AGRICULTURAL PRODUCTS SORTING SYSTEM BY USING HIGH-SPEED IMAGE PIPELINED PROCESSOR AND FA COMPORNENTS

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ABSTRACT

Eggplants sorting plant has been constructed by using image processors, programmable controllers and FA personal computers. In order tomeasure and analyze an eggplant's size and shape quality, high-speed image processor and high precision shape sorting algorithm has been developped. The sorting algorithm consists of several classification factors such as volume factor, shape factors, symmetry factor and color factor. A gray-scale image of eggplant is grabbed by electronically shuttered CCD camera and the grabbed image is analized and its shape and quality is classified in accordance with the classification tables. This sorting plant consists of six conveyor lines, six image processors, six color sensors, five programmable controllers, two FA personal computers, two operator's consoles and several display panels. These components are connected by FA oriented field network system. The sorting performance is 18 eggplants per second.

INTRODUCTION

Accompanied by shrinkage in the farm population, the mechanization of agricultural production has been extremely needed.

The rapid progress of image processing technology and equipments enables machine vision system to apply not only to the industrial field, but also to the agricultural field. The feature of machine vision application to the agricultural field is that random shape analysis must be used and the criteria of shape discription are rather ambiguous. Therefore, image analysis and classification must be flexible. The purpose of this developped system is to provide the eggplants into agricultural food markets with uniform size and shape quality.

SYSTEM CONFIGURATION

The sorting system is shown in fig.1.

This system consists of six conveyor lines, six image processors, six color sensors, five programmable controllers, two FA personal computers, two operator's consoles and sorted results' display panels. These components are combined by the field network system (P-link system). Programable controllers(sequencers) control these conveyor line's buckets and outlets in accordance with the classification results. And FA personal computer collects the sorted results and takes charge of man-machine interface operations, such as setting up the size and shape classification criteria in accordance with the season's crop quality.

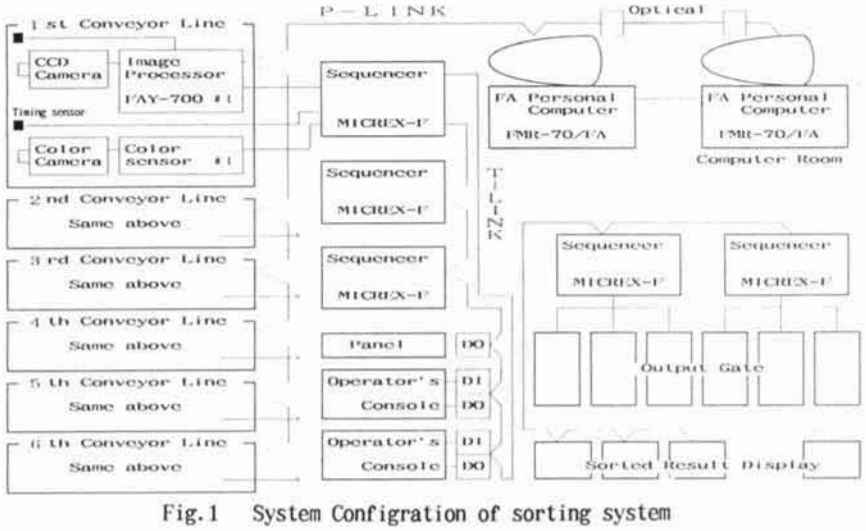


Fig.1 System Configration of sorting system

Furthermore, these sorted data are communicated by P-link system into another FA personal computer which is located in central computer room, and this FA personal computer calculates the sorted results and issues payment slips etc.

SORTING PRINCIPLE

In order to measure and analyze an eggplant's size and shape quality, a newly developped image processor and high precision shape sorting algorithm are used.

1. Image input method

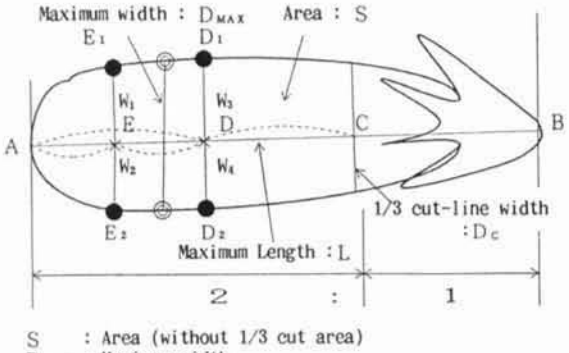
An eggplant's surface color is mainly purple or black, but some eggplants have white, red, green surface color, and its surface reflects light by electric lamp. Accordingly, the gray-scale signal level difference between the eggplant image and the background image is not clear on the normal condition. But by making use of the property of the vegetable's infra-red rays radiation, we can get the eggplant's image in white level signal and the background image in black level signal, by removing optical infra-red cut filter in CCD camera lens.

