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Procedia Computer Science 107 (2017) 836 – 841

Procedia Computer Science

International Congress of Information and Communication Technology (ICICT 2017)

Automatic Wheat Leaf Rust Detection and Grading Diagnosis via Embedded Image Processing System

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Abstract

Wheat leaf rust is one of the major fungal diseases that makes severe drop in the wheat production. With the desire for rapid and accurate identification of disease, real-time access to the degree of that and timely measures, a wheat leaf diseases detection system based on embedded image recognition technology is designed. The system adopted the ARM9 processor with the embedded Linux platform as the main body, and the program is developed in the Qt integrated environment. At first, the captured clear disease picture of wheat leaf rust was transformed into G single channel gray image of RGB model. Second, based on exploration Sobel operator method, vertical edges detection were implemented on the gray image, eliminate the background of image and extracts binary feature point set of disease spot. Third, the noisy points in the point set is further filtered out by flood filling algorithm. Finally, the area ratio of disease spots and leaf is calculated to get the precise diagnosis of disease level. It has been verified that the recognition rate reaches 96.2% and accuracy rated reaches 92.3% with the method of image processing, which is approximately equal to the result of human vision. This system can be used as agricultural robot to inspect in the field, realizing the intelligentization in detection, identification, diagnosis and classification of crop disease.

Keywords: Wheat Leaf Rust; image processing; disease diagnosis; Embedded system;

1. Introduction

Wheat, with large planting area and wide distribution on the world, also is the main grain and cash crops in China. Wheat leaf rust (WLR) is the typical leaf disease of wheat, can lead to the output decreasing 35%, resulting in serious economic losses[1]. Currently, the main methods of diagnosing the diseases on leaves are qualitative analysis by experience, pathogen identification and hyperspectral remote sensing[2-5]. Among them, qualitative analysis by experience is easy to result in erroneous judgment because the symptom of wheat leaf rust, not evident enough in preliminary stage, is similar to that of yellow rust and powdery mildew; and pathogen identification usually needs a

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Peer-review under responsibility of the scientific committee of the 7th International Congress of Information and Communication Technology
doi:10.1016/j.procs.2017.03.177

long time to diagnose the diseases, leading to missing the best control period; and hyperspectral remote sensing may cause the unstable result and low precision due to the phenomenon of 'different object with same spectrums' and 'same object with different spectrums' and that the equipment based on this technology is so valuable that it is not easy to promote.

With the development of the computer hardware and software technology, the recognition technology, based on image processing and machine vision technology, gradually becomes a hot pot because it can realize the automatic rapid identification of crop diseases[6-8]. Tao Meng proposed a subspace-based multi-layer classification framework of annotating temporal stages for biological images[9]. According to these researches, applying image processing technology to crop disease identification and diagnosis has many advantages compared to traditional methods, such as accuracy, immediacy, intelligentialize and so on. However, in order to extract the disease feature correctly, different image processing algorithms, such as the Graying processing of image pretreatment, should be adopted because the symptoms of kinds of diseases are different. It can be concluded that B single channel is fit for Rice sheath blight disease, but as far as wheat leaf rust is concerned, G single channel should be adopted, while in terms of the leaf with more complicated background such as grape gray mold rot, the image enhancement in advance is necessary and the mean value method is more likely to be used. Many researchers have made unified principles of data acquisition and stage treatment and have tried to build a widely-used diagnosis algorithm based on image data fusion and data mining technology[10], but with the restriction of the disease characteristic mentioned above, the low accuracy, even miscalculation can not be avoided when it is applied in actual diagnosis. In this study, it tends to build a specific image processing algorithm for the special disease so that the result is more accurate, processing speed is faster and the embedded system is more easily to be integrated.

According to the preamble, a diseases detection system based on embedded image processing technology is designed, and that the complete process of image processing and grading diagnosis is introduced by taking the example of wheat leaf rust. This system not only overcomes those shortcomings possessed by traditional crop disease detection, but also has many advantages including integration, high processing speed, less errors, etc. And it can be used as a robot being able to make an inspection tour of the wheat field, which can complete crop disease detection, diagnosis and grading automatically.

