AN ON-LINE OPTICAL SENSOR FOR SIZING PEACHES, APRICOTS, KIWIFRUITS AND TOMATOES RANDOMLY ORIENTED

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INTRODUCTION

Size is one of the main fruit quality parameters. The customer preference internationally is for products that are sorted into sizes (Studman, 2001); the consumer subconsciously feels that if someone went to the trouble of uniformly sizing the produce, it must be of high quality (Peleg, 1985).

The Marketing Standards for Fresh Fruit and Vegetables state that size is determined by the maximum diameter of the equatorial section or by the unit weight, depending on the product.

Most modern sizers at fruit packinghouses use either machine vision, electronic weighing or both systems combined in the same machine.
With the machine vision systems the product is classified according to its dimensional size, colour and sometimes external defects. The latter issue has a limited success, depending on the fruit and type of blemish [*].

Focussing in size, it is convenient to remark that machine vision equipment sometimes perform sorting errors. Even though size was one of the first parameters estimated automatically, there are still unsolved problems that can cause wrong estimations, mainly due to an excess of fruit in the sorter input (Aleixos et al., 2002).

If we have to size e.g. grapefruit, wherein misshapen fruits ("sheepnosed") often are present, many machine vision sizers will not classify them correctly. The reason is that *a priori*, taking into account the typical shape of this product, the user will configure the program to classify them according to their major axis, which corresponds to the equatorial in the case of grapefruits, but when a 'sheepnosed' fruit passes, the major axis will be the polar instead of the equatorial, and thus the sorting will fail. A way of overcoming this drawback would be the development of algorithms capable of recognizing the stem-calyx axis of the grapefruits.

Because of the foregoing considerations it was considered interesting to keep on studying alternative low-cost systems for the fruit and vegetable sizing operation. One of them is the Optical Ring, matter of this report. We can mention some devices, somehow predecessors of the optical ring, since they are based on the same principle: duration of the light blocking, double pairs of transducers according to size ranges (Iwamoto and Chuma, 1981) and array phototransistors (Fon et al., 1990; Chen et al., 1992).

(*) Apart from this, which can be defined as external quality, in the last few years new spectrophotometry-based equipments are appearing for on-line inspection of internal quality

OBJECTIVES

The objectives of this research were: (a) to assess the sizing performance of an optical ring sensor on different fruits and vegetables, and (b) to compare it with commercial machine vision equipment.

MATERIALS AND METHODS

The optical ring relies upon the shadow principle, i.e. blocking of beams of light.
It consists of a circular frame which has arranged on it a large number of optical transducers -emitters and receivers- of infrared light, being the transmitters sequentially switched. The emitters and receivers are alternately arranged, as shown in fig. 1.

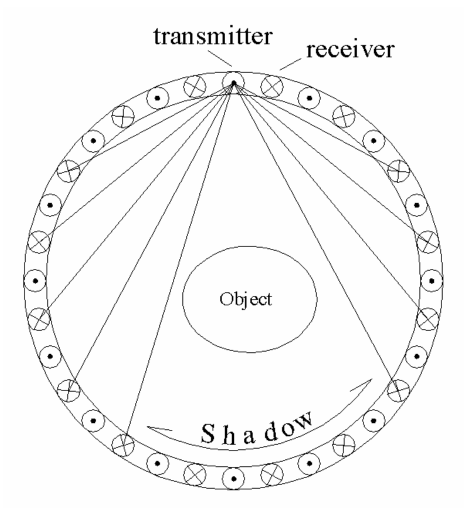

Fig. 1. Ring sensor's principle of working.

The fruits to be sized must pass through the ring one by one, as depicted in fig. 2.

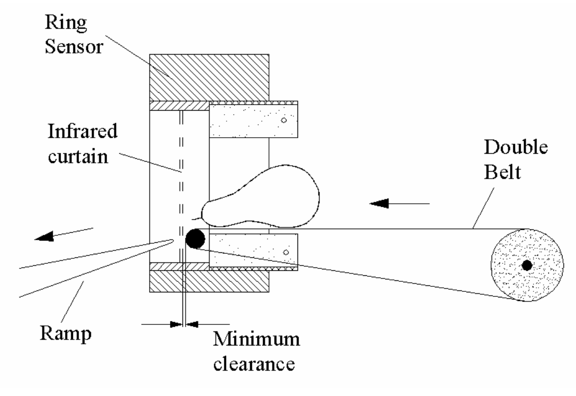

Fig. 2. Simplified scheme of the ring sensor system studied.

