UDC 681.184

FRUITS AND VEGETABLES SORTERS USING PATTERN TREATMENT

Nariyuki Nagura
Toshimi Kodaira

I. INTRODUCTION

As one of the application equipment for pattern recognition, there is an automatic fruit and vegetable sorter. This sorter checks shapes and colored degrees of fluits in two dimensions (plane). In Japanese agricultural industries, many people have checked fruits visually through their eyes. However, differences among people for abilities and times are involved in decisions by the people, and it is difficult to make a constant evaluations or decisions. This problem cannot be avoided because it is a matter of nature. In other words, the objects are natural products, and existence or non-existence of noxious insect, volume of usued manure, day light hours and other factors cause the shape, color and taste to change complicatedly.

Practically, there are two types of idea for fruit sorting method. One of them is to find taste, and real values of the amount of sugar and acid degree are measured and further, measurement of fragrance which is particular to the fruit is made. At present, this is practically difficult because of the technical limitations, and it is very hard to use a non-desctive and non-contact type measuring instrument in fruit sorting plants.

The second method makes decision for appearance of fruits. Fruits having beautiful appearances are judged to be class A. This fruit selecting method is based on such an assumption as that statistically those having beautiful appearances would have good taste. Actually, those fruits selected carefully under this idea are highly evaluated at Japanese markets.

This paper discusses the actual data of the visual judgements, judgements by the use of the application equipment for pattern recognition (Trade Name: Fuji Video Sensor), and actual distributions of the amount of sugar.

II. OUTLINE OF FRUIT SORTER

Fruits are classified by their sizes. Generally, fruits are classified into five to eight classes like 4L, 3L, 2L, L, M, S, 2S and 3S, and fruits in a size classification are contained in a case (10 kg case, etc.). Further, the fruits are classified into grades based on the characters and qualities. The characters and qualities are related to the tastes. The fruits are sorted based on the appearances, degrees of color, and existence and non-existence of projection or dots. Generally, they are graded into A, B, C and D. Combining the size classifications and grade classifications, fruits are totally sorted into 15 to 32 groups. Fuji Video Sensor uses a high performance ITV and color sensor camera, and with this equipment, fruits can be sorted into the above described sizes and grades automatically. This is a kind of photoelectric converter, called "Robot of Eyes", and the outputs (video signals) are handled as input signals for deciding sizes and grades as shown in *Table 1*.

Table 1 Table of judgement of grade and size classifications

Item \ Type	Color sensor camera	ITV	
Principle	Judgement by color saturation and color tone distributions	Size and shape are judged by cross-sectionally projected image	
Arithmetic control method	Analogue arithmetic control (colorimetric)	Digital arithmetic control by binary system and picture divisions (Pattern recognition technique)	
Judgement parameter	Color saturation (Value *L*) Color tone Red-green distribution (Value *a*) Blue-yellow distribution (Value *b*)	Fruit deformation value Deviation of fruit center (calyz) (Value Δz) Abnormal black dot (white dot) detection	Measuring area (Value *S*) Diameters (Values *x, y, z*) Binary length (Value *l*) Other parameters
Judgement time	10 ~ 20 ms	100 ~ 300 ms	100 ~ 200 ms
Judgement	Grade judgement (A, B, C, D, etc.)		Size judgement (3L, 2L, L, M, S, S2, S3, etc.)

