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Design of Intelligent Robot for Underwater Pipeline Inspection

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Abstract

The use of underwater pipelines to discharge waste liquid and transport energy is universal in the world. Based on the economic losses caused by the frequent leakage and destruction of underwater pipelines, this paper designs an underwater intelligent robot that integrates autonomous inspection, identification, cleaning and collection to ensure the normal maintenance of underwater pipelines. It includes the design of mechanical structure and control part using the control mode of raspberry pie combined with ARDUINO to realize the functions of tracing, image recognition, garbage cleaning and collection.

Keywords

Underwater Intelligent Robot, pipeline inspection, self-identification , feature extraction.

1. Introduction

With the deterioration of the environment in recent years and the continuous heavy rainfall leading to urban waterlogging, it is necessary to increase the capacity of urban drainage pipelines; in addition, with the improvement of living standards of urban residents and the rapid development of urban industrial parks, the emission of domestic and industrial waste liquid and the demand for energy are rapidly increasing [1], and the number of pipelines is required more and more. The laying distance is gradually increasing and the operation time is continuously prolonged. At the same time, due to the particularity of the underwater pipeline environment, leakage and damage accidents caused by external forces and environmental corrosion occur frequently, resulting in serious environmental pollution, waste of resources, economic losses, and even casualties. Therefore, the cleaning, defect prediction and flaw detection of underwater pipelines are very important.

At present, the maintenance and clean-up of pipelines in China still takes manual maintenance and clean-up as the main clean-up method, that is, manual drainage is supplemented by necessary measurement to obtain the status and corresponding data of pipelines, internal and surface. The pipeline is located in most urban population and building-intensive areas. The traditional manual maintenance and cleaning operations cover a large area, which is easy to cause sludge spilling on the ground, polluting the environment and stanching, it brings inconvenience to the surrounding residents and affects the appearance of the city. Moreover, the traditional manual efficiency is low, and the internal environment of the urban pipeline is very bad, smelling, there may be a large number of toxic gases such as methane, which seriously affects the life safety of front-line workers [2]. Therefore, it is necessary to develop an efficient underwater detection robot with cleaning function to achieve full-length and all-weather detection of various underwater pipelines [3].

2. Related research

Many scholars have studied the underwater robot in many aspects, such as Li Hongyu and so on. In view of the slow convergence speed and poor anti-interference ability of underwater

robot in attitude control, a coordinated control method based on PSO-GA algorithm and RBF neural network is proposed[4]. Liu Yuqing,et al's improved ant colony algorithm[5] and Shi Yinghui,et al's improved RRT * algorithm[6]get a better path planning scheme for underwater vehicles ; yang ,et al. studied the technology of non-communication high-precision formation of underwater vehicles based on visual positioning[7] . Luo,et al designed a ROV underwater vehicle based on bionic manipulator and AI depth vision[8] .

Underwater robots can be widely used in underwater construction, infrastructure maintenance, public security forensics, aquaculture, underwater archaeology and other fields, helping the construction of a maritime power . At the same time, they are also a highly nonlinear dynamic system with complex variables and strong coupling. Their motion environment is also highly time-varying, complex and unstable, which greatly increases the difficulty of establishing an accurate underwater robot model . When conducting underwater operations, its tracking system and identification system are particularly important, which is the core to ensure that underwater robots can successfully complete the task. At present, most of the underwater vehicle control mode is single, only STM32 or raspberry pie, its limitations are obvious.

ARDUINO processor has the advantages of easy to handle and master, low cost, high degree of freedom, and strong expansibility. It can also perceive the environment through a variety of sensors, and feedback and influence the environment by controlling lights, motors and other devices. Raspberry pie as a small computer, low power consumption, features, is widely used in image processing and recognition. Based on this, this paper adopts the dual-processor system combined with ARDUINO chip and raspberry pie, and uses the unique advantages of the chip to realize the tracking and image recognition function of the underwater robot. This system has the following characteristics :①abandoning visual tracking, and using the dual-processor to complete specific functions independently, which can greatly improve the operation speed and accuracy of the robot ; ②low development cost and short cycle ; ③using the communication function of raspberry pie, and detecting the underwater recognition of the robot in real time through VNC.