All the transmitters and receivers have a Lambertian angular response, so that in a given instant, if no object is inside the ring, every receiver detects light from the activated transmitter. When an object is introduced, a shadow zone is generated; the details of the algorithms employed in the optical ring sensor are described in Gall (1997) and Gall et al. (1998).

The system studied is basically made up of an optical ring with an inside diameter of 180 mm, fed by a two-metre length singulator. The sensor features 128 optical transducers, distributed into 64 transmitters and 64 receivers. The scanning rate is of 400 cross sections[*] per second. The main parameters estimated for each object measured are: volume, length and maximum diameter of the largest cross section.

Concerning to the methodology used in this study, two comparison tests between the optical ring and a commercial machine vision equipment were conducted. The commodities utilized in those trials were peaches and apricots. The computer vision system featured a CCD color camera, acquiring four images per fruit.

In another direction two trials were conducted, one with kiwifruit and the other with tomato, with the objective of evaluating the optical ring's performance under different operating conditions.

Throughout the four tests, the actual or reference maximum diameter was gauged with a vernier caliper, whereas the actual volume was obtained from hydrostatic scales.

<u>Trials for comparing the sizing performance of the optical ring and the vision system</u>

<u>Design of the Peach test</u>

The number of fruits was 30 peaches 'fresquilla', pertaining to one commercial size. The working speed was a design factor, with two levels tested: 0.6 m/s and 1 m/s, for both optical ring and camera system. The orientation was random throughout the test. The runs were replicated 10 times for each speed and device.

<u>Design of the Apricot test</u>

The number of fruits was 30 apricots (Currot), belonging to a pair of commercial sizes. The rest of parameters were the same than in the peach trial.

<u>Trials for evaluating the sizing performance of the optical ring on kiwifruit and tomato</u>

<u>Design of the kiwifruit test</u>

The number of fruits was 50 kiwis (Hayward), pertaining to a couple of commercial sizes. Two different orientations were tested: lengthwise or supervised and random or unsupervised. Besides, two speed levels (1 m/s and 1.4 m/s) were operated. No replications were performed in this trial.

<u>Design of the tomato test</u>

The number of fruits was 50, belonging to a traditional variety, that is to say not e.g. oblong nor 'cherry' tomatoes. The mean maximum diameter was 84.2 mm, and the range was 74 to 100 mm.

The operating speed was fix (1 m/s), while two orientations, calyx-upwards or assumed orientation and random orientation, were tested. Every fruit was run through the ring

(*) strictly they are not real cross sections, but "wires" of a helicoid, due to the motion of the fruit during a whole transmitter's switching sequence just once, for regression analysis. Additionally, 15 tomatoes (five small, five medium and five large) were chosen among the 50 for repeatability assessment; in this case the number of replications was 10, and the orientation was random.

RESULTS AND DISCUSSION

It is convenient to recall at this point an important concept: the difference between accuracy and precision. Accuracy refers to the difference between the estimated value and the actual or reference one, whereas precision[*] accounts for the repeatability of a series of estimated values.

Trials for comparing the sizing performance of the optical ring and the vision system

The analysed parameter was the repeatability of the two equipments (table 1). The reason for having studied precision is that it is often more important than accuracy, since the latter can be easily modified by calibrating the measurement instrument; in spite of this, from a practical point of view, the accuracy is a major issue.

	Speed (m/s)	Ring sensor CV (%)	Machine Vision CV (%)
Peach	0.6	1.84	5.5
	1	2.08	5.82
Apricot	0.6	2.33	2.20
	1	2.43	2.54

Table 1. Precision at maximum diameter estimations for the comparative tests between the optical ring and the machine vision system, expressed as Coefficient of Variation.

It is deduced from the table above that for apricot the performance of both systems is similar, whereas on peach the optical ring is more precise.

In the case of the computer vision apparatus, the smaller precision on peach compared with apricot has two probable reasons: (a) the greater shape irregularity of peaches, which makes their rolling motion beneath the camera less stable, and (b) the presence of the blush cheek, which hinders its inspection by a color camera as the one utilized.

Trials for evaluating the sizing performance of the optical ring on kiwifruit and tomato

The estimations of volume and maximum diameter were regressed against their respective actual (reference) values.