1. Color sensor camera

The color sensor camera uses halogen lights for the

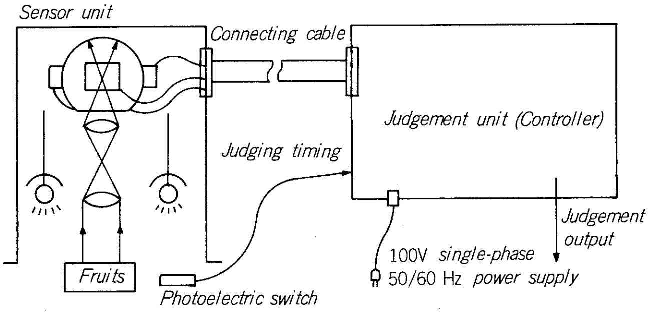

Fig. 1 Schematic diagram of color sensor camera

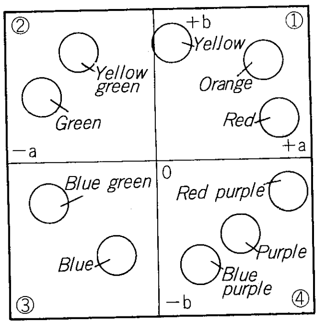

Fig. 2 Digital picture of fruits

Table 2 Color index of prince melon

Appearance \ Color code	Color index		
	R (Red)	*Y* (Green)	*Z* (Blue)
White (A)	50.78	52.83	39.06
Blue/white (B)	35.60	37.31	27.48
Blue (C)	25.21	26.81	16.52
With dark blue stripe (D)	20.15	21.03	10.05
With growing yellowish (D)	39.63	41.81	24.91
With projection or dots (D)	30.08	31.47	17.83

illumination, lights reflected from fruits are condensed with a lens, mean value of the condensed lights is analyzed into specification of colors according to three attributes (red, green and blue), and thus, makes judgements based on the tone of color and darkness. Three component voltages (X for red, Y for green and Z for blue) are taken out from the lights reflected from fruits, and the analogue values are arithmetically operated, and L, a, and b shown below are obtained. (Color indicating method by three attributes)

$$L = \sqrt{Y} \cdot 100\ (\%)$$

$$a = 175\,(1.02X - Z)/\sqrt{Y}$$

$$b = 70\,(Y - 0.847Z)/\sqrt{Y}$$

L is equivalent to darkness, and a and b respectively indicate tone of color and saturation. Values a and b have positive and negative values, and they indicates color ring as shown in *Fig. 2*.

In Japanese pear color sortings, those having strong red colors are sun burn fruits and over ripe fruits, and those having strong blue color are unripe fruits. These can be judged by value a. In the case of prince melon, judgement is made at the top side. As the top side is more white, it is judged to be grade A, and as the top side is more blue, it is judged to be grade C. These are judged by value L. For other fruits, the above method can be applied to persimmon, apple and tomato, but not to peach, sweet melon and mandline orange due to their characteristics. (Regarding tomato, the main purpose of sorting by the colors is to keep same appearances rather than grade judgements. Red tomato is shipped to the near markets, and green ones are shipped to long-distanced markets.) Reasons why the above method cannot be applied to peach, sweet melon and mandline orange are because coloring of peach is partial, stripe pattern of sweet melon has a small contrast and orange color of mandline orange is delicate, and these cannot be identified.

2. ITV camera (pattern recognizing camera)

Fruits are placed on black buckets and moved continuously by a chain conveyor. The ITV camera is equipped with a mechanical shutter, and fruits in twin rows are statilized one piece by one piece. In other words, two pieces of fruit in the left and right are made to white images, and photographed as shown in *Fig. 3*. The picture is divided into 240 horizontal lines and 320 vertical lines, and shapes are judged based on these picture elements. Generally, one picture element is equivalent to 1 to 1.2 sq.mm. To make judgements of fruit size, the following parameters are used.

(1) Measuring area (S): Equivalent to projected cross-sectional area of fruits
(2) Binary length (ℓ): Circumferential length of fruits
(3) Maximum diameter (x or y): Maximum width toward two direct angle directions
(4) Mean diameter $(x+y)/2$: Mean value of (3) above.

The above parameters are selected depending on kind of fruits, how to place the fruits, dimensions of a pack, and how to pack the fruits in a cartone. (In Japan, the pack is a molded synthetic resin pack used to protect apple and peach from damaging. The size is standardized to be one for 12 pieces of apple or peach, etc.) Generally, for apple and peach, measuring area at the side is used and for prince melon and Japanese pear, measuring area of the top side or mean diameters are used. Judgements on abnormal shape fruits are described next.

