Acta Technica 62 (2017), No. 7A, 149–158

Defect detection and location of bearing images based on predictive matching difference and global local thresholding

Tiancheng Wang[1]

Abstract. To solve the inaccurate detection caused by small defects in the current workpiece surface in the case of blurry edges and obscure features, the Paper proposes the workpiece surface small defect detection algorithm based on image pixel level segmentation and label mapping. First, the workpiece image shall be collected by industrial microscope to obtain the microscopic defect map; and according to the efficient principle, through the replacement of the floating-point with integer and replacement of multiplication with displacement, design of displacement brightness filter operator and conversion of platform data, based on the label mapping of pixel brightness threshold, the binary image of pixel brightness distribution of micrograph shall be obtained. Then, couple the Gauss smooth filter and shape filter, strengthen image edge contour feature and carry out connected region labeling to identify and locate the small defects correctly. Last, the characteristic calculation and label display shall be carried out for the defect target, and the automatic detection and quantitative calculation of small defects shall be completed. Experimental test results show that: compared with the current workpiece surface defect detection algorithm, the detection technique proposed in this Paper has higher recognition accuracy.

Key words. Defect detection, Pixel segmentation, Label mapping, Brightness filter, Gauss smooth filter, Shape filter, Characteristic calculation.

1. Introduction

Prior to the automatic processing of the workpiece, it is necessary to detect small defects on the surface of the workpiece to improve the quality of workpiece products [1-2]. In the current manufacturing sector, small defects are generally nanoscale, although they can be observed under the industrial microscopic imaging system, there are problems of blurry edges and obscure features of defect target, together with the impurity interference, affecting the detection results of the machine vision

[1]School of Information Science and Engineering, Changzhou University, Changzhou, Jiangsu, 213164, China

in the end. For this purpose, scholars at home and abroad have put forward the corresponding workpiece surface defect detection technology, and have achieved some research results, such as Jiang Caiyun [3], proposed surface defect detection algorithm of metal workpiece based on CPU, that is, first to collect the surface image of metal workpiece with image sampling equipment, conduct the image registration and split image with difference image method after completing the pretreatment of mixed noise filtering, and then make the defects and extract defect texture features, in the end, conduct the classification and identification of workpiece defects to complete the automatic check-out of sub-quality workpiece. Luo Sanding [4] proposed the projection analysis and algorithm of workpiece surface defect detection, in which the vertical grain defect detection algorithm for peak and valley decision and workpiece edge line detection and injection defect integral value decision algorithm based on block projection are designed by analyzing the characteristics of the defects to realize the automatic inspection of computer on surface vertical lines and injection defects of workpiece. However, this technique only considers the condition that the edge of image defect is clearer, when edges are blurred, the defects cannot be detected accurately.

2. Small defect detection algorithm in this paper

As there are nanoscale small defects on the surface of workpiece, the edge fuzziness and the feature weakness put forward higher requirements for the accuracy of the detection algorithm. The algorithm in this Paper conducts the segmentation, enhancement and localization detection for the workpiece from pixel aspect.

First, the conversion of image data from QT platform to ITK (Insight Segmentation and Registration Toolkit) platform shall be achieved, and the brightness filter and pixel threshold mapping mark shall be coupled to obtain the binary image including defects. Next, the defect image shall be strengthened by combing with the Gauss filter and smoothing treatment; the defect targets shall be separated by label function in ITK connected region and the impurity interference shall be removed to form complete workpiece surface small target detection system, of which the overall logical architecture is shown in Fig.1. Microscopic defect image to be detected, as shown in the Fig. 2, shows that the surface of defect is blurry and the characteristics are not obvious.

