Defect Detection Algorithm of Printing Roller Based on Visual Salience

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Abstract. Aiming at the complex surface condition of the printing roller and the requirement of high precision and high efficiency of the surface defect detection of the printing roller, a detection algorithm based on visual salience is proposed. Firstly, the dodging processing is used to eliminate the uneven illumination of the printing roller image; secondly, the non local means denoising algorithm is used to weaken the surface texture based on the redundant information commonly existing in the printing roller image; secondly, the spectral residual salience algorithm is used to calculate the salience of defects in the image and obtain the saliency map; finally, Sobel is used to detect the saliency map of defects and the manually labeled defect images were compared and analyzed. Experimental results show that the algorithm has high recognition rate and accuracy, and can meet the needs of surface defect detection of printing roller.

1. Introduction

1.1. Printing roller defect
The printing machine plays an important role in the printing industry[1]. As the core part of the printing machine (as shown in Figure 1), the bottom of the cylindrical roller is 120mm long and 400mm high. The collected image of the roller surface is shown in Figure 2. In the process of production and processing, there may be various defects, whose quality directly affects the quality of printed products. At present, the domestic roller defect detection is generally based on manual, the main problem of manual detection is that this situation leads to low detection efficiency, high production cost, and poor quality control. In view of these practical problems, it is an inevitable trend to improve the production efficiency and detect the surface defects of the printing roller with the method of visual salience.

![Figure 1. Printing roller image](image1)
![Figure 2. Roller surface image](image2)
1.2. Salient Object Detection
Salience object detection is an important branch of computer vision, which has become a hot research topic in recent years[2]. It means that human can extract more salient region from the scene through the vision system than other areas, which is helpful to eliminate the worthless areas in the image in the following visual tasks. Early researches on this kind of Context-Aware and processing ability mainly come from cognitive scientists. In recent years, researchers in the field of computer vision also have great interest in this field, and put forward a large number of salient target detection algorithms through research.

2. Printing roller defect detection algorithm
The purpose of this algorithm is to detect tiny defects in the surface image of the printing roller. Firstly, the algorithm compensates the brightness of different brightness areas in the surface image of the printing roller to make the brightness background of the whole surface image of the printing roller consistent. Then the image noise is removed by using the non local means denoising algorithm. Through the redundancy and domain of the image itself similarity can enhance the information of geometric space structure of image, and then achieve better denoising effect. Then the image input spectrum residual salience algorithm is processed to obtain the final saliency map and carry out Sobel detection. The algorithm flow is shown in Figure 3.

![Figure 3. Process algorithm of detection](image)

2.1. Dodging processing
For the surface image of the printing roller, there is a great difference between the high brightness area and the low brightness area, thus affecting the next processing effect[3]. To avoid this situation, an image brightness equalization algorithm is used.

Algorithm principle: set a \( M \times N \) image with grayscale of \((0, \cdots, L)\). The average brightness is:

\[
Lum_{av} = \frac{\sum_{i=0}^{M-1} \sum_{j=0}^{N-1} p(i, j)}{M \times N}
\]  

(1)

Where \( P(i, j) \) is the pixel brightness value in the image with the coordinate of \((i, j)\).

The image is divided into blocks with a sub block size of \( m \times n \), and the average brightness of each sub block is:

\[
Lum_{av, bm} = \frac{\sum_{i=0}^{m-1} \sum_{j=0}^{n-1} p(i, j)}{M \times N}
\]  

(2)

The Luminance difference is:

\[
\Delta_{lum} = Lum_{av, bm} - Lum_{av}
\]  

(3)

The algorithm steps are as follows:
(1) input the image to get the global average brightness of the image;
(2) the average luminance of each block (16 × 16 or 32 × 32) of the image is obtained by scanning;
(3) subtract the global average luminance from each value in the sub block luminance matrix to obtain the sub block luminance difference matrix;
(4) extend the sub block luminance difference matrix to the same size as the original image by interpolation, and obtain the luminance difference matrix of the whole image;
(5) the luminance values of each pixel of the original image are subtracted from the corresponding values in the luminance difference matrix of the whole image;
(6) adjust the brightness of each sub block pixel according to the minimum and maximum brightness in the original image to make it conform to the whole brightness range;

2.2. Non-local means denoising
Assuming that the noise signal is Gaussian white noise independent of the image[4], the noise model is:

\[ V(i) = X(i) + N(i) \]  

(4)

where, \( X(i) \) is the original image that is not polluted by noise; \( N(i) \) is the white noise whose mean value is 0 and variance is \( \sigma^2 \); \( V(i) \) is the contaminated noise image; For a discrete noisy image (\( v = \{v(\alpha)|\alpha \in I\} \)), the non-local means denoising method uses the weighted average of the gray values of all pixels in the whole image to get the gray estimation value of the point:

\[ NL[v](\alpha) = \sum_{\beta=1}^{N} \omega(\alpha, \beta) v(\beta) \]  

