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Development of a Prototype Automatic Sorting System for Dried Oak Mushrooms

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적 요

한국과 일본의 경우 건표고를 외관의 품질상태에 따라 12등급에서 16등급으로 구분하고 있다. 그리고 등급판정 작업은 임의로 추출한 샘플을 대상으로 전문 감정가에 의해 수작업으로 수행되고 있다. 건표고의 품질을 결정짓는 외관의 품질인자들은 갓과 내피에 고루 분포하고 있다. 본 논문에서는 컴퓨터 영상처리 시스템에 의거하여 개발한 건표고 자동 등급판정 및 선별 시작시스템의 구조와 기능 그리고 성능에 대하여 설명하였다. 개발한 시작시스템은 표고의 이송과 취급자동화를 위한 진동이송기, 반전장치, 컨베이어 이송장치와 두 세트의 컴퓨터 영상처리 시스템, 그리고 시스템 통괄제어를 위한 IBM PC AT 호환 컴퓨터, 디지털 입출력 보드, 전공압실린더 구동제어를 위한 PLC 등으로 구성하였다. 등급판정의 효율성 및 실시간 작업시스템을 고려하여 건표고의 등급판정은 두 세트의 컴퓨터 영상처리 시스템을 이용하여 이송되는 건표고의 갓 또는 내피 중 어디가 위를 향하는 지에 따라 두 단계에 걸쳐 독립적으로 판정을 수행하도록 하였다. 첫 번째 영상처리부에서는 갓표면 영상으로부터 4등급의 고품질 표고를 분류하며 두 번째 영상처리부에서는 내피표면 영상으로부터 중간 및 저품질 표고를 8개의 등급으로 분류한다. 실시간 영상정보처리를 목적으로 기존에 개발한 신경회로망을 이용한 등급판정 알고리즘을 시작시스템에 적용하였다. 개발한 시작기는 88% 이상의 등급판정 정확도를 보여 주었으며, 전공압시스템의 구동제약으로 인하여 표고 1개당 약 0.7초의 선별시간이 소요되었다. 일조 선별라인의 경우 본 연구에서 제안한 시작기의 선별능력은 표고가 일차 처리부로 갓이 위로 올라와 있는 상태로 계속 공급된다면 시간당 대략 5,000여개의 표고를 처리할 수 있을 것으로 기대된다.

주요 용어(Key Words) : 건표고(Dried Oak Mushroom), 컴퓨터시각(Computer Vision), 자동선별 시스템(Automatic Sorting System), 신경회로망(Neural Network), 자동 등급판정(Automatic Grading)

1. INTRODUCTION

Automation has provided feasible solutions for improving 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 is very different from other industries. In a case of dried oak mushrooms, sorting has been roughly done manually and grading has been performed via ins-

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pecting randomly selected samples by the human expert.

Generally, human expert is the best in grading an individual oak mushroom in a sense of precision, adaptability, and robustness. Human grading, however, usually suffers from the speed and the lack of consistency because of the fatigue and illusion and the time-varying emotional state. As a result, the overall productivity is quite low.

Considering the inherent quality factors of agricultural products, the automatic grading and sorting system should be developed in a real time manner while preserving the human like robust and efficient visual data processing. As a substitute of human vision, computer vision technology has shown great potential in the evaluation of different quality attributes of agricultural and food products. Currently computer image processing is incorporated with the emerging AI technologies such as expert system, neural network, genetic algorithm, fuzzy logic, etc., to improve information processing ability. And this kind of approach is very effective in agricultural processing.

In this paper, a prototype of automatic grading and sorting system for dried oak mushrooms which has been built in our laboratory was presented. And an efficient and robust grading algorithms which was developed for real time implementation were also presented.

2. GRADING AND SORTING SYSTEM

A computer vision based prototype grading and sorting system has been developed considering the practical aspects such as processing capability and performance and the 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 grading decision. However, this is limited to only randomly selected samples. In fact, it is impossible to investigate all of mushrooms one by one, especially when mushrooms are moving continuously via conveyor.

Considering system implementation, simultaneous investigation of both sides of mushrooms using computer vision systems were quite difficult. We adopted the sequential side investigation of the mushroom and as a result, the system was composed of two sets of computer vision systems one for the cap side image processing and the other for the gill side. Two sets of vision systems were mounted on two sets of variable speed conveyor. Two conveyors were aligned end to end with certain height difference to ensure the side reversion. Two lighting chambers were designed for each set of computer vision system and high frequency(20,000Hz) inverter fluorescent lighting was installed in the chamber.

Large vibrating hopper was installed to store and feed the dried mushrooms. Two vibrating feeders were installed to control the number of mushrooms to be fed and to avoid overlapping and to precisely feed one by one. Specially designed round cross-sectioned plate was mounted on the vibrating feeder. Utilizing the speed variation of feeding between the vibrating feeder and the conveyor, mushrooms could be successfully isolated and fed while maintaining certain distance interval.

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

PLC(programmable logic controller), I/O board and several optic sensors were used to control the electro-pneumatic handling devices. IBM PC-AT compatible computer was used for 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.

