Structure design and simulation analysis of the water surface cleaning robot

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Abstract. In order to effectively carry out water management and reduce people's labor intensity, a double-hull water surface garbage cleaning robot is designed, using a pair of adjustable speed pump propellers to provide driving and steering power to the robot. It identifies the water surface garbage position through the binocular camera and algorithm, and the linkage mechanism is designed to complete the garbage pickup function. Through the Raspberry Pi as a controller, the robot has an autonomous intelligent recognition function and an autonomous recovery system. The kinematic simulation analysis shows that the robot garbage picks quickly and accurately; through the prototype function test, the robot is suitable for various complex water environment, with high operation efficiency and reliable performance, and can be widely used in water management.

1. Introduction
Water is one of the necessary resources and important environment for people's survival. It is the indispensable material basis for the survival and development of people and all organisms. With the development of the times, the water surface pollution is more serious, but at present, China is mainly cleaned by manual salvage. Although the cleaning quality is high, the work efficiency is low, the work intensity is high and the environment is bad. So far, water transportation has become the first important way for people to transport. In recent years, the quality of national water sources has been declining and the water surface pollution is serious. Therefore, many passing ships are entangled by garbage, and propeller accidents occur frequently, resulting in more losses in economy and seriously threatening the sustainable development of society. Due to the large amount of garbage on the water surface, the water pollution is the most serious. The pollution leads to the stench of the water body, and the sewage directly endangers the safety of people's drinking water; Crop sewage irrigation leads to the decline of yield and quality and soil pollution; The aquatic ecosystem has also been persecuted in a large area, resulting in a large number of marine organisms on the verge of extinction. Agriculture, fishery and industry have been seriously affected and restricted economic development. Its pollution is mainly reflected in the water surface. Aiming at the problem of water surface environmental pollution, the water surface waste cleaning robot is committed to the cleaning of floating solid waste in small and medium-sized lakes, rivers and other waters, such as plastic bags, beverage bottles, straw, surface vegetation, branches and leaves, dead floating animal bodies and other easily cleaned water surface.
waste. The floating garbage on the water is salvaged from the water surface and transported directly or compressed to the garbage treatment plant for treatment.

At present, there are research precedents at home and abroad. The "trash cat" series cleaning ship developed by UMI company of the United States, the "dolphin" cleaning ship developed by globeco company of Italy [1], and the a series 1010 cleaning ship developed by Pelican company of Canada adopt the single hull ship type, which has the functions of cleaning garbage on the water surface, oily water treatment, aeration and fire prevention. The main working machines and tools include collection bins, garbage bins, oil-water separation equipment, oil tanks, air-jet aeration devices and fire water guns. In recent years, China has gradually independently developed a highly efficient automatic surface garbage salvage ship. The surface floating object fishing ship developed by Shanghai waste disposal company adopts the catamaran type and the fishing device adopts the form of conveyor belt for the purpose of continuous operation of diversion, fishing, compression, storage and transportation. Mechanized operation is realized from salvage to transfer, which reduces the labor intensity of workers. It is applicable to various large-scale water environment operations. "Qingpiao 1", developed by CSIC 701, adopts a double ship structure and uses many advanced technologies and equipment. It is huge and expensive [2]. "Light of the century" developed by Shanghai Water Environment Development Co., Ltd. is the first new water surface cleaning ship with self intellectual property rights in China. The motor driving device is controlled by embedded technology. It is equipped with wireless navigation Internet device, GPS positioning system and other equipment, with beautiful appearance [3]. The production price of the above ships is high, the volume is large, it is not suitable for small and medium-sized lakes, it can not be completely separated from manual operation, and the hull flexibility is small. In view of the above situation, it is necessary to design a new type of water surface cleaning machine suitable for small and medium-sized lakes and rivers, so as to improve the working intensity and working environment of workers. Therefore, a water surface cleaning robot is designed, which can operate independently and complete the large-area water work of small and medium-sized water areas. In order to make up for the shortcomings of the existing surface garbage cleaning machinery. It has great practical significance for ecological restoration, breaking away from manual operation, improving work efficiency, improving working conditions and reducing operation difficulty. Structural design of the water surface cleaning robot

2. Structural design of the water surface cleaning robot

2.1 General structure setting

The water cleaning robot consists of dual hull, box, rod, Raspberry pie, binocular, motor, battery, receiver, dual position sensor, cam vibrator, pusher, and slave reducer. It is mainly composed of four parts: dual-hull system, power unit, garbage identification unit, garbage collection unit and control unit. FIG. 1 is a brief diagram of the overall structure scheme of the water surface cleaning robot.

