Development of On-line Quality Sorting System for Dried Oak Mushroom - 3rd Prototype -

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Abstract: In Korea, quality evaluation of dried oak mushrooms are done first by classifying them into more than 10 different categories based on the state of opening of the cap, surface pattern, and colors. And mushrooms of each category are further classified into 3 or 4 groups based on its shape and size, resulting into total 30 to 40 different grades. Quality evaluation and sorting based on the external visual features are usually done manually. Since visual features of mushroom affecting quality grades are distributed over the entire surface of the mushroom, both front (cap) and back (stem and gill) surfaces should be inspected thoroughly. In fact, it is almost impossible for human to inspect every mushroom, especially when they are fed continuously via conveyor. In this paper, considering real time on-line system implementation, image processing algorithms utilizing artificial neural network have been developed for the quality grading of a mushroom. The neural network based image processing utilized the raw gray value image of fed mushrooms captured by the camera without any complex image processing such as feature enhancement and extraction to identify the feeding state and to grade the quality of a mushroom. Developed algorithms were implemented to the prototype on-line grading and sorting system. The prototype was developed to simplify the system requirement and the overall mechanism. The system was composed of automatic devices for mushroom feeding and handling, a set of computer vision system with lighting chamber, one chip microprocessor based controller, and pneumatic actuators. The proposed grading scheme was tested using the prototype. Network training for the feeding state recognition and grading was done using static images. 200 samples (20 grade levels and 10 per each grade) were used for training. 300 samples (20 grade levels and 15 per each grade) were used to validate the trained network. By changing orientation of each sample, 600 data sets were made for the test and the trained network showed around 91% of the grading accuracy. Though image processing itself required approximately less than 0.3 second depending on a mushroom, because of the actuating device and control response, average 0.6 to 0.7 second was required for grading and sorting of a mushroom resulting into the processing capability of 5,000/hr to 6,000/hr.

Keywords : Automatic Sorting and Grading System, Dried Oak Mushroom, Neural Network, Gray Image Processing

Introduction

Most bio-production processes involve labor intensive and tedious simple repetitive tasks. In fact, automating simple repetitive task of handling bio-products often requires real time computer image (gray or color) processing, artificial intelligence based information processing, and sophisticated handling maneuver because of their various and irregular shape characteristics. Since amongst of various agricultural processes, the process of quality inspection and control has been one of the most labor intensive and time consuming operations, researches and developments for quality grading and sorting automation of bio-products have been very active throughout the world.

Generally, human expert is the best in grading an individual object 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, illusion, and time-varying emotional state, which are popular symptoms of the

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mental state caused by the long-lasting continuous work. As a result, the overall productivity gets usually lower as the amount of objects to be graded increases.

Considering the inherent quality factors of bio-products, grading and sorting system should be developed in a manner of being capable of human like robust and efficient visual data processing while keeping in real time speed. As a substitute of human vision, computer vision technology has shown great potential in the evaluation of different quality attribute of agricultural and food products. Currently computer image processing has been incorporated with the emerging artificial intelligence (AI) technologies such as expert system, neural network, genetic algorithm, fuzzy logic, etc. Since quality of bio-products is usually determined synthetically from various features, this kind of approach is very effective in quality control of bio-products.

In Korea, dried oak mushrooms distributed in the market are classified into many different categories based on its external visual quality. They are classified into more than 10 different categories based on the state of the cap opening, the surface pattern, and color of the cap and gill. And mushrooms of each category are further classified into 3 or 4 groups based on their shapes and sizes, resulting into total 30 to 40 different grades. However, only size sorting is done partially by a series of conveyors and vibrating feed plate having different sizes of punched round holes. Since visual quality features of a dried mushroom are distributed over both sides of the gill and the cap surface, precise grading used to be done manually one by one via shape and texture. In fact, it is almost impossible for human to inspect every mushroom, especially when they are fed continuously via conveyor.