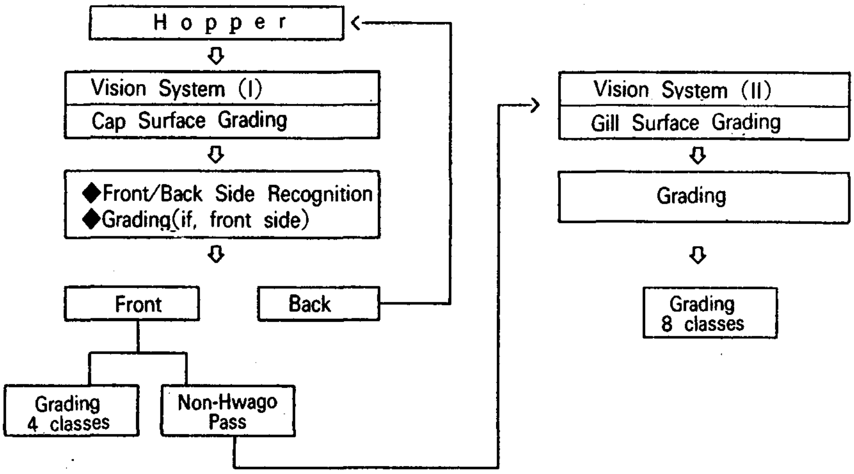
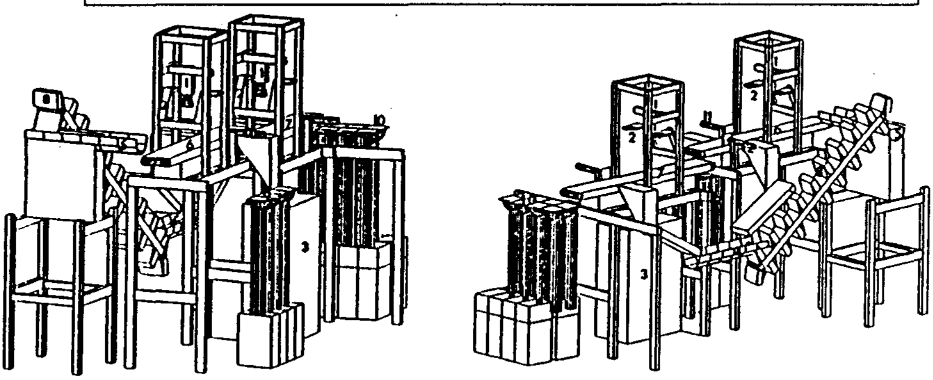


Fig. 1 Schematic block diagram of automatic grading and sorting system.

1. camera 2. illuminator 3. PLC controller 4. 1st vibrating feeder
5. 2nd vibrating feeder 6. 1st conveyor 7. 2nd conveyor
8. carrier conveyor 9. receipt buckets for 4 high quality grade mushrooms
10. receipt buckets for 8 medium and low quality grade mushrooms
11. feedback cylinder 12. hwago out cylinder



(a) front side view (b) back side view

Fig. 2 Schematic view of overall system.

3. NEURO-GRADING

Considering real time system implementation and the hardware complexness, the neuro-net based real time on-line grading algorithm was developed for the prototype. The neuro-net based grading utilized the gray valued raw images of fed mushrooms captured by 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(1, 2) was executed to obtain the size data of the mushroom and to determine the network input region.

A. Image Compensation

Since training of the network was affected mostly by the distribution of the gray values of captured images, it is crucial to compensate differences of gray values of the input image due to the variation of the illumination states. Usually the state of the illumination at the network training stage may differ from the one at the network implementation stage.

A sample white sheet was used to compensate variations of the illumination between the two stages. Gray values at the selected region of the sample sheet image were measured and averaged. The average gray value was divided by 255 and its reciprocal was used as illumination compensation coefficient K. The input mushroom image was multiplied by this coefficient at the training stage. At the implementation stage, the coefficient K was determined again using the same sample sheet and then the input mushroom image was compensated. The compensation process provided nearly the external lighting invariant consistency of the input image to the trained network.

B. Structure of Network and Input Representation

Neuro-based image processing was developed to achieve the real time robust classification. Though grading of dried oak mushrooms has been done usually via external features distributed over both cap and gill surfaces, it is necessary and desirable to develop the grading algorithm using either cap or gill surface image to simplify the system implementation. Various types of network input representations were tested and compared to ensure the successful grading performance.

First, seven quantitative geometrical data which represent visual features of mushrooms were used as network inputs to classify mushrooms into 12 grades. Features of mushroom were quantified as area, roundness, edge thickness of the gill surface, average gray value of the cap surface, average gray value of the gill side membrane, crack ratio of the cap surface, and element C_{22} of the texture co-occurrence matrix C using right and lower directional path mask. Crack ratio was computed as the difference between the maximum and minimum numbers of white pixels among the 4 quadrants of the mushroom image.

Second, cap surface were directly used as network inputs to classify 4 grades of high quality mushrooms and gill surface gray level images were used to classify 8 grades of medium and low quality mushrooms. Finally, both cap and gill surface images were used as network inputs to classify 12 grades of mushrooms.