Results of the kiwifruit test

In what concerns to the volume estimations on kiwifruit, within the speed of 1m/s, the coefficient of determination for lengthwise oriented fruit was r^2 = 0.96 (fig. 3) whereas it was r^2 = 0.67 for random feeding (fig. 4). Their corresponding standard errors were 2.87 cm^3 and 9.82 cm^3. For the unsupervised orientation, the result was worse than expected [**]; the reason is the relative movement of the fruits on the singulator when crossing the ring. It can be forecasted that with a longer singulator the results would have been better, since the fruits would have had enough time for fully stabilizing.

In regard to maximum diameter at speed of 1 m/s, the results are shown in fig. 5 for assumed orientation and fig. 6 for unsupervised. It is evident that for the latter orientation there is no correlation at all, whereas under supervised feeding conditions

(*) commonly known as consistency

(**) because of the kiwifruit convexity, theoretically the direction of presentation should not affect the accuracy the results are quite good (r^2=0.87 and standard error of 0.87 mm).

Results of the Tomato test

Concerning to volume estimations on tomato, the regression for supervised orientation (fig. 7) yielded a r^2 higher than for random orientation (fig. 8). This fact, analogously to what happens in kiwifruit, is related to the lack of stability under the unsupervised feeding.

In the case of maximum diameter, the results were somehow unexpected, since they are better for random orientation (fig. 9) than for supervised (fig. 10).

The statistical analysis of the repeatability test, delivered coefficients of variation (CV) of 2.13 % for maximum diameter and 6.12 % for volume.

Observe that for random orientation the volume correlation (r^2 = 0.86) is greater than the maximum diameter correlation (r^2 = 0.80).

Tomatoes' size is determined by the maximum diameter of the equatorial section (EC marketing standards for tomatoes). Sargent et al. (1988) found that volume did not correlate sufficiently with maximum diameter (r^2 =0.88) to meet size standards, due to the irregular shape of the tomatoes. In our research, the coefficient of determination for the linear regression between the reference maximum diameter and the reference volume is r^2=0.87. Hence the same idea could be concluded, as European standard for tomato is even stricter[*] than the case studied by those authors.

CONCLUSIONS

- The comparison between the optical ring and the machine vision equipment delivered more consistent results from the ring sensor on peaches and similar for both systems on apricots.

- Kiwifruit: The results are always better with assumed lengthwise orientation, both for diameter and volume estimations, although at volume the difference is not so significative. In fact, theoretically the orientation should not affect the volume estimations of predominantly convex objects such as kiwifruit, although in the practice it does due to the lack of stability of the fruits under the random orientation.

- Concerning tomato, the diameter correlation is a little higher for random orientation than for assumed orientation. This is a desirable feature, since it would circumvent the need to pre-orient the fruits, at least for the shape of tomatoes tested.

ACKNOWLEDGMENTS

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[3] Commission Regulation (EC) No 790/2000 of 14 April 2000 laying down the marketing standards for tomatoes.

(*) there is no overlap between sizes

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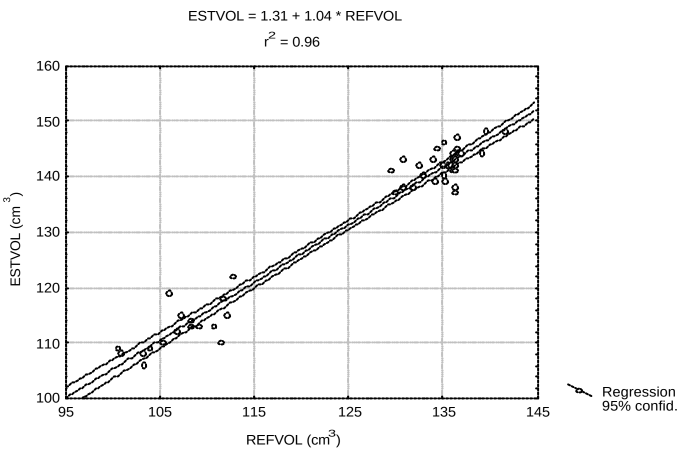

Fig. 3. Relationship of Estimated Volume to Reference Volume for lengthwise oriented kiwifruit and speed of 1m/s.

