A coloured oil level indicator detection method based on simple linear iterative clustering

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Abstract. A detection method of coloured oil level indicator is put forward. The method is applied to inspection robot in substation, which realized the automatic inspection and recognition of oil level indicator. Firstly, the detected image of the oil level indicator is collected, and the detected image is clustered and segmented to obtain the label matrix of the image. Secondly, the detection image is processed by colour space transformation, and the feature matrix of the image is obtained. Finally, the label matrix and feature matrix are used to locate and segment the detected image, and the upper edge of the recognized region is obtained. If the upper limb line exceeds the preset oil level threshold, the alarm will alert the station staff. Through the above-mentioned image processing, the inspection robot can independently recognize the oil level of the oil level indicator, and instead of manual inspection. It embodies the automatic and intelligent level of unattended operation.

1. Introduction
In the substation, many devices are filled with oil that for losing heat and insulation. These devices are equipped with an oil level indicator for indicating how many of these oils are. The inspection of the oil level indicator can determine if the oil level is reasonable. Too much oil, or not enough of it, have a negative impact on the protection of its equipment. Therefore, the real-time detection of the oil level meter is also an important task of the patrol task of the substation.

At present, there are two ways of substation inspection, that is manual-style inspection and patrol method of substation inspection robot. Manual inspection is the staff of the substation with their eyes to see the state of the information one by one equipment; patrol method of substation inspection robot is to use robot instead of artificial inspection. However, manual inspection method is still adopted in the inspection of power substation equipment in our country [1,2]. Manual inspection is a subjective qualitative judgment analysis of substation staff, and it requires the staff to have rich experience and high level of business [3]. Substation is a high-risk place, the equipment inspection for the staff is a big potentially dangerous in bad weather. Using the robot instead of manual inspection of the oil level indicator can not only improve work efficiency, but also ensure the personal safety of the staff.

In view of this, an oil level indicator identification method is presented in this paper. The method is applied to the substation inspection robot, which ensures that the inspection robot can independently determine the oil level in the oil level meter, and completes the early warning work according to the actual situation of the oil level indicator.

2. Colour space

2.1. HSV color space
In image processing, the most commonly used color space is the RGB model, which is often used in color display and image processing. The HSV (Hue, Saturation, Value) model is a color space created by A. R. Smith in 1978 based on the intuitive nature of color, also known as the Hexcone Model. The model is a color model of user perception which focusing on color representation, such as color, depth, brightness and so on[4]. The parameters of the color in this model are: hue (H), saturation (S), brightness (V). As shown in Figure 1.

The HSV model is sensitive to color and insensitive to external conditions such as light[5]. HSV has a larger role in specifying color segmentation. The H and S components represent color information. The color distance is represented by the H and S components, and the color distance means the difference between the two colors. For different color regions, mixed H and S variables are used to delineate thresholds so that simple segmentation can be made. The RGB color space is converted to HSV as follows:

\[ V = \max\{R, G, B\} \]
\[ S = \begin{cases} 0 & V = 0 \\ \left( V - \min\{R, G, B\} \right)/V & V \neq 0 \end{cases} \]
\[ H = \begin{cases} 60 \times \left( G - B \right)/(S \times V), S \neq 0 \text{and } \max\{R, G, B\} = R \\ 60 \times \left( 2 + (B - R) \right)/(S \times V), S \neq 0 \text{and } \max\{R, G, B\} = G \\ 60 \times \left( 4 + (R - G) \right)/(S \times V), S \neq 0 \text{and } \max\{R, G, B\} = B \\ H \text{ is undefined, if } S = 0; H = H + 360, \text{ if } H < 0. \end{cases} \]

2.2. Lab color space

Compared with the RGB color space, Lab color model is an unusual color space. It was established on the basis of the international standards of color measurement developed by the Commission Internationale de l'Eclairage (CIE) in 1931. In 1976, it was officially named CIELab after its revision. It is color system which has nothing to do with the device and a color system that based on physiological characteristics. This means that it uses digital methods to describe human visual perception. The L component in the Lab color space is used to represent the luminosity of the pixel, the range of values is [0, 100], that is, the range of L is from 0 (black) to 100 (white), from pure black to pure white. a indicates the range from red to green and the range of values is [127, -128], which negative value indicating green and positive value indicates red. b represents the range from yellow to blue and the range of values is [127, -128], which negative value indicating blue and positive value indicates yellow[6,7]. The Lab color space is shown in Figure 2.

The advantages of the Lab color space are as follows:
1) Lab color is closer to human physiological vision.
2) It work on perception uniformity, and its L component is closely matched to human brightness perception.
3) Lab color model has nothing to do with device.
3) color gamut is wide.

![Figure 2. Lab color model.](image)

Therefore, in the processing of digital graphics, if you want to keep as wide gamut and rich colors as possible, you'd better choose Lab color space.

3. **SLIC superpixel segmentation**

Super pixel concept is image segmentation technology that proposed and developed by Xiaofeng Ren in 2003, which is an irregular pixel block consisting of adjacent pixels with similar texture, color, brightness and other features. It uses the characteristic similarity between pixels to group the pixels and with a small amount of super pixels instead of the pixel to express image features[8]. Greatly it reduces the complexity of image postprocessing, and usually used as a preprocessing step of segmentation algorithm.