![Figure 1. Brief picture of the overall structure scheme of the water surface cleaning robot](image-url)
2.2 Structure and function principle
Figure 2 shows the schematic diagram of structure and function. The water cleaning robot completes the whole process of garbage cleaning through the cooperation of three systems. First, after identifying the garbage through the Raspberry Pi control binocular recognition system in the control system, the motor and the reducer can connect the remote link through the shaft to drive the robot to conduct the garbage collection work. The specific structural scheme is shown in Figure 1. The robot uses the motor driving water injection propeller as the driving unit of the robot, which effectively reduces the noise pollution and has a strong adaptability for the shallow water areas with low sediment; Use rod structure and net components as garbage collection unit; The Raspberry Pi binocular recognition system is used to identify, screen and locate the garbage, and can adjust the depth of the net into the water according to the specific situation of the water surface, so as to realize the salvage of different garbage in different waters. During the process of garbage collection, there will be a accumulation state. By setting the specified time, the vibration device will open the garbage to complete the uniform distribution. The garbage collection box is equipped with the gravity sensing device to replace the garbage in the box. When the garbage is full, the boat will be returned and the garbage can can be replaced.

![Figure 2. Schematic diagram of structural function](image)

2.3 Proof principle
The power unit is mainly divided into battery, water spray thruster and reducer. In Fig. 3, the battery provides power for the motor of the water garbage cleaning robot, the motor powers the garbage collection device, and the water spraying propulsion device pushes the robot forward for [4]. The reverse baffle can reverse water flow to achieve reverse driving purpose.

![Figure 3. Brief diagram of water jet propeller structure](image)
2.4 Design of garbage collection unit

The garbage collection system is mainly composed of linkage mechanism and mesh parts (Figure 4). Powder by the drive motor, transmit power to the rocker arm through the coupling, allowing the mesh to move along a predetermined trajectory. When the net is directly below the garbage, the link will reverse turn, bring the net and the garbage above the garbage collection box, pull the collection box handle by the tank wheel, and then the handle will fall down, the chain turns to open the mouth of the collection box. Garbage collection will begin after the opening of the garbage collection box is completed. After full collection, guide the chain to turn, complete the collection box return and replacement, complete the collection and treatment of garbage.

![Figure 4. Brief diagram of garbage collection system structure](image)

1. Motor coupling 2. Shake arm 3. Connection rod 4. Lift frame 5. Balance frame 6. Rocker rod 7. Roller wheel 8. Main guide

Figure 4. Brief diagram of garbage collection system structure

2.5 Binocular recognition system

2.5.1 Stereovisual vision. Based on a single camera to identify the specific location of garbage, there may be a problem that we can not accurately judge the specific location of garbage. We propose that binocular recognition can be used to identify the real surface garbage. In short, the human eye is simulated by two cameras. When the human eye focuses on a certain point in space, the object at that point will be imaged in the center of the fovea of the retina, which is a plane in a two-dimensional space. However, we can perceive the three-dimensional spatial information of the image through such a two-dimensional spatial information, namely spatial vision. By comparing and calculating the garbage image positions collected by two cameras, we can get the specific location of garbage on the water surface.

![Figure 5. Binocular head recognition](image)

![Figure 6. Confirm the specific position of the object through dual cameras](image)
2.5.2. Camera model and camera calibration. Camera is the basic sensor to obtain 2D image information in binocular recognition system. Firstly, an image coordinate system needs to be established to reflect the position of pixels on the captured image. The coordinate system takes the intersection a of the camera optical axis and the image plane as the far point \( O_n \), and the X-axis and Y-axis are parallel to the U-axis and V-axis respectively. If the coordinate of \( O_n \) is \((u_0, v_0)\) in the U-V coordinate system, any pixel in the image has the same coordinate in the coordinate system, as shown in the figure below[5].

The geometric relationship of camera imaging is shown in Figure 7. P is the middle point, and point P is the imaging of the point in the image plane through the camera. Where is \( O_C = x_C y_C z_C \) camera coordinate system, which takes the origin \( O_C \) as the camera optical center, the \( x_C \) axis and \( y_C \) axis are parallel to the X axis and Y axis in the image coordinate system respectively, and the \( z_C \) axis coincides with the optical axis and is perpendicular to the image plane. The intersection of the optical axis and the image plane is the origin of the image coordinate system. \( O_f O_C O_i \) is the focal length of the camera, and \( O_w = x_w y_w z_w \) is the world coordinate system, which is used as the reference coordinate system to describe the camera and the garbage position in space.

2.5.3. System construction. The binocular recognition system is divided into three parts: acquisition of binocular camera image, analysis of raspberry party image and output of raspberry party analysis results.
2.5.4. Simulation experiment. The program is written by Visual C++ language and the functional modules are.

- Image acquisition.
- Identification of the edge pixels.
- The location of the pixel concentration part is calculated.
- Results are output to the power module.

Simulate the experimental process:
The simulation experiment used a picture of a plastic bottle on the water surface.