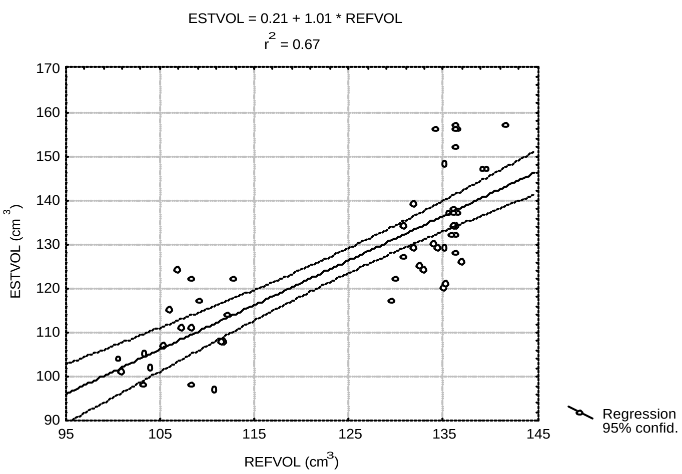

Fig. 4. Relationship of Estimated Volume to Reference Volume for randomly oriented kiwifruit and speed of 1m/s.

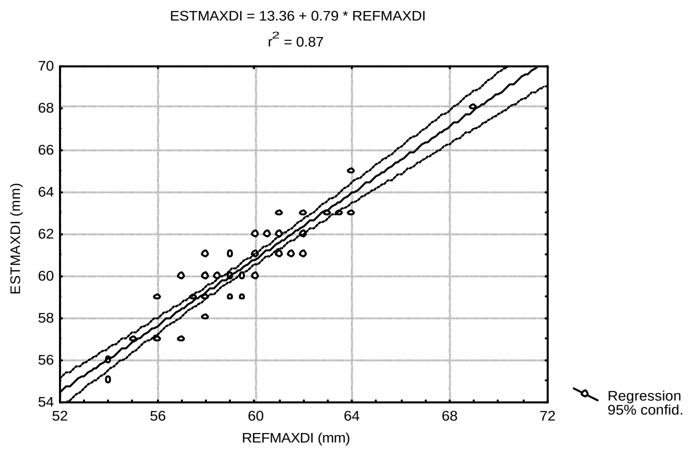

Fig. 5. Relationship of Estimated Maximum Diameter to Reference Maximum Diameter for lengthwise oriented kiwifruit and speed of 1m/s.

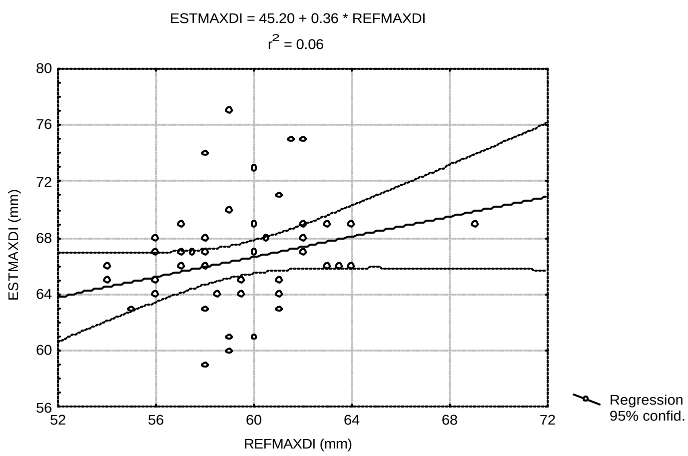

Fig. 6. Relationship of Estimated Maximum Diameter to Reference Maximum Diameter for randomly oriented kiwifruit and speed of 1m/s.

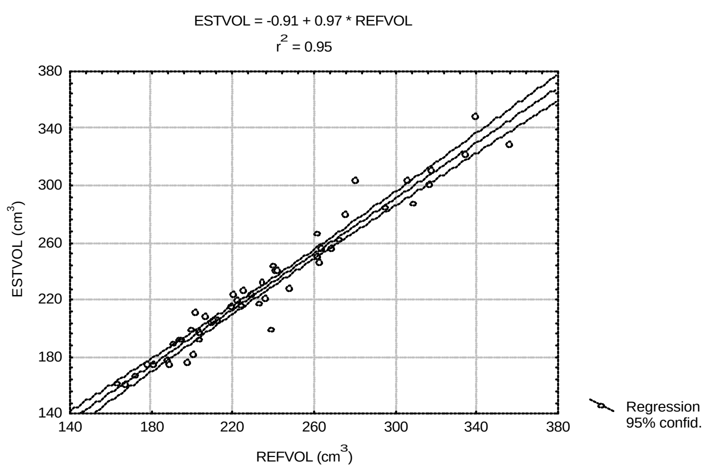

Fig. 7. Relationship of Estimated Volume to Reference Volume for calyx-upwards oriented tomato.