In this paper, considering real time on-line system implementation, the system hardware and neural network based image processing algorithms for quality grading are presented. The neural network based mushroom identification and grading utilized the raw gray value image of fed mushrooms directly captured by the camera without any complex image processing such as feature extraction and enhancement. Proposed algorithms were implemented to the prototype automatic grading and sorting system, which has been developed in our laboratory. Results of grading and sorting performance of the proposed system are also presented.

Materials and Methods

1. Quality Grading

Quality grading of bio-products via extracting visual features often requires too much computing and time-consuming operation. Real-time and on-line image processing constraint used to be a bottleneck to the successful system implementation of quality evaluation algorithms. And visual features extracted from certain image processing may sometimes lose certain important information due to the enhancement and the simplification processes resulting into inaccurate results. If a pattern can be recognized without extracting quantitative features, the real time and robust system implementation can be easily achieved. The neural network based image processing was devised to realize the quality grading of a mushroom without employing the complex feature extraction.

Since visual quality features of a dried mushroom are distributed over both sides of the gill and the cap surface, both side images should be captured and inspected. To automate the grading process, the recognition of the side should be done first from the image captured by the camera. In this paper, the well known Back-propagation (BP) network was utilized to identify the feeding state of a mushroom, whether the mushroom is fed as the front side (cap) up or back side (stem and gill) up. Also BP network was used for quality grading of a mushroom.

For the front and backside recognition, two types of network inputs were previously tested. First, the segmented binary image obtained from the execution of combined type automatic thresholding was tested for network inputs. And gray valued raw camera image was tested directly as an input to the network. Since the segmented binary image by the combined type thresholding may lose important details of the gray valued image or distort some information, the recognition performance of the network with the binarized image input was worse than the network with the raw gray valued image (Hwang, 1994).

Once the fed mushroom was identified from the optic sensor, the image was captured. Using the captured raw gray level image, location of the mushroom was identified and the network input region was assigned from the measuring window (170×180) by scanning gray level difference between the background and the mushroom pixels. The network input region was determined from the min/max pixel coordinate obtained after scanning. The network input region was converted to the rectangular input grids being composed of 64 (8×8) grids. Though the size of rectangular input grid varies according to the size of the fed mushroom, the total number of grids is kept same. Value of each grid was computed by averaging the gray values of pixels that belong to each grid and was normalized between 0 and 1. Using these converted input values the feeding states of mushrooms were identified as either front side up or not via network processing. The converted network input values were kept for further processing.

Then, mushroom was reversed via automatic reversing device and the image was captured again. Exactly same process was repeated for the reversed mushroom. The converted network input values of the reversed mushroom were also kept after identifying the feeding state. Two sets of the converted network inputs, 128 normalized grid values with normalized 8 size factors (x, y, |x y|, x+y) computed from two measuring windows were used for network inputs for quality grading. The size difference of two images (before and after reversing) caused by the distance difference from the camera was compensated at the initial system set up.

Since the network was trained by the spatial distribution of gray levels of each grid, the network performance is sensitive to the illumination condition. The brightness level of the camera input gray level image varies very sensitively to the lighting condition. Hence, the average brightness of the input window was measured. Then according to the predefined values at the initial stage of training, gray values of input image were compensated. The compensation process provides nearly the external lighting invariant consistent input image to the trained network. Fig. 1 shows the grading scheme and the network structure.

Network training for the feeding state recognition and grading was done using static images. 200 samples (20 grade levels and 10 per each grade) were used for training. 300 sample mushrooms (20 grade levels and 15 per each grade) were used for validation of the trained network. By changing orientation of each sample, 600 sample data sets were made and used for the test.

