multi-beam sonar sounding system adopting multi-beam sonar sounding data filtering de-noising algorithm filter abnormal data, the system realized the ship draft outline clear and accurate imaging, and digital, real-time display of ship draught, feasibility for inland river ships draft regulation control to a certain extent, but the system exist draft depth, but it has problems in practice, however, it is difficult to promote (Chen et al. 2016). Lu et al. designed a lower computer system based on STM32 and FPGA dual-core structure and an upper computer early-warning software system based on MFC. Based on the propagation model of underwater ultrasonic wave and the diffraction effect of ultrasonic wave, combined with the real-time water level variation information, this system collects the lattice sequence of the draught of navigable ships, and finally calculates the draft depth of navigable ships, but the detection error of this system is large (Lu et al. 2017). Wu et al. proposed a method for ship draft detection based on differential scanning with dual sonar probes. On the basis of detailed analysis of ship curved contour shape, using double differential scanning sonar sensor technology, detection of important mathematical model is set up, on this basis to design a ship draft detection system, the implementation of inland ship draught detection, but the system is too simple, the existence question of error detection (Wu et al. 2017).

From the point of view of machine vision, this paper designs an inland ship draft depth detection system, which can accurately detect the inland ship draft depth when the inland water body is clear and when the inland water body is turbid. It is widely used and it is applied to the actual ship draft depth detection. This system mainly fills the blank of using machine vision to detect the depth of ship's draught, and is also a further extension of the application scope of machine vision, which has certain applicability and reliability.

2. Materials and methods

2.1. System architecture

The intake depth detection of inland ships based on machine vision is mainly composed of the following modules: image acquisition module, image processing module, detection module, human-computer interaction module and result storage module. The system can not only reflect the characteristics of human recognition of single frame waterline, but also replace the human brain to analyze the results of the waterline. The image acquisition module is similar to the human eye, which obtains the ship draft image and initializes the camera with Opence. The image processing module is equivalent to the human brain nerve, which is used to think, calculate and solve problems. The main functions of the image acquisition module are preprocessing, image denoising, ROI positioning, edge detection or projection positioning, etc. The detection module determines the ship draft line in several wave cycles. The detection module mainly detects the image processed by the image processing module (Goren et al. 2017). Human-computer interaction module is equivalent to human subjective consciousness. After receiving comprehensive information, the final action and decision are made. The results are displayed to users in the form of human-computer interaction, which is convenient for users to observe. Storage module accesses and verifies the current recognition image. The architecture of the detection system is shown in Figure 1.

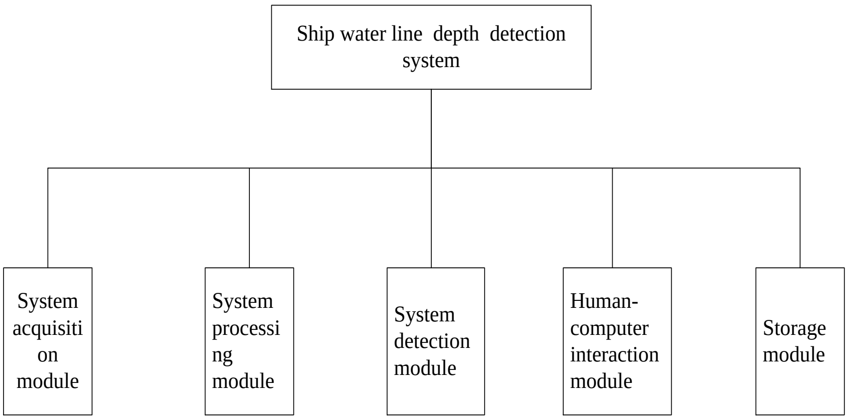


Figure 1. Test system architecture

2.1.1. Image acquisition module

The structure of the image acquisition module in the system is described in Figure 2. From Figure 2, it can be seen that the light source, lens, industrial camera and so on are the important components of the module.

In the image acquisition module, three industrial cameras are set up to acquire accurate and comprehensive visual images of ship draft. The industrial cameras are placed in the same two-dimensional plane perpendicular to the detected ship. When the image acquisition module collects the ship draft image, the encoder rotates with the guide wheel driving, the pulse counter card receives the signal transmitted by the encoder, and the related parameters of the detected ship are stored in the counter card. The counter card sends the trigger command to the camera after running a frame of the image. After the camera collects the image data of the ship draft image, it is provided to the industrial control computer and the reasonable detector is adopted. The method implements the detection of ship draft depth, and the results are stored in the database and displayed in real time.

2.1.2. Detection Module

This system uses machine vision technology to realize intake detection of inland ships. Machine vision technology is a technology that converts the signal to be measured into image signal by image sensor, and uses special image processing system to process the image signal pertinently and recognize the undetermined results automatically (Haase et al. 2016; Yan 2015). At present, on-line machine vision inspection has become an important part of ship draft depth detection, which has great economic and social benefits. With the development of high-speed image sensor, high-speed DSP and highly integrated FPGA, the technology of high-speed online machine vision is becoming more and more perfect (Zheng et al. 2015). Based on machine vision detection technology, the system designs a depth of draft detection module for inland ships. The principle is shown in Figure 3.