This method is applied to large size fruits such as sweet melon and other melons or those in various sizes such as tomato and apple, and used to down grade those having bad shapes. Frist of all, for judgements on fruits of elliptic shapes, three methods shown below are available.

(1) Arithmetic operations of $\Delta R = |x - y|$
(2) Arithmetic operations of $S - \ell^2/4x$; Arithmetic operations of true circle

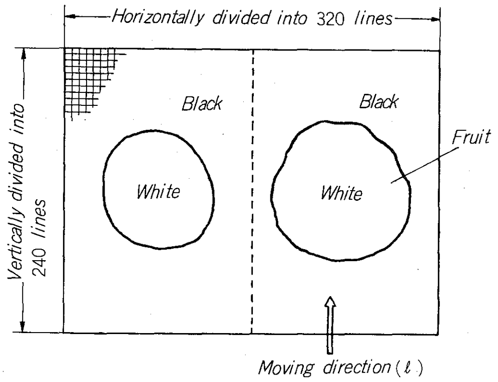

Fig. 3 Parameters of fruits

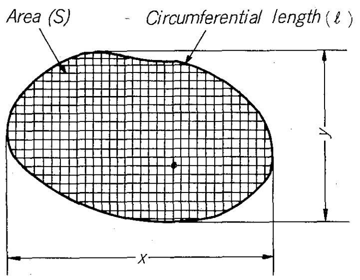

Fig. 4 Parameters of fruits

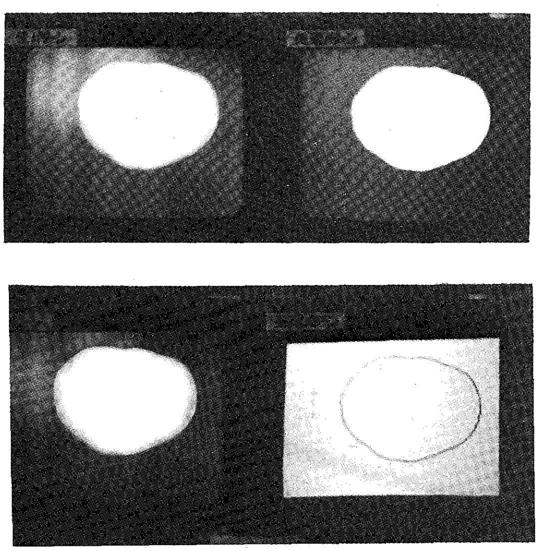

Fig. 5 Measuring area (upper) and binary length (lower) of tomato

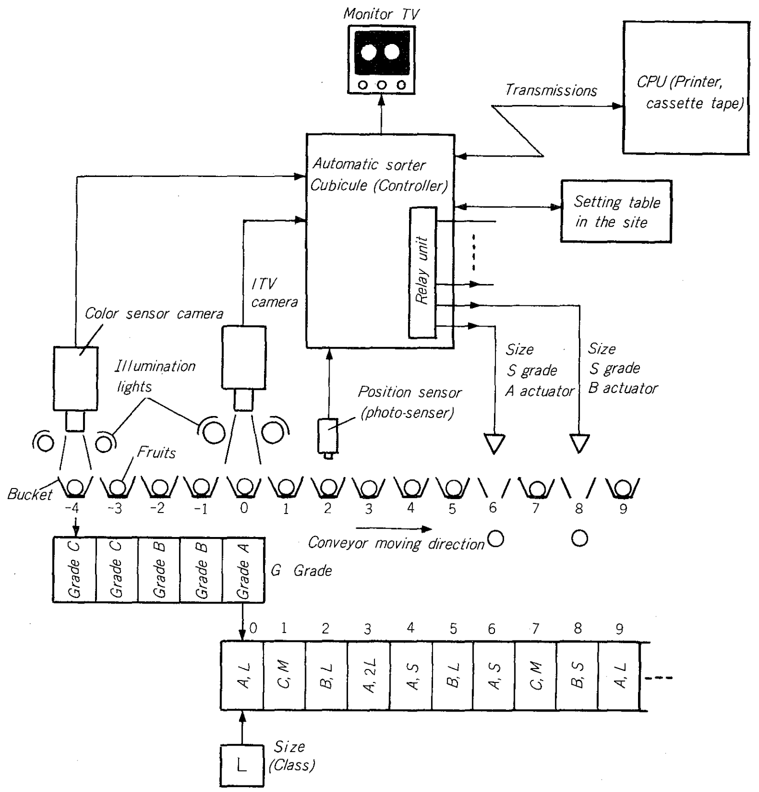

Fig. 6 Block diagram of automatic sorter

(3) Measurement of Δz; This is described later, but this is a measurement of difference between top or bottom hollow position and gravity center cordination of image.

Out of those three methods shown above, the arithmetic operations (1) and (2) are required in sorting tomato, and suited to sorting of oval fruits and star fruits. Method (3) has problems for the practical use, however, the application to apple and pear is considered. On the line extended from the above described technique, sorting of cabbage or water melon exists. For these large size fruits, two ITV cameras are used, judgements are