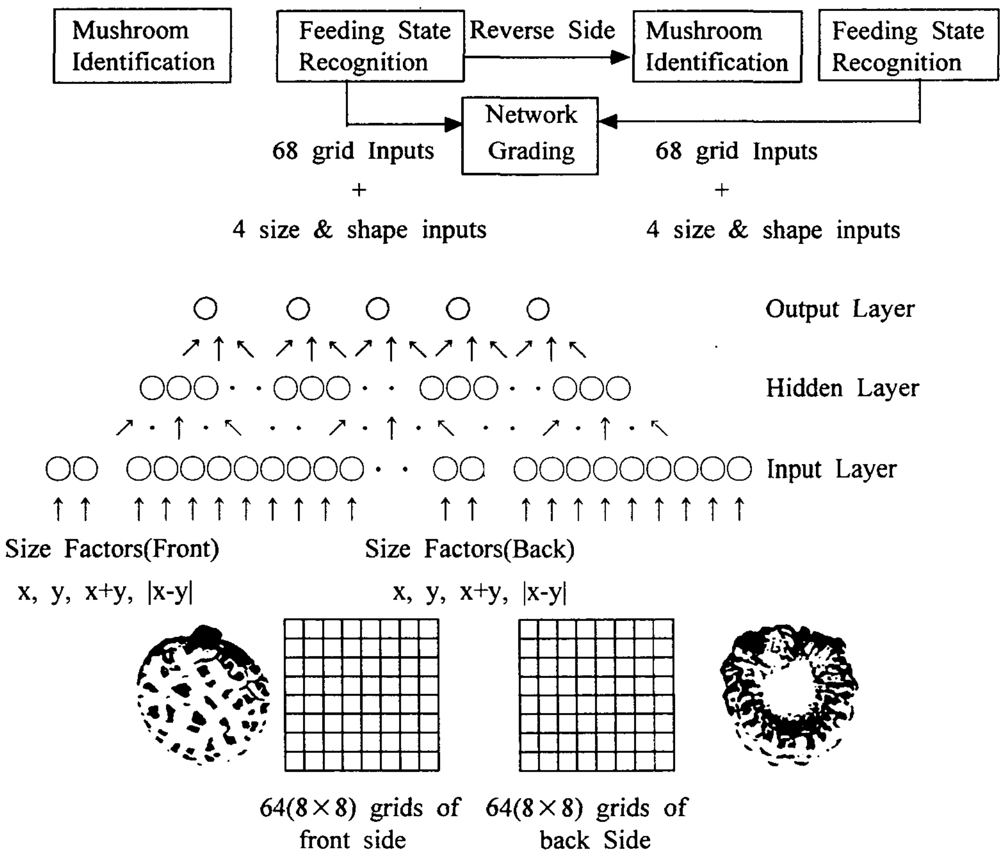


Fig. 1 Grading scheme and network structure composed of 136 input.

2. Implementations

The previously mentioned neural network based image processing algorithm has been implemented to the prototype automatic grading and sorting systems (Hwang et. al, 1999, 2001). The 3rd prototype was designed and built to meet the requirements of the developed algorithm and then to improve the grading performance and sorting capacity while simplifying the system requirement. As mentioned previously, the grading algorithm utilized both side images of a mushroom. Since simultaneous acquisition of both side images of the incoming mushroom required two cameras and was quite difficult from a viewpoint of the system implementation, the mushroom image was sequentially acquired. Either side image of a fed mushroom was acquired sequentially via automatic side reversing device. One set of vision system was used and the field of view of the camera was adjusted enough to cover the both side images of mushrooms before and after reversing. And then both side images were utilized for quality grading of a mushroom.

Once the fed mushroom was checked from the optic sensor, the image was captured. Using the raw gray level image captured from the camera, the location of the fed mushroom was identified and the network input range was assigned from the predetermined measuring window (170×180) by scanning the gray level difference. Fig. 2 shows the schematic diagram of the process that generates the network input from the mushroom fed on a conveyor. Then recognition of feeding status (either front or back side up) was done first via trained network and the network grid input data and size data were kept with side labeling.

