Development of Oval-shaped Agricultural Product Inspection and Sorting System with Simultaneous Six-angle Photograph Taking and Its Practice

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***Abstract*-In the agricultural market, uniform appearance quality of products is becoming more important. In this paper, we propose a total surface inspection and sorting system of an oval-shaped agricultural product for the fully automated ranking operation under the uniform criteria. The system consists of a conveyance part, an image acquisition part, and a classification part. The conveyance part uses a sensor-driven independent driving system, which is constructed by three sets of the "V shape" arranged belt conveyors. In the image acquisition part, photographs of the object are taken from six different angles simultaneously. The classification part identifies the size, shape, and damage existence of the object. The experiment is performed using red peppers as an example of the oval-shaped agricultural product. This experiment is to confirm the effectiveness of conveyance and classification performance of the system and to make possible latent problems tangible. Furthermore, we newly adopt a sequence photographs camera for high-speed acquisition of the image. So we design a prototype of the industrial use with knowledge of the proposed system. We also refer to its feasibility of the practical use.**

Keywords- Surface Inspection; Oval-shaped Agricultural Product; Image Processing; Ranking; Reflection

I. INTRODUCTION

In the agricultural market, uniform appearance quality of products is becoming more important to keep high commercial value of products. Agricultural producers and area organizations, therefore, are making efforts to establish reliable brand by equalizing the appearance quality of their commodity. On the other hand, many sorting machines deal with weight, leaving the sorting operation according to the shape and damage to time-consuming macroscopic human inspection. Fig. 1 is an example of a ranking standard table for the purpose. However, no clear sorting criterion is shown for the inspection by the shape or damage, because the inspection is mainly performed by comparing the product with photographs of unacceptable objects. As a result, the judgment greatly differs between each sorting operator, making equalizing difficult. This causes a problem of the product value deterioration. In addition, manual selection requires observation of all sides of product, increasing physical load to operators.

