Research on pavement garbage detection based on machine vision

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Abstract. With the continuous advancement of China's urbanization process and the continuous development of autonomous driving technology in recent years, it has become a trend to use unmanned garbage sweepers to clean up and maintain the road surface. Garbage detection is an important part of the operation process of unmanned garbage sweeping trucks. It replaces human brains in the process of observing, judging, and locating garbage on the road, which directly affects the efficiency of sweeping trucks. This paper takes Halcon software as the main platform to introduce the research of road garbage detection based on machine vision.

1. Introduction

As China's urban road traffic and other infrastructure are more and more complete, and the requirements for the image of modern cities are also increasing. Road cleaning has become an important part of municipal work. At present, the use of self-driving garbage sweepers for operations has gradually become a trend. It can not only reduce the workload of sanitation workers, greatly improve the safety and efficiency of sanitation operations, but also reduce economic costs, and achieve the purpose of beautifying the urban environment. It is really necessary for the sustainable development of China's urbanization.

Machine vision is a branch of artificial intelligence technology that has developed rapidly in recent years. In short, machine vision is the use of machines instead of human eyes for measurement and judgment [1]. At present, there are few researches on image processing methods of pavement garbage detection. Tang Wei et and Gao Han proposed an improved convolutional neural network water surface garbage detection algorithm, which can classify floating garbage on the water surface and mark the garbage location [2]. Ning Kai et al. proposed a YOLOv2-dense network to effectively identify different types of common garbage types [3]. However, due to the complexity of its neural network training process, it is difficult to meet the actual needs of pavement garbage detection.

This article uses Halcon software as the main platform to introduce the road surface garbage detection research based on machine vision. In image acquisition, the on-board camera is used to collect road images with pavement garbage. Due to image distortion, image noise and other interference factors, it is not possible to directly perform recognition processing, corresponding pre-processing such as distortion correction and image filtering is required [4]. The image obtained after preprocessing can be used for image segmentation based on the regional features, boundary features or related matching of the image [5]. Then perform feature extraction, select and exclude areas based on...
the parameters such as area, shape, threshold, etc. Finally, extract and display the pavement garbage areas we need to identify.

2. Image preprocessing

2.1. Image filtering

Under sunlight, the degree of reflection of pavement garbage on the light varies, which will cause the brightness of the garbage surface to be different [6]. In addition, due to the influence of sensor material properties, working environment, electronic components and circuit structure of image acquisition equipment, variable noise interference may occur, which is false information for garbage detection and seriously affects the feature extraction of road garbage [7]. Therefore, it is necessary to choose a suitable image filter to reduce the interference information and emphasize the road garbage information in the collected images [8].

Here we use the mean filter operator 'mean_image', the mean filter template parameter is 5×5, and perform the mean filter processing on the acquired image [9]. The road image obtained in this way has less noise and the picture is clearer, which is conducive to subsequent operations. As shown in Figure 1.

![The original image.](image1) ![Image after mean filtering.](image2)

**Figure 1.** Effect of median filtering.

2.2. Delineate garbage detection area

The field of view in the image obtained after the mean filtering is still relatively wide, and road debris in the vicinity can be obviously perceived, while it is more difficult in the distance [10]. It is difficult to identify the entire image as garbage, and it cannot be directly achieved [11]. Therefore, the road garbage detection area needs to be demarcated, and about one third of the image area is selected as the garbage detection area for further processing [12]. The 'gen_region_polygon_filled' operator is mainly used here to create a region from a polygon containing the corner points of the region (line and column coordinates), as shown in Figure 2.

![Delineated garbage detection area.](image3)

**Figure 2.** Delineated garbage detection area.
After the road garbage recognition area is demarcated, the average filter image can be cropped to the size of the designated garbage recognition area using the 'reduce_domain' operator. The subsequent garbage recognition operations are performed only in the demarcated area, which can speed up the program operation and reduce the interference caused by other unrelated features. It can also greatly improve the efficiency of garbage detection work [13].

3. Image segmentation

After the collected road garbage images have undergone the above image pre-processing operations, we need to separate the road garbage from the road background [14]. This technology and process of extracting target from image is called image segmentation. In this paper, threshold segmentation is used to segment image [15]. Threshold segmentation is simple to implement. It has a small amount of calculation and stable performance. This segmentation method is the most basic method because it is not only simple but also effective. Because it sets the gray level threshold to distinguish the target from the background region, threshold segmentation can be considered as an image segmentation method based on region features.

