The Summary of Researches on Detections of Potato Surface Defects by Machine Vision

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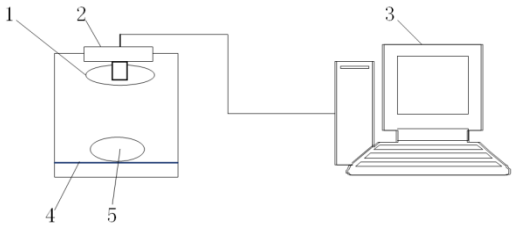
Abstract: The research of potato surface defect detection has an important signification on nondestructive detection and automation grading of potato. This paper summarizes the primary researches on potato surface defect detection by machine vision at home and abroad, and, based on clear and concise logical frame, divides the contents into 3 parts: the preprocessing of defective-potato image, the judgment of serious defect and the classification of mixed defect on potatoes. It mainly elaborates the approach on judging serious defect and the representative methods of classification of mixed defect, which would provide reference for the later researches. Meanwhile, it summarizes advantages and disadvantages in present researches, and look into the future approach on potato defect detection.

1. Introduction

At the end of last century, China has became the most potato yield country in the world. The development of potato industry can't go well without controlling the quality of individual's surface, because the surface quality of potatoes would directly determine the reserve time and production value of them, which caused the research of detecting potato surface defect has became a hot point. Scholars at home and abroad utilized machine vision to research the detection of potato surface value by detecting potato's weight, shape and classification. The most important advantage of machine vision technique is only need to process the potato images indirectly, which can avoid damaging potatoes, and be high feasibility. In recent years, scholars has finished many researches of potato surface defect detection using machine vision. Although there are many mature study results, the researches of potato surface defect detection confronts difficulties: potato species is various, which caused various surface colors and shapes of potato; with the course of harvest and transportation, huge difference will continue enlarge the difference between individuals. According to <Professional Standards of the PRC-potatoes> and <Agricultural Industry Standards of the PRC> (NY/ T 1066-2006) , the major defects of potato include sprouting, green skin, cracks, worm biting marks, rat biting marks, machine damage, rot, scab, and so on. If the recognition and grading of the potato surface defects came true, the potatoes NDT (nondestructive testing) will be promoted efficiently.

2. The hardware system of machine vision

The quality of hardware system is an important premise of detection system, which determines the quality of image collection and efficiency of algorithm operation. As shown in the figure 1, the hardware system include illumination environment, image sensor and PC. The image collection process as follows: the light signals on the potato surface are transformed into electrical signals as an AD transformation; and then these electrical signals are stored as digital matrix by PC which is displayed on the screen, that is digital image people would see.



1 circle lamp; 2 camera; 3 PC; 4 objective table; 5 analyte

Figure1 Hardware System of Machine Vision

3. The preprocessing of gray images

The principles of preprocessing color and gray images are almost same, so it mainly introduces the gray image preprocess of defect potatoes. Before extracting the features of potato images stored in PC, it is necessary to preprocess them in advance, which aim at promoting the feature of ROI(region of interesting), and decrease the interference of irrelevant regions and noises. This course includes the image intensification, image filtering and background removing, under the human's subjective judgment with obvious purposefulness.

The image noises would be generated at the course of AD transforming, image collecting and image transforming. Meanwhile, the illumination or other environment factors can cause images narrow DR (dynamic range) , so it is necessary to filter and intensify images beforehand. There are many image filtering methods in spatial domain and frequency domain. Literatures [1][2][3][4] indicated that median filter can efficiently eliminate the noises. Median filter is one of the nonlinearity spatial domain filters. Firstly, it chooses a fixed size template. Secondly, from top left corner pixel, the template is slide from one pixel to another, and meanwhile takes out the median value in the template domain pixels ranged from small to large. At last, it replaces every pixel by the corresponding median pixel. The median filter can not only eliminate efficiently, but also keep the boundary of potato and surface defects clear, and it is simple and effective. The gray transform same can stretch the contrast of DR, which would lay the foundation of later processes. Zhou Zhu [5] used nonlinearity Gamma gray transformation to intensify potato images. In this method, the X axis means gray value of image, the Y axis means mapped gray value. The effect of transform would be changed by changing γ form one value to the next. The above-mentioned methods have obvious intensification effects, and can be mirrored by other scholars. There are many approaches on image intensification, and it is necessary to put forward more adaptable methods for enriching the researches of potato surface detecting.