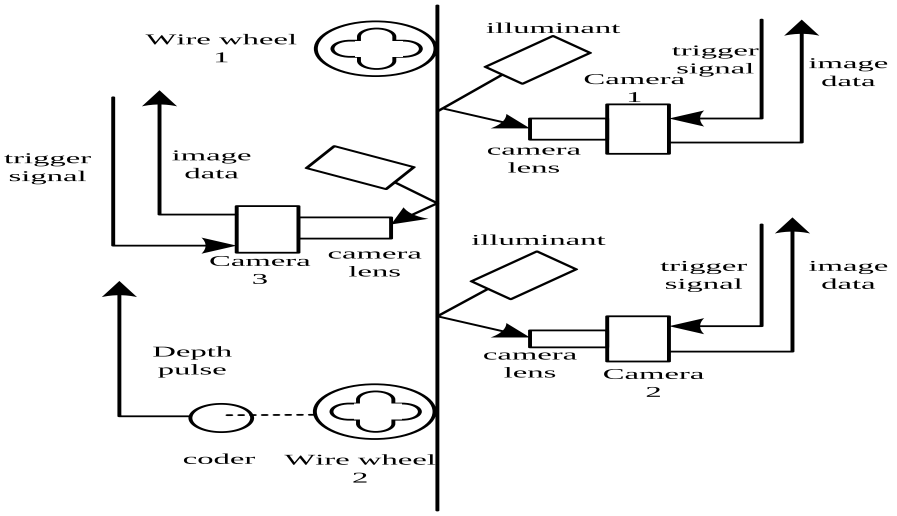


Figure 2. Image acquisition module structure

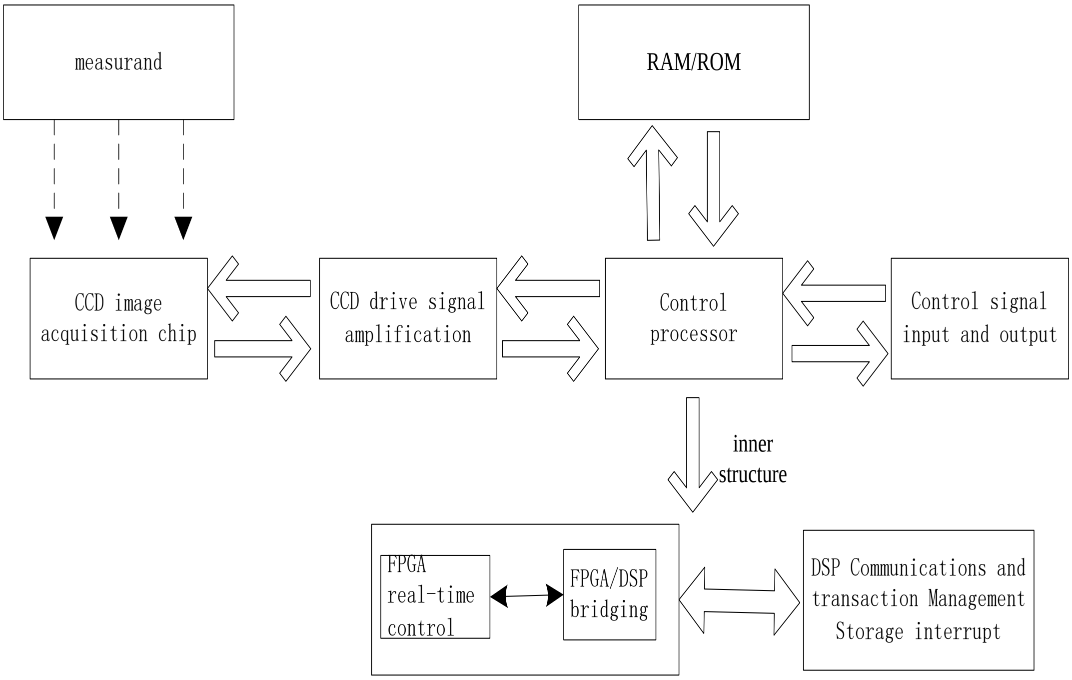


Figure 3. Detection principle of testing system

The core part of the detection module is composed of the hardware of FPGA and DSP. The real-time control of the system is carried out by the FPGA, and the core algorithm is realized. The complex algorithm is completed through the communication, transaction management, storage and terminal management of the DSP with pipeline operation and efficient data processing ability. The bridge connection between the FPGA and the DSP is used to realize seamless connection and improve the efficiency of the system.