3.1. Threshold segmentation

Assuming that there is an image \( f(x, y) \), and its gray range is \([t_1, t_2]\). At this time, if a threshold \( T \in [t_1, t_2] \) is given, then this gray threshold can divide the original image. For two parts. Generally, two different grayscale values are assigned to these two parts, namely

\[
h(x, y) = \begin{cases} 
a & f(x, y) > T \\
b & f(x, y) \leq T
\end{cases}
\]

In the above formula, \( a \) and \( b \) are given gray scale values. If \( a = 1 \) and \( b = 0 \), the segmented image becomes a binary image (that is, the gray value of the entire image is only 0 and 1), and the contrast between the background and the target of the image shows the greatest effect. If the threshold is greater than the gray level of the background, \( a = f(x, y) \), \( b = 0 \), the segmented target remains the same, and the background of the image is 0, so that the entire image is uniform. The threshold \( T \) can be set to a numerical value or a numerical interval. The target and background phase segmentation in the image is realized by using the set pixel range.

In most cases, it can be considered that there is a large difference in the gray value between the two regions of the image target and the background, and the difference in pixel gray between the two regions is small [16]. According to this, setting a suitable and appropriate Feature thresholds can separate them [17]. In the selection of specific thresholds, this article adopts the threshold segmentation using the 'var_threshold' operator. This operator thresholds the image by local mean and standard deviation analysis. The operator structure is:

\[
\text{var\_threshold(Image: Region: MaskWidth, MaskHeight, StdDevScale, AbsThreshold, LightDark: )}
\]

Specifically, 'var\_threshold' is an area from the input image where those pixels satisfy the threshold condition [18]. The threshold is calculated from the average gray value and standard deviation in the local window of \( \text{MaskWidth} \times \text{MaskHeight} \) around each pixel \((x, y)\), which can better separate the target and the background. The image obtained after threshold segmentation is shown in Figure 3.

Figure 3. Threshold segmentation effect diagram.
3.2. Morphological processing
There is adhesion between objects in the image obtained after threshold segmentation, and there are many small particle noises in the image [19]. Therefore, mathematical morphological image processing such as corrosion or open operation is needed. This paper adopts the open operation, which uses a structural element to perform an erosion operation on the target image, and then performs an expansion operation on the etched image. Both the erosion operation and the opening operation can remove the image components with a smaller area in the image compared to the structural elements, but compared with the erosion operation, the opening operation can better maintain the size of the target object in the image [20]. The morphologically processed image is shown in Figure 4.

3.3. Area split
After the above-mentioned processing, there are road garbage area, part of the ground and some small interference areas in the image. The 'connection' operator is used to separate the divided regions from each other, and the unconnected regions divided by the threshold can be divided into a single region, which is convenient for the subsequent feature extraction of pavement garbage [21].

4. Feature extraction
Among the images after the above processing, only the road garbage is what we really want to get, and the rest are interference areas [22]. Therefore, we need to perform feature extraction on the image to get the road garbage area we need. Because the shape of some areas is extremely irregular, we use the 'shape_trans' operator to perform the area shape conversion. Here we use the 'convex' convex hull shape to convert the shape of the pavement garbage area obtained from each segmentation into convex polygons. Then use the 'select_shape' operator for feature selection extraction. Due to the existence of a narrow floor tile gap and some ground potholes in the experiment, we chose to use 'area', 'compactness' and other regional feature parameters for feature extraction for getting the more accurate garbage area required. The image obtained after feature extraction is shown in Figure 5.
5. Displaying garbage detection results
After the road garbage in the above image is identified, the garbage recognition results need to be displayed. First use the 'sort_region' operator to sort the regions according to their relative positions, and then use 'area_center' to output the pixel area and row position information of the garbage area in the image in the variable window to establish the coordinates based on the garbage sweeper. Then calculate and display the garbage coverage rate of the garbage identification area based on the area of the garbage area. Finally, the result of garbage recognition is displayed by 'dev_display'. The test results are shown in Figure 6.

![Figure 6. Waste detection results.](image)

6. Analysis of results
In order to verify the real-time and effectiveness of the garbage detection algorithm, the road video images under different road environments are collected for testing, and the results are shown in Figure 7. On a good cement pavement or floor tile pavement, general-sized pavement garbage can be detected more accurately, such as leaves, cans, small clods, etc. In the process of the experiment, we also found some problems. When there are shadows and large road defects in the image, it is easy to appear false detection. In addition, due to the constraints of the parameters set in image segmentation, the detection effect is limited for the smallest size, the color close to the road and the transparent object garbage.

![Figure 7. Test results of the collected video pavement garbage detection.](image)

7. Conclusion
In this paper, we preprocess the road image collected by the garbage sweeper and segment it to extract the garbage detection algorithm on the exit surface. The test is carried out in the actual good road environment with good open light, the accurate detection results of road garbage can be obtained. The garbage coverage of the detection area and other information can be given, but it is still affected by weather conditions, light intensity, road defects and so on. The detection effect is limited for the smallest size, the color close to the road and the transparent object garbage, and the intelligent recognition and classification of the road garbage cannot be carried out yet, which needs to be further improved.
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