made from two directions and images are handled in three dimensions. Further, for cucumber, eggplant, asparagus, pepper, etc., the sizes and grades are judged by using length, width, changes in thickness and bending angles are parameters.

III. ACTUAL VISUAL JUDGEMENTS

1. Judgement tolerance among sorting workers

Examinations were made to find out universality in visual grade judgements by sorting workers. In the examinations, the backet conveyor were moving under speed of 12 m/min., and prince melons equally spaced on one line were moved 60 pieces per minute. Three specialists checked these prince melons and judged into grades A, B, C and D. *Table 3* shows the data. As the results, those judged by the three specialists to be same grades occupied about a half and it was 57.6%.

This fact proves that the visual judgements have no standards or bases to judge fruits to be grades A, B and C, the standards cannot be quantitized but judgements are made relatively by experience and inspector's own subjective point of view.

Table 3 Real data of visual inspection by human eyes

(Unit of measure: %)

Judge \ Grade	A	B	C	Total
Specialist A	6.1	51.5	42.4	
Specialist B	3.0	60.6	36.4	
Specialist C	3.0	69.7	27.3	
Average	4.0	60.6	35.4	
Those agreed by three	3.0	36.6	18.0	57.6
Those agreed by two	0	12.0	30.4	42.4
Those not agreed by three	0	0	0	0