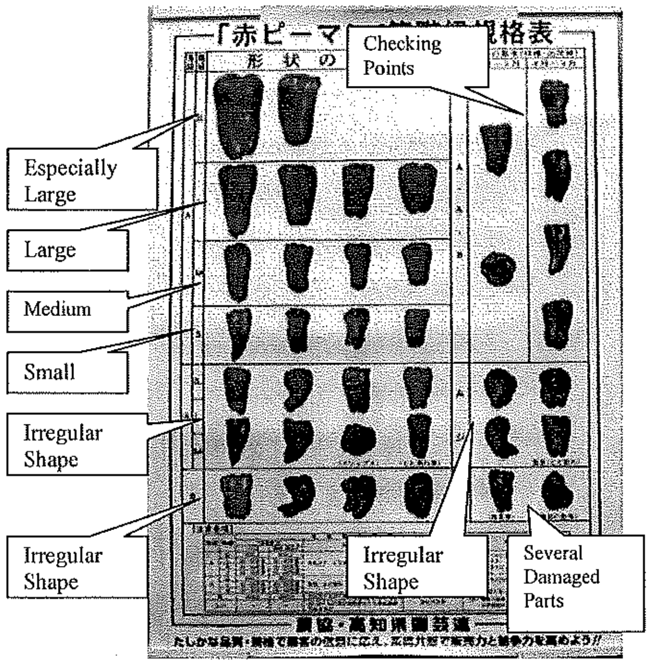


Fig. 1 Ranking standard table

In recent years, R&D of automated agricultural product sorting system using image processing has been often performed [1-4]. The ranking criteria in the image processing are appearance quality as the size, damage, shape, etc. Since damage and color irregularity often appear on the surface, entire surface of the object must be inspected. However, one of major problems is the difficulty of image acquisition around the contact area of package material and object agricultural product. So far many approaches have been proposed for that. For example, after a photograph is taken, the surface of object is pinched with a pair of rollers and then turned over for the next shot of contact area [4]. Or, when the object is conveyed between conveyers, the contact area is photographed [5-6]. In another method, the object is lifted up with adsorbing pad and contact part of carrier and agricultural product is photographed [7-8]. However, any of these methods cannot be applied to different kinds of agricultural product, because depending on the size and the shape of the agricultural product applicable methods are quite limited. Further problem is that it takes long time to shoot and recognize entire surface since photographs must be taken from the upper side, horizontal side, and then for contact area with carrying part. In this study, we propose a total surface inspection and sorting system of an oval-shaped agricultural product for the fully automated ranking operation under uniform criteria. The proposed system consists of a conveyance part, an image acquisition part, and a classification part. The conveyance part uses sensor-driven independent driving system [9-11], which is constructed by three sets of the "V shape" arranged belt conveyers. This enables to convey the object to be sorted to the image acquisition part separated one by one. In the image acquisition part, photographs of the object are taken from six different angles simultaneously with six web cameras. As a light source an LED with diffusion plate on which a diffusion filter is mounted is used to suppress the reflection from the object surface. The classification part identifies the size, shape, and damage existence of the object with six photo images. Otherwise, it is easy to apply the proposed system for a cucumber; an eggplant and a capsicum, whose shape is similar to the red pepper. Namely they are oval-shaped agricultural products. However, conveying speed, image acquisition timing and several threshold values for judge should be tuned for each product, which is exampled in this experiment, respectively. It is still be care that even if the inspection product is oval-shaped, its size, weight and surface condition of the product are sometimes so different from the ones of the red pepper. The proposed inspection and sorting system should be redesign with using this concept such as the sensor-driven independent driving system, the photographs of the products taken from six different angles simultaneously and identifying the size, the shape, and damage existence of the products. In this paper, the experiment of conveyance and classification is performed using red peppers which are easily influenced by reflection as an example of the oval-shaped agricultural product. This experiment is to confirm the effectiveness of conveyance and classification performance of the proposed system and to make possible latent problems tangible. Furthermore, we newly adopt a sequence photographs camera for high-speed acquisition of the image. So we design a prototype of the industrial use with knowledge of the proposed system. We also refer to its feasibility of the practical use.

II. SYSTEM CONSTRUCTION

The general view of the proposed system is shown in Fig. 2. This system consists of a conveyance part, an image acquisition part, and a classification part. Since the proposed system recognizes the photo image of entire surface of the object, when objects are close to each other entire surface image cannot be taken making the classification impossible. Thus, using plural sensor-driven type belt conveyers always just one object is separately conveyed among objects thrown into the conveyance part [9-10]. Next, for taking six surface picture images simultaneously, the object is conveyed to the image acquisition position with silken guts, which does not interfere the shot. To suppress the reflection at the object surface an LED light source with a diffusion filter is used. The classification part uses three personal computers, each one connected to two web cameras. Each PC is linked to each other with 100Base LAN, and taken images are sent to the server PC. Next, the size, shape, and damage are inspected for each of six images. The operation procedures of the system are shown below in Fig. 3.

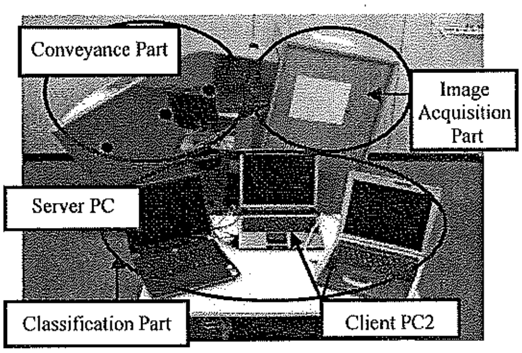


Fig. 2 System overview

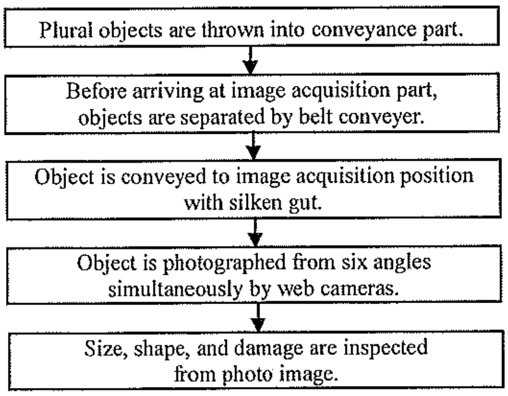


Fig. 3 Operational flowchart

A. Conveyance Part

As shown in Fig. 4, the conveyance part of the proposed system consists of six belt conveyers which have own sensor on them and two silken guts, and the conveyer is arranged in three stages, each stage composed of two belt conveyers forming V-shape. Here, before arranging the object on the two silken guts, the longitudinal direction of the object should be aligned with the one of the silken guts. This is reason for arranging the two belt conveyers in V-shape for each stage. Furthermore, this system cannot perform normal operation when objects are adjacent to each other, and each object must be completely separated before it comes to the image acquisition part.