2.1. Coarse segmentation based on brightness filter and mapping label

To obtain the approximate location of defect target, that is to mark out the pixel in defect region, the Research first adopts the brightness filter and brightness spectrum image to highlight defect brightness information; according to the pixel threshold, the map treatment shall be implemented on the brightness spectrum image to obtain the binary image containing defect targets and impurities. First, microscopic defect map shall be treated by brightness spectrum conversion function

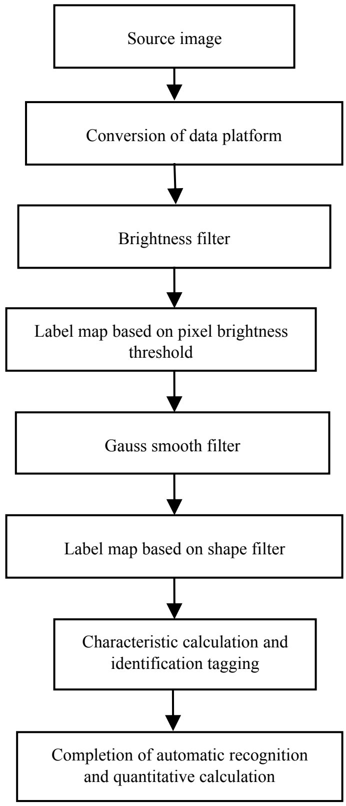


Fig. 1. Mechanism framework of the paper

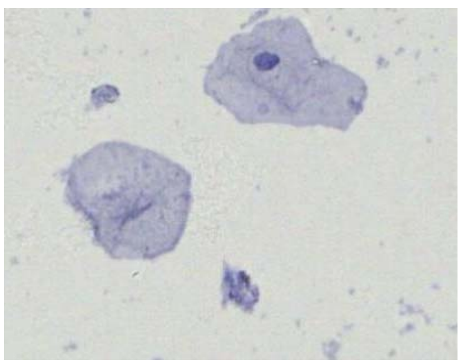


Fig. 2. Workpiece surface micrograph containing impurities and defects

[5]:

$$\text{Light} = R * 0.299 + G * 0.587 + B * 0.114\,. \tag{1}$$

In above formula, Light represents brightness spectrum image, R refers to the content of red channel image, G represents content of green channel image and B refers to the content of blue channel image. In the practical application experiment, the integral algorithm is used instead of low-speed floating-point calculation and the displacement is used instead of multiplication in this Research:

$$\mathrm{LightApr} = (R * 30 + G * 59 + B * 11 + 50) << 2\,. \tag{2}$$

Where, LightApr represents the improved brightness spectrum image, and the system efficiency shall be improved on the premise of guaranteeing the imaging quality of image.

Next, the conversion of data platform shall be carried out, and the Research UI adopts QT for development. The algorithm is achieved on the basis of high-efficiency open source library ITK. First, the local image file shall be converted to QImage-type data of QT platform and then converted to the data that can be processed by the ITK library function to obtain the brightness spectrum image, as shown in Fig. 3, showing that the defect image shall be strengthened further.

then, pixel level operation shall be carried out for the image to output the binary image based on pixel threshold mapping [6]:

$$Value = \begin{cases} 1 & pixel > threshold \\ 0 & pixel \leq threshold \end{cases} \tag{3}$$

In above formula, Value means the binary image treated by mapping label, pixel represents the pixel brightness and threshold refers to the pixel threshold from the project standard, not to be repeated here.

Disposed by formula 3, the binary image containing defects and impurity is obtained, that is completing the coarse segmentation of small defects on the surface. To show the effect effectively, here, take the left half of Figure 3 for example for analysis; and the defects and impurities in local area are shown in Fig. 4(a); and binary pixel labeled graph of defects and impurities is shown in the Fig. 4(b), reflecting the correct course segmentation of defect target and removal of a small amount of impurity.

