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Detection of Watermelon Seeds Exterior Quality based on Machine Vision

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Abstract

To investigate the detection of watermelon seeds exterior quality, a machine vision system based on least square support vector machine was developed. Appearance characteristics of watermelon seeds included area, perimeter, roughness, minimum enclosing rectangle and solidity were calculated by image analysis after image preprocess. The broken seeds, normal seeds and high-quality seeds were distinguished by least square support vector machine optimized by genetic algorithm. Compared to the grid search algorithm, the classification results of watermelon seeds exterior quality achieved by genetic algorithm were analyzed in detail. Meanwhile machine vision grid laser was applied to detect the surface irregularities defects of watermelon seeds. This study demonstrated the feasible of detecting the watermelon seeds exterior quality by machine vision.

Keywords: *machine vision, image processing, watermelon seeds, genetic algorithm, LS-SVM*

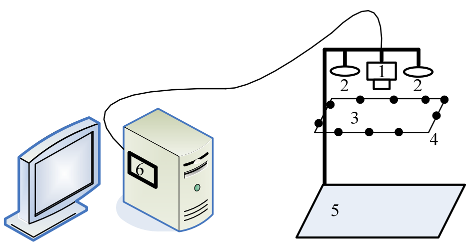
1. Introduction

Machine vision is the technology and methods used to provide imaging-based automatic inspection and analysis for such applications as automatic inspection, process control, and robot guidance in industry, which play an important role in promoting the automation of production and the growth of the national economy [1-6].

Currently, the sorting processes of watermelon seeds are all done manually, which inefficient, time-consuming and labor-intensive and poor stability. Until recently there was little research on the detection and classification of watermelon seeds exterior quality. So research on the detection system of watermelon seeds exterior quality based on machine vision has an important economic value and significance. Based on machine vision and least squares support vector machine, an automatic device was developed for detection of watermelon seeds in this article.

2. Machine Vision

The machine vision system used in this experiment composed of three parts: image processing, image analysis and display. The hardware components schematic diagram was shown as Figure 1.



(1)Camera, (2)Ring LED light, (3)Grid laser support frame, (4)Line laser, (5)Workbench, (6)Computer

Figure 1. Hardware Components Schematic of Visual Inspection System

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The 500 mega pixel industrial camera DH-HV5051UC was applied in this system. The image preprocessing algorithm including graying, Gaussian filtering, corrosion, expansion, binarization, edge detection, and fill algorithm were used. The original image, gray image and binary image of high quality watermelon seeds of were shown in Figure 2, Figure 3, and Figure 4.

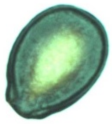

Figure 2. Original Image

Figure 3. Grayscale Image

Figure 4. Binary Image

The eight characteristics of watermelon seeds were calculated by image analysis algorithms which shown in Table 1.

Table 1. Shape Parameters of Watermelon Seeds

ID	characteristic	Description
1	perimeter	perimeter of the watermelon seeds image
2	Area	pixels number of the watermelon seeds image
3	Roughness	Perimeter2/ (4×π×Area)
4	MERL	length of minimum enclosing rectangle
5	MERW	width of minimum enclosing rectangle
6	MERArea	MERL × MERW
7	MERProportion	MERL/MERW
8	solidity	Area/MERArea

In order to further enhance the robustness of the visual detection and reduce image background noise interference, the image subtraction method was used in this article, which was realized by subtracting the nearest time pure background image from the image of watermelon seeds. In order to further improve the accuracy of the image detection and recognition, the regularly updated strategy of pure background image was applied.

3. Classification and Recognition

Detection and classification process of the quality grade of watermelon seeds was shown in Figure 5.

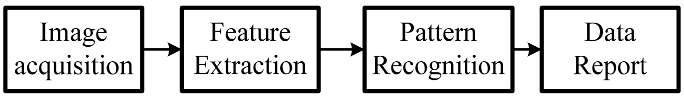

Figure 5. Detection and Classification of Watermelon Seeds

Least squares support vector machine was applied as the pattern recognition method [7-10]. The watermelon seeds were divided into broken seeds and complete seeds according to the shape characteristics first. Then the complete seeds were divided into high-quality seeds and normal seeds according to the color of the outer ring and the inner ring of their appearance.