2.2. Inspection of inland watercraft drainage depth based on machine vision technology

2.2.1. Method of inland vessel drainage depth detection based on edge detection

Based on edge detection, the position of intake line of inland ship is obtained, and the intake depth of inland ship is calculated by intake line. When the water body of inland river is clear, transparent, bright and the water line state is relatively flat, it is easy to get the target edge by direct edge testing. In order to ensure the extraction of the target water line, it is necessary to obtain as much image gradient information as possible. Therefore, the detection system uses image global information, because histogram technology is an important means of image enhancement, and histogram technology should be adopted. The method corrects the gray level of the image, enlarges the dynamic contrast range of the image, expands the contrast, makes the image clearer and has obvious features. It obtains the image with better effect after the correction. By using the difference of gray level characteristics between the object and background to be extracted from the image, the horizontal gradient information of the whole gray level image is detected according to the direction of Sobel operator, and the appropriate threshold is selected. The image is divided into meaningful regions, and the target is extracted from the image for further analysis (Khalili & Vahidnia 2015). Then the binary image is obtained by Hough line, and the longest line is detected. The midpoint of the detected line is taken as a horizontal line, that is, a single frame draft line, and the draft depth is obtained according to the known draft line.

Firstly, the edge detection of the segmented image is carried out. The commonly used operators of edge detection include Rebort, Sobel, Guass and Canny operators. In view of the comprehensive consideration of edge orientation and sensitivity to interference (Howarth et al. 2015), this paper mainly applies Sobel edge segmentation. Sobel detection operator is an algorithm that uses the adjacent points of the pixel points to obtain gray weights, which mainly depends on the direction of the detection edge and the sensitivity to interference (Howarth et al. 2015). According to the principle that the gradient at the edge points reaches the extreme value, the following equations are needed for edge detection.

$$f_x(x,y) = f(x+1,y-1) + 2f(x+1, y) + f(x+1,y+1) - f(x-1,y-1) - 2f(x-1,y) - f(x-1,y+1) \quad (1)$$

$$f_y = f(x-1,y+1) + 2\mathrm{f}(\mathrm{x},\mathrm{y}+1) + f(x+1, \mathrm{y}+1) - f(x-1,y-1) - 2f(x,y-1) - f(x+1,y-1) \quad (2)$$

$$g(x,y) = | f_x | + | f_y | \quad (3)$$

The Sobel operator template is shown as follows:

$-f_x$	f_0	f_x
$-f_{x+y}$	$g(x,y)$	f_{x+y}
$-f_y$	f_0	f_y

Figure 4. Sobel operator template diagram

Through the above template which detects the draft line, and according to the test results, it can be seen that the introduction of local average value in the algorithm has little impact on noise. Sobel operator is an algorithm with high detection continuity, and can also detect the details of the image very well. So when the inland water surface is calm and the water line is straight, the Sobel detection line along the X direction can often achieve the detection purpose.

The purpose of edge detection is to identify the points with obvious gradient change in gray image. When these points are adjacent and have similar directions, special edge line segments can be constructed by using detection algorithm, but these detection lines are not completely required waterlines. After the detection of scratches and exposure edges of inland river hulls, pseudo-edges will be generated, and some constraints need to be added. At present, Hough transform is the most effective method for line detection. Its advantage is that it is easy to transform geometric figures quickly and efficiently. In the plane rectangular coordinate (x-y), the linear equation can be expressed as y=kx+ b.

For a fixed point (x_0, y_0) on a straight line, there is a definite equation $y = kx_0 + b$, which represents a straight line in the parameter plane (kx-b). Therefore, a point in the image needs to correspond to a sinusoidal curve in the plane. For all points in the image, Hough transform is used. The final line to be detected must correspond to the point groups where the lines intersect in the parameter plane. The parameter equation $p = x\cos\phi + \mathrm{y}\sin\phi$ is usually used to detect the exact position of the intake line of inland ships and get the intake depth of inland ships. However, this system is only suitable for transparent water, i.e. bright water line and relatively flat water line condition.

When the water body is turbid and unstable, that is, the clarity of the water body is not high, the fluctuation of the water line is large, and the brightness of the water line is reduced, it is difficult to detect the draft depth of inland ships by edge detection and Hough transform (Yang et al. 2015). At this time, the detection system uses binocular stereo vision three-dimensional detection method to detect the intake depth of inland ships.

2.2.2. Three-dimensional detection method of binocular stereovision

Binocular stereo vision system is used to detect ship heave. The draft depth of the ship is determined mainly according to the relative position distance between the supply ship and shore base. Two cameras, a computer (or DSP system) and a characteristic object are used in the binocular stereo vision three-dimensional measurement. The binocular camera of the system is fixed on the crane boom. When installed, the optical axis plane of the two cameras is perpendicular to the horizontal plane. Characteristic objects are placed near the landing point of the cargo on the replenished ship. The relative position between the camera and the characteristic objects can be detected by the binocular stereo vision three-dimensional measurement and detection system (Cheng et al. 2015; Zhou et al. 2015), and the relative height can be obtained. In order to facilitate image processing, the system uses the feature object as a circular color block. The principle of three-dimensional measurement of ship heave by binocular stereo vision is shown in Figure 5. The left camera O-xyz is located at the origin of the coordinate system without rotation, the image coordinate system is Ol-XlYl, the effective focal length is fl, the right camera coordinate is Or-xryrzr, the image coordinate system is Or-XrYr, and the effective focal length is fr.