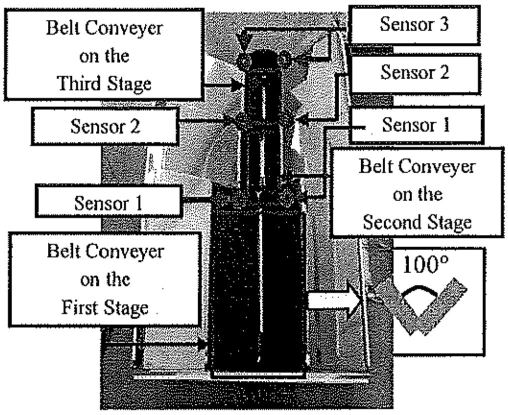


Fig. 4 Outline of conveyance part

So each belt conveyer rotates or stops according to some sensor activations. For example, if the object exists on the conveyer newly, sensor is activated immediately and the conveyer will be stopped to prevent a stream of the objects to the latter conveyer any more. Finally, several objects will be isolated to one object gradually with repeating this procedure. Therefore, the conveyance part is equipped with independently driven mechanism for each stage so that the belt conveyer and silken gut are separately driven by the sensor of each stage. Finally, the independent driving system separates the objects one by one with the operation of belt conveyers on three stages then conveys each object to the image acquisition part with two silken guts as shown in Fig. 5.

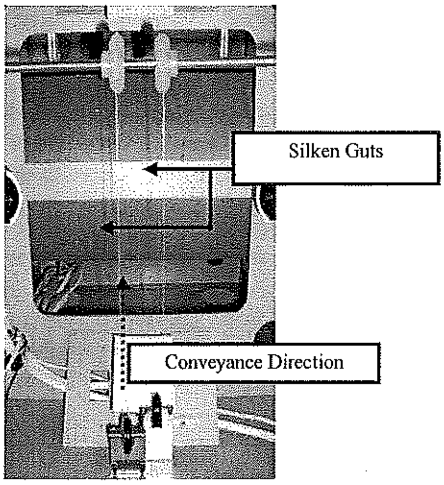


Fig. 5 Object holding part with silken guts

At first the operational procedures of the independent driving system are described as follows. In the beginning, all belt conveyers and silken guts are rotated in the conveyance (positive) direction. Next, when the sensor 1 shown in Fig. 6 detects a signal, the object is regarded as being conveyed to the belt conveyer on the second stage and the belt conveyer on the first stage stops. On the other hand, when the sensor 1 continues to respond for t1 seconds, the belt conveyer on the first stage rotates for t2 seconds again in positive direction. Next, when the sensor 2 responds, the object is regarded as being conveyed to the belt conveyer on the third stage and the belt conveyer on the second stage stops. When the sensor 2 continues to respond for t1 seconds, the belt conveyer on the second stage rotates for t2 seconds again in the positive direction. Next, when the sensor 3 responds, the object is regarded as being conveyed to the silken gut and the belt conveyer on the third stage stops. After the silken guts rotates for x seconds in the positive direction, the guts stop for y seconds for image taking. Finally, the guts rotate again in positive direction to exhaust the object. When all sensors do not respond for s seconds, the conveyance stops automatically. Values of t1, t2, x, y, and s are determined in a preliminary conveyance experiment by trail and error. The flowchart in Fig. 7 shows above-mentioned operational procedures.

