A Study on Vision-based Rust Boundary Recognition for Derusting Robot

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Abstract. In this paper, a new type of surface rust detection for wall-climbing robot is proposed in order to surmount the shortcomings of current wall-climbing-cleaning robots. It takes advantage of OpenCV to establish a detection system, and uses QT to do the experimental analysis. The experimental results show that the detection system can complete the rust spot recognition of the image of the wall-climbing-cleaning robot, which makes the foundation for the intelligent trajectory planning of the wall-climbing-cleaning robot.

Introduction

The shipbuilding industry is a strategic industry that provides technical equipment for water transportation, marine development and national defense construction, and is an important component of the industry of advanced equipment manufacturing. The rust of hull needs to be cleaned in regular time. Nowadays, the efficient way to clean the rust of hull is to use cleaning tools and do man-made job. As shown in Figure 1, this operation is inefficient and time-consuming with high labor intensity, which betrays the philosophy of people-oriented. As a branch of special robots, wall-climbing robots can realize free movements on metal wall by combining the technology of mobile and wall adsorption, which have been paid more and more attention by researchers. Climbing robots have already been widely applied in the nuclear industry, petrochemical industry, building industry, fire department, shipbuilding industry and some other fields, especially have a good application prospect in derusting the ship[1]. With the rapid development of high pressure water jet and mechanical automation, the wall-climbing-cleaning robot, as a kind of cleaning technology, has been a key role to solve this problem[2].

Figure 1. Manual removal of hull rust.
Firstly, as shown in Figure 2, the manual remote control method currently used by the wall-climbing-cleaning robot, so there are subjective influences of manual operation, and its precision is low and reliability is weak. Secondly, the large ships of several hundred thousand tons have exceeded the scope of human visual observation. As a kind of high-altitude operation, the wall-climbing-cleaning robot requires workers to use high-altitude vehicles to observe the rust removal, which is very troublesome, costly and inefficient. In many cases, human vision is increasingly unable to meet the requirements of high speed, high precision, super vision, macro, objective, fatigue-free, and environmental constraints. In this case, it is put forward to replace the current high-altitude vehicle-mounted operation by means of a real-time image processing of the camera, which can improve robot productivity and reduce lapses and risks. It is means to develop a wall-climbing-cleaning robot vision system with high degree of automation, convenient control and high efficiency. The above problems can be solved very conveniently after the development of the vision system of the wall-climbing-cleaning robot. The automatic detection effect is stable and reliable, the work can be stopped for 24 hours, the information integration is also very convenient, and the visibility is good.

**Figure 2. Shortcomings of manual remote wall-climbing-cleaning robot.**

**Vision System Design of Wall-Climbing-Cleaning Robot**

**System Structure**

Based on the wall-climbing-cleaning robot's moving is slow. There is a fixed working mode in an open environment. The design idea can be proposed by referring to the automatic method for determining the degree of derusting as Figure 3. System development using QT and OpneCV, and the camera installation method is as shown in Figure 4. Mount the camera behind the robot and shoot it at a distance of one meter from the robot in an oblique view. Set to collect information every two seconds. Comparing the color difference between the rust spot and the rust-removing grade sa2.5.

**Figure 3. The algorithm of the proposed method.**

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Spray or projectile derusting, indicated by the letter "Sa". Divided into four levels[8]: Sa1 is mild spray or projectile derusting. Sa2 is thoroughly spray or eject the rust. The surface of the steel should be free of visible grease and dirt, oxide scale, rust and other attachments have been basically removed, and the residue should be firmly attached. Sa2.5 is spray or throw rust very thoroughly. The surface of the steel shall be free of visible deposits such as grease, dirt, scale, rust and paint coating. Any traces of residue shall be only slight spots of spots or strips. Sa3 is spray or project rust to clean the surface of the steel.

Among them, the color of the rust spot and the color of the rust removal level sa2.5 are as shown in Figure 5.

**Camera Selection and Calibration**

Because the camera is on the robot during actual shooting. The picture taken is an oblique view. Moreover, the top view can be obtained by perspective transforming an oblique view. The no-pixel portion of the modified image is set to black (as shown in Figure 6(b)) for post-processing (as shown in Figure 6(c)). The time required to perspective transform the image for the first time is 0.4 seconds. Then it takes 0.01 seconds to perspective transform the image each time.