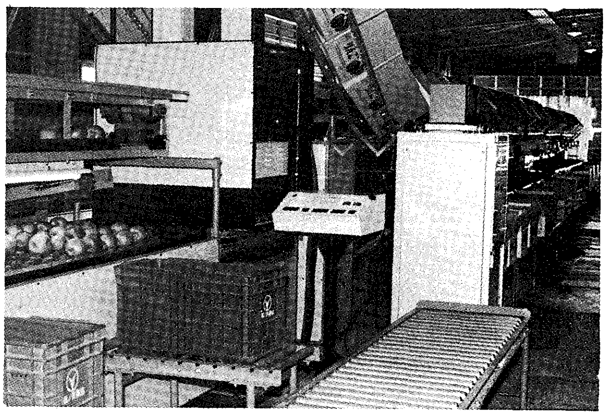

Fig. 7 Sorting machine for apples

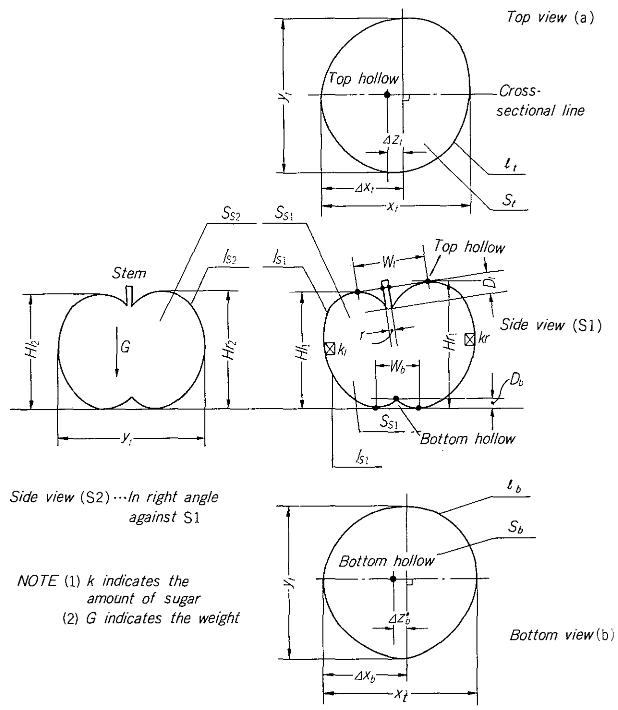

Fig. 8 Parameters of Japanese pear

IV. RELATIONSHIP BETWEEN APPERANCE MEASUREMENTS AND THE AMOUNT OF SUGAR

The data introduced in this Chapter are based on the thorough examinations conducted actually on 159 pieces of Japanese pear in 1980 at Tottori Prefectural Government Fruit Test Laboratory. In this examination, three dimensional sizes of Japanese pears were actually measured, the actual sizes were compared with the values measured by Fuji Video Sensor, and further, the relationship between weight and the amount of sugar of the fruits was examined.

1. Objective values of measurements and measurement errors

With the pears placed on a horizontal plane, values to be measured were decided as shown in *Fig. 8*. All pieces of the pear were size *L* and grade A packed in a box after being sorted by a sorter. Therefore, sizes and grades were uniform, it was very interesting to examine how large the fluctuation would be.

First of all, out of the measurement parameters shown in *Fig. 8*, *St*, *lt*, Ss_1, ls_1, Ss_n, ls_n were measured automatically, and the measurement errors were examined. *Table 4* shows the results. In the measurements, each parameter was measured 20 times. The measurement error within was plus or minus 0.5% for the measuring area and within plus or minus 2% for the binary length. In the *Table 4*, however, for Ss_n and ls_n, the direction was changed

Table 4 Measuring errors of same pear

Parameter / Method	Measured value (bits)	Maximum value (max)	Minimum value (min)	Mean value (mean)	Maximum tolerance $\left(\frac{\text{max or min}}{\text{mean}}\right)$
St 1	5,172, 5,164, 5,149, 5,160, 5,164, 5,162, 5,164, 5,165, 5,163, 5,167, 5,169, 5,168, 5,160, 5,165, 5,173, 5,173, 5,168, 5,166, 5,163, 5,170	5,173	1,160	5,165.25	+0.15
lt	249, 247, 251, 248, 247, 247, 247, 249, 249, 247, 248, 247, 247, 248, 249, 249, 248, 247, 249, 249	251	247	248.1	+1.17
Ss_1	5,067, 5,067, 5,068, 5,070, 5,067, 5,068, 5,064, 5,068, 5,068, 5,068, 5,067, 5,067, 5,068, 5,067, 5,066, 5,064, 5,066, 5,068, 5,064, 5,066	5,068	5,064	5,066.9	−0.057
ls_1	246, 246, 244, 246, 246, 246, 246, 244, 246, 245, 244, 246, 246, 246, 246, 246, 244, 245, 245, 246	246	244	245.45	−0.59
Ss_n	5,100, 5,067, 5,063, 5,082, 5,099, 5,069, 5,092, 5,091, 5,101	5,101	5,063	5,084.9	−0.43
ls_n	246, 248, 249, 243, 246, 245, 242, 247, 248	249	242	246	−1.63

every 20 ° at the side in nine times, which indicates this fruit is slightly warped.