The elimination of irrelevant image background is an important operation, which can highlight the DR and be convenient for later image process. The background elimination can be handled by many methods. Yu Zhihong [1] used the iterative threshold segmentation to eliminate the background. It sets the mean of the maximum and minimum value of the image as the threshold T, and uses T separating the image into 2 parts. Then it continues figuring out the separated images mean, and repeating last step until the T is invariant, which is considered as the best threshold. Jin Jing [2] utilized the OTSU method to separate the foreground and background, which got good results. The OTSU method is based on duster idea: firstly, it gets the histogram of gray image; secondly, it sets an arbitrary threshold T to segment the image and figures out the interclass variance K. At last, it continues changing the T in order to getting the lager K until the K is invariant, which, at this time, this T is considered as the best threshold. Wang Chenglong [3] utilized the saliency map method to eliminate the image background, which can automatically get the pixel position in foreground without supervision, and meanwhile eliminate the irrelevant information in image.

The research results indicated that: the iterative threshold segmentation is efficiency, but there are many steps before finding the best threshold with long time; the OSTU method is also efficiency and is operated on the histogram without the influence of illumination and contrast, but sometimes would appear the imperfect segmentation and noises; the saliency map method is simple and effective, which performs well in eliminating background.

4. The detection of surface defects

Defect detection is the core of defective-potato image process, which need label and classify the defects. In the industrial inspection, potatoes carried severe defects should be abandoned, and others could be taken to grading

4.1 The judgment of severe defects

Severe defects on the surface of potato mainly include machine damages, sprout and green skin, which would influence the potato's value and edible safety. The existing researches mainly aim at detecting one severe defect type, and obtain various detecting methods, which can be a reference for later researches.

(1) The detection of machine damage

At the process of harvest and transportation, potatoes could be easily damaged, which would dramatically influence the potato's storage and sale. The machine damages on the surface of potato can be classified into straight damage and curvilinear damage. Yu Zhihong [1] utilized the Hough Transform to detect straight damage, whose recognition ratio is 94.5%, and its principle is simple. Wang Chenglong [3] utilized PCA (principal component analysis), Isomap and LLE (Locally Linear Embedding) to extract the feature of defects, and built, respectively, 3 models: PCA-SVM, Isomap-SVM and LLE-SVM. He proposed using Grid Search Method, Genetic Algorithm and PSO (particle swarm optimization algorithm) to optimize the arguments. The eventual results indicated that PCA-SVM had the best detection effect with 100% success ratio. Liu Wei [4] treat the ratio of the width and length of minimum enclosing rectangle as the feature parameter of machine damages, and Zhou Zhu [5] diagonal of defect region.

These researches above indicate that: When using Hough Transform to detect machine damage, the straight edge and pit on the potato surface is easy to be wrongly judge as defects. And Hough Transform can't detect curvilinear damage, which is circumscribed. To efficiently recognize straight damage and curvilinear damage, there need extract more features of them. The manifold method proposed by Wang Chenglong can get high recognition rate.

(2) The recognition of sprouting

The sprouted potatoes have a large of solanine which is poisonous and inedible. The potato's bud have different colors and gray values. Yu Zhihong [6] utilized the bud's color to recognize it, who used Euclidean distance to segment buds and used Mathematical morphology to label bud boundary with 90% success rate. Thierry [7] proposed a method called the local energy variance which is suitable to recognize light buds compared with general buds. Zheng Guannan [8] calculated the difference between the means of gray value of bud region and skin region, and set threshold to segment bud out. The method did well when confront hot spot on the bud images. Li jingewei [9] raised fast gray interception segmentation threshold and fast interception segmentation based on G to recognize buds, and the former is do well with dark buds, and the latter is do well with light buds. By combining these two method, the recognition rate can be 97.5%.