3. Scheme Design of Underwater Intelligent Robot System

As a more complex intelligent system, the working stability and efficiency of the underwater robot are related to the establishment of dynamic model, motion control and recognitional gorithm.However,the current underwater robots generally have problems such as weak endurance,low intalligence,poor detection ability,and large environmental disturbance[9].

Therefore, the underwater robot in this paper is based on the realization of autonomous inspection, identification, cleaning and collection of sewage and garbage and other cleaning materials for underwater pipelines to ensure the normal maintenance of underwater pipelines. The designed underwater vehicle includes overall mechanical structure and control structure. The mechanical structure includes motion module and cleaning module. The control structure includes tracking control module and recognition control module. After the robot works in the water, the diffuse reflection photoelectric infrared sensor and the front wide angle camera work at the same time. The diffuse reflection photoelectric sensor is responsible for the steering and position adjustment of the robot, and the purpose is to complete the whole line patrol target. At the same time, the camera is responsible for capturing and responding to the real-time situation of the pipeline. Finally, through the processing and analysis of the raspberry pie algorithm, the goal of cleaning and detecting the pipeline is realized. Each module cooperates with each other to complete the underwater operation. The working principle is shown in Figure1.

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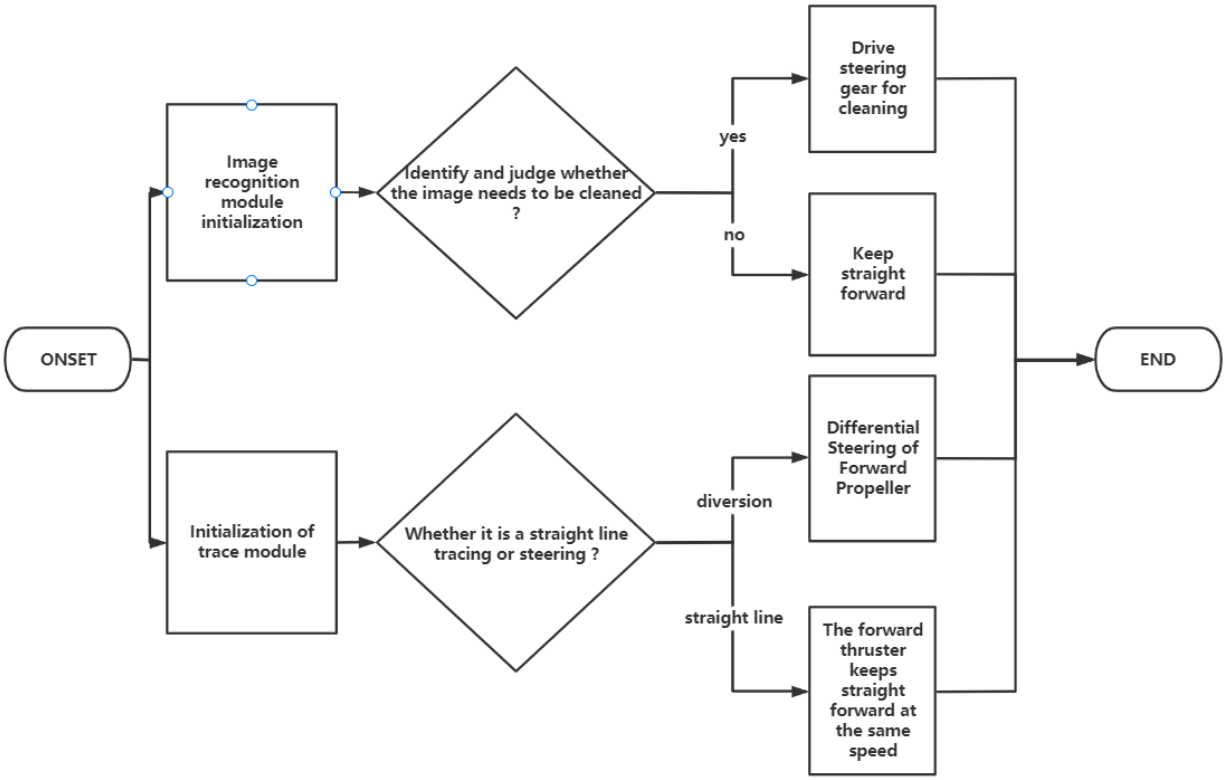