In order to make mushroom image be suitable to the network input, captured image of the mushroom was converted to 76 rectangular grids. As shown in fig.3, rectangular grids were formed along the 8 directions of the rectangular shape of bounded image. And x and y size factors of the bounded input image were also added as network inputs to provide a network with information of the mushroom size. Since the total number of input grids was fixed to 76, the size of rectangular input grid of bounded image of each mushroom varied according to the mushroom size. Table 1 shows the classification performance of the various input representations. As seen in the test results of the various input representations, grading from either cap or gill surface image was as efficient as that from both surfaces and was better than the quantitative input data from both surfaces. High quality oak mushrooms such as Hwago and Gureum-Hwago had a turtle shaped cap surface with dark brown spots uniformly distributed over the surface. Other medium and low quality mushrooms such as Donggo, Hyanggo and Hyangsin did not have distinct shape and texture patterns and they differed from only cap size, brightness, and the amount of the rolled cap edge in the gill surface. Therefore, 2 types (Hwago, Gureum-Hwago) with 4 categories were classified successfully from the cap surface image processing and other 3 types(Donggo, Hyangsin, Hyanggo) with 8 categories were classified from the gill surface image processing.

According to the pre-specified compensation value of the illumination at the initial stage, grid values of the captured image were compensated. Each grid value was the average gray value of pixels in the grid and was normalized between 0 and 1.

As shown in fig.3, network structure 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 could classify all the input patterns into 12 categories. Learning and momentum rates were assigned as 0.7 and 0.9 respectively.

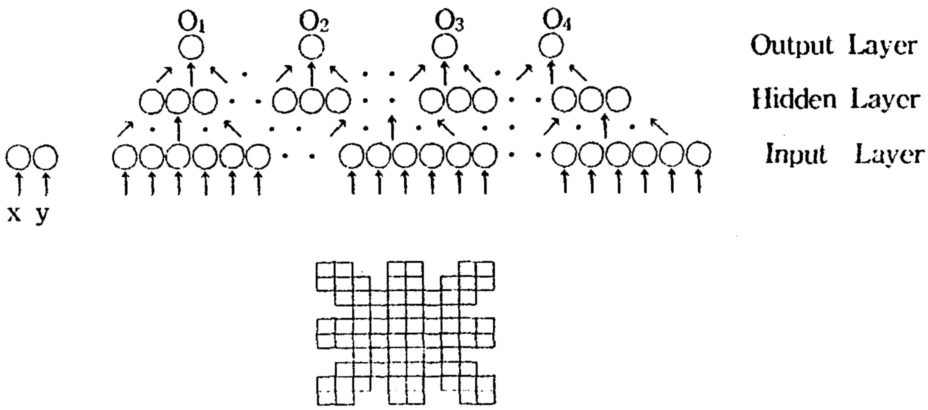


Fig. 3 Network structure composed of 78 grid input

Table 1 The classification performance of the various network inputs

Types of Network Inputs	No. of Misclassification (Total)	Classification Performance(%)
−7 Geometrical Features (12 grades)	20(240)	90.8
−Cap Surface Gray Image (4 grades)	5(80)	93.8
−Gill Surface Gray Image (8 grades)	13(160)	90.4
−Cap and Gill surface Gray Image(12 grades)	19(240)	92.1

4. RESULTS

A. Blurring Effect

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. In a case of processing the moving image, the captured image was blurred and it caused incorrect results of the measurement. Though the blurring effect could 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 prototype, considering response time of the actuating 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 2 showed measurement errors of the sample square due to the vaiious conveyor speeds under 1/500 second shutter speed.

Table 2. Measurement error of sample square

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

B. Grading

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 categories 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 arbitrarily selected and tested. Grading accuracy was 88.3% and the trained network misclassified 14 mushrooms. Most of misgrading occurred at the Donggo. In fact, samples used for grades of Donggo types had little variation in their shapes because of the lackness 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 the performance of grading.

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, approximately 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 capacity. The estimated amount of handling capacity could be decreased to be half if the system is operated without operator's assistance because of the 50% probability of "the cap surface up state" of the fed mushrooms at the first image processing stage.

5. CONCLUSION

The grading scheme which was based on the rule set up with some experimental heuristic utilizing the quantitative features extracted from the segmented oak mushroom image showed the inherent deficiency of the robustness and the problem of real time implementation. Since all oak mushrooms have their own unique and irregular visual features and some were very fuzzy and abnormal, recognition rules could not handle all the shape patterns correctly though they were enforced by the heuristic. To satisfy the real time on-line processing and to overcome the inherent deficiency of the robustness, neuro-processing of the visual image of the moving mushrooms was developed.

The neural net processing has been done by converting structure of the network input. An adaptive size of the grid input of gray valued raw images of mushrooms to the network was utilized to train the grading results 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 its processing 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 prototype system for the automatic oak mushroom grading and sorting has been developed utilizing proposed 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 implementation scheme for automatic grading of dried oak mushrooms fed on the conveyor belt revealed successful results of more than 88% grading accuracy. Processing capacity of 5,000 mushrooms per hour was expected if mushrooms were fed continuously as cap surface up at the first processing stage.

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.

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