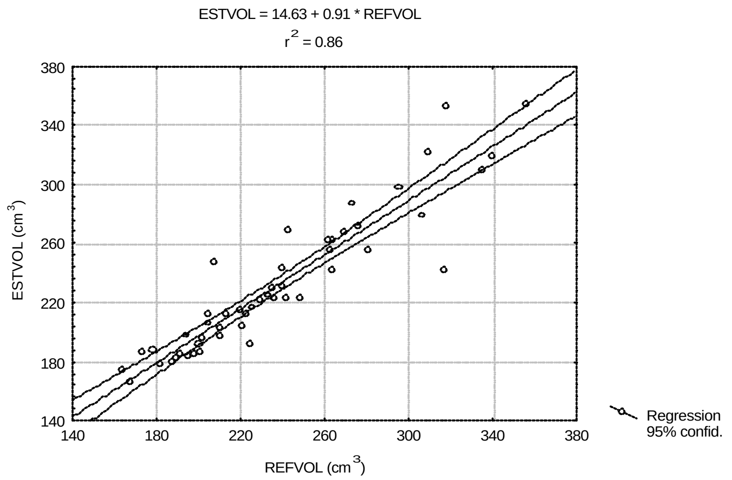

Fig. 8. Relationship of Estimated Volume to Reference Volume for randomly oriented tomato.

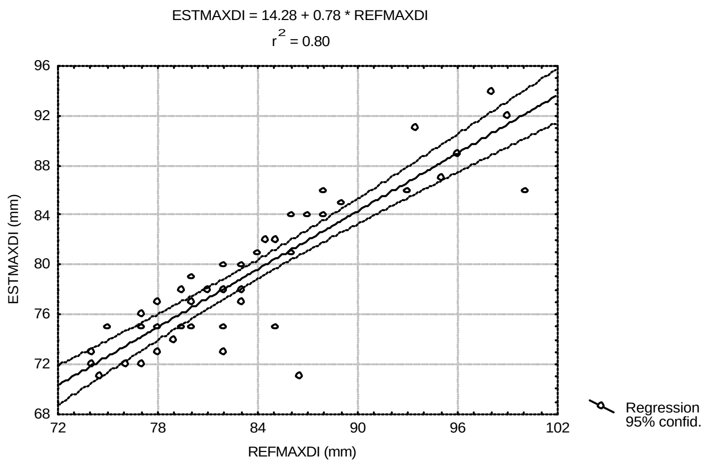

Fig. 9. Relationship of Estimated Maximum Diameter to Reference Maximum Diameter for randomly oriented tomato.

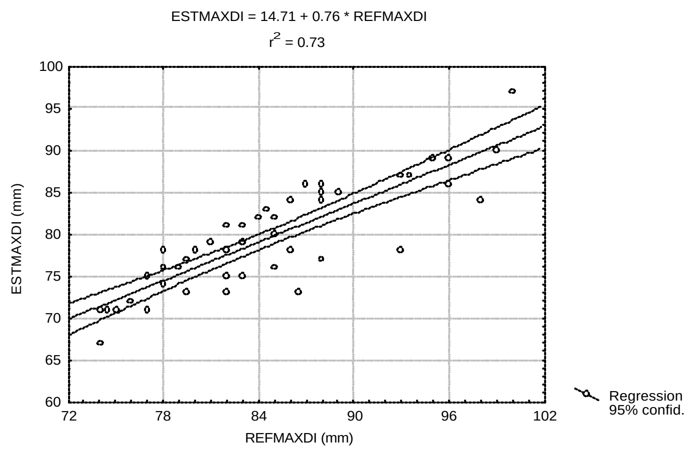

Fig. 10. Relationship of Estimated Maximum Diameter to Reference Maximum Diameter for calyx-upwards oriented tomato.

ENGINEERING THE FUTURE

Session 26

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234	G. Moreda	*An on-line optical sensor for sizing peaches, apricots, kiwifruits and tomatoes randomly oriented*	G. Moreda, J. Ortiz-Cañavate, and M. Ruiz-Altisent, Universidad Politécnica de Madrid, LPF. Dpto. Ingeniería Rural, Madrid, ES J. García-Ramos, Universidad de Zaragoza, Escuela Polit. Sup. de Huesca, Zaragoza, SE I. Homer, Universidad de Chile, Dpto. Ingeniería y Suelos, CL
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