Though, some modifications were made from defects of the previously developed 1st prototype (Lee, 1996; Hwang 1996) and 2nd one (Hwang, 1999; Hwang et al, 2001), the 3rd prototype was composed of similar components of the previous ones such as vibrating hopper and feeder for storage and feeding, variable speed conveyors, one set of computer vision system, automatic side reversing device, and multi-stage sorting device. Two vibrating feeders were installed to control the amount of mushrooms being fed and to feed one by one in a row while avoiding overlapping each other. The pendulum type narrow thin plate with the proximity switch was installed over the vibrating feeder to control the feeding amount of mushroom from the storage/feeding hopper as shown in Fig. 3.

When the amount of mushrooms in a feeder was too much to be aligned in a row, the pendulum switch

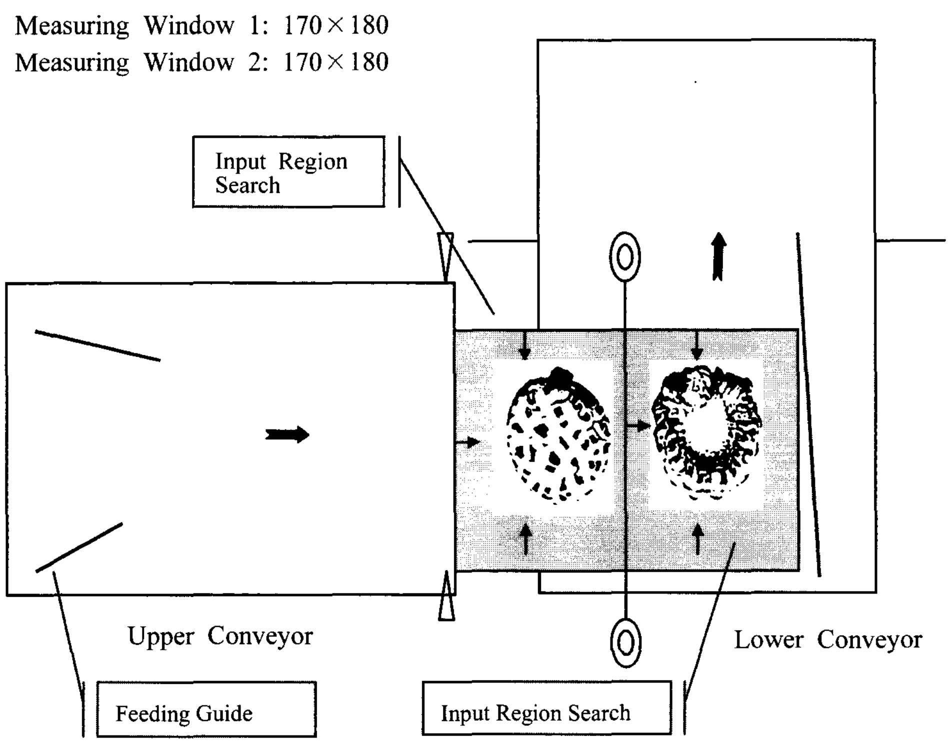


Fig. 2 Schematic diagram of the process generating network input from the mushroom fed on a conveyor.