SLIC that is simple linear iterative clustering. It is a simple and easy to implement algorithm that proposed in 2010. The color image is transformed into 5 dimensional feature vectors in CIELAB color space and XY coordinate, then the distance measure is constructed for 5 dimensional feature vectors, and the local clustering process of image pixels is carried out. SLIC algorithm can generate compact and approximately uniform hyper pixels, and it has a higher overall evaluation in terms of speed, contour preserving and hyper pixel shape, which is more in line with the desired segmentation results[9,10].

The advantages of SLIC are as follows:

1) super pixels that generated are as compact and tidy as cells, and the neighborhood features are easier to express.

   If the image has a total of $N$ pixels, and is pre divided into $K$ pixels of the same size. Then, the size of each sub pixel is $N/K$, and the distance (step) of the adjacent seed point is approximately $S=\sqrt{N/K}$.

2) not only can split color image, but also can be compatible with splitting grayscale image.

3) there are very few parameters that need to be set. By default, you only need to set a pre split number of super pixels.

4) SLIC is ideal in terms of running speed, superpixel compactness and contour retention.

SLIC specific implementation steps as follows:

   Step1: seed points are initialized (clustering center).
   Step2: Re-select the seed point in the $n \times n$ neighborhood of the seed point (generally, $n = 3$)
   Step3: class labels are assigned (that is, which cluster center does it belong to) for each pixel within the neighborhood of each seed point.
   Step4: distance measure.

The distance measure include color distance and space distance. For each pixel searched, the distance between it and the seed point is calculated respectively. The distance is calculated as follows:
\[ d_c = \sqrt{(l_j - l_i)^2 + (a_j - a_i)^2 + (b_j - b_i)^2} \]  
\[ d_s = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \]  
\[ D' = \sqrt{\left(\frac{d_c}{N_c}\right)^2 + \left(\frac{d_s}{N_s}\right)^2} \]

Where \( d_c \) represents the color distance, \( d_s \) represents the spatial distance, \( N_c \) is the maximum space distance within class. Defined as \( N_c = S \) for each cluster. \( N_s \) is the maximum color distance which varies with the image and the clustering, so we take a fixed constant \( m \) (the range of values [1,40], generally take 10) instead. The final distance metric \( D' \) is as follows:

\[ D' = \sqrt{\left(\frac{d_c}{m}\right)^2 + \left(\frac{d_s}{S}\right)^2} \]

Step5: iteration and optimization.
Step6: connectivity enhanced.

4. Experimental design and analysis of the results
The data of the oil level indicator images in the experiment are taken by the substation inspection robot during the inspection process. The process diagram of the algorithm is as follows:

As shown in Figure 4, the target detection consists of three parts:
(1) upper and lower limit positioning, the steps are as follows:
  Step1: collect the image template, calibrate the upper and lower ordinate of the oil level indicator, as shown in Figure 4.
  Step2: the inspection image and the template image are matched, and the longitudinal deviation is calculated.
  Step3: the upper and lower ordinates of the image are obtained based on the deviation and the upper and lower ordinates of the template.
(2) clustering segmentation, the steps are as follows:
Step1: the image template is used to determine the oil level indicator device area, as shown in Figure 5.
Step 2: SLIC segmentation is performed on the device area;
Step 3: Label matrix is calculated to obtain segmentation results, as shown in Figure 6.
Each region of the segmentation has a unique tag and formed a label matrix consistent with the original size; according to the tag matrix, the area of each label area (pixels) is calculated.

![Figure 4. Upper and lower limit calibration of template image (the upper and lower sides of the rectangle).](image)

Figure 4. Upper and lower limit calibration of template image (the upper and lower sides of the rectangle).

![Figure 5. Equipment area.](image) ![Figure 6. Segmentation results.](image)

Figure 5. Equipment area. Figure 6. Segmentation results.

(3) color space transformation, the steps are as follows:
Step1: RGB color space is converted into HSV space and the H component is extracted, as shown in Figure 7(a).
Step2: H component contrast is stretched.
Histogram equalization is done to make the image clearer, as shown in Figure 7(b).
Step3: coarse localization of interest region (ROI).
According to the experience, the processed H channel image is segmented, and the edge regions, such as the border, are eliminated, and the filtered image is filtered by Gauss filter, and the pixel value is changed after the equalization, as shown in Figure 7(c).
Step4: suspected location separation.
The pixel extremum of the image after segmentation is calculated. The extremum is used for coarse location segmentation, and morphological operation is performed to remove the noise and obtain the suspected position mask MaskH, as shown in Figure 7(d).
Step5: using the label matrix and MaskH for positioning segmentation, and the edge is determined.
The recognition results are shown in Figure 7(e).
Camera virtual focus or outdoor light changes are one of the important reasons for equipment blurring. The experiment also tested the image blurring for these reasons, and the test results were shown in Figure 8. Where the left is the original image, and the right is the recognition result.
The results of the above show that even if the image cannot be recognized by the human eye is still able to get a good effect, as shown in Figure 8(c).
5. Conclusion
The method proposed in this paper has been tested in substations, and shows better robustness to field light interference. The algorithm still shows very good recognition results in the case of blurred image, low-luminosity image, the image quality is not good enough that caused by camera virtual focus. It can be adapted to various sizes or styles of oil level gauge in substation. The implementation of this method obviously improves the correct rate of the oil level meter identification of the substation inspection robot in the bad situation, and effectively reduces the inspection intensity of the staff in the substation, Which promotes the substation intelligent development and unattended operation process.

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