Figure 1: Flow chart of robot working principle

3.1. Overall mechanical structure design

As shown in Figure 2, the mechanical structure of underwater intelligent robot is designed symmetrically, including motion module and cleaning module. The motion mechanism mainly includes symmetrically arranged thrusters, electronic governors and metalworking materials. The 7.6 KG thrust race ship model propeller is used, and the electronic governor controls the corresponding speed of the propeller by receiving the corresponding instructions to realize the movement of the robot such as diving, floating, left and right steering. Metalworking materials not only connect the external propeller and photoelectric sensor, but also connect the metal waterproof box to provide a stable frame structure for the underwater robot and make the whole robot focus on the center of the overall structure, which can greatly ensure the normal operation of the robot ;The metal waterproof box adopts cross arrangement, so that the overall gravity of raspberry pie, battery, step-down module, arduin chip and electric regulation is dispersed to every part of the waterproof box.

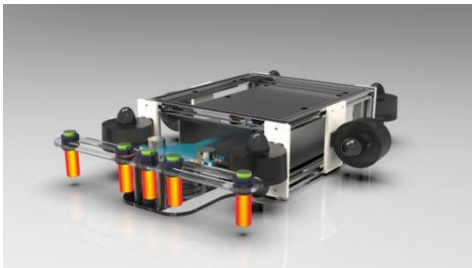

Figure 2: Mechanical structure of robot

As shown in Fig. 3, the cleaning device of underwater intelligent robot is composed of the leaning mechanism of fitting pipeline, waterproof steering gear and special fishing net, and the cleaning mechanism is printed by 3D printing material. As shown in Fig. 4, the working principle of the cleaning device is to identify the pipeline status in real time according to the camera, process the actual picture through the raspberry pie and control the steering gear after judgment. The steering gear drives the cleaning mechanism to rotate, and cooperates with the

robot to realize the cleaning and collection of pipeline dirt. The rotation angle and size of the cleaning mechanism can be adjusted according to the actual situation of the pipeline. The cleaning efficiency of the robot is maximized.