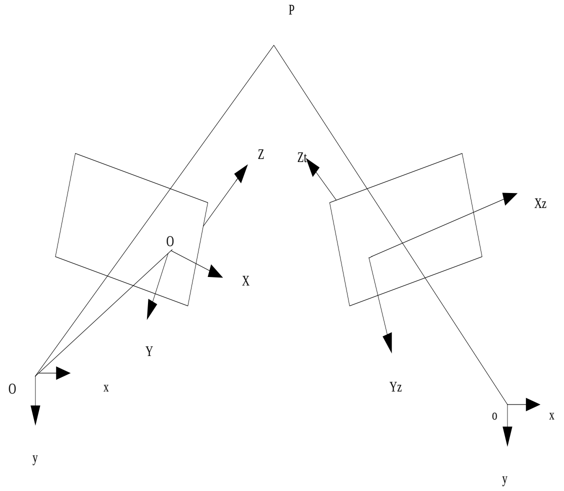


Figure 5. Three-dimensional reconstruction of spatial points in binocular stereo vision measurement

For the same characteristic point P in the process of ship heave, the three-dimensional coordinates of the two cameras are Pl=(Xl, Yl) and Pr=(Xr, Yr), respectively. Then the three-dimensional coordinates of the space P point can be expressed as follows:

$$\left\{\begin{aligned} & x = zX_t / f_t \\ & y = zY_t / f_t \\ & z = \frac{f_t(f_\mathrm{r}\,\mathrm{t}_x - \mathrm{X}_r\mathrm{t}_z)}{X_r(r_7X_l + r_8Y_l + f_1r_9) - f_r(r_1X_l + r_2Y_1 + f_lr_3)} \\ & = \frac{f_t(f_\mathrm{r}\,\mathrm{t}_x - Y_r\,\mathrm{t}_z)}{Y_\mathrm{r}(r_7X_l + r_8Y_l + f_1r_9)\ \text{-}f_r(r_4X_l + r_5Y_1 + f_lr_6)} \end{aligned}\right\} \tag{4}$$

The space transformation matrix between O-xyz coordinate system and Or-xryrzr coordinate system is Ml:

$$M_{\mathrm{lr}} = [R\,T] \tag{5}$$

$$R = \begin{bmatrix} r_1 & r_2 & r_3 \\ r_4 & r_5 & r_6 \\ r_7 & r_8 & r_9 \end{bmatrix} T = \begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix}$$

R and T are rotation matrices and translation vectors between O-xyz coordinate system and Or-xryrzr coordinate system respectively. By calibrating R and T parameters, the actual coordinate position of P point can be obtained according to the output result of image processing. When the left and right cameras are installed in the detection system, because the optical axes of the two cameras intersect and the plane formed is perpendicular to the plane of the two cameras' images, Or-XrYr rotates θ angle around the Y axis on the basis of coincidence with the O-xyz system and moves to (tx, tz) on the xz plane. If the rotation matrix is represented by Euler angles, the following R and T can be obtained.

$$R = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{bmatrix} T = \begin{bmatrix} t_x \\ 0 \\ t_z \end{bmatrix} \tag{6}$$

In the binocular ranging system, image processing is the key. The image processing methods are as follows: after the binocular camera obtains the image, in order to make the target feature color block stand out, the image is first enhanced for the characteristic color, and the difference of the image pigmentation value is widened as far as possible (Boss et al. 2017). At the same time, in order to save time and space for subsequent image processing, the color image is converted into gray-scale image, and then binarized. Then, the image is filtered by median filter, the discrete solitary points are removed, and some blank points in the target are repaired. Finally, in MATLAB, the centroid method of region description sub-region is used, that is, the function regionprops (L,'Centroid'), L is the image matrix, and Centroid is the image matrix. The X and Y coordinate vectors of the center of mass of each color block can be obtained from these vectors. According to the maximum area of the feature block, the coordinates Pl= (X_1, Y_l) and Pr= (X_r, Y_r) of the target feature block point in the left and right plane images can be obtained. By substituting X_1, Y_1, X_r and Y_r into the calibrated binocular ranging equation, the spatial coordinates (X, Y, Z) of the target point can be obtained, which directly reflects the relative vertical distance Z between the replenishment vessel (or shore base) and the replenished vessel, i.e. the heave of the Inland vessel, and thus the draft depth of the inland vessel can be obtained. The specific steps are shown in Figure 6.

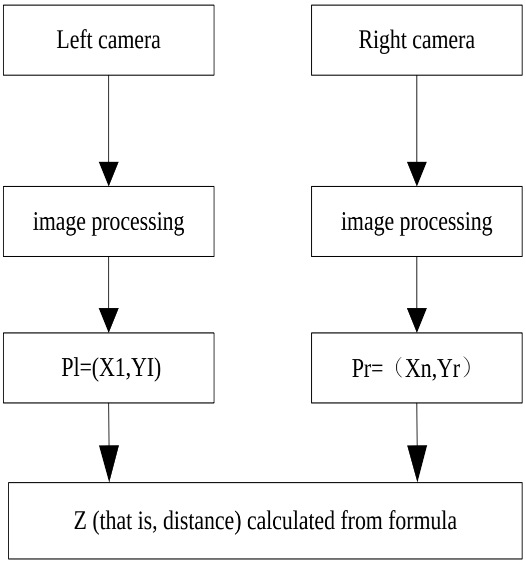


Figure 6. flow chart of system data processing

3. Results

In order to verify whether the detection system in this paper can get the depth of intake line of inland ships for practical needs or not, the detection effect of this system is as follows: if the actual intake depth of an inland ship is detected by video tape, the depth of intake of the ship is detected under clear and turbid conditions, the visual field is 22 s, the frame number is 25 f/s, and the resolution is 720×576 (16: 9). The hardware environment of the experiment is intel pemtium. 73 GHz, Windows XP, 1GB memory PC, and software platform: The program is written by using OpenCV visual algorithm library in the environment of VC6.0.