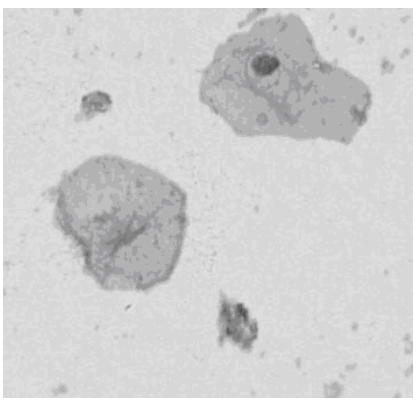
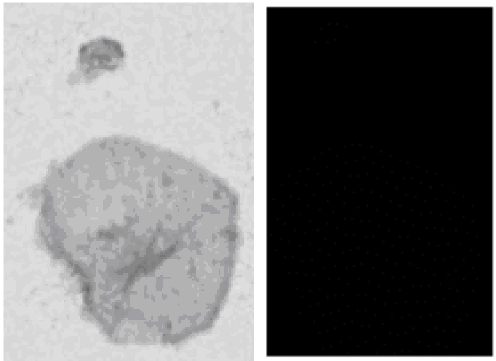


Fig. 3. Results of brightness filter



(a) (b)

Fig. 4. Results of mapping label

Some of the key codes are as follows:

```
itkUCharImageType::Pointer cellMaskImage = itkUCharImageType::New();
cellMaskImage->SetRegions(imageGray->GetLargestPossibleRegion());
cellMaskImage->Allocate();
cellMaskImage->CopyInformation(imageGray);
itkUCharImageType::PixelType* imageGrayPointer = imageGray
->GetBufferPointer();
itkUCharImageType::PixelType* cellMaskImagePointer = cellMaskImage
->GetBufferPointer();
for (int j=0; j<width*height; j++){
if (imageGrayPointer[j] < 210){
    cellMaskImagePointer[j] = 1;}
else{
    cellMaskImagePointer[j] = 0;}}
```

2.2. Resegmentation based on Gauss smooth filter and connected region labeling

To further strengthen the binary image, the defect targets and impurity interference shall be distinguished. The Research couples 2-d Gaussian filters [7] and image smooth processing [8]. First, Gauss equation is built as follows:

$$O(x, y) = G(x, y)I(x, y)\,. \tag{4}$$

In formula (4), I represents pre-processing image, O refers to processed image and G represents the Gaussian kernel, as follows:

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}\,. \tag{5}$$

In above formula, $G(x, y)$ represents the Gaussian kernel, where x and y respectively refer to the pixel of image in abscissa and ordinate. And then the smoothing shall be carried out, of which the equation is as follows:

$$OI(x,y) = P(x,y)II(x,y)\,. \tag{6}$$

In formula (6), II represents pre-processing image, OI refers to processed image and P represents the smoothing kernel, as follows:

$$p = \frac{1}{273}\begin{bmatrix} 1 & 4 & 7 & 4 & 1 \\ 4 & 16 & 26 & 16 & 4 \\ 7 & 26 & 41 & 26 & 7 \\ 4 & 16 & 26 & 16 & 4 \\ 1 & 4 & 7 & 4 & 1 \end{bmatrix}. \tag{7}$$

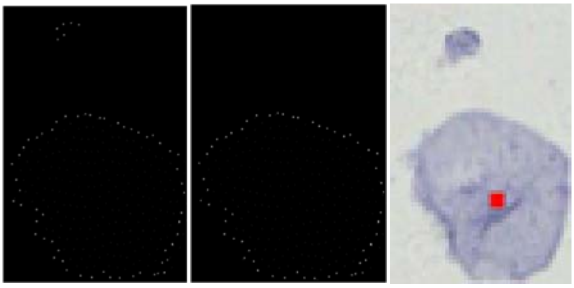
In formula (7), p represents the smoothing kernel. Because of its structure smoothing principle, it can enhance the defect target and reduce the interference of impurity.

For Fig. 4(b), after the Gauss smoothing of the Research, 5(a) is obtained, showing that the target profile of defects and impurities has been enhanced. Based on such results, the removal of impurities and marking defects can be achieved through the treatment of connected region labeling function in ITK.