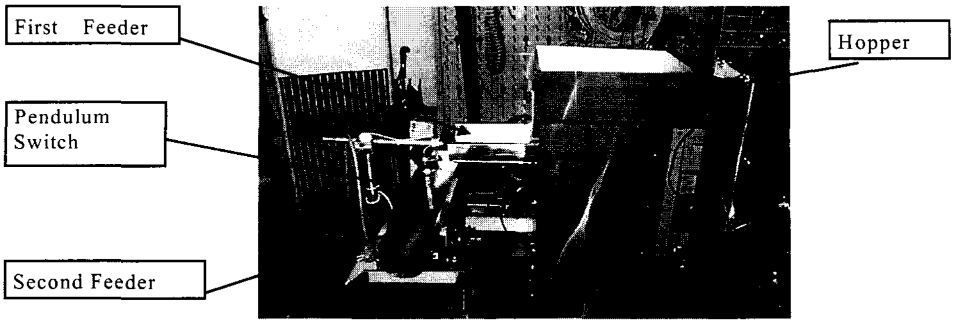


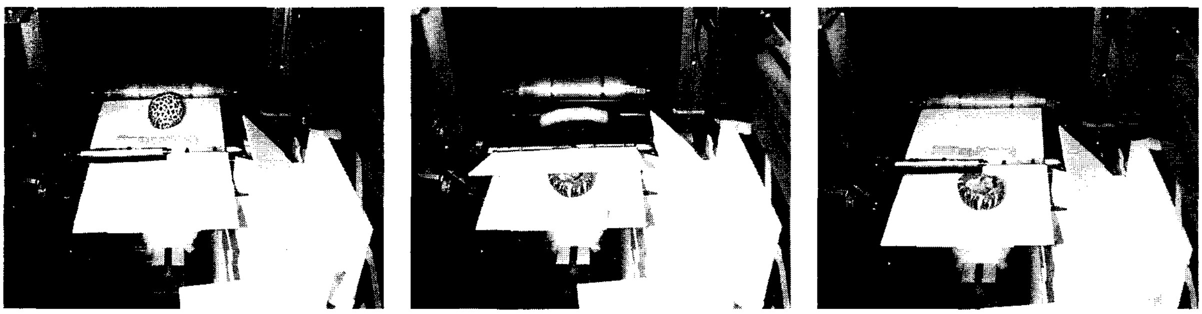
Fig. 3 Vibrating hopper and two vibrating feeders attached with feeding amount control unit.

was turned on. Then, the vibrating storage/feeding hopper was turned off and stopped feeding to the next vibrating feeder until the signal backed up. By adjusting the height of the tip of the pendulum plate, the amount of mushrooms to be fed was controlled. The "U" shape cross-sectioned plate was specially designed and mounted on the vibrating feeder to make mushrooms feed in a row. Utilizing the speed variation of feedings between the vibrating feeder and the conveyor, mushrooms were isolated each other and fed at a certain distance apart.

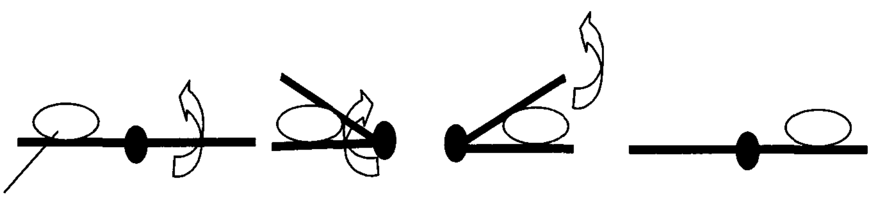
An automatic reversing device driven by DC motor was devised and installed between the two feeding conveyors to automatically reverses the side of continuously fed mushrooms as shown in Fig. 4. Fig. 4(d) shows the sequence of operation of the reversing device. This reversing device allowed capturing each side image sequentially. Fig. 5 shows the functional sequence of the automatic grading and sorting process.

An illumination chamber was designed and 4 high frequency (20,000Hz) inverter fluorescent lighting was installed in the chamber to reduce the shade. Oculus B/W frame grabber (TC-MX, CORECO Inc.) was used to digitize and store the incoming video signal. Multiple sorting stations were built and each sorting station was composed of a set of air nozzles and flexible bellows mounted over the bucket along the conveyor. The optic sensor was mounted at each sorting station to check the mushroom passing. Bad mushroom was sorted to the bucket located at the end of the conveyor.

Five sorting stations were built and each sorting



(a) (b) (c)



(d)

Fig. 4 (a) Automatic reversing device actuated by DC motor and optical switch (d) Schematic sequence of operation.

Vibrating Hopper ⇦

* Mushrooms are fed. ⇧

⇩ ⇧ * The amount of mushrooms to be fed is adjusted.

Vibrating Feeder with Lever Switch

⇩ * Mushrooms are fed in a row.