The inland waterway vessel is a 2500-ton inland waterway bulk carrier with a length of 94.57m, the molded breadth of 16m, the moulded depth of 6.2m, maximum loading capacity of 2476 t and speed of 21km/h. The wave height of this test section is 0.5m-1.5m, which corresponds to the level 4 of beaufort wind, and the velocity on the beach in the navigation area is below 3.5m/s. The visual image of the ship is shown in Figure 7.

3.1. Deep drainage line of inland ships based on edge detection

3.1.1. Edge detection, geometric correction experiments and result analysis

When the water body of the inland river is clear, the gray level of the forecasted draft image of the experimental ship needs to be processed when the detection system is used to detect the edge. Histogram technology can treat the gray level of the image as a random number set. The gray level of the image can be modified by histogram to improve the visibility of the image and the contrast of the image while brightening. Thus, the experimental image can be processed. Histogram processing, as shown in Figure 8, can be seen that each histogram shows obvious double peaks, and the minimum gray level is selected as the threshold for effective image segmentation.

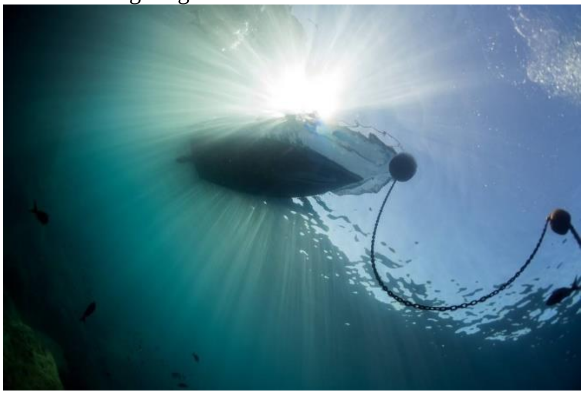
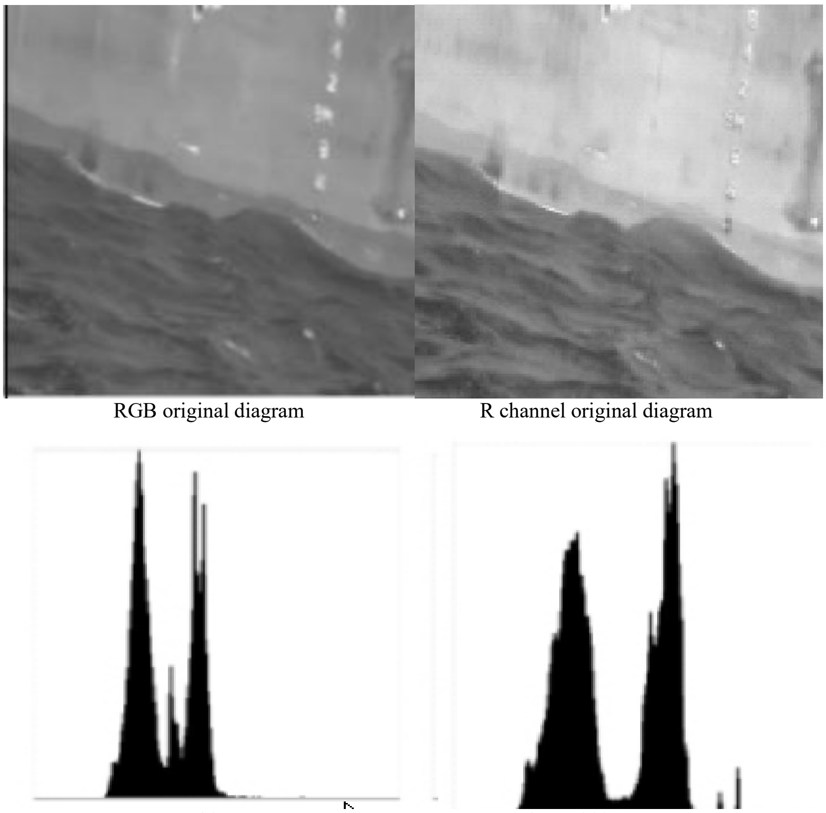


Figure. 7 Visual image of ship



RGB original diagram R channel original diagram

RGB histogram R-channel histogram

Figure 8. Image cut space selection

The aim of smoothing before edge detection is to improve the signal-to-noise ratio of ship draft image and eliminate noise interference. After verification, Sobel operator is the best edge detection operator. It uses the Gauss filter to smooth the edge. The Gauss filter is a low-pass filter. It can suppress the higher frequency signal, so it can reduce the interference of false edge points. In addition, Sobel operator detects the edges of pixels through edge connection to ensure the integrity of edges. After many experiments, it is found that when the double threshold of Sobel operator is (18, 54), edge detection is the best. After edge detection, it cannot be determined whether the obtained waterline is a real waterline. Hough transform is needed to transform it to get the exact waterline.