**Removing Image Foreground Using the HSV**

Due to the influence of the detection environment, for example, uneven illumination, jitter caused by the movement of the robot and other interference noise[9]. So we consider using HSV color features to preprocess the image. As shown in Figure 7, because of there is a different between the chromaticity and perception of the object in the RGB color space. The HSV color space is relatively uniform, and the reflected luminance component has little correlation with the color difference information, so the segmentation effect is better than the RGB color space. Therefore, it is widely used in color image processing.
First, the system performs HSV color segmentation on the first image through an initialization algorithm, and determines whether the image is properly segmented, that is, whether a suitable number of pixels are replaced, thereby completing initialization and outputting the HSV color range[10]. Then the system uses the inRange image segmentation function and the morphological transformation of the morphologyEx function to determine whether there is rust in the ROI region. Detection of the rust of hull. Print FIGURE V and then as shown in Figure 8. First, the original image is color-divided and then expanded and etched. Finally, connect some connection domains and eliminate noise. After rust removal, the hull rust is obviously different from the color of Sa2.5 class. The processing time of the pattern is 0.01, and the effect is very good.

Figure 8. Experimental results of hsv division.

**Extraction of Eigenvalues**

The rust removal level achieved by the wall-climbing-cleaning robot under normal working is Sa2.5. Therefore, the difference between Sa2 and Sa2.5 is whether the firm attachment such as paint coating is removed. Because some spots or strips of rust are acceptable, it is not necessary to classify and judge the shape features. Just need to judge the overall color of the sanding.

Since the crawling trajectory of the wall-climbing-cleaning robot is straight, the rust spot detection is mainly for the trajectory of the robot after walking. Therefore, we can observe the value of the grayscale coordinate point (2, 2) after scaling to 5×5 pixels. If the value is not 255, or if the value is below a certain value, we can judge that there is still rust residue. For example, the rust removal comparison chart shown in Figure 9(c). On the right side of the picture is the ejection descaling grade Sa2.5. The scaling of the Lanczos interpolation based on the 8×8 pixel neighborhood is performed on the pre-processed graph of the original image. As shown in Figure 9 (d), the average value of the pixels in the area can be obtained.
Experimental Results and Discussion

The camera was mounted on the wall-climbing-cleaning robot body at a height of 0.4 m from the steel plate. The image center is a steel plate 0.5 m behind the robot. Images are acquired under normal indoor lighting conditions.

As shown in Figure 9, the method is insensitive to the light source, and there are some misjudgments to water stains and shadows. However, considering that Sa2.5 allows slight spots or strips of light spots, the image can be expanded and corroded. Zoom in into a black spot, eliminate the loose point noise, and get the picture shown in Figure 9(c). Finally, the coordinate (2, 2) point value in Figure 9(d) is 255, and the rust-removing success information is obtained. From reading the image to outputting the result, it takes 0.2s.

According to Figure 10, even if the image is under uneven illumination environment, the use of specific HSV and specific morphological operations in the system can achieve the purpose of hull corrosion detection. However, simple color recognition has some misjudgments to water and white paint. These can be solved by repeating the photographing while the wall climbing robot is running. Or introduce multiple sensors in later studies. Working environment with different conditions were selected. In the ten experimental runs in which the vision system was put into use, there were eight normal operations. In other operations, the water spots were identified as rust spots.
Conclusion

This paper proposed a new kind of the detection of surface rust for wall-climbing-cleaning robot which depends on the specific HSV (Hue, Saturation, Value) color space and the morphological operations. This algorithm by using a cheap and easily accessible RGB camera. The color images of the hull rust were captured under natural light. At the first stage, the system performs HSV color segmentation on the image through the inRange function, and uses contour detection to determine whether the image has an appropriate number of contours to determine whether the image is properly segmented. So the system can adjust the V value of the algorithm to complete the initialization and output the HSV color range. The system then uses the morphologyEx function to eliminate negligible traces of residue, such as some spots or slight stains. Finally, the system scales the image to determine if it is rusting (based on the value of the ROI area pixel). The experimental results show that the algorithm is feasible and can be used as the feature input of the classifier, and can also be directly used to improve the working efficiency of the wall cleaning robot.

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