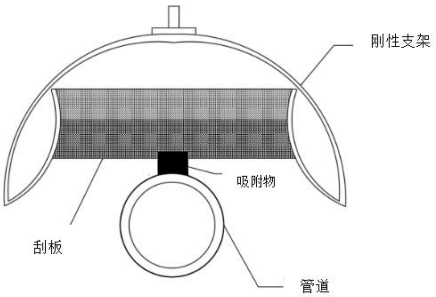

Figure 3: Effect diagram of cleaning device

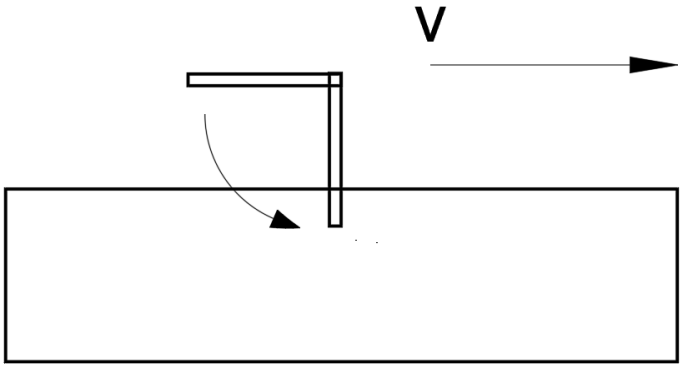

Figure 4: Working principle of cleaning device

Finally, the underwater intelligent robot uses 12 V POWFR battery, and uses DC-DC buck module to convert 12 V battery input into 5 V output, which supplies power to ARDUINO chip, raspberry pie, camera, propeller motor and photoelectric sensor. At the same time, the step-down module is equipped with a power display module to ensure the normal operation of the whole robot. Then the tracking sensor adopts E3F-DS30C4 ordinary open diffuse reflection photoelectric infrared sensor, which can not only manually adjust the photoelectric sensor detection distance according to the water level to change the working height of the robot ; moreover, the interval between sensors can be changed according to the diameter of the pipeline, so as to improve the accuracy of the robot when working in water.

3.2. Overall control structure design

The overall control of the underwater vehicle is divided into tracking control module, recognition control module, power module and sensor module. The four modules cooperate with each other to complete the underwater operation of the underwater vehicle.

3.2.1. Tracing module

The tracking control module adopts the ARDUINO2560 chip. Through five independent photoelectric sensors, a series of position coordinate parameters of the robot are transmitted to the ARDUINO chip. The ARDUINO chip real-time processes the feedback information of the photoelectric sensor and obtains the actual position of the fuselage at this time, so as to determine whether the fuselage has deviated from the pipeline or whether the steering action should be carried out. Subsequently, the ARDUINO chip sends the corresponding PWM pulse flow with a certain frequency and width to the electronic governor. After receiving the signal, the TB6612 actuator inside the brushless DC motor makes the appropriate “ control ” of the current according to the signal, and then outputs the current signal after the “ control ” to the thruster motor, so as to control the start and stop of the motor and the rotation speed. Based on this, the forward and backward, left and right steering, braking and attitude adjustment of

the underwater intelligent robot relative to the operating pipeline are realized. The actual situation is shown in Figure 5 and Figure 6.

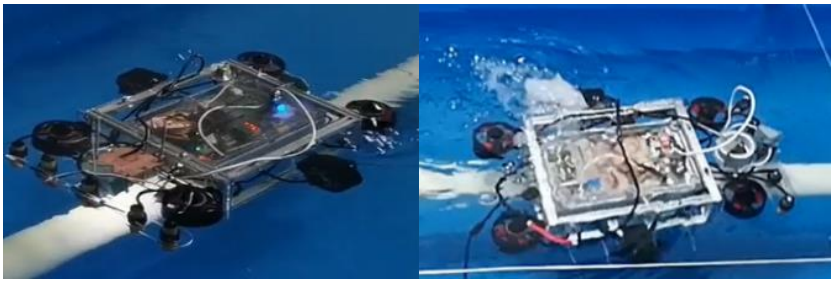

Figure 5: Robot tracking and attitude adjustment

Figure 6: Robot steering

3.2.2. Identification module

lmage recognition refers to the technology that uses computers to process, analyze and understand images to identify targets and objeots of various patterns[10].The recognition control module uses 3B + model raspberry pie. Firstly, the real-time image of the whole underwater pipeline and the surrounding water is transmitted to the raspberry pie. The raspberry pie processes and recognizes the image through the visual algorithm. The HSV principle is used to obtain the images of three different channels and integrate them. Finally, the final image is obtained. The essence of this division of different color spaces is to better distinguish the pipeline from other pollutants. The final recognition results are shown in Figure 7. Subsequently, according to this image, the raspberry pie judges whether there are dirt or garbage around the pipeline at this time, and if there is dirt or garbage, the raspberry pie will output instructions to drive the waterproof steering gear to drive the cleaning device for cleaning. The flow chart of recognition principle is shown in Figure 8.