2. Materials and digital image processing

The identification of the color image mainly includes the processes of image captured, image processing and identification, diagnosis and classification of disease. The method adopted in each process is different according to the characteristics of different disease. The logical structure of the model is shown in figure 1. In this essay, the process and methods to realize the image recognition are introduced, with wheat leaf rust as the research object.

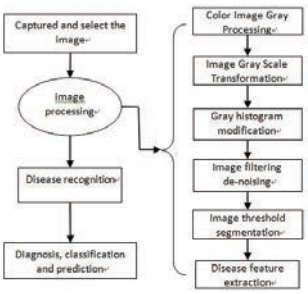

Fig. 1. the image recognition model of wheat leaf diseases

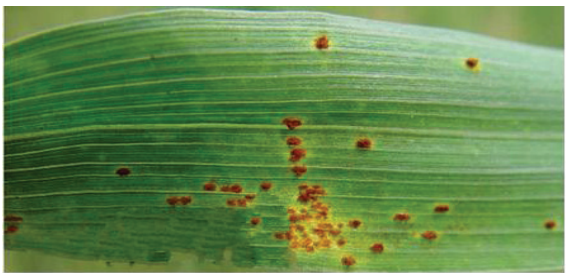

Fig. 2. the original image

2.1. Capture the image and runtime environment

Figure 2 is a captured disease leaf image of WLR. The image was taken from Jiangsu Polytechnic College of Agriculture and Forestry's experimental field on 10, April, 2015.

The proposed crop disease detection system in this research, for hardware, SAMSUNG's S3C2440A is chosen as the microprocessor[11,12]. For software, embedded Linux is chosen as the operating system and Qt is used to write application software programs[13,14].The block diagram of Real-time detection based on ARM9 is shown in figure 3.

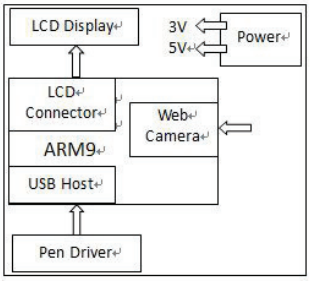

Fig. 3. system block diagram

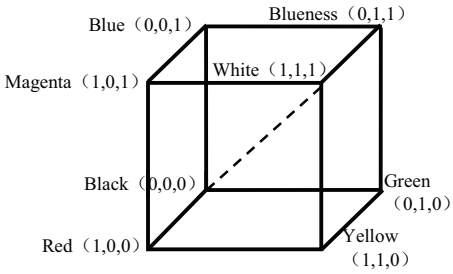

Fig. 4. co-ordinates of RGB model

This system takes captured image by means of web camera connected to ARM microcontroller through USB. The whole process showed up and results are displayed with the help of LCD.

2.2. Image processing

2.2.1. Color image gray processing

The image is selected with the format JPEG. If this unprocessed image is to be dealt, the image processing speed will be slow and processing precision will be low because the image contains much data. So, this selected image was pretreated by graying firstly.

RGB, HSV, CMYK are common color model, the method of converting the original image into single color channel is usually adopted in the extraction of color parameter. This research adopts the single channel of RGB model.

In the RGB model, according to the classification law of natural light, red, green and blue are combined together, forming many colors. As is shown in figure 4, each color corresponds to a point in three-dimensional coordinate.

The image of wheat leaf rust shown in figure 2 is decomposed according to different color scheme, the image of wheat leaf rust in each color channel as well as the corresponding histogram is shown in figure 5.