First, the binary image shall be converted to the label image and its shape attributes shall be evaluated by adopting BinaryImageToShapeLabelMapFilter function [9], and a binary image shall be converted to the label mapping and its shape attributes shall be evaluated; and then small attribute value of target image in the label set shall be deleted by adopting ShapeOpeningLabelMapFilter function. A LabelMap shall be converted to labeled image by adopting LabelMapToBinaryImageFilter function; and the object of connected region labeling function [10] ConnectedComponentImageFilter label is in a binary image, and each different object is distributed with a special label. According to the characteristics differences of perimeter, area and form of the label, the impurities shall be filtered to obtain the defect target, as shown in Fig. 5(b), showing that the connected region labeling function achieves the desired effect. In the end, to further display the effects of location detection, the center of gravity of defect is marked with red rectangle, as shown in Fig. 5(c).

Some of the key code is as follows:

```
typedef itk::ConnectedComponentImageFilter <itkUCharImageType, itkIntImageType > ConnectedComponentImageFilterType;
typedef itk::LabelImageToShapeLabelMapFilter< itkIntImageType,
LabelMapType> I2LType;
ConnectedComponentImageFilterType::Pointer connected = ConnectedComponentImageFilterType::New ();
connected->SetInput(cellMaskImage);
connected->Update();
I2LType::Pointer i2l = I2LType::New();
i2l->SetInput( connected->GetOutput() );
```



(a) (b) (c)

Fig. 5. Results of resegmentation

```
i2l->SetComputePerimeter(true);
i2l->Update();
LabelMapType *labelMap = i2l->GetOutput();
```

3. Experiment and discussion

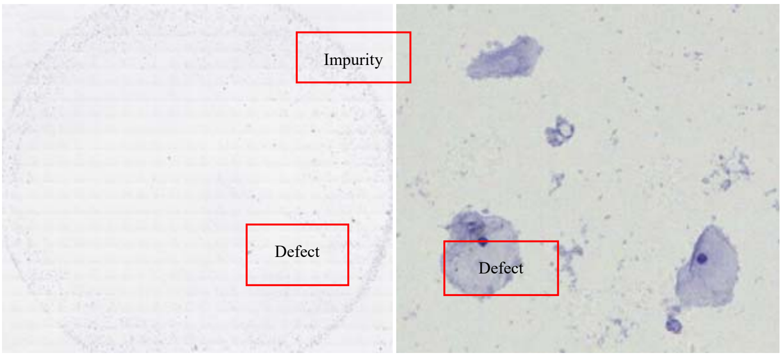
For purpose of reflecting the advantages of the algorithm in the Paper, the technology with better performance of defect detection –Literature [3] and Literature [4] is set as the control group. The paper system is developed and achieved on the basis of QTCreator4.2 platform, C++ language and ITK4.11, with experimental parameters of algorithm such as: brightness threshold for 200, Gauss smoothing coefficient for 0.62, together with region mark characteristic number for 500.

Due to small nanoscale defects that cannot be identified under comprehensive view of industrial camera, as shown in Fig. 6(a), after obtaining the microscopic defect image by magnifying the defects via microscope, treatment shall be performed, as shown in Fig. 6(b), with defect and impurity interference in the image.

In this paper, the image defect detection algorithm first achieves the binaryzation of image target combined with brightness filter and threshold mapping label, and then removes the impurity interference and correctly locates the detected defects via Gauss smooth filter and connected region label. As shown in Fig. 7 (a), highlight defect area processed by brightness filter; and enhance the contour characteristics of image edge by coupling the Gauss smooth filter and shape filter, as shown in Fig. 7(b). In the end, conducting connected region label, characteristics calculation and annotation display shall be carried out for the defect target to correctly identify and locate the small defects, as shown in Fig.8, showing that defect detection is correct.