At the same time, due to the unpredictable underwater environment, the images captured by the camera are often disturbed, which makes the judgment of dirt and pipeline inaccurate. In order to improve the accuracy of image recognition, machine learning is introduced to train the target image in the algorithm. As shown in Figure 9, the images of different pollutants and damaged pipelines are extracted, calibrated and integrated, and the corresponding calibration files are obtained. After a series of data processing, the SVM model is generated. The image recognition algorithm based on this model can greatly improve the accuracy of recognition and removal, and significantly reduce the misjudgment rate of body shaking caused by underwater illumination and water flow machine. The VNC platform can also be used to communicate with raspberry pie to monitor the pipeline in real time. If the pipeline has dirt, damage, leakage and other conditions can be found in the first time, it can timely repair the pipeline and reduce unnecessary losses.

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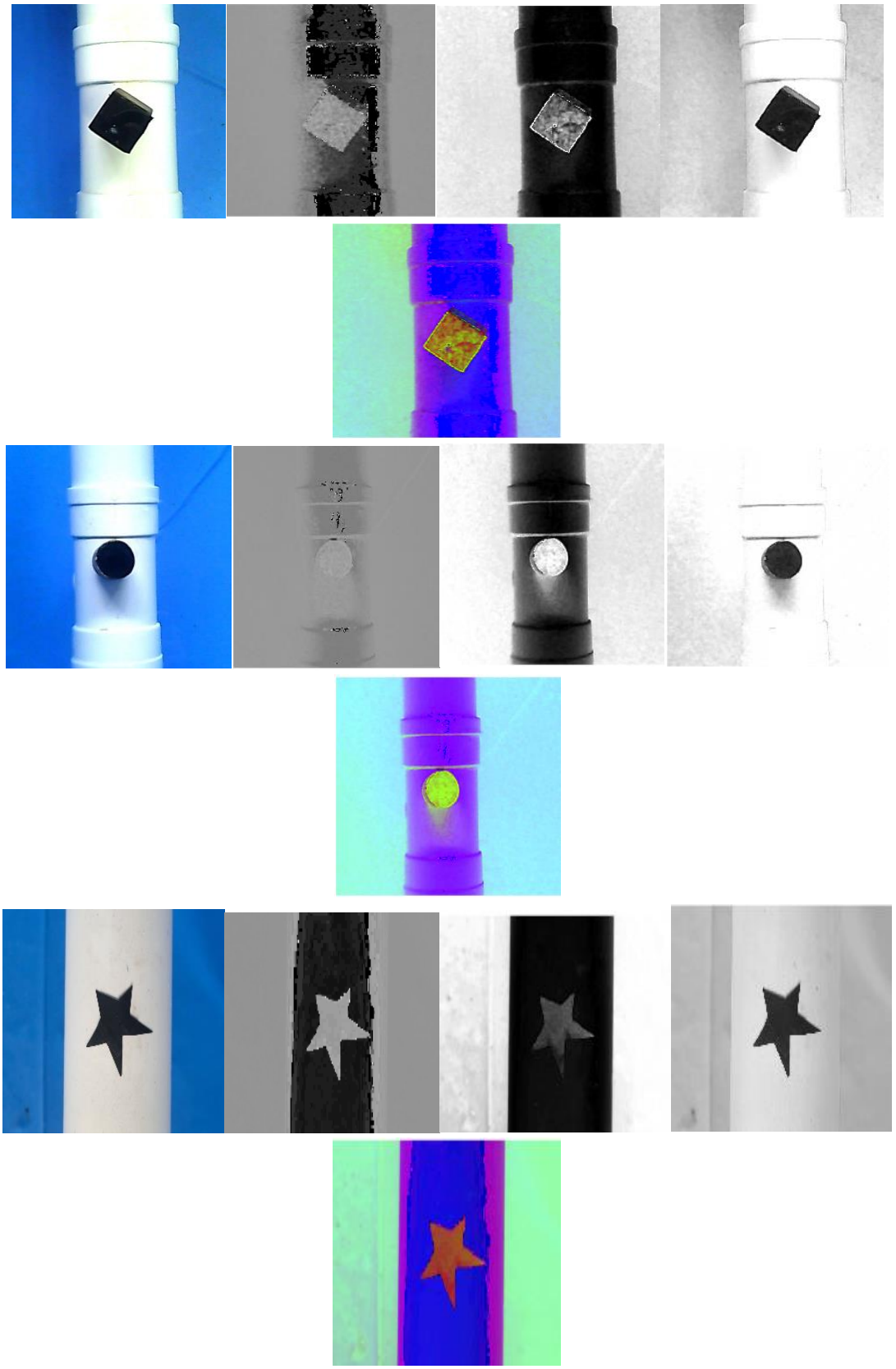