Variable Speed Conveyor

⇩ * Mushrooms are fed apart.

Computer Vision System

⇩ * Image is captured.

Side Reversing Device

⇩ * Side of the fed mushroom is reversed and image is captured again. Grading is done using both images.

⇩

Multiple Sorting Station
Set of Air Nozzle & Bucket

* Mushroom is sorted to the proper bucket.

Fig. 5 Functional sequence of automatic grading and sorting process.

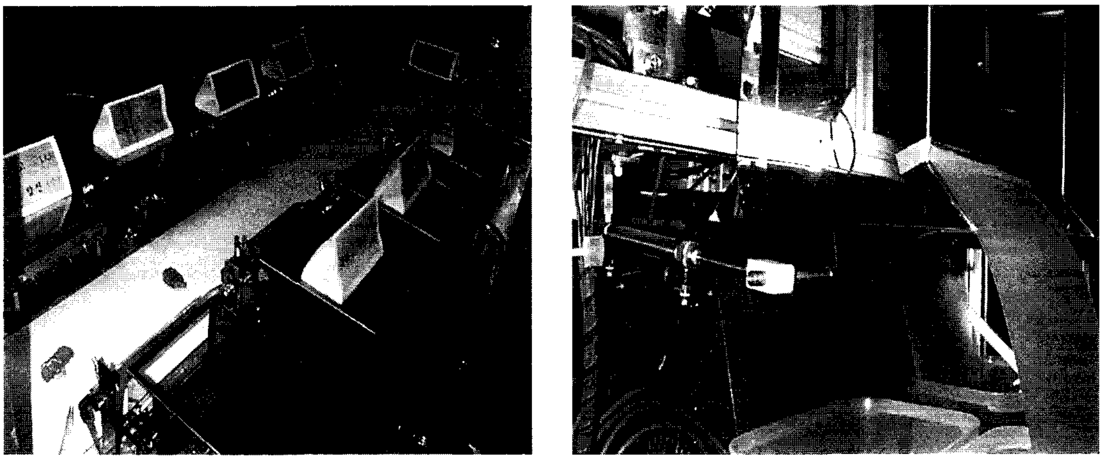


Fig. 6 Multi-sorting stations with double channel bucket.

station was composed of a set of air nozzles mounted over two-channel bucket along the conveyor as shown in Fig. 6. The crevice type pneumatic cylinder was used to move the inside guide plate of the two-channel bucket. The position and blowing angle of the air nozzle at each sorting stage was adjusted based on the size of mushrooms to be sorted. Each sorting station was designed to handle 4 grading categories. The optic sensor was mounted at each sorting station to check the mushroom passing. Bad mushroom was sorted to the bucket located at the end of the conveyor.

An automatic multi-station-sorting algorithm was developed to handle mushrooms being fed randomly and continuously on the conveyor (Kim, 1999). The controller for sorting mechanism was built using one chip microprocessor (Chips F8086, Chips Tech Inc.), I/O board, and driver for solenoid valves. Fig. 7 shows the block diagram of the function of the controller.

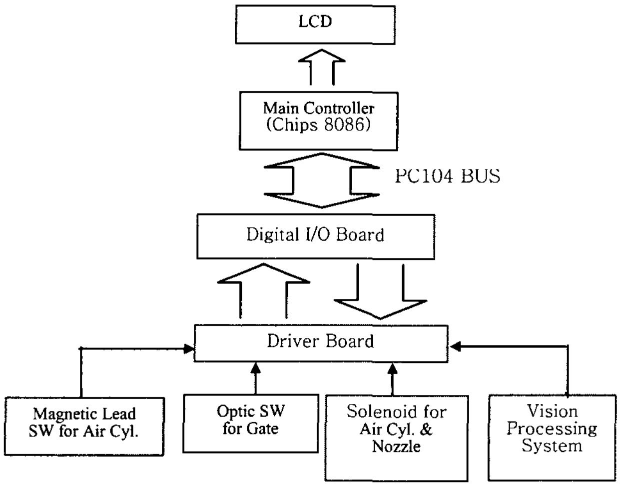


Fig. 7 Block diagram of the function of the controller.