2. Sorting algorithm

The sorting algorithm consists of volume ratio, shape ratio(two types), symmetry ratio, and color factor. Volume, shape and symmetry ratio are measu red by CCD monochrome camera, and color factor is measured by color sensors. Volume ratio is related to the eggplant's shape grade(or size). And shape ratio, symmetrical ratio and color factor are related to the eggplant's shape quality.

2.1. Eggplant's geometrical analysis

Fig.2 shows the main geometrical parameters used in this eggplant's image analysis.



S : Area (without 1/3 cut area)
D_{MAX} : Maximum width
D_C : 1/3 cut-line width
W_1 : Length between E and E_1
W_2 : Length between E and E_2
(E is a mediam point of A to D)
W_3 : Length between D and D_1
W_4 : Length between D and D_2
(D is a mediam point of A to C)

Fig.2 Eggplant's geometrical parameters

2.2 Shape grade sorting method

Shape grade is analyzed by using volume ratio. Volume ratio's formula is as follows.

$$V/ = K_1 [V_0 + K_2(D_C{}^2 \times L/3)]$$
$$V_0 = K_0 [S \times (D_{MAX} + D_C)/2)] \quad \cdots\cdots (1)$$

K_0, K_1, K_2 are coeficients.

2.3 Shape quality sorting method

Shape quality is analyzed as follows.

Shape ratio(two types:No.1 and No.2) grade the eggplant's shape's smartness, and symmetry ratio grades the shape's bend rate, and color factor rejects the eggplant surface's bad color portions such as red, green and white.

Shape factor No.1(K)'s formula is as follows.

$$K = (D_{MAX} - D_C) / L \quad \cdots\cdots (2)$$

Shape factor No.2(D)'s formula is as follows.

$$D = D_{MAX} / L \quad \cdots\cdots (3)$$

Symmetry factor(T)'s formula is as follows.

$$T = [| W_1 - W_2 | + | W_3 - W_4 |] / L \quad \cdots\cdots (4)$$

Fig.3 shows the result of eggplant's image analysis.

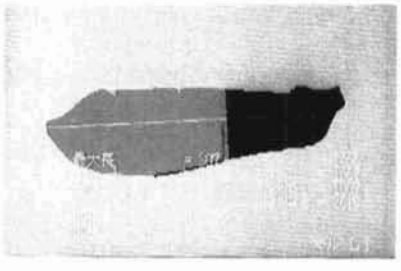


Fig.3 Result of the eggplant's shape analysis

2.4 Sorting criteria

Table.1 and Table.2 show the criteria of the shape grade and the shape quality.

Shape grade rank	Classification criteria by V	Classification criteria by D	
4 L	2800 pixels		
3 L			
2 L_1	2250 pixels	Long 2 L	2900
2 L_2		Fat 2 L	
L_1	1750 pixels	Long L	3000
L_2		Fat L	
M_1	1300 pixels	Long M	3000
M_2	1000 pixels	Fat M	
S	800 pixels		
2 S			

Table.1 Shape grade classification table

Shape quality rank	Classification criteria					
	Shape ratio K	Shape ratio D		Symmetry ratio T	Color Rank	
					red	blue white
□	0	2000	3700	1450	1	1
	1100					
○	1600	1800	4000	1850	1	1
A	2800	1600	5000	2150	1	1
B					3	3
Outside rank	3500	1400	6000	2950	3	3

Table.2 Shape quality classification table

IMAGE PROCESSING SYSTEM

For the purpose of performing high speed geometrical shape analysis, high-speed image processor has been developped.

Fig.4 shows the appearance the image processor. (FAY-700 system).

Fig.4 Appearance of the image processor

Fig.5 shows the architecture of this image processor.

This image processor consists of control CPU board, image input/output board, high speed image pipelined processor board and network(P-Link) interface board. These boards are combined by international standard bus(MULTIBUS Ⅱ) and high speed video bus.

