INTELLIGENT AUTOMATIC SORTING SYSTEM FOR DRIED OAK MUSHROOMS

C.H. Lee and H. Hwang
Dept. of Bio-Mechatronic Eng., Sun Kyun Kwan University
Suwon, Kyunggi-Do 440-746, Korea

ABSTRACT

A computer vision based automatic intelligent sorting system for dried oak mushrooms has been developed. The developed system was composed of automatic devices for mushroom feeding and handling, two sets of computer vision system for grading, and computer with digital I/O board for PLC interface, and pneumatic actuators for the system control. Considering the efficiency of grading process and the real time on-line system implementation, grading was done sequentially at two consecutive independent stages using the captured image of either side. At the first stage, four grades of high quality categories were determined from the cap surface images and at the second stage 8 grades of medium and low quality categories were determined from the gill side images. The previously developed neuro-net based mushroom grading algorithm which allowed real time on-line processing was implemented and tested. Developed system revealed successful performance of sorting capability of approximately 5,000 mushrooms/hr per each line i.e. average 0.75 sec/mushroom with the grading accuracy of more than 88%.

Key Words: Computer vision, Automatic grading and sorting system, PLC control, Pneumatic actuators, Neuro-net, Real time

INTRODUCTION

Automation has provided feasible solutions to improve the production efficiency in many labor intensive manufacturing processes. Most agricultural production processes involve labor intensive and tedious tasks. Because of the various and irregular shape characteristics of agricultural products, automation in the agricultural field should approach in a different manner from other industries.

In Korea and Japan, dried oak mushrooms are classified into 12 to 16 different categories based on its external visual quality. In a case of dried oak mushrooms, sorting has been roughly done manually and grading has been performed by the human expert with randomly selected samples.

Generally, human expert is the best for grading oak mushroom one by one in a sense of precision, adaptibility, and robustness. Human grading, however, usually suffers from the speed and the lack of consistency because of the fatigue, visual illusion, and the time-varying emotional state. As a result, the overall grading productivity is quite low especially when grading task is to be done to all of the products.

The automatic grading and sorting system for agricultural products should be developed considering the inherent quality factors of agricultural products. And the system should be operated in a real time manner while preserving the human like robust and efficient visual data processing. As a substitute of the human vision, computer vision technology has shown great potential in the evaluation of different quality attributes of agricultural and food products. Currently computer vision technology is incorporated with the emerging AI technologies such as expert system, neural network, genetic algorithm, fuzzy logic, etc., to improve the information processing capability. In this paper, an automatic sorting system for dried oak mushrooms which has been built in our laboratory is presented.

MATERIALS AND METHODS

A computer vision based grading and sorting system has been developed considering the practical aspects such as the processing capability, system performance, and system complexness. Though quality factors of a dried oak mushroom are distributed over the both front(cap) and back(stipe and gill) sides. In a case of manual grading, human expert does investigate both sides closely and makes a grading decision. However, this manual process is limited to the small number of the randomly selected samples. In fact, it is almost impossible to investigate all of mushrooms one by one, especially when mushrooms are fed continuously via conveyor.

Considering system implementation, simultaneous investigation of both sides of mushrooms using computer vision systems are quite complex. We adopted the sequantial side investigation of a mushroom. And the system was composed of two sets of computer vision systems one for the front side image processing and the other for the back side. Two sets of vision systems were mounted on two sets of variable speed conveyor. PFG frame grabber(Imaging Technology Inc.) was used to digitize and store the incoming video signal to eight bits of accuracy at a rate of 30 frames per second. Two conveyors were aligned end to end with certain height difference. Two lighting chambers were designed for each set of computer vision system and high frequency(20,000Hz) inverter fluorescent lighting was installed in the measurement chamber.

Large vibrating hopper was installed to store and feed the dried oak mushrooms. Two vibrating feeders were installed to control the number of mushrooms to be fed. Specially designed round cross-sectioned plate was mounted on the vibrating feeder to precisely feed mushroom one by one without overlapping. Utilizing the difference of the feeding speed between the vibrating feeder and the conveyor, mushrooms could be succesfully isolated and fed maintaining certain distance interval.

To sort the graded mushrooms into the designated buckets, pneumatic cylinders were installed. Auotmatic device for side reversing of the continously fed mushrooms were devised and installed. White conveyor belt was used to make mushroom segmentation easy from the camera captured image. The electronic variable shutter speed controller was mounted to the B/W CCD camera to reduce the blurring effect of the captured image caused by the mushroom in motion.

PLC(programmable logic controller), digital I/O board and several optic sensors were used to control the electro-pneumatic handling devices. Two sets of computer were used for the overall system control and for each set of the vision system.

Schematic functional block diagram of automatic grading and sorting system was shown in fig. 1. The schematic view of overall system was shown in fig. 2.

Real time neuro-net based on-line grading algorithm was developed for the designed structure of the system. The neuro net based grading utilized gray valued raw image of the fed mushrooms captured from the camera without any complex image processings such as visual feature extraction and image enhancement.