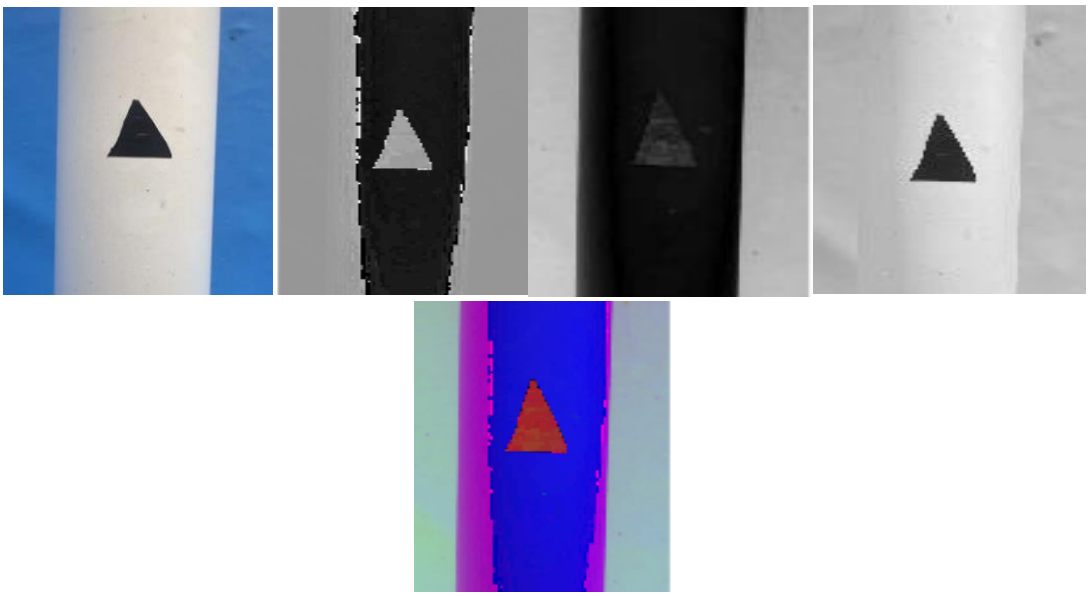

(a) Input image (b) color rendering (c) saturation rendering (d) brightness rendering (e) recognition results