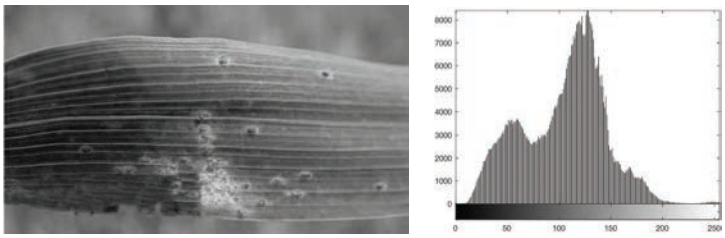

Fig. 5 (a) R channel component of wheat leaf rust and its histogram

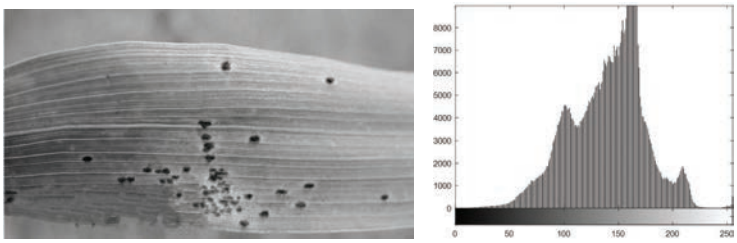

Fig. 5 (b) G channel component of wheat leaf rust and its histogram

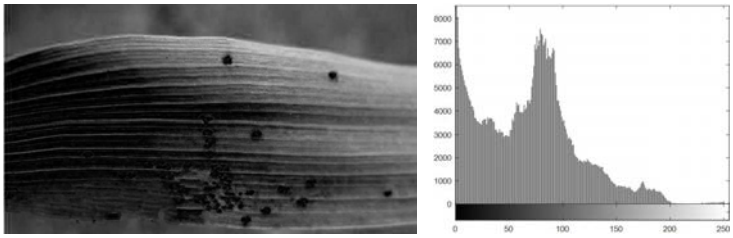

Fig. 5 (c) B channel component of wheat leaf rust and its histogram

According to the analysis of three channel histograms and the comparison with original image, the image in G channel is the clearest. As a result, G channel is chosen in the process of graying.

2.2.2. Edge detection and segmentation of binary image

Edge detection is to remove the irrelevant factors and extract the pixel point whose gray value is larger through the processing of gradient informations caused by mutation of image gray, forming the simple edge structure. A large number of image information can be gained by analyzing the edge, so the edge detection is basic problem in image processing and computer vision. Currently, common edge detection is mainly based on exploration and zero crossing. In this research, Sobel operator edge detection based on exploration is adopted.

The edge detection based on Sobel operator, in which the direction is optional, uses a 3 * 3 matrix filter, and as is shown in formula 1, there are two kinds of matrix. The brightness value can be got through the convolution of the images by two operators.

$$M_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} * A \qquad M_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} * A \tag{1}$$

The gradient value is:

$$G = \sqrt{M_x^{\ 2} + M_y^{\ 2}} \tag{2}$$

The direction of gradient is:

$$\theta = \arctan\left(\frac{M_y}{M_x}\right) \tag{3}$$

The longitudinal and lateral edge detection of Sobel operator is done on the graying image of wheat leaf rust shown in figure 5 (b), and the result is shown in figure 6 and figure 7.

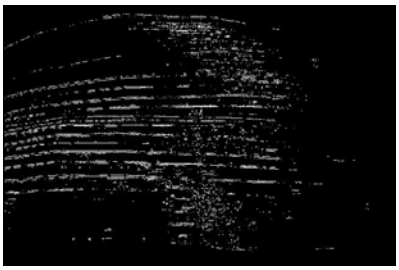

Fig. 6. longitudinal edge detection of Sobel operator

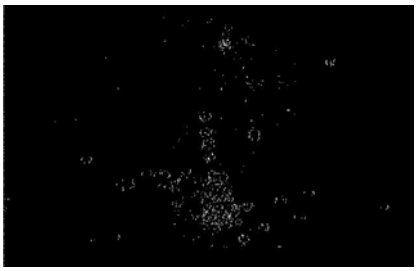

Fig. 7. lateral edge detection of Sobel operator

It can be concluded that the result of longitudinal Sobel operator keeps the information of the disease point, and fetches binary point set of scab by filtering the background of the image.