To locate the mushroom fed on the conveyor, automatic thresholding based on the window extension was done first. And the modified chain coding algorithm(Hwang et al, 1993) was executed to obtain the size data of mushroom and to determine the network input region.

Neuro based image processing was developed to achieve the real time robust classification. The network input structure was formed using 76 rectangular grids composed of 8 directions and x and y size factors of input images. The size of rectangular input grids varied according to the size of the mushroom while maintaining the total number of the grids.

Though grading of a dried oak mushroom is usually done via external features distributed over both front and back sides, it was desirable for the system implementation to grade using either front or back side image.

Various kinds of input representations for the network were tested and compared to ensure the grading performance. Detailed results and methods were referred to Lee(1995). As seen from test results of the various input representations, grading using the either front or back side image was as efficient as that using both sides and was better than the quantitative input data from both sides. High quality oak mushrooms such as Hwago and Gureum-Hwago have the turtle shaped cap surfaces with dark brown spots uniformly distributed over the surface. Other medium and low quality mushrooms such as Donggo, Hyanggo and Hyangsin do not have distinct shape and texture patterns and they differ from only cap size, color, and the amount of the rolled cap edge in the back side. Therfore, 2 type(Hwago, Gureum-Hwago) 4 categories were classified from the front side image processing and other 3(Donggo, Hyangsin, Hyanggo)type 8 categories were classified from the back side image processing. Network(BP) model was formed with 78 units for the input layer, 10 units for the hidden layer, and 4 units for the output layer. 4 units in the output layer can classify all the input patterns into 12 categories. Learning and momentum rates were assigned as 0.7 and 0.9 respectively.

RESULTS AND DISCUSSIONS

Without either controling the shutter speed of the camera or using the strobe lighting and sychronized acquisition of the image, the image captured from the moving object has a problem of blurring and it causes incorrect results of image measurement. Though the blurring effect can be compensated through filtering by convolution theorem, high speed electronic shutter could reduce the blurring effect easily.

Generally, high speed shutter can reduce the blurring effect, but requires more intense illumination. For the developed system, considering response time of the actauting parts, the shutter speed of 1/500 second was good enough. The area variance from the blurring effect was testified using the sample square primitive(side length : 5cm) with various conveyor speeds. Table 1 shows the measurment error of sample square according to the various conveyor speeds under 1/500 second shutter speed.

After we trained the network using static images, we tested first the classification performance of the trained network for the static image of mushrooms. 120 sample mushrooms(10 per each grade level) graded by the expert as 5 types with 12 grade levels were trained. Network grading for training samples showed 100% accuracy. To verify the generalization of the trained network, 20 untrained sample mushrooms per each grade, total 240 mushrooms were tested. The network misgraded 19 mushrooms and showed 91.2% accuracy.

For the moving mushrooms, the grading performance of the network which was trained by 120 static samples was tested. First, same 120 samples were fed on the conveyor speed of 150.6mm/sec. 8 mushrooms were misgraded resulting into 93.3% accuracy of grading. And untrained 10 samples per each grade, total 120 samples were arbitrarilly selected and tested. Grading accuracy was 88.3% and the trained network misclassified 14 mushrooms. Most of misgrading ocurred at the Donggo. In fact, samples used for grades of Donggo types had little variation in their grading boundaries because of the lack of the number of samples. This problem might be solved with enough amount of samples. As a result, it could be seen that the blurring effect of the camera captured moving image under the 1/500 sec shutter speed was negligible in grading performance.

The proposed grading scheme required average 0.23 second per mushroom. Theoretical grading capacity was 15,000/hr without considering actuator delay. Considering the actuating device and control response, average 0.6 to 0.7 second was enough for grading and sorting of one mushroom resulting into 5,000/hr to 6,000/hr processing capability.

CONCLUSIONS

To satisfy the real time on-line processing and to overcome the inherent deficiency of the robustness of the image processing based on the feature extraction, neuro processing of the visual image of the moving mushrooms was developed. The neural net processing has been done first, by converting the acquired image to the prespecified structure of the network input. The size of the grid of B/W raw images of mushrooms to the network input was varied according to the overall size of the fed mushroom and the betwork was trained with the side recognition. The gray valued raw camera image was directly input to the network without extracting any visual features. The neural net based gray valued raw image processing showed successful results for our grading task in the prosessing speed, grading accuracy, and the robustness. The algorithms applied and developed were coded using MS_C language Ver.6.0 as a menu driven way.

The automatic intelligent sorting system of oak mushrooms has been developed utilizing proposed grading algorithms. The system was composed of two sets of computer vision system and automatic handling devices such as feeding in a line, side reversing, backward feeding and sorting. The proposed inplementation scheme for automatic grading of dried oak mushrooms fed on the conveyor belt revealed successful results which has a processing capability of 5,000/hr with more than 88% grading accuracy.

Researches on the improvement of the system performance such as simplified grading algorithm and efficient sorting mechanism, and more simplified PC based control and sorting system are on-going to develop the better prototype.