3.1.2. Hough transform, drainage depth determination experiments and result analysis

The binary image of a single frame image is obtained by Hough transform, and the current draft value is obtained from the suspected water line for detecting the draft depth. The draft line is determined based on the algorithm of converting the curve into a straight line, and then the draft depth is detected. Traditional draught line detection is based on least squares method, but the actual use of least squares fitting is a regression method, processing efficiency is slow, its shortcoming is that if there are some errors deviating from larger points, it will affect the overall fitting effect, resulting in inaccurate detection of draught depth. This detection system uses a method based on edge detection of draught depth detection, according to binary images. The projection is used to determine the draft depth of a single-frame water scale image. The total number of white pixels in each row is counted. The ratio of bright pixels to the total number is set as a threshold to determine the final draft depth of a single-frame image, as shown in Figure 9.

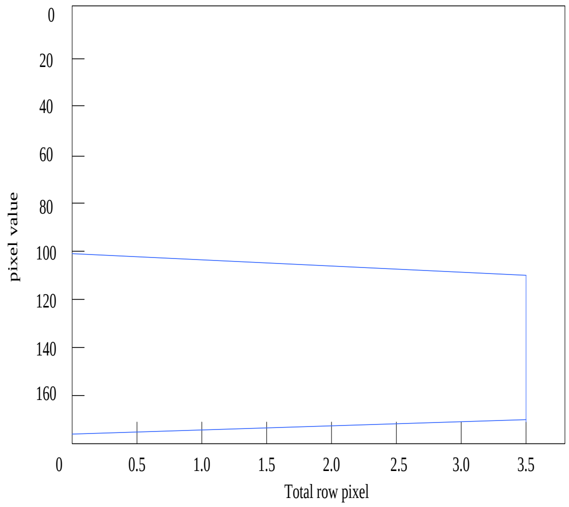


Figure 9 . Horizontal projection graph of bright Pixels

According to Figure 9, the number of pixels after projection of binary image is approximately straight line. When the threshold is set to 50% of the total line pixels, it is exactly the center of the vertical coordinates of the oblique line. Since the first detected draft line may be caused by noise such as scratches on the ship's surface, the horizontal line of the line is fixed as a suspected draft line, and the suspected draft line is scanned downward to check the suspected draft line. If the statistical proportion of continuous bright pixels is more than 50%, the suspected draught line is determined as a single frame draught line. Otherwise, the detection of the frame is invalid. Then it is tested. The results of manual observation and experiment are compared, the error is calculated as follows:

$$k = f - z \tag{7}$$

Where, f represents the detect draft depth, z represents the actual draft depth.

The experimental error is shown in Table 1.

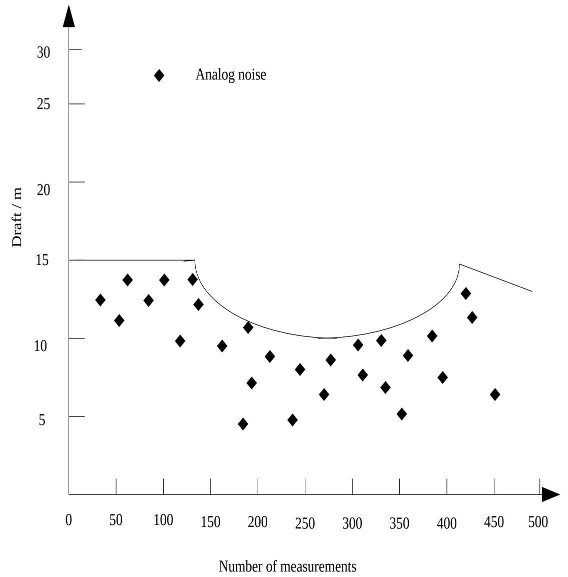
Table 1. Experimental error Analysis

number of times	Detect draft depth/m	Actual draft depth/m	Error/m
1	4.28	4.26	0.02
2	3.13	3.13	0
3	4.47	4.45	0.02
4	2.49	2.30	-0.01
5	4.17	4.18	-0.01
6	3.43	3.45	-0.02
7	4.77	4.76	0.01
8	2.89	2.90	-0.01
9	3.65	3.66	-0.01
10	4.23	4.22	0.01

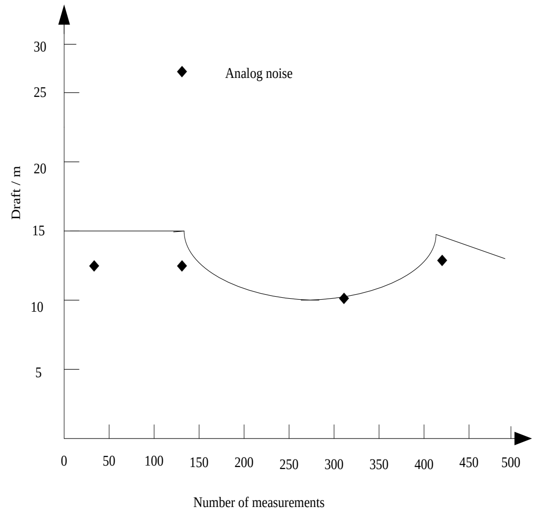
By comparing the measured data and calibration values, it can be concluded that when the water body of the inland river is clear in the experiment, the error of the draft depth value of inland ship detected by the detection system in this paper is ±+0.05m, which meets the detection requirements. It can be seen that the edge detection method used in this detection system has low error and high accuracy in actual draught line monitoring. To determine the draught depth through the draught line is of great significance to the measurement of the draught depth, and can meet the needs of actual detection.