Results and Discussion

Network training for the front and back side recognition was done using static images of 200 samples (20 grades and 10 per each grade). Results of feeding state recognition for training samples showed near 100% accuracy. 300 sample mushrooms (20 grades and 15 per each grade) were used for verification of the trained network. By changing orientation of each sample, 600 sample data sets were made and used for the test. And the trained network showed around 91% grading accuracy for the static images.

Grading performance of the network, which was trained by 200 static samples, was then tested for moving mushrooms. And it showed around 94% accuracy of grading. And 10 untrained samples per each grade (20 grades), total 200 samples were arbitrarily selected and tested. Grading accuracy was around 88% with the conveyor speed of 150.6 mm/sec. As a result, it could be seen that the blurring effect of the camera captured moving image under the 1/500sec shutter speed was negligible in grading performance. The fact of blurring could be also overcome by using the progressive camera.

The proposed grading scheme required average 0.23 second per mushroom. Theoretical grading capacity was 15,000/hr without considering actuator delay. Considering the actuator including the reversing device and control response, average 0.6 to 0.7 second was required for grading and sorting of one mushroom resulting into 5,000/hr to 6,000/hr processing capability. Considering the graphic user interface, the main system software was developed using Visual C++ as shown in Fig. 8. Main system software was composed of 5 different windows such as command input window, window for the continuous image display of mushroom fed on the conveyor, display window for the still image of both sides of a mushroom, window for information display, and window for grade output (Hwang et. al. 2001).

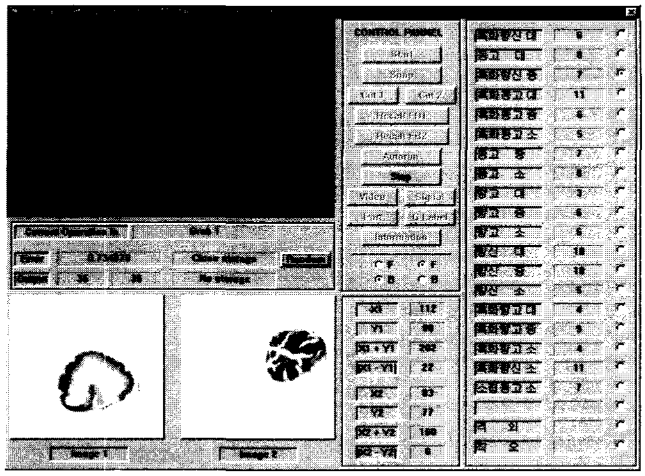


Fig. 8 GUI based system software.

Conclusions

According to the previous research, grading scheme based on the rule set up with some experimental heuristic utilizing quantitative features showed the inherent deficiency of the robustness and the problem of real time implementation. Since all oak mushrooms have their own unique shapes and unfortunatly some of those have fuzzy and abnormal features, recognition rules could not handle all shape patterns correctly though they were enforced by the heuristic. Neural network based image processing for the mushroom grading was developed to satisfy the real time on line processing and to overcome the robustness problem.

The gray valued raw camera images of both sides of mushrooms were directly input to the network without extracting any visual features. The neural network based gray valued raw image processing showed successful results for our grading task in its processing speed, grading accuracy, and the robustness. The prototype was developed to implement the proposed neural network based grading algorithm appropriately.

The system was composed of one set of computer vision system and automatic handling devices such as feeding in a line, side reversing, and simultaneous sorting. A series of a set composed of two pneumatic air nozzle and two two-channel buckets were designed and built to reduce the activation and reset time of the sorting mechanism. 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, the sorting capability of around 5,000 to 6,000 mushrooms/hr per each line i.e. average 0.6~0.7 sec/mushroom. The major constraint of the processing speed was due to sequential acquisition of the image followed by the reversing mechanism.

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