3.1. Least Squares Support Vector Machine

Least squares support vector machine(LS-SVM) is proposed by Suykens J.A.K, it's an improved algorithm of support vector machine (SVM) [11-13]. Given a set of training data set

$\{x_k, y_k\}_{k=1}^{N}$, with input data $x_k \in R^n$ and output data $y_k \in R^n$, LS-SVM construct a classifier as follows.

$$y(x) = sign[\sum_{k=1}^{N} a_k y_k \psi(x, x_k) + b] \quad (1)$$

Where, a_k is a positive real constants, $\psi(x, x_k)$ is a kernel function and *b* is a real number. Then the aim of LS-SVM classification is to solve the optimization function as follows:

$$\min_{w,b,e} J_3(w,b,e) = \frac{1}{2} w^T w + \gamma \frac{1}{2} \sum_{k=1}^{N} e_k^2 \quad (2)$$

The constraint condition of the Equation 2 is as follows:

$$y_k \left[w^T \varphi(x_k) + b \right] = 1 - e_k \qquad , k = 1, \cdots, N \quad (3)$$

To solve this quadratic programming, Lagrange multiplier is used as follows:

$$L_3(w,b,e,a) = J_3(w,b,e) - \sum_{k=1}^{N} a_k \{ y_k [w^T \varphi(x_k) + b] - 1 + e_k \} \quad (4)$$

Where, a_k is Lagrange multiplier, the most optimal conditions are shown as follows:

$$\begin{cases} \frac{\partial L_3}{\partial w} = 0 \rightarrow w = \sum_{k=1}^{N} a_k y_k \varphi(x_k) \\ \frac{\partial L_3}{\partial b} = 0 \rightarrow w = \sum_{k=1}^{N} a_k y_k = 0 \\ \frac{\partial L_3}{\partial e_k} = 0 \rightarrow a_k = \gamma e_k & k = 1, \cdots, N \\ \frac{\partial L_3}{\partial a_k} = 0 \rightarrow y_k [w^T \varphi(x_k) + b] - 1 + e_k = 0, & k = 1, \cdots, N \end{cases} \quad (5)$$

Written as the linear equations, the Equation 5 can be converted into the following form:

$$\begin{bmatrix} I & 0 & 0 & -Z^T \\ 0 & 0 & 0 & -Y^T \\ 0 & 0 & \gamma I & -I \\ Z & Y & I & 0 \end{bmatrix} \begin{bmatrix} w \\ b \\ e \\ a \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \vec{1} \end{bmatrix} \quad (6)$$

Where, $Z = [\varphi(x_1)^T y_1; \cdots; \varphi(x_N)^T y_N]$, $Y = [y_1; \cdots; y_N]$, $\vec{1} = [1; \cdots; 1]$, $e = [e_1; \cdots; e_N]$, $a = [a_1; \cdots; a_N]$.

The Radial Basis Function (RBF) kernel $\psi(x_i, x_k) = \exp\{-\|x_i - x_k\|^2\}$ was applied in the article.

3.2. Genetic Algorithm

The Genetic Algorithm (GA) is a global searching and optimization algorithm, which includes five steps: initialization, selection, recombination, mutation and termination [14-20]. The algorithm simulated biosphere natural selection principle. First, it generates a certain amount of variable group (chromosome) constitute the initial population, and using the objective function to evaluate the performance of each chromosome in the population. Then through the recombination process, chromosomes with the higher probability are preserved. Followed by mutation, the introduction of a new variable values, to prevent the optimization process from falling into the local optimum region. Finally, through the evaluation of the continuous cycle of recombination and mutation process, after some algebra evolved to obtain the optimal solution to meet the requirements.

Genetic algorithm was applied to calculate the regularization parameter γ and the kernel parameter σ of LS-SVM in this article. Compared to the traditional grid search method of LS-SVM parameters, genetic algorithm greatly improved the speed of problem solving.

4. Classification Result

4.1. Classification of Complete Seeds and Broken Seeds

The 400 complete seeds which composed by 200 high-quality seeds and 200 normal melon seeds and the 200 broken seeds were classified at first step in this study. The eight shape parameters of these 400 watermelon seeds which described in Table 1 were used as the training and testing data of support vector machine.

Detection and recognition results of complete seeds and broken seeds acquired by GA-LS-SVM (genetic algorithm optimized support vector machine) and GS-LS-SVM (grid search optimized support vector machine) were shown in Table 2.