3.2. Binocular ranging experiment

When the inland water is turbid in the experiment, the effect of the binocular stereo vision three-dimensional detection method used in this system to detect the draft depth of ships is tested. For discrete abnormal data, the median filtering algorithm is used to simulate the ship draught profile and discrete jump data. The simulation steps are divided into three steps. Firstly, the horizontal line and sinusoidal curve are used to simulate the water surface and ship draught profile respectively. Secondly, the uniformly distributed random number is added to simulate the noise. Finally, the median filtering method is applied to deal with the abnormal data. After eliminating a large amount of noise, the input is obtained. The filtered image is shown in Figure 10.



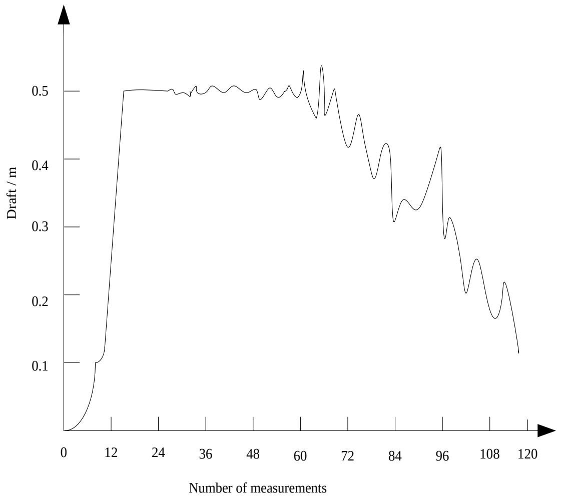
(a) Simulation of ship draft profile before filtering



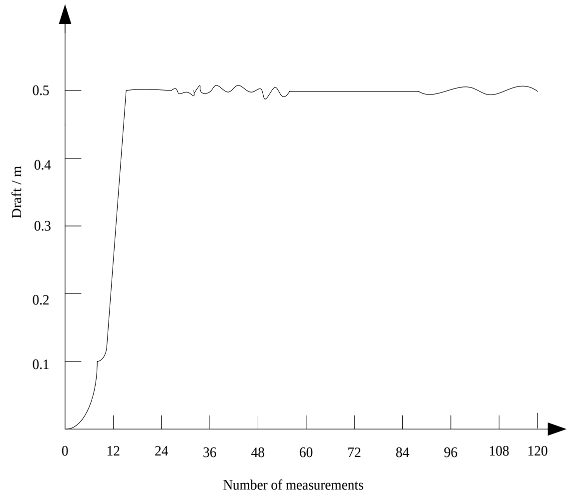
(b) Simulation of ship draft profile after median filtering

Figure 10. Effect of median filter on removing discrete jump anomaly data

From the simulation results of the median filtering algorithm presented in the above figure, it can be seen that the median filtering has good filtering effect on random noise generated in ship draught imaging. The features of the continuous jump abnormal data are concentrated and continuous, and generally distributed in the stern of the ship. The median filtering and other algorithms for random noise are not suitable. For this feature, the curve should be fitted according to the normal data and the abnormal data should be fitted. The centralized area is forecasted, but machine vision technology is used to detect the ship stern according to the image. When detecting the stern, the detection data are all abnormal data. There is no normal data to fit and predict. The least square method is needed to fit and forecast the normal data. The results are shown in Figure 11.



(a) Filter front



(b) After filtering

Figure 11. Least square fitting

The results of anomaly data processing are shown in Figure 11, Figure 11(a) is the continuous jump anomaly data, and Figure 11(b) is the normal data after fitting prediction. It can be seen that the least squares fitting prediction data used in this detection system can effectively identify the continuous anomaly data and obtain the normal data segment.

Based on the normal data of the minimum binary fitting prediction, the experiment of detecting the draft depth of inland ships is carried out. The experimental ships are tested systematically. The feature color blocks are placed in different directions (i.e. space coordinates X, Y) and different distances (i.e. space coordinates Z) of the experimental ships. After obtaining the image coordinates Pl (X_1, Y_1) and Pr (X_r, Y_r) captured by the left and right cameras, the feature points are captured by using MATLAB. After processing, the vertical distance Z from the feature point to the camera can be calculated, as shown in Table 2.