(5)

Where \( \omega(\alpha, \beta) \) is dependent on the similarity between \( \alpha \) and \( \beta \), and meets the following conditions: \( 0 \leq \omega(\alpha, \beta) \leq 1 \), \( \sum \omega(\alpha, \beta) = 1 \). The similarity between pixels \( \alpha \) and \( \beta \) is determined by the similarity between the corresponding gray value vectors \( v(N_\alpha) \) and \( v(N_\beta) \). \( N_k \) is a fixed size square field centered on pixel \( k \). For example, \( v(N_\alpha) \) is a vector composed of gray values in domain \( N_k \). Assuming that \( \alpha \) is the current pixel to be processed, the similarity of pixels \( \alpha, \beta_1 \) and \( \beta_2 \) is determined by the similarity of \( v(N_\alpha) \), \( v(N_{\beta_1}) \) and \( v(N_{\beta_2}) \). The similarity of gray value vectors among different fields is measured by Gaussian weighted Euclidean distance. The weight \( \omega(\alpha, \beta) \) expressed by Euclidean distance is defined as:

\[ \omega(\alpha, \beta) = \frac{1}{Z(\alpha)} e^{-\frac{1}{h^2} \frac{1}{h^2} \| v(N_\alpha) - v(N_{\beta}) \|^2} \]  

(6)

Where \( Z(\alpha) \) is the normalization constant.

2.3. Calculation and extraction of defect salience
Firstly, the image is Fourier transformed into frequency domain[5], and the amplitude spectrum and phase spectrum are calculated.

\[ A(f) = R(\xi[I(x)]) \]  

(7)

\[ P(f) = S(\xi[I(x)]) \]  

(8)

Then, the amplitude spectrum is changed to log spectrum (log the amplitude spectrum), and then the log spectrum is filtered in linear space (3 * 3 mean filtering), and the difference between them is made to get the residual spectrum.

\[ L(f) = \log(A(f)) \]  

(9)

\[ R(f) = L(f) - h_n(f) * L(f) \]  

(10)

The residual spectrum and the phase spectrum are used for the inverse Fourier transform to obtain the saliency map. Perform linear space filtering (Gaussian filter with 8 * 8 mean value).
\[ S(x) = g(x) \ast \epsilon^{-1}[\exp(R(f) + P(f))]^2 \] (11)

2.4. Sobel edge detection

Algorithm principle: Sobel algorithm is one of the most commonly used algorithms because of its simplicity, small computation, high speed and low hardware requirements[6]. Assuming that \( H(x, y) \) is the image function, the gradient vector of the image can be calculated according to equation (12).

\[
\nabla H(x, y) = \begin{bmatrix} H_x \\ H_y \end{bmatrix} = \begin{bmatrix} \frac{\partial H}{\partial x} \\ \frac{\partial H}{\partial y} \end{bmatrix}
\] (12)

Where \( \nabla H(x, y) \) is the gradient vector of the image function, \( H_x \) is the horizontal gradient of the image, and \( H_y \) is the vertical gradient of the image.

\[
\begin{bmatrix}
H(i-1, j-1) & H(i-1, j) & H(i-1, j+1) \\
H(i, j-1) & H(i, j) & H(i, j+1) \\
H(i+1, j-1) & H(i+1, j) & H(i+1, j+1)
\end{bmatrix}
\] (13)

In digital image, the modulus of image gradient is also called gradient, which can be obtained by (14).

\[
|\nabla H(x, y)| = \sqrt{H_x^2 + H_y^2}
\] (14)

In practical application, for the convenience of calculation, direction of gradient is:

\[
\theta = \arctan \frac{H_y}{H_x}
\] (15)

Formula (15) is the direction in which image intensity changes.

The algorithm steps are as follows:

1) each pixel of the image is convoluted with the convolution template , and the pixel value corresponding to the center of the convolution template is replaced by the maximum value of the convolution result as the gray value of the new image:

\[
G(i, j) = \max[H_x(i, j), H_y(i, j)]
\] (16)

Where, \( G(i, j) \) is the new gray image pixel, \( H_x(i, j) \) and \( H_y(i, j) \) are the convolution values of the same pixel of the horizontal and vertical templates respectively.

2) after all the pixel convolution operations, a new gray image is obtained.

