Physical characteristics and spillage detection Using multi-feature fusion

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Abstract. As an important part of road maintenance, the detection of road sprinkles has attracted extensive attention from scholars. However, after years of research, there are still some problems in the detection of road sprinkles. First of all, the detection accuracy of traditional detection algorithm is deficient. Second, deep learning approaches have great limitations for there are various kinds of sprinkles which makes it difficult to build a data set. In view of the above problems, this paper proposes a road sprinkling detection method based on multi-feature fusion. The characteristics of color, gradient, luminance and neighborhood information were considered in our method. Compared with other traditional methods, our method has higher detection accuracy. In addition, compared with deep learning-based methods, our approach doesn't involve creating a complex data set and reduces costs. The main contributions of this paper are as follows: I. For the first time, the density clustering algorithm is combined with the detection of sprinkles, which provides a new idea for this field. II. The use of multi-feature fusion improves the accuracy and robustness of the traditional method which makes the algorithm usable in many real-world scenarios.

Keywords: spillage detection, multi-feature fusion, density clustering.

1. Introduction
In recent years, with the development of intelligent transportation, more and more researchers began to pay attention to the detection and identification of road traffic incidents and road spills. In 2013, Khatoonabadi et al. [1] proposed using adaptive motion vector and space-time Markov random field model to track moving targets in compressed video sequences. By manually selecting the target object in the first frame, the moving object can be detected in the subsequent frames by means of intra-frame coding block and global motion compensation calculation, but this method has the defects of large amount of calculation. In 2015, Asvadi et al. [2] proposed an advanced vehicle system design scheme to describe the dynamic environment of each frame image through the 2.5D feature map measured by the sensor. The algorithm has high accuracy, but poor detection performance under bad weather conditions. In 2017, Wang Gui ping et al. [3] used five-frame difference method to detect the thrown...
objects on expressways. In 2018, Li Qing yao et al. [4] proposed the detection of vehicle sprinkles based on the inter-frame difference adaptive method. The detection of vehicle sprinkles was carried out by moving object detection algorithms such as the continuous inter-frame difference method and the mean value method. In 2019, Jin Yao et al. [5] proposed an improved small pixel target detection method for urban road video based on YOLOv3, and introduced the deep learning target detection algorithm into the urban road target detection. In recent years, researchers have proposed feature extraction algorithm [6] or moving object tracking and detection algorithm [7,8], including inter-frame difference method [9], background subtraction method [10] and optical flow method [11], which have realized road sprinkling detection to a certain extent. But these methods are not robust enough, and the detection accuracy is low. Therefore, the detection of road sprinkles is still an urgent problem to be studied.

2. Algorithm process

2.1. Delineate the ROI area

In the detection of road sprinkles, we use the on-board camera to collect road information, as shown in Figure 1. It can be seen that in this figure, there are a lot of interference information (trees, vehicles and some interference on both sides of the road). The existence of these interference will not only affect the detection accuracy of the sprinkles, but also seriously affect the detection speed. Therefore, we demarcated the ROI area by setting a mask, through which we were able to obtain a pure lane area.

![Figure 1. Original image and extracted ROI areas](image)

2.2. Extract brightness information

After getting the ROI region, we first analyze the brightness information of this region. We first get the gray distribution histogram of ROI area as shown in figure 2. In order to further remove noise interference, we use median filtering for grayscale images. The grayscale distribution after median filtering is shown in FIG. 2. It can be seen that the grayscale distribution of images after median filtering is more concentrated and generates a clear boundary.

![Figure 2. Histogram of gray distribution and gray distribution after median filtering](image)
2.3. Extraction of gradient information

After obtaining the gray distribution information, we can further compress the gray level to improve the contrast through gray grading operation. The core of grayscale grading operation is to compress the original 256 grayscale levels from 0 to 255 to 26 grayscale levels from 0 to 25 (the number of compressed grayscale levels can be changed according to different needs). The calculation method is as follows:

First, assume that the gray value of a pixel in the image is $X$, the total number of gray levels you want to compress is $Y$, and the compressed gray value is $X_1$, then $X_1$ can be calculated by the following formula.

$$X_1 = \lceil X Y / 256 \rceil \tag{1}$$

Figure 3. the histogram of gray distribution before and after compression of gray level.

Figure 4. the gray histograms after median filtering and after compression of gray level.

After gray grading, we use the adaptive Canny operator [12] to extract the gradient information of gray image, the two threshold values required by the Canny operator are extracted from the gray histogram.

Figure 5. Gradient information of road image
2.4. Remove the lane line area

Since our method uses a lot of gradient information of road images, but there are also rich gradient features in the lane line area of road images so we need to remove the interference of lane lines. Considering the fixed and special color of lane lines (that is, all lane lines and road markings are white and yellow), we can eliminate the interference of lane lines by color characteristics. First, the image is converted from RGB color space to HSV [13] color space. Compared with RGB color space, different kinds of colors can be distinguished in HSV space.