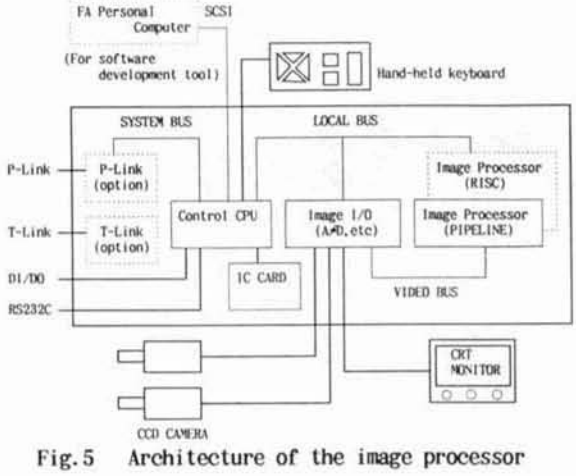


Fig.5 Architecture of the image processor

Table.3 shows the specifications of this image processor.

This image processor can process the eggplant's gray-scale image at high speed and extract it's several geometrical feature values precisely, such as maximum length, maximum width, area value, edge points etc., irrespective of blob's position and orientation within a camera view. And an gray-scale image of eggplant on coveyor bucket is grabbed by electronically shuttered CCD camera and image inpu t/output board, which can grab an video signal by 512 X 480 X 8bits scale at 1/1000 second shuttered speed.

Item		Specification	
Camera Input		· Monochrome camera (interlaced) · Monochrome camera (electronical shutter) · Color camera (interlaced)	
Monitor Output		· Monochrome display · Full-color display	
MMI device		· Hand-held keyboard	
Interface		· DO : 12points · DI : 8points · RS-232C ×1ch · SCSI×1ch · T-Link×1ch	
Network		· P-Link×1ch	
Parameter memory		· E²PROM (256KB) (non-volatile)	
Auxiliary memory		· IC Card (256KB,512KB,1MB,2MB)	
RAS Function		· Error check (temperature,fuse,camera) · Power on check(hardware check etc.)	
Image processing function	Gray-scale function	Gray-scale tranformation	Look-up table transform, Gamma transform, etc.
		Image calculation	Comvolution(add,subtract,etc.) Image calculation
		Edge enphasis	X-direction, Y-direction, XY-direction
		Histgram analysis	Histgram generation, Smoothing Equalization, etc.
		Distance tranformation	Distance transformation with gray-scale weighted
		Spatial filtering	Sobel, Roberts, Kirsch, Laplacian, Median, etc.
	Binary function	Binarization	P-tile, Peak, Mode Discriminant analysis, etc.
		Image calc.	Boolian (AND, OR, EXOR, etc.)
		Matching	Patern matching
		Boundary	Boundary analysis, Chain-code
		Connectivity analysis	Labeling, Thinning, Erosion, Dilation, etc.
	Geometrical processing	Geometrical parameter	Area,Shape factor,Euler number Max. and Min. length (width) Feret's diameter, Gravity, Secondary-moment, etc.
		Geometrical structure	Edge point coordinates, Turning point coordinates Horizontal chord, Vertical chord, etc.
	Color	Color look-up table, Pseudo color Hue, Saturation, Intensity, Color area, etc.	
	Image trans.	Affine transform, FFT, etc.	

Table.3 Specifications of image processing system

Table.4 shows the performance of this image processor.

This system can process major image processing algorithms within video-rate speed(33ms).

Item		Processing speed
Neighborhood operation	3×3 Convolution	16ms
	3×3 Median filtering	32ms
	3×3 Boolian operation	16ms
	3×3 Template matching	16ms
Image calculation	Boolian operation	16ms
	Arithmethic operation	16ms
Binary operation	Binarization	16ms
	P-tile method	16ms
	Histogram method	30ms
Geometrical feature extracting operation	Area	16ms
	Feret's diameter	30ms
	Profile	30ms
	Projection	30ms
	Thinning	16ms/pixel
	Erosion	16ms
	Dilation	16ms

Table.4 Performance of the image processer (512×480 pixel image)

SYSTEM PERFORMANCE

Table.5 shows this sorting plant's total sorting performance.

Item	System performance	
Conveyor	6 lines + 2 lines (outside-rank)	
Sorted classes	shape grade	9 classes
	shape quality	5 classes
Classification	9 grades × 5 quality classes = 45 classes	
Turning spot	15 turning spots (outlet)	
Sorting speed	18 eggplants/second (6 conveyor lines) 31.45 tons/day	

Table.5 System Performance

CONCLUSION

Eggplants sorting plant has been developped by using image processors, programmable controllers and FA personal computers. In this stage, this system processes the 2-dimensional image of eggplants. But in the near future, agricultural products sorting stem will need the combination of image sensing and other sensing such as taste, sweetness, freshness, softness and hardness. In order to approach human sensing, we will make an effort to advance not only machine vision technology but also other sensing technology.

ACKNOWLEDGEMENTS

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REFERENCES

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