Figure 7: Final identification results

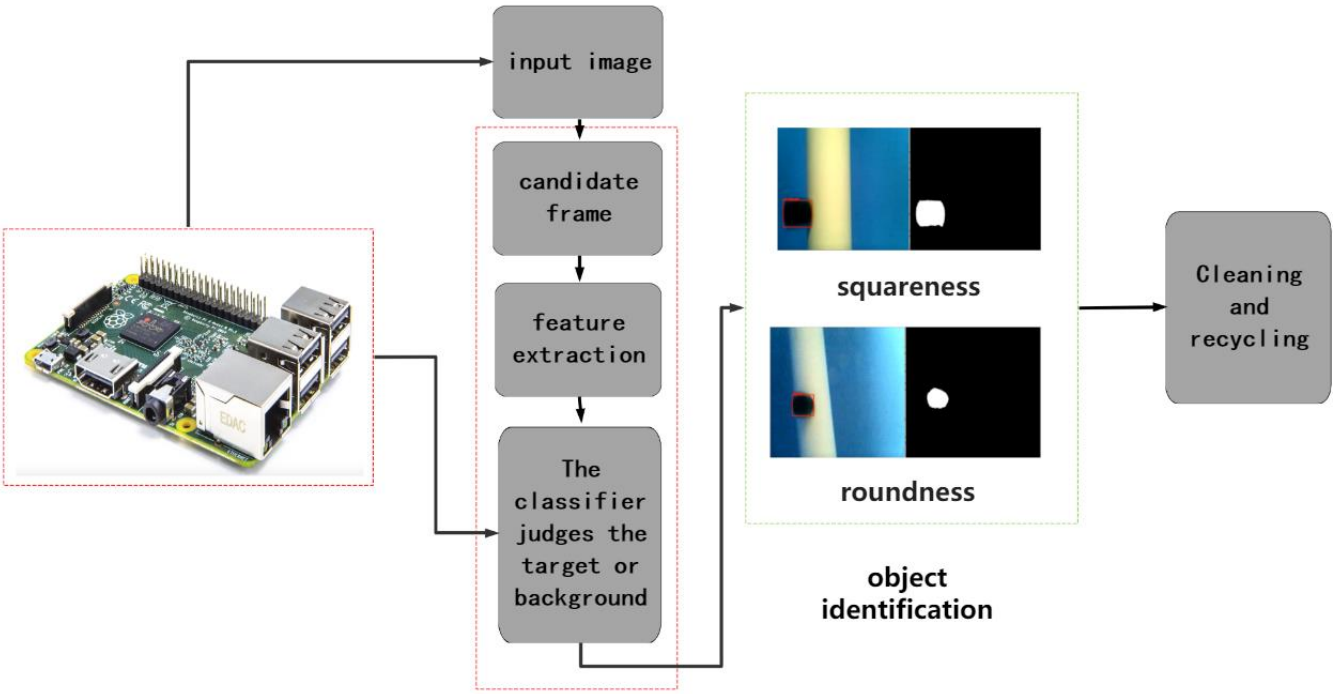

Figure 8: Flow chart of recognition principle

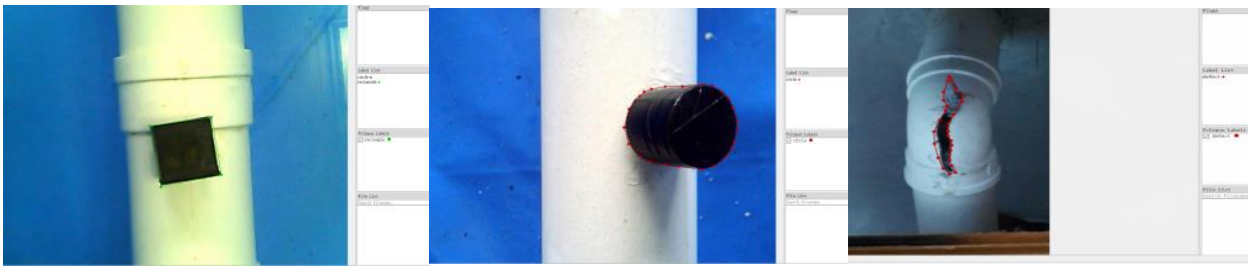

Figure 9: Calibration of pipeline garbage and damaged images

4. Conclusion

This design is an intelligent underwater pipeline detection and cleaning robot based on raspberry pie and ARDUINO chip, which integrates tracing inspection, cleaning and collection. The cooperation between the internal modules enables the underwater robot to independently complete the task of autonomous inspection and cleaning of underwater pipelines. In practical applications, the robot is relatively low cost, efficient and accurate, and can save manpower. It can be widely used in the detection and cleaning of various pipelines, and has good promotion value for environmental protection.

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