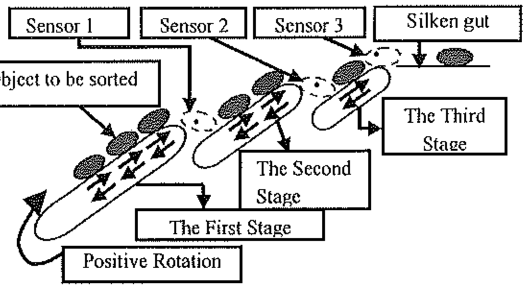


Fig. 6 Structure of independent driving system

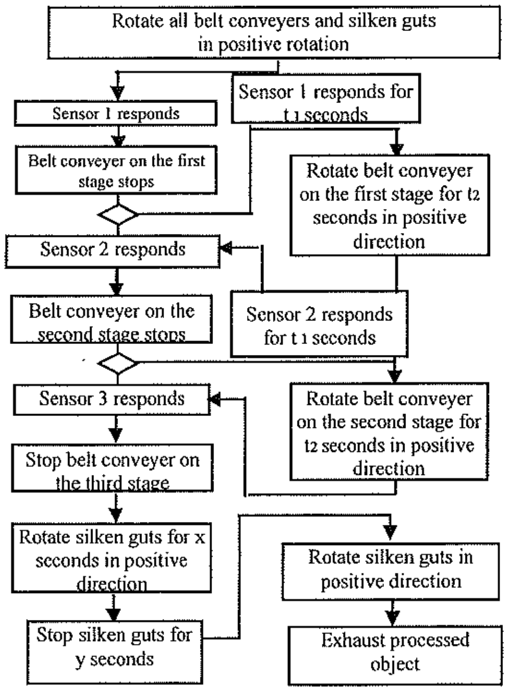


Fig. 7 Flowchart of independent driving system

B. Image Acquisition Part

In this section, the image acquisition part is explained. We estimate red peppers as a rectangular parallelepiped. So it has six surfaces, such as front surface, back one, and four side surfaces. Thus, we need six cameras for image acquisition. This part consists of six web cameras and eight light sources. The arrangement of cameras and light sources in this part is shown in Fig. 8. The specification of used web camera (ELECOM UCAM-E1L30MNWH) is Maximum resolution: 640x480 [pixels], Image receiving element: 1/4 [inch], 300 k-element CCD, Quantization: 24 [bit/pixel], Resolution: 0.3 [mm/pixel]. Total surface of an object is photographed by placing two cameras in the front and back and the other four cameras on the four sides with an angular interval of 90 degrees. In addition, eight LED light sources (ELPA PM-L200 W), each attached with a diffusion plate, are used in this system. A diffusion filter is attached to each diffusion plate on the light source to suppress specula reflection at the object.

C. Classification Part

The classification part is explained here. The classification part consists of one server PC and two client PCs. In the classification part, every PC is connected with two web cameras used in the image acquisition part. Six images obtained in the image acquisition part are sent from client PC to server PC to classify the size, the shape, and damage. Firstly, the client PC takes photographs with an interval of t seconds, and specifies the object using color information around the image acquisition area. In this case, L*a*b* space, configured to be similar to human visual perception, is adopted as the color space. When a hue of classification object is detected within the specified interval by n times continuously, it is recognized that the object has come to the image acquisition position, and the image is transferred to the server PC. The server performs a binary conversion for six pictures taken. Next, the binary-converted image is processed by expansion/contraction for the noise reduction and the object is extracted. The object size is determined by counting pixels inside the extracted edge of the object.

Next, the extracted object is approximated to a rectangle, that is, the ratio of long axis to short axis is calculated and compared with predetermined threshold value to judge whether the shape of the object is accepted. Finally, when an area of extracted object is less bright than a threshold level and the area is larger than a separately defined size, the area is judged to be damaged. The image processing procedures and operational flowchart of the classification part are shown in Figs. 9 and 10, respectively. In the experiments of conveyance and classification, the objects of red pepper are conveyed to the image acquisition position.