3) select a suitable threshold \( T \), if the image gradient value is greater than the threshold \( T \), then the pixel is considered as an edge point. Explain mathematically, as shown in formula (17).

\[
H(i, j) = \begin{cases} 
255 & |\nabla H(x, y)| > T \\
0 & |\nabla H(x, y)| < T 
\end{cases}
\] (17)

In conclusion, the flow chart of the specific algorithm steps of the detection algorithm in this paper is shown in Figure 4.
Frank processing
Non-local means denoising
The spectral residual algorithm
Input image
Calculate the average brightness of the image
Calculate the average brightness matrix of the sub block
Calculate sub block brightness difference matrix
Calculate global brightness difference matrix
Obtain brightness equalization image
Gray scale estimate
Compare all pixels one by one
Get denoised image
Image Fourier transform
Calculation of residual spectrum
Saliency map obtained by inverse Fourier transform
Sobel edge detection
Output image

**Figure 4.** Flow chart of specific algorithm steps of detection algorithm in this paper

### 3. Experimental results and analysis

#### 3.1. Experimental comparison

50 surface images of printing roller with 126 defects were selected from the image library, and the actual defects on the surface of printing roller were manually marked, with the marking results as the standard. Sobel detection is applied to the salience map of RC algorithm and ITTI algorithm respectively. The detection results are compared with the detection algorithm in this paper.

#### 3.2. Experimental evaluation

Taking Figure 5 as an example, the image of printing roller with multiple defects is detected by the algorithm in this paper and other algorithms, and the results of manual annotation are compared with the detection results of various algorithms for evaluation. Through comparison, it can be found that in the detection of printing roller defects, RC algorithm detects defects 2 and 3, but there is defect 1 missed, as shown in Figure 6. The ITTI algorithm detects defects 1, 2, 3 and 4, in which defect 4 is the false detection point, as shown in Figure 7. This algorithm accurately detects defects 1, 2 and 3, and there is no false detection, as shown in Figure 8.

**Figure 5.** Manual defect marking diagram  
**Figure 6.** Defect marking diagram of RC algorithm.

**Figure 7.** Defect marking diagram of ITTI algorithm  
**Figure 8.** The algorithm defect annotation graph in this paper

In this paper, the accuracy rate \( P \), recall rate \( R \) and comprehensive index \( F \) are used to determine the proximity between the defect area detected by the algorithm and the manually marked area[7]. The calculation formula is:
\[ p = \frac{R_{TD}}{R_D}, R = \frac{R_{TD}}{R_T}, F = \frac{2PR}{P + R} \]  \hspace{1cm} (18)

Where: \( R_T \) is the true value manually marked, \( R_D \) is the defect area detected by the algorithm, \( R_{TD} \) is the intersection of the two. \( P \) is used to evaluate the accuracy of the algorithm, \( R \) is used to evaluate the ability of the algorithm to find defects, and \( F \) is a comprehensive evaluation index related to the two.

50 surface images of printing roller with 126 defects are selected from the image library for algorithm comparison and analysis. The calculation results of evaluation indexes are shown in Table 1.

| Table 1. This algorithm is compared with other similar algorithms |
|-------------------|---|---|---|
|                  | P  | R  | F  |
| RC               | 0.69 | 0.90 | 0.78 |
| ITTI             | 0.64 | 0.98 | 0.77 |
| Algorithm in this paper | 0.78 | 0.97 | 0.86 |

From the experimental analysis in Table 1, it can be seen that the ability of RC algorithm to find defects is strong but the accuracy is too low, and the ability and accuracy of RC algorithm to find defects are not ideal. The algorithm in this paper performs well in both aspects, so the algorithm is more suitable for the defect detection of printing roller.

4. Conclusion

The visual salience algorithm is applied to the defect detection of printing roller. Through the comparison and analysis with other algorithms, it is proved that the algorithm has better accuracy and reliability than other algorithms, and can achieve real-time detection in industrial production. The following research will be devoted to the detection of defects with small discrimination and accurate positioning of irregular defects, so as to improve the general applicability of the algorithm to various defects and the detection accuracy of composite defects.

Acknowledgments

This paper is supported by the scientific research program of Beijing Municipal Education Commission. The project name is "Research on the intelligent recognition system of printing roller surface defects based on machine vision" (No. KZ202010015021)

References

[1] Wang MD. Research on the surface defect detection technology of printing roller based on machine vision[J]
[2] Zhang SD, Yang M, Hu T. Salient target detection algorithm based on multi feature fusion[J]. *Journal of Frontiers of Computer Science and Technology*, 2019, 13(05):118-129
[3] Peng XB, Jiang JG. An image threshold segmentation technique based on brightness equalization[J]. *Computer Technology and Development*, 2006, 16(11):10-12
[4] Qian HM, Sun JY, Wang CH. Research on image denoising method based on non local mean algorithm[J]. *Journal of Anhui Technical College of Water Resources and Hydroelectric Power*, 2019(1)
[5] Wei Y. Research on the method and application of image saliency region detection[D]. Shandong University
[6] Han LF, Lu C. Implementation of edge detection based on improved Sobel operator[J]. *Automobile Applied Technology*, 2019, 287(08):117-119
[7] Qin ZW, Chen J, Hong RJ, et al. Visual salience detection algorithm for surface defects of friction sheets[J]. *Journal of Zhejiang University-Science A (Applied Physics & Engineering)*, 2019(10)