2.2.3. Image denoising

The characteristics of scab are extracted after the vertical Sobel calculation, but many noise points can be found existing on figure 5 by contrasting the figure 2, so the noise point should be removed in order to improve the stability of the image characteristics and get the accurate values of scab area. In this research, first, all the connected

pixel objects is marked by flooding to search filling, then the area of each connected domain is calculated and the connected domain whose area is less than P is deleted, and the noise points are removed in this way, finally, the outline of scab is constructed by canny operator. The processing result is shown in figure 8.

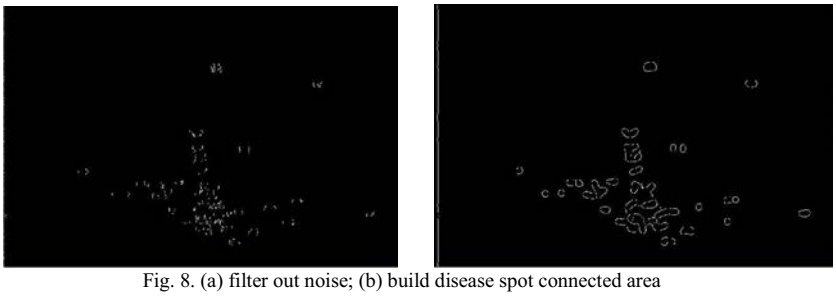

Fig. 8. (a) filter out noise; (b) build disease spot connected area

3. WLR diagnose, grading and test results

According to the percentage of the scab area, the ministry of agriculture divides leaf rust into 5 levels, shown in Table 1, which is measured by the ratio of leaf rust spore. In this essay, by digital image processing, the number of corresponding pixel number and error value is calculated, then the area of scab and leaf is used to get the area ratio, finally, the diagnosis of scab level is concluded, providing evidence for confirming the disease index and making control plan.

$$s = \frac{A_d}{A_1} = \frac{P\sum_{(x,y)\in R_d} 1}{P\sum_{(x,y)\in R_1} 1} \times 100\% = \frac{\sum_{(x,y)\in R_d} 1}{\sum_{(x,y)\in R_1} 1} \times 100\% \quad (4)$$

As shown in the equation 4, A_d is the area of WLR, A_1 is the whole leaf area, P is the area of an unit pixel, R_d is the region of WLR, R_1 is the region of the whole leaf. According to this formula, the percentage of WLR's area in the whole leaf area can be calculated and recorded as s. In this paper, s is used as the standard of WLR grading.

Table 1.Grade of wheat leaf rust

WLR Grade	The percentage of lesion size in the leaf's total area
T0	0≤ K ≤0.15
T1	0.15≤ K ≤0.3
T2	0.3≤ K ≤0.45
T3	0.45≤ K ≤0.6
T4	0.6≤ K ≤1

Figure 9 and Figure 10 shows the user interface and operation effect of the system.

Fig. 9. the graphics import interface

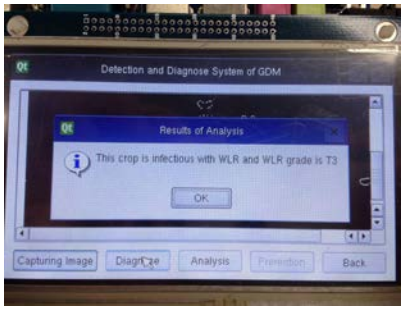

Fig. 10. result showing interface

Diagnosis and classification are done on the 30 images of wheat leaf rust by artificial method and image processing, and the result contrast is shown in Tabel 2.

Table 2.Recognition results contrast of wheat leaf rust

Recognition rate %		Rank accuracy %	
human eye recognition	image processing and recognition	human eye recognition	image processing and recognition
98.6	96.2	95.6	92.3

Conclusion

In this paper, an efficient automated system for crop disease detection and grading in WLR is proposed. As far as the features of wheat leaf rust are concerned, the image processing is putting forward, which means that diagnosis and classification of wheat leaf rust is done by graying processing, edge detection and segmentation and filtering the noise points. The proposed system is a connection between embedded Linux and digital image processing techniques and it has been successfully implemented on ARM9. With the help of Qt, programs of digital image processing and GUI are written, compiled and downloaded to the development broad to realize crop disease detection and grading. GUI and results are displayed with the help of LCD.