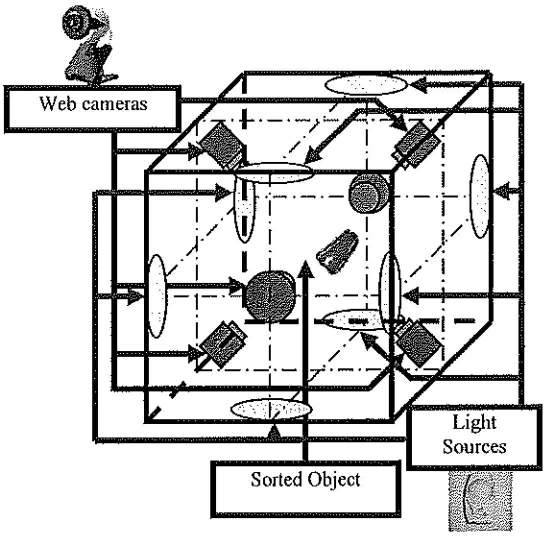


Fig. 8 Arrangement of web cameras and light sources

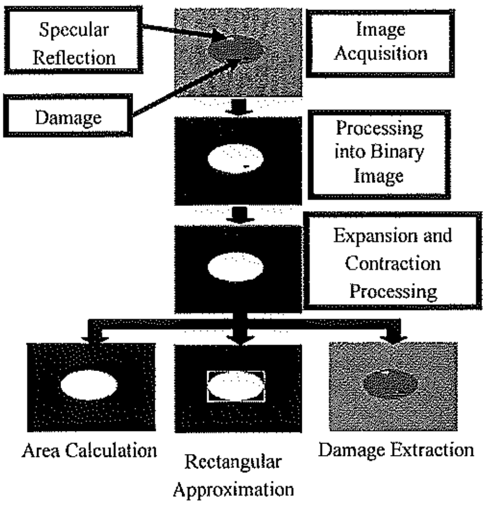


Fig. 9 Image processing procedures

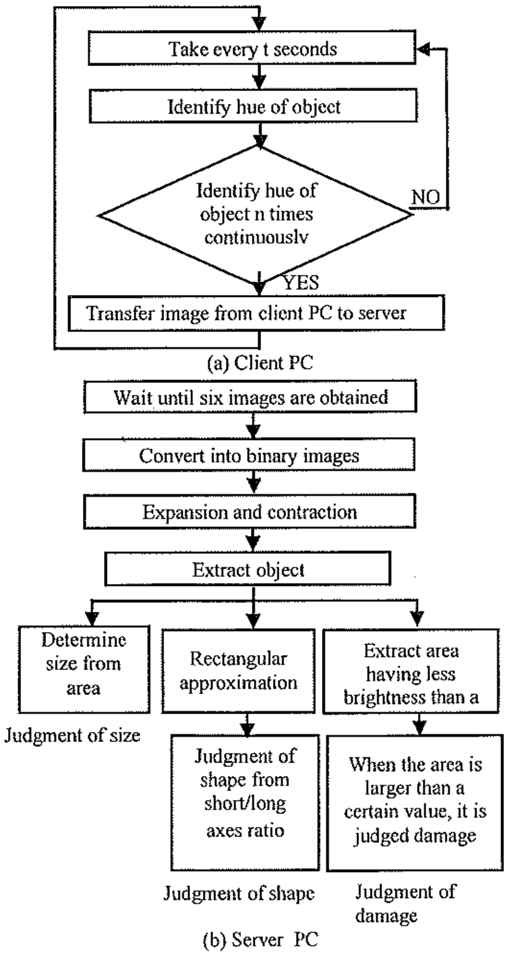
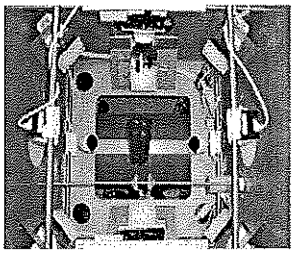


Fig. 10 Operational flowchart of the classification part

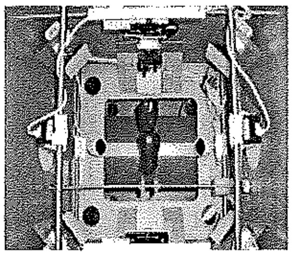
III. EXPERIMENT

A. Conveyance Experiments

Here, plural red peppers of different quality levels are thrown into the proposed system, and separation/conveyance experiment is performed to see whether only one object is sent to the image acquisition part. At first, eleven red peppers are thrown into the conveyance part. Next, all red peppers are sent to the image acquisition position of the image acquisition part. This conveyance is repeated 22 times; 242 times conveyance in total. When one of red peppers is separated from others after being conveyed to the image acquisition part as shown in Fig. 11(a), the experiment is regarded "succeeded". On the other hand, when two or more objects are simultaneously conveyed as shown in Fig. 11(b), or when no object is conveyed, the experiment is regarded "failed". In other words, when conveyed to the image acquisition part, one red pepper means "succeeded" and plural red peppers mean "failed". Experimental result is shown in Table 1. According to this result, the rate of separation success is 75.2%. On the other hand, some red peppers failed to reach the next belt conveyer continuously rolling at the same place. In some other cases, objects were rolled into the conveyer or plural objects are simultaneously conveyed to the entrance of image acquisition part, occurring "stuffed" failure.