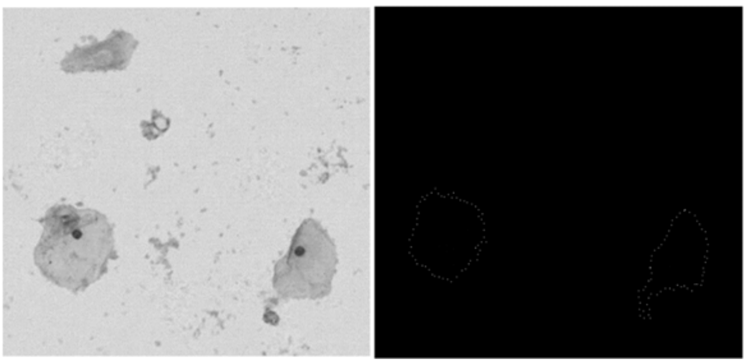
Based on the technology of Literature [3] in control group, the image shall be registered and segmented with difference image method after the pretreatment of mixed noise filtering, followed by marking the defect and extracting the characteristics of defect texture, and the automatic check-out of sub-quality workpiece shall be completed in the end. However, this technology detects only from computer accelerated processing and preprocessing and often ignores the influence of non-obvious characteristics, resulting in error detection. The Fig.9 reflects the over strict inspection of the image.

Based on technology of Literature [4] in control group, the vertical grain defect detection algorithm for peak and valley decision and workpiece edge line detection and injection defect integral value decision algorithm based on block projection are designed by analyzing the characteristics of the defects to realize the automatic detection of defects. However, this technique only considers the condition that the edge of image defect is clearer, when edges are blurred, the defects cannot be detected accurately. The Fig. 10 shows inaccurate detection of the image.



(a) Full field image (b) Micrograph

Fig. 6. Undetected curves image



(a) Brightness filtering processing (b) Edge contour enhancement results

Fig. 7. Segmentation results of this paper

4. Conclusion

To solve the insufficient inspection output for small defects detection caused by current defect detection algorithm in the case of non-obvious defect characteristics and blurry edge of the image, the Paper, respectively from the image pixel segmentation and ITK function, proposes the image enhancement method based on

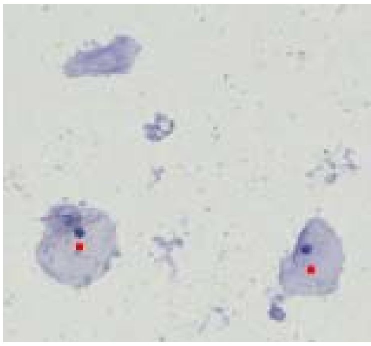


Fig. 8. Detection result of this paper

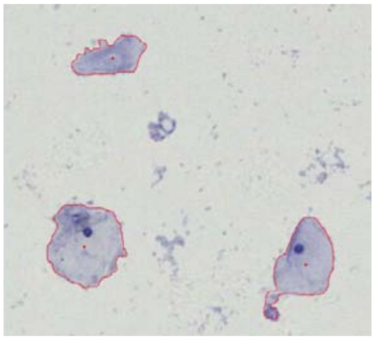


Fig. 9. Detection result chart of literature [3]

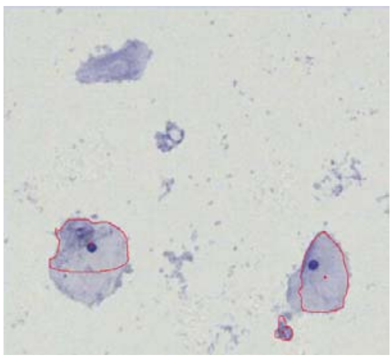


Fig. 10. Detection result chart of literature [4]

brightness filter and Gauss smooth filter. By designing and coupling pixel threshold mapping and connected region processing, the removal of impurity interference and the detection of small defects are achieved. The experimental results show that the proposed method of small defect detection has better detection ability.

References

[1] M. A. Laguna, J. M. Marqués, R. C. Guillermo: (2011) *Feature Diagram Formalization Based on Directed Hypergraphs*[J]. Computer Science & Information Systems, 8(3):611–633.

[2] F. Amato, V. Moscato, A. Picariello, et al.: *Centrality in heterogeneous social networks for lurkers detection: An approach based on hypergraphs*[J]. Concurrency & Computation Practice & Experience, *2017* (2017), No. 1-2.