The initial population of genetic algorithm was 20 and the search range was from 0 to 150. The starting coordinate of grid search algorithm was set at (0,0), the search step size was 1. Grid search is one of the conventional approaches to determine hyper-parameters. However, it needs an exhaustive search over the space of hyper-parameters, which must be time consuming.

The value of punish parameters γ and kernel function parameters σ of LS-SVM were then caculated by Genetic algorithm and grid search algorithm. The Operating System of tested computer was windows XP, which had 2GB DDRII memory, Intel Core 2 Duo P8600 processors, Intel GMA X4500 Graphics card and 320G hard drive. LOOCV (leave-one-out cross-validation) was choosed as model validation method in this experiment.

Table 2. Classification Result of Complete Seeds and Broken Seeds

Algorithm	Recognition rate				
	Total	Complete seeds	Broken seeds	Optimizing time	Parameters
GA-LS-SVM	100%	100%	100%	1.1038e+4s	γ 99.4, δ 17.6
GS-LS-SVM	100%	100%	100%	6.409e+5s	γ 95, δ 16

The experimental results show that both the parameters of least squares support vector obtained by GA-LS-SVM and GS-LS-SVM were optimal parameters. Due to the randomness of genetic algorithm mutation process, the optimization value of the parameters of the solution will be slightly different every time and may produce multiple solutions. Optimization modeling experiment was carried out 50 times to verify the robustness of GA-LS-SVM algorithm. Experimental results show that all 50 optimization modeling results could obtain the optimal parameters. The optimizing time in Table 2 was average of 50 times modeling of GA-LS-SVM and the Parameters in Table 2 were the solution of GA-LS-SVM which nearst the starting search point (0, 0) of grid search algorithm.

4.2. Classification of High-quality Seeds and Normal Seeds

Then 200 high-quality seeds and 200 normal seeds were classified in this experiment. The 16 parameters of outer ring (Black ring in Figure 4) and inner ring (White oval in Figure 4) of watermelon seeds were caculated according toTable 1.

The 16 shape parameters of these 400 watermelon seeds were used as the training and testing data of least square support vector machine, and using the same modeling method which described as section 4.2.The classification result of of high-quality seeds and normal seeds were shown in Table 3.

Table 3. Classification Result of of High-quality Seeds and Normal Seeds

Algorithm	Recognition rate				
	Total	Complete seeds	Broken seeds	Optimizing time	Parameters
GA-LS-SVM	97.5%	97%	98%	9.3471e+3s	γ 68.3, δ 20.1
GS-LS-SVM	97.5%	97%	98%	5.0983e+5s	γ 63, δ 18

The experimental results demostrated that both the parameters of least squares support vector obtained by GA-LS-SVM and GS-LS-SVM were optimal parameters.

5. Detection of Surface Defects

Machine vision grid laser was applied for the detection of the surface irregularities defects of watermelon seeds. The grid laser employed in this experiment was constructed by two groups of high-brightness, linear fine collimator combination line laser. The laser generated by machine vision grid was shown as Figure 6. The laser grid will be bent and deformed when projected onto curved surface, which shown as Figure 7.

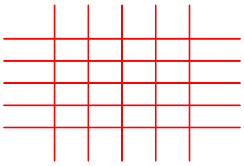

Figure 6. Laser Grid

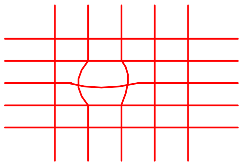

Figure 7. Laser Grid Projected onto Curved Surface

After image acquisition, image pre-processing and image processing using Hough transform algorithm, the Laser grid projected onto watermelon seeds was analyzed, and the surface irregularities defects were detected.

6. Conclusion

The shape characteristics of watermelon seeds including area, perimeter, roundness, and the smallest enclosing rectangle parameters were detected by machine in this paper. The experimental results show that based on the shape parameters of watermelon seeds detected by machine vision, watermelon seeds quality could be well classified and identified by least squares support vector machine based on genetic algorithm optimization. And finally the surface irregularities defect of watermelon seeds were detected by machine vision grid laser.

Compared to the traditional watermelon seeds artificial hand-selected, the system has high reliability, and sorting speed and good stability. However, this experimental was limited by the number of samples and haven't tested by a large amount of watermelon seeds in different batches, different manufacturers and different varieties, thus there are still many problems to be solved and optimization in practical applications.

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