(a) Succeeded example of separated conveyance



(b) Failed example of separated conveyance

Fig. 11 State of separated conveyance

TABLE 1 RESULT OF CONVEYANCE EXPERIMENT

	Occurrence ratio (Occurrence/Evaluated Number)
Succeeded separation	75.20%(182/242)
Failed separation	21.5%(52/242)
Roll-up	1.2%(3/242)
Entangle or clogging	2.1%(5/242)

Other failure causes of conveyance were drop-out from the belt conveyer due to conveyance failure to the silken gut, position shift due to conveyance stop outside image acquisition range of the web camera, and vertical riding that the object is conveyed in a vertical posture to the silken gut. The reason of dropout is considered that in the present structure of conveyance part some objects are conveyed in a transverse position instead of longitudinal position. The cause of vertical riding is considered that present width of silken gut does not cover the range of all red peppers' size. The reason for rolling is estimated that the incline of belt conveyer is not always suitable for any red pepper. For rolling-in, it is considered that since the first belt conveyer is wider than the second conveyer the object is easily rolled in between the first conveyer and the housing wall. Because the belt conveyers are combined as V shape, it is quite possible that two objects were conveyed on top of each other and collided with the entrance of the image acquisition part. At the first stage eleven thrown-in red peppers are all conveyed, at the second stage one fourth of them were conveyed, and in the conveyer of the third stage they were separated into three or less individuals. Consequently, when the number of stages increases to four, five, or more, it is highly possible that every object will be separated from each other.

B. Classification Experiment

This experiment uses following twelve red peppers.

(a)-(l). They are selected by visual observation compared with standard table shown in Fig. 1.

(a)-(b): L (Large)

(c)-(d): M (Middle-sized or Small)

(e)-(h): Unacceptably curved

(i)-(l): As damaged sample, a 3x3[mm] black mark is painted on the surface with marker pen, whose hue is so similar to one of the real damage (spoiled) on the red pepper. All samples are shown in Fig. 12. In the experiment, each sample is individually placed at the image acquisition position by hand. Firstly, for each of four samples,

(a)-(d) the classification is performed ten times, and for each of eight samples.

(e)-(l) five times. Let the longitudinal axis, horizontal axis, and vertical axis be x-axis, y-axis, and z-axis, respectively. At every inspection y is changed 180 degrees and the angle around x-axis is randomly changed. Here the proposed system automatically detects failure state of the conveying and reuse the material for experiment.

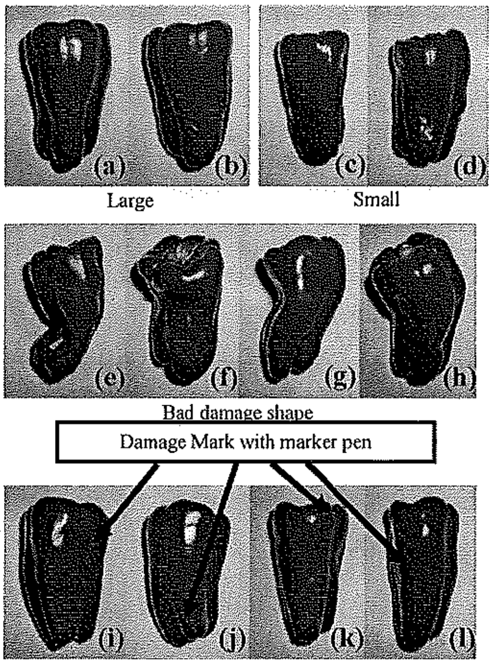


Fig. 12 Red peppers used for experiment

The experimental results are shown in Table 2. It is confirmed the correct classification rate for the size is 100%. On the other hand, the rate is 65% for shape inspection and 75% for damage inspection. In the case of shape inspection, it is considered that since the criterion is short/long axis ratio by rectangular approximation, slightly curved red peppers would pass the test depending on observation angle. For some wrong results of damage detecting test, it is considered that the size of specified area is less than a certain value because reflection point overlaps damage point, or damage is not extracted by the influence of noise due to the web camera's performance. For future studies, the light source should further suppress the reflection and the camera should restrain the noise much more. In addition, for shape classification, image acquisition method not influenced by installed angle will be examined.