2. Relationship between arithmetic parameter and amount of sugar

Using the measured values shown in *Fig. 8*, the following arithmetic data were obtained:

1) Parameters in one dimension
   - Mean fruit height: $H = (Hl_1 + Hr_1)/2$
   - Unbalance in fruit height: $\Delta H = | Hl_1 - Hr_1 |$
   - Mean fruit diameter: $R = (xt + yt)/2$
   - Unbalance in fruit diameter: $\Delta R = | xt - yt |$
   - Deviation of top hollow from the center: Δzt
   - Deviation of bottom hollow from the center: Δzb
   - Top hollow width: Wt/xt
   - Bottom hollow width: Wb/xt
   - Top hollow depth: Dt/H
   - Bottom hollow depth: Db/H
   - Rate of top hollow: Dt/Wt
   - Rate of bottom hollow: Db/Wb
   - Stem diameter: r
2) Parameters of two dimensions
   - Vertical section area: $S = (St + Sb)/2$
   - Cross section area: $Ss = (Ss_1 + Ss_2)/2$
   - Calculation area: $Se = \pi/4 \times xt \times yt$
   - Degree of oval 1: $\Delta S_1 = Sb - St$
   - Degree of oval 2: $\Delta S_2 = Ss_1 - Ss_2$
   - Degree of oval 3: $\Delta St = St - lt^2/4\pi$
3) Parameters of three dimensions
   - Cubic volume 1: $V_1 = xt \times yt \times H$
   - Cubic volume 2: $V_2 = 3/4 \times Ss \times R$
   - Weight: G

Out of these parameters, *Table 5* compares those which are assumed to be effective with amount of sugar of fruit based on the color data. This table indicates that the data have no remarkable characteristics. This happens because size *L* and grade A pears selected by hand were checked. In addition, they grew in the year of cool summer, resulted in an insufficient amount of sugar, and the satisfactory as long as mutual relationship could be obtained for the amount of sugar and external dimensions.

In the *Table 5*, typical data are Δzt (deviation of top from the center), ΔH (depth of top and bottom hollows), Wb/xt (bottom width), Dt/H. Db/H (depth of top and bottom hollows), r (stem diameter) and a (saturation). It has been found that out of these parameters, the top depth and saturation parameters can be used practically in the actual measurements.

3. Color camera data of Japanese pears

Fig. 9 shows over ripe and unripe bears selected from the above described samples, and *Table 6* shows measurements of values *L*, *a* and *b* for the samples. As it may be understood from this table, as long as appearances are concerned, external sizes of fruits can be unified by combining values *L* and *a* or *b*. Somehow, in this method, fruits are stored by their appearances and assumed to be tasty fruits based on the probability.

4. Selection of fruits considered packing

This idea is the same as the above described color camera data, but at a sorting system considered the appearance and then made packing work easy, a mutual relationship with the amount of sugar.

In other words, by packing deformed fruits in the same boxes, a system can be assembled as desired by the fruit sorring plants in response to oval fruits, or fruits which top is deviated from the center, etc. by each kind and picking timing. In this case, when relationship with the weight is examined in the ratio against the measuring area, the former is about plus or minus 0.8%, the latter is about plus or minus 2% per piece, and there is no problem. Actually, all pieces of pear were size *L* and grade A, and errors were ±17% in the weight, ±5% in the mean diameter ($(xt + yt)/2$), ±11.5% in the mean measuring area ($(St + Sb)/2$), and highest ±18% in the cubic volume conversion.