Table2. Detection of draft depth

Number of times	Detect draft depth/m	Actual draft depth/m	Error/m
1	1.39	1.45	-0.06
2	3.22	3.16	0.06
3	4.02	4.27	-0.07
4	4.29	4.28	0.01
5	3.31	3.29	0.02
6	4.31	4.30	0.01
7	2.28	2.31	-0.03
8	3.37	3.32	0.05
9	4.35	4.33	0.02
10	4.32	4.34	-0.02

From several sets of data in Table 2, it can be seen that when the inland water body is turbid in the experiment, the difference between the detection distance and the actual distance of this system is small, all within the range of ±0.07 m. That is to say, the error between the actual depth of intake and the binocular stereo vision is relatively small, which can measure the actual depth of intake of inland water vessels well. Therefore, binocular stereo vision three-dimensional measurement detection is used in practice. The intake depth of inland ships is maneuverable and accurate, which is superior to manual detection method and reduces the difficulty of detection for ship administrators.

4. Discussions

As a means of transportation, ships play an important role in the transport industry. Drainage depth of inland ships is an important measurement parameter. The actual draft depth of overdraft phenomenon is 5.5m, so no overdraft phenomenon was found during the test in this paper. However, accurate detection of draft depth will reduce the occurrence of overdraft phenomenon, which is conducive to the claim of ship for channel damage, and effectively protect channel resources and smooth channel. At the same time, it can also protect the ship in the normal state of navigation, reduce navigation resistance, and is also an important measure of energy saving and emission reduction. From the point of view of machine vision, this paper designed system overcomes the drawback of traditional artificial observation, get rid of the subjectivity of manual reading scale value, due to the flow speed and reduces the error caused by manual measurement, avoid the water flow rate on the measurement results of adverse effects, improves the accuracy of measurement, obtain more accurate testing data of ship draught.

In this paper, through a lot of research, combined with the convenience of the actual scene and the requirement of sampling stability, according to machine vision technology, the collected images are analyzed. According to the different clarity of river water body, the detection method of inland ship draft depth is designed. For transparent water body, when the water line is bright and smooth, the global image edge detection and Hough line detection are used. Firstly, the S-ray method is used. The experiment shows that when the double threshold of Sobel operator is set at (18, 54), the value obtained by edge detection is the most rational. The suspected waterline can be obtained by edge detection. In order to determine the waterline, Hough transform should be used to get the binary image of a single image. The total number of white pixels in each line is counted and the proportion of bright pixels is set. From the results, we can see that the statistical proportion of continuous bright pixels is more than 50%, and the suspected draught line is determined as a single frame draught line. Then we compare and analyze the difference between the actual inland ship draught depth and the experimental results. Through the above error analysis, we find that the error value of the two is 0.001m. The error requirement is far less than the expected ±0.01m. It can be seen that the edge detection method used in the detection system in this paper can meet the needs of actual detection because of the low error and high accuracy of the actual draft line of the detected ship in the case of clear inland waters.

Aiming at the turbid inland river water body, i.e. the clarity of the river water body is not high, the water line fluctuates greatly and the brightness of the water line is low, so we should use binocular stereo vision three-dimensional measurement method to detect the draft depth of the ship. Firstly, the abnormal data are filtered, and the horizontal straight line and sinusoidal function curve are used to simulate the water surface and the draft profile of the ship respectively. Secondly, the uniformly distributed random number is added to simulate noise. Finally, through median filtering and output filtered image, it can be seen from the output filtered image that the noise generated in the process of ship draught imaging is greatly reduced, that is, median filtering has good filtering effect on random noise generated in the process of ship draught imaging. Least squares are used for regression prediction and fitting processing of information. It is found that after fitting, the connection can be effectively identified. Continuous anomalous data have little influence on the normal data section. Finally, the experimental prediction of the intake depth of inland watercraft is obtained through the processed data. Compared with the actual intake depth of the ship, it is found that the error between the two is relatively small, fluctuating up and down ±0.1m, and is close to the actual intake depth of the ship. Therefore, when the water body fluctuates greatly, binocular stereo vision three-dimensional measurement is adopted. It can detect the draft depth of the ship very well.

In this paper, machine vision technology is used to detect the draft depth of inland ships. It can not only accurately detect the draft depth under normal conditions, but also has strong applicability to exposure, scratches on the surface of the ship, and the location of the water trace is not obvious. The detection system in this paper has good prospects for popularization and application in inland river lock, diving controlled channel, port and load reduction base areas where strict control of ship draught is needed. Especially for the design of artificial structures with clear draught control standards, such as ship lock and lift, it plays an important role in ensuring the safety of facilities and smooth navigation.

5. Conclusions

In this paper, according to different river water conditions, different theories are adopted to design the inland ship draft depth detection system, so that the ship managers can efficiently and accurately detect the ship draft depth, and can timely detect the phenomenon of ship over draft, so as to avoid the danger to the river course and the staff on board. In this paper, the detection system uses machine vision technology to realize the high-precision detection of the draft depth of inland river vessels under clear and turbid water conditions through the detection method of draft depth based on edge detection and binocular stereo vision three-dimensional detection. It provides an important reference for real-time monitoring and early warning of ship draft, and reduces the occurrence of ship grounding, antennae and other safety accidents. The safety of ships and waterways is of great significance to the shipping industry.

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