The developed technology through this research may open the new way of the quality inspection and sorting especially for the agricultural products whose visual features are fuzzy and not uniquely defined.

ACKNOWLEDGEMENTS

This research was funded by the MAFF-SGRP(Ministry of Agriculture, Forestry, and Fisheries-Special Grants Research Program) in Korea.

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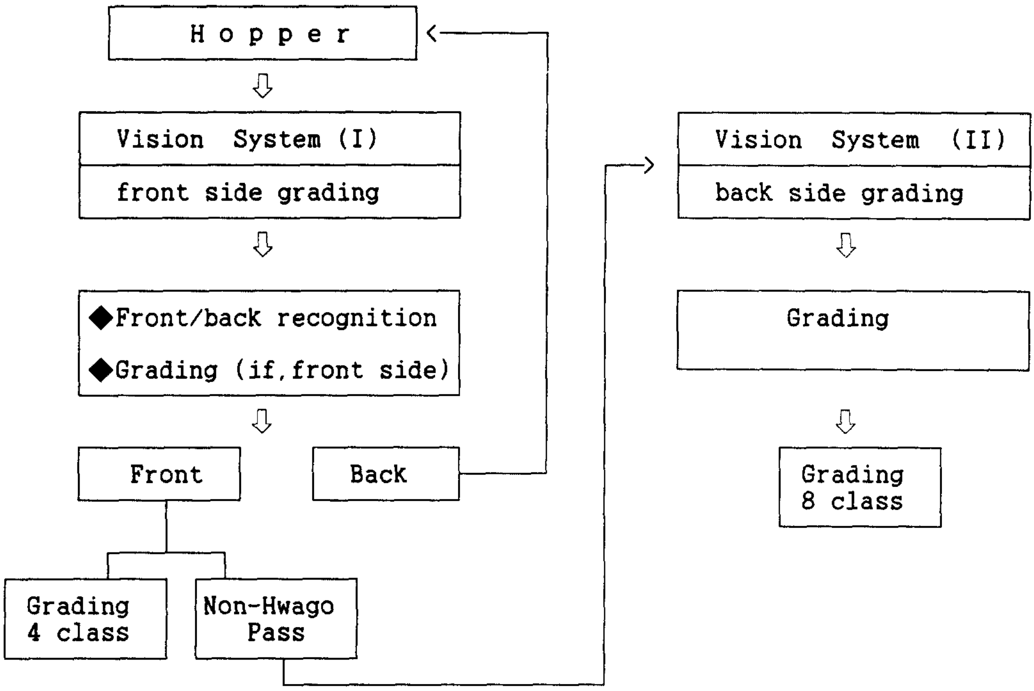

Fig. 1 Schematic block diagram of automatic grading and sorting system.

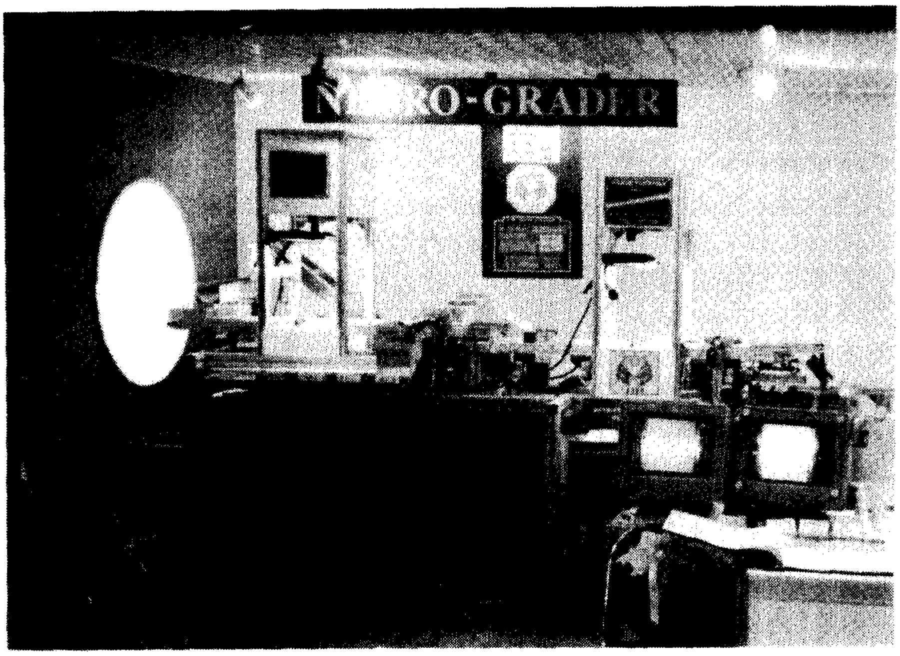

Fig. 2 View of the developed system.

Table 1 Measurement error of sample square according to the object in motion.

Index		Conveyor Speed (mm/s)		
		50.8	100.5	150.6
Area(mm^2)		2548.3	2567.0	2593.4
Number of Pixels		8356	8395	8472
Relative Error (%)	Area	0.56	1.30	2.34
	No. of Pixel	0.60	1.07	2.00