Table 5 Table of judge parameter and contain sugar

Mean amount of sugar of fruit (%)	Number of pieces of fruit	Difference of amount of sugar $kl - kr$	Parameters of one dimensions							Parameters of two dimension			Parameters of three dimensions		Parameters of color	
			ΔZt	ΔZb	ΔH	Wb/xt	Dt/H	Db/H	r	S	ΔS_2	ΔSt	V_1	G	L	a
11.85 ~ 10.5	14	−0.06	8.10	13.11	4.8	0.42	0.11	0.14	2.69	4,731	95.5	246	449,267	266	11.1	8.74
10.45 ~ 10.0	21	−0.12	6.86	8.32	3.67	0.41	0.09	0.14	2.97	4,891	120.2	250	474,602	277	11.24	8.56
9.95 ~ 9.5	38	−0.00	5.29	8.77	3.71	0.41	0.09	0.14	3.83	4,840	83.6	239	467,368	275	11.25	8.36
9.45 ~ 9.0	46	−0.02	5.51	5.18	3.41	0.40	0.09	0.14	4.79	5,093	90.9	258	494,032	293	11.64	8.08
8.95 ~ 8.5	31	0.07	4.63	8.22	3.52	0.39	0.08	0.12	4.67	4,972	105.2	268	489,961	286	11.27	7.07
8.45 ~ 8.1	9	0.39	4.20	8.18	3.66	0.38	0.08	0.11	4.24	4,806	102.1	249	465,001	273	9.64	6.33
Average 9.597	Total 159	Average 0.04	Average 5.77	Average 8.63	Average 3.80	Average 0.40	Average 0.09	Average 0.13	Average 3.87	Average 4,889	Average 99.6	Average 252	Average 473,372	Average 278	Average 11.02	Average 7.86

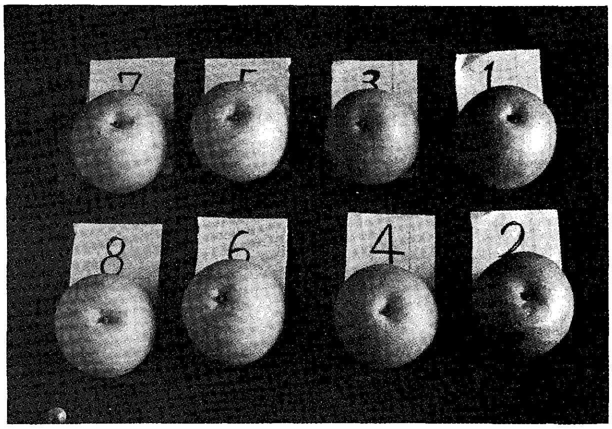

Fig. 9 Photograph of pears

Table 6 Data of Japanese pears by color camera

Value Sample No.	*L* (Darkness)	*a* (Color)	*b* (Color)	Remarks
1	11	7	11	Unripe fruits
2	11	5	11	
3	10	7	11	Ripe fruits
4	11	6	12	
5	13	8	14	
6	13	8	14	
7	13	10	14	Over ripe fruits
8	13	10	13	

V. CONCLUSION

Many more years and months will be required in succeeding the realization of an automatic sorter by sizes and grades which can be used commonly for various different kinds of fruits. However, this equipment will provide many advantages when the fruits to which the equipment is used are limited and practical idea is led into the sorting method. This equipment increases market prices, improves man saving effects, durability and stabilization of performance and has many other features. In Japan, fruit sorting plants are tending to be larger scales and many more different kinds of fruits are becoming to be sorted by their sizes and grades, requiring faster fruit sortings.

The system introduced in this paper is the most advanced digital data processing technique using micro computer, and at a medium size fruit sorting plant, it is planned to reduce number of workers from 120 to 70.

Beside the fair and correct fruit sorting, the largest problem for fruit sorting systems is the development of a machine which never damage fruits. When such a machine is developed, it will no longer be a dream to sort fruits under such a high speed as 50,000 pieces per hour on single line. This means the performance is five times as great as the conventional system, and it will be a powerful weapon for improvement of productivity in fruit sorting work. This system will also be applied as an fruit evaluator. This will collect two dimensional data of fruits from multiple number of directions and grade them more correctly.

VI. POST SCRIPT

New technique of automatic fruit sorting and present problems in manual fruit sorting were described. The authors hope this paper will assist improvements of technologies in this field and productivity at the level of farmers. We expect the users will continue to provide us with valuable guidance and advice so that we will be able to place better products in the world.

Closing this paper, we express our deepest appreciations to the members of Tottori Prefectural Fruit Farming Union and Tottori Prefectural Government Fruit Test Laboratory.