![Figure 6. Example of extracting lane lines in different scenarios](image)

After the lane area was extracted by using color feature, we take an expansion operation on the lane line area, which is an important step, because the lane line area that we extract is usually smaller than the real lane line area, and we can make up for this loss through the expansion operation. After that, we create a black mask in the lane line area then we mask the road gradient map to remove the lane line area. The process is shown in Figure 6.

Table 1 shows the corresponding values of different colors in the H (hue), S (saturation) and V (brightness) Spaces.

|         | black | gray | white | red  | orange | yellow | green | cyan | blue | purple |
|---------|-------|------|-------|------|--------|--------|-------|------|------|--------|
| hmin    | 0     | 0    | 0     | 0 156| 11     | 26     | 35    | 78   | 100  | 125    |
| hmax    | 180   | 180  | 180   | 180  | 25     | 34     | 77    | 99   | 124  | 155    |
| smin    | 0     | 0    | 0     | 43   | 43     | 43     | 43    | 43   | 43   | 43     |
| smax    | 255   | 43   | 30    | 255  | 255    | 255    | 255   | 255  | 255  | 255    |
| vmin    | 0     | 46   | 221   | 255  | 255    | 255    | 255   | 255  | 255  | 255    |
| vmax    | 46    | 220  | 255   | 255  | 255    | 255    | 255   | 255  | 255  | 255    |
2.5. Density clustering

After obtaining the gradient information of the road image, we used the DBSCAN density clustering algorithm [14] to perform clustering analysis on the edge points detected. DBSCAN describes the tightness of the sample set based on a set of neighborhoods, and the parameter \((\epsilon, MinPts)\) is used to describe the tightness of the sample distribution in the neighborhood. \(MinPts\) describes the threshold for the number of samples in a neighborhood whose distance is \(\epsilon\). Assuming that my sample set is \(D = (x_1, x_2, \ldots, x_m)\), then the specific density description of DBSCAN is defined as follows:

1) \(\epsilon\) neighborhood: for \(x_j \in D\), its \(\epsilon\) neighborhood contains the subsample set in sample set \(D\) whose distance from \(x_j\) is no greater than \(\epsilon\), namely \(N_\epsilon(x_j) = \{x_i \in D | distance(x_i, x_j) \leq \epsilon\}\), the number of the sample set of notes for \(|N_\epsilon(x_j)|\)

2) core object: for any sample \(x_j \in D\), if its \(\epsilon\)-neighborhood corresponding to \(N_\epsilon(x_j)\) contains at least \(MinPts\) samples, that is, if \(|N_\epsilon(x_j)| \geq MinPts\), \(x_j\) is the core object.

3) Density of direct: If \(x_i\) is in the \(\epsilon\)-neighborhood of \(x_j\), and \(x_j\) is the core object, then \(x_i\) is said to be direct from the density of \(x_j\).

4) Density is accessible: for \(x_i\) and \(x_j\), if there are sample sequences \(P_1, P_2, \ldots, P_t\), where \(P_1 = x_i, P_t = x_j,\) and \(P(t + 1)\) is directly connected by the density of \(P_t, x_j\) is said to be accessible by the density of \(x_i\).

5) Density connection: For \(x_i\) and \(x_j\), if there is a core object sample \(x_k\) and both \(x_i\) and \(x_j\) are reachable by the density of \(x_k\), then \(x_i\) and \(x_j\) are said to be density-connected.

Figure 8 illustrates the DBSCAN clustering process. in the figure \(MinPts=5\), the red dots are all core objects because its \(\epsilon\)-neighborhood has at least 5 samples. The black samples are non-core objects. All samples with direct density of the core object are in the hypersphere centered on the red core object. If they are not in the hypersphere, they cannot have direct density. The core objects connected by green arrows in the figure constitute a sequence of samples with reachable density. All samples in the \(\epsilon\)-neighborhood of these density-accessible sample sequences are density-related to each other.

Figure 9 shows the clustering results of DBSCAN algorithm for the road gradient information graph in Figure 8. The left figure is the original image and the right figure is the clustering results. Different colors represent different categories.
Figure 9. Clustering results of DBSCAN algorithm

After obtaining the clustering results, we first excluded the categories with few pixels, and the lane line area was also removed by the operation in 2.4. Finally, just need to draw the outer rectangles for the remaining categories to be the areas where the spilled objects exist, as shown in Figure 10.

Figure 10. Detection result

3. Experimental results
Figure 11 shows the detection results of our algorithm in different environments and different shooting angles when there are different sprinkles. It can be seen that our algorithm can achieve wonderful detection effects in most scenes.
4. Conclusions

In this paper, multi-feature fusion and density clustering algorithm are used to detect spilt objects. It can be seen from experimental results that our method has strong robustness and can achieve good detection results under different environments. However, the paper still has the following shortcomings need to be further studied: I) It is insufficient to exclude lane line area only by color feature II) It is unable to detect very small sprinkles by using gradient information.

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