The experiment results indicated that: the difficulties during the recognition of bud are features extraction, recognizing dark buds and distinguish light pots on the bud image, and it is necessary to figure out bust arithmetic conquering these problems; considering the harm of budded potatoes, there is a necessary to design more misjudgment punishment for budded potatoes than that for normal potatoes; the existing recognition methods mainly utilize the color of bud to recognize it, but there are difference between various potato species, so the color feature is not robust, and it is necessary to utilize the morphology of buds on potatoes.

(3) The recognition of green skin

Potatoes attached with green skin carry lots of solanine, which is harm for people. Deck [10] used 2 cameras to collect potato color images, and designed MLFNN (multilayer feed forward neural network) to recognition the green skin. Yu Xiaojuan [11] raised a nine-colors system based on HSVspace, which can make use of chroma probability value on the surface of potatoes to segment green skin. She compared this method with two traditional pattern recognition methods, and found that this method is more stable and accurate than the traditional pattern recognition methods whose recognition results rely on features and samples. Zhang Baochao [12] found

Euclidean distance was inappropriate for segmenting potato color images, and raised a Relative Distance to segmentation, which is fast and accurate with 93% of recognition rate. But the threshold selection is a difficult point. Yang Dongfeng [13] designed NNC (Neural Network Classifier) based on color features of green skin potatoes, which comprehensively trained the samples. The results indicate this method's recognition rate is 96.88%, and can measure the area of green skin.

4.2 defects classification

The elaborate classification of defects on the surface of potato has enormous help for improving its utilization, which play an important role in the potato automation industry. The existing researches of defects classification have bits of quantities. Shi Chongsheng [14] respectively extracted texture describers at gray image and color image's 3 channels, and utilized Bayes classifier to build the prediction model. The experiment result indicate that, by extracting features at 3 channels and filtering the image, the defect of insect-bite can be recognized 85.71%, and machine damages 92.86%, green-skin and rate-bite 100%. In addition, utilized the area of defects, Dacal [15] proposed a special arithmetic named maximizing the percentage of classification, which can recognize 86% of healthy potatoes, 88.5%of rotten potatoes and 86.2% of green potatoes. Zhou Zhu [5] used the features of defect's area to recognize dark defects, the length of diagonal to recognize machinery damages and the bracketing method to recognize sprouting defects. And the recognition rate respectively is 87.5%, 92.5%, 97.5%. Noordam [16] designed a RT(real time) potato defects classification system, which can process 50 images per second, and use LDA (linear discriminant analysis) and Mahalanobis distance to segment defects, and use the features of area, eccentricity and center distance to distinguish the near color defects.

The defects classification is a difficult point at the course of potato detection. The key of classification is feature extracting from potato surface. Meanwhile, extracted features would disturb each other during the recognition, which will be an emphasis during the subsequent researches.

5. Conclusion and outlook

So far, there are many researches of detecting potato surface defects, which successfully applied machine vision to detecting potato surface defects. These methods appear efficiently and lay the foundation of later researches, but, at the same time, there are some problems:

(1) Most of existing researches only focus on one kind of potatoes, and a small amount samples, so it is unrepresentative. For the influence intervened by natural factor during the process of growth, the different species and individuals of potato have vast difference, which determines the recognition arithmetic must be robust.

(2) Many researches only focus on the static images, which can't meet the require of instantaneity detection. And considering of the complexity of potato surface, the accurate arithmetic and instantaneity detection will be contradiction, which should be weighted in the subsequent researches.

(3) The existing algorithm have obvious differences, so it is difficult to unify them as a set of theory.

The detection of potato surface defects is an important part of potato automation industry. Machine vision system is cheap, fast, and convenient, and based on it, the next importance of arithmetic design is real-time, robust and accurate.

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