![Simulated experimental images](image1)

![pixel processing Fig](image2)

The edge identification of the target picture is completed, the grayscale treatment is performed first, and then the processed picture is edge identified to extract the pixels of the garbage, and the specific distance of the garbage is calculated according to the parallax of the binocular recognition.

3. Water surface cleaning robot control strategy and process
The control system flow of the water garbage cleaning ship is shown in the figure, which is mainly composed of microprocessor module, binocular recognition system module, motion control module and function execution module [8]. Figure 11 shows the flow chart of the control system of the water garbage cleaning ship.

Before starting the work, put the offshore garbage cleaning ship into the water and turn on the work switch. When the red work indicator light is on, it means that the garbage cleaning ship enters the working state. According to the data collected by the binocular recognition system, the microcontroller sends control commands to the motion module and function execution module to make the water garbage cleaning ship run near the garbage according to the predetermined track. The salvage mechanism accurately picks up the garbage through the position information and pours it into the hull garbage bin. After picking up, shake the dustbin, and the inclination sensor in the ship will timely obtain the inclination data of the ship. Once it exceeds the maximum limit that the hull can bear, the collection of water surface garbage will be stopped and the ship will return automatically. If there is no garbage or it is not in the pickup area, reissue the control command to the motion module and energy supply execution module, coordinate and control the speed regulation, forward and reverse rotation of the water jet thruster and reverse baffle, and continue to drive to the pickup area [9].

4. Linkage strength simulation analysis
The garbage collection system mainly consists of linkage mechanism and net pocket part. Powby the drive motor, transmit power to the rocker arm through the coupling, allowing the mesh to move along a predetermined trajectory. Therefore, the strength of the link is used as a priority for water environmentally friendly robot design content [10]. Through SOLIDWORK software, the data simulation analysis of connecting rod is carried out: the reliability analysis of strength design is carried out by establishing the three-dimensional finite element model of connecting rod assembly. As shown
in FIG. 12, the stress and load of the rod are calculated through calculation, and it is verified that the strength of the rod is sufficient,

\[ I_z = \frac{bh^3}{12} = 1.5 \times 9 = 13.5 \]  
(1)

\[ M = F \cdot l = 3 \times \frac{116.8}{2} = 175.2 \text{N} \cdot \text{mm} \]  
(2)

\[ y = 11.5 \text{mm} \]

\[ \sigma = \frac{M \cdot y}{I_z} = \frac{175.2 \times 11.5}{13.5} \approx 149.2 \text{MPa} \]  
(3)
As shown in Figure 13 below, ADAMS simulation curve group.

- In Figure group (a), according to the data diagram obtained from the motion analysis, we can see that the linear velocity maximum here is 0.5 m/s, and the speed of the slider is always relatively uniform during the process of the movement of the ship, which is so that the hull does not shake the ship to varying degrees due to the movement of the bend rod.
- In Figure group (b), the movement completed in the X direction is mainly the process of dumping the garbage collected on the sea surface into the temporary storage tank, namely the analysis of the horizontal section of the curved track, and the maximum speed value in the X direction is 0.32 m/s.
- In Figure group (c), according to the image, it can be seen that the slide bar stays slowly at 0.04 m/s² during the movement, giving the hull enough time to slow transition in the movement process, making the overall movement more smooth.
- In Figure group (d), the size of the ship slide rod movement always fluctuates around 0.021 m/s² in the X direction, except for transient large jumps at individual points, which are normal small range of\[11\].

5. Conclusion
After making a one-to-one prototype, the performance of the surface garbage cleaning ship mainly reflects the following points:

- According to the speed of the pusher and the garbage cleaning time, the garbage cleaning ship can clean one square kilometer of beach per hour.
- The actual size of the hull is about 4m, 8m and 5m, and the overall weight is about 45kg. The dustbin can accommodate 27m³ of garbage, and can support 30kg of garbage in full load. The full dustbin is replaced every 1-1.5 hours.
- The battery can maintain the normal working time of garbage cleaning ship for 3-4 hours.

At the present stage, China's water waste treatment problem is increasingly serious. In order to solve the problem of garbage cleaning in rivers, lakes, ports, the structural design of water cleaning robot and functional test. The binocular identification system can accurately identify the range of garbage through the comparison of the two cameras and improve the collection efficiency. The garbage collection system composed of linkage and network part greatly improves the collection efficiency of surface garbage, and can realize the rapid search and collection of surface garbage. At the same time, the Raspberry Pi as the control system, combined with the corresponding sensor actuator, the hull can independently clean the water garbage without human interference, and in the machine failure, can timely manual control. Through kinematic simulation analysis and prototype function test, the robot has stable function, high operation efficiency and reliable performance, which is suitable for various complex water environment, and can be widely used in the water governance field.

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