By comparing with the judgment and diagnosis of experts, the proposed system has an accuracy rate up to 96.2% and 92.3%, which is close to human eyes' judgment accuracy. In addition, it is more convenient than human judgment. Because of its intelligence, this proposed system can be used as a robot being able to make an inspection tour of the grape field, which can complete the grape WLR detection, diagnosis and grading automatically.

Acknowledgements

This work was supported by the Primary Research & Development Plan (Modern Agriculture) of Zhenjiang (NY2015026), Science and Technology projects plan of Jiangsu Polytechnic College of Agriculture and Forestry (2016kj016), Jiangsu Province Higher Vocational College Teachers' Academic Pacesetter High-end Study and Training (2016GRFX022), Jiangsu Province Agricultural Independent Innovation Project (CX(14)2092).

References

1. Zhihua Diao. Research and Application of Intelligent System of Field Wheat Leaf Disease Detection. University of Science and Technology of China. A dissertation for doctor's degree; 2010.
2. Mingsheng Hou, Junbin Huang. Agricultural Plant Pathology. China Science Publishing & Media Ltd; 2011.
3. Guanlin Li, Zhanhong Ma, Haiguang Wang. Image recognition of wheat stripe rust and wheat leaf rust based on support vector machine. Journal of China Agricultural University. 2012. 17(2): 72-79.
4. Hongbo Qiao, Bin Xia, Xinming Ma,Dengfa Cheng, Yilin Zhou. Identification of Damage by Diseases and Insect Pests in Winter Wheat. Journal of Triticeae Crops. 2010. 30(4):770-774.
5. Xiuli Yu, Chao Xu, Dandan Wang, Weiyuan Zhang. Identification of Wheat Leaf Diseases Based on SVM Method. Journal of Agricultural Mechanization Research. 2014. 36 (11): 151-155.
6. Rupil, C. Development of image processing and its applications on cryptography. International Journal of Engineering Sciences & Research Technology, 2015. 4(7):1160-1162.
7. Woebbecke, D.M., Meyer, G.E., Von Bargen, K., and Mortensen, D.A. Shape features for identifying young weeds using image analysis. Transactions of the ASAE, 1995. 38(1): 271-281.
8. Baum, T., Navarro-Quezada, A., Knogge, W., Douchkov,Seiffert. HyphArea—automated analysis of spatiotemporal fungal patterns. Journal of plant physiology, 2011. 168(1): 72-78.
9. Tao Meng, Mei-Ling Shyu. Biological Image Temporal Stage Classification via Multi-Layer Model Collaboration. IEEE International Symposium on Multimedia; 2013. p. 30-37.
10. Bingqi Chen, Xuemei Guo, Xiaohua Li. Image Diagnosis Algorithm of Diseased Wheat. Transactions of the Chinese Society for Agricultural Machinery. 2009. 40(12): 190-195.
11. Goodacre, J., and Sloss, A.N. Parallelism and the ARM instruction set architecture. Computer. 2005. 38(7): 42-50.
12. Tech, M. Real-time object detection based on ARM9. International Journal of Engineering Trends and Technology. (2013). 4(9): 4080-4083.
13.Zang, Chuanqiang, Gao, Mingyu, and He, Zhiwei. The Transplantion And Realization Of Qt4. 7.0 Based On ARM9 And Linux. Applied Mechanics & Materials. 2015.p.719-720: 527-533.
14.Patel, K.S., and Kalpesh, R.J. Implementation of embedded ARM9 platform using Qt and openCV for human upper body detection. IOSR Journal of Electronics and Communication Engineering, 2014. 9(2): 73-79.