[3] J. Huang, G. Li, N. Li, et al.: *A Violence Detection Approach Based on Spatio-temporal Hypergraph Transition*[J]. *2017* (2017), 218–229.

[4] Y. Park: *Anomaly Detection in Time-Series of Graphs and Hypergraphs using Graph Features*[J]. (2011)

[5] Y. Z. Li, D. Wu, J. D. Ren, et al.: *An Improved Outlier Detection Method in High-dimension Based on Weighted Hypergraph*[M]. IEEE Computer Society. (2009).

[6] Y. Zhan, J. Sun, D. Niu, et al.: *A semi-supervised incremental learning method based on adaptive probabilistic hypergraph for video semantic detection*[J]. Multimedia Tools & Applications, *74* (2015) (15), 5513–5531.

[7] Z. Hu, J. Li, M. Zheng, et al.: *Hypergraph-Based Data Reduced Scheduling Policy for Data-Intensive Workflow in Clouds*[C]// International Conference of Pioneering Computer Scientists, Engineers and Educators. Springer, Singapore, *2017* (2017): 335–349.

[8] K. W. Park, D. H. Lee: (2015) *Visual saliency detection via hypergraph based reranking using background priors*[C]// International Conference on Ubiquitous Information Management and Communication. ACM, 2015:62.

[9] I. Dinur, V. Guruswami, S. Khot, et al.: *A new multilayered PCP and the hardness of hypergraph vertex cover*[C]// ACM Symposium on Theory of Computing. ACM, *2003* (2003), 595–601.

[10] V. Ümit, Çatalyürek, C. Aykanat, E. Kayaaslan: *Hypergraph Partitioning-Based Fill-Reducing Ordering for Symmetric Matrices.*[J]. Siam Journal on Scientific Computing, *33* (2011), No. 4, 1996–2023.

[11] J. Hu, D. Fang, X. Wei, et al.: *Colluder Detection Based on Hypergraph Decomposition*[C]// Ninth International Conference on Computational Intelligence and Security. IEEE Computer Society, *2013* (2013), 630–634.

[12] H. Debar, M. Dacier, A. Wespi: *A revised taxonomy for intrusion-detection systems.*[J]. Annales Des Télécommunications, *55* (1999), No. 7-8, 361–378.

[13] F. Jemili, M. Zaghdoud, M. B. Ahmed: *Hybrid Intrusion Detection and Prediction multiAgent System HIDPAS*[J]. Biomedical & Environmental Sciences, *4* (2009), No. 2, 136–140.

[14] J. Zhang, S. Fang, K. A. Ehinger, et al.: *Probabilistic Hypergraph Optimization for Salient Object Detection*[J]. *2017* (2017), 368–378.

[15] Q. Cheng, Z. Liu, J. Huang, et al.: *Hierarchical Clustering Based on Hyper-edge Similarity for Community Detection*[C]// Ieee/wic/acm International Conferences on Web Intelligence and Intelligent Agent Technology. IEEE, *2013* (2013), 238–242.

[16] B. Koszteczky, G. Simon: *Sensor Fusion for Intrusion Detection With Sensor Networks*[J]. Macro, *1* (2015), No. 1, 275–282.

[17] S. Dalia, Y. Y. Abdelhamid, D. R. Zhang,Lewis, P. V. Moghe, W. J. Welsh, and K. E. Uhrich: *Tartaric Acid-based Amphiphilic Macromolecules with Ether Linkages Exhibit Enhanced Repression of Oxidized Low Density Lipoprotein Uptake*, Biomaterials, *53* (2015), 32–39.

[18] Y. Y. Zhang, J. W. Chan, A. Moretti, and K. E. Uhrich: *Designing Polymers with Sugar-based Advantages for Bioactive Delivery Applications*, Journal of Controlled Release, *219* (2015), 355–368.

Received May 7, 2017