TABLE 2 SUCCESS RATE OF CLASSIFICATION

	Success rate of classification (success number/Evaluation number)	
Large	100%(20/20)	15000 pixel < Value < 30000 pixel
Small	100%(20/20)	3000 pixel < Value < 10000 pixel
Unacceptable shape	65%(13/20)	1.4> Value, Value >2.0
Damaged	75%(15/20)	30 pixel < Value

IV. PRACTICE FOR INDUSTRY

We design a prototype of the industrial use with knowledge of the proposed system. We newly adopt a sequence photographs camera for high-speed acquisition of the image. It can acquire the 30 frames image per second. Its image specification is resolution: 640x480 [pixels], Quantization: 24 [bit/pixel]. So on way to conveying the red peppers through the acquisition part, this prototype can acquire its single image in high speed and transact classification calculation.

Especially, the experimental system described in section II and the prototype described in this section is not conflicted. Different point is acquisition speed of the camera. Namely, the experimental system's camera needs 2 s and 500 ms for one image frame. Otherwise the prototype's camera needs only 500 ms for one image frame. Finally, both image acquisition parts have six cameras for acquisition of the six angle image with parallel. Calculation time for the several judges needs 500 ms. In total, the experimental system needs 3 s (2 s and 500 ms + 500 ms), otherwise the prototype needs only 1 s (500 ms + 500 ms), respectively. Here, the both calculation PC are same. Adopting the sequence photographs camera for the high speed acquisition of the image, the prototype can be used sufficiently for the industry.

Fig. 13 shows appearance of the prototype and Fig. 14 shows its acquired image. From this figure, image is clear enough for classification. We could get more than 90% classification capability for the size, the shape, and damage inspection with this prototype.

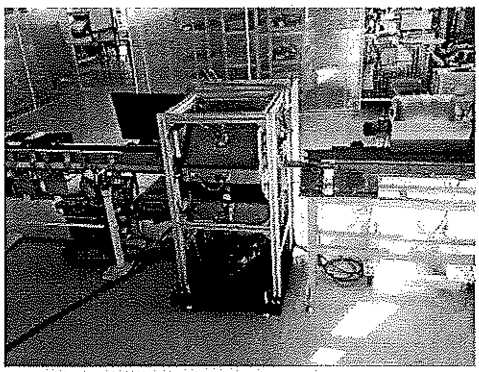


Fig. 13 Industrial prototype for high speed transaction

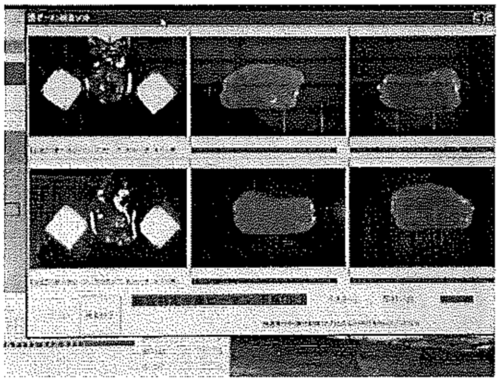


Fig. 14 Captured image by the sequence photographs camera

V. SUMMARY

In this study, we propose a total inspection/sorting system for oval-shaped agricultural product to replace manual operation with automated processing for labour saving and equalization and standardization of sorting criteria.

In a conveyance experiment using red peppers, the success rate of separation was 75%. Such plural failure phenomena were also confirmed as drop from the silken guts, position shift when conveyance stopped, vertical riding on the silken guts, rolling-in, and stuffing. In addition, classification of the size, the shape, and damage was performed for red peppers, and it was confirmed that the right classification rate of the size was 100%. On the other hand, classification rate for the shape and damage was 65% and 75%, respectively. Consequently, total surface inspection and sorting of oval-shaped agricultural product can be performed to some extent by using sensor-driven type independent conveyance system and six-surface simultaneous image acquisition.

Furthermore, we adopt a sequence photographs camera for the high-speed acquisition of the image to an industrial prototype system. It can acquire the 30 frames image per second. So on way to conveying the red peppers, this prototype system can acquire its single image in high speed and transact classification calculation with about one second per one red pepper. This transaction time is sufficient for industrial use.

In addition, the criteria for color irregularity and sunscald of object are not yet clear. This will be solved to some extent by introducing neural network, learning, and generalization ability using real photograph.

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