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# Design of a computational application for the evaluation of the quality of export lemon

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**Abstract**

The automation of food processes increases the quality, productivity, and economy of the companies. This study aimed at the development of a Computer Vision System (CVS) to classify lemons in real-time according to their diameter. The CVS consisted of a software, coded in Java programming language, which covers the acquisition, pre-processing, segmentation, description, recognition, and interpretation of the images. The classification criteria were in accord with the CODEX STAN 213 standard for lime-lemon. The CVS reached a 0% error in the classification of the diameter of the lemons and required 0.33 seconds as processing time to detect and classify each lemon. The CVS showed high performance in the automatic classification of lemons according to their diameter. This CVS could avoid the disadvantages of manual classification.

**Palabras clave:** Artificial vision; *Citrus aurantifolia*; image analysis; Java language; digital image processing.

## 1. Introduction

Classification is an important operation in the modern food industry, hence, when done wrong, can lead to considerable economic losses. The classification is susceptible to errors when it is performed manually since human vision makes it a subjective, inconsistent, and slow operation (Zhang et al., 2014; Salazar-Campos et al., 2019). In this context, contact-free technologies are used successfully in food industries to control processes, measure quality and classify products, which generates improvements in performance and economic income in small as well as large companies (Magwaza et al., 2012; Siche et al., 2016; Aredo et al., 2019). Computer Vision System (CVS) is a contact-free, practical and easy-to-implement technology used in food industry for the simultaneous and real-time evaluation of different quality parameters with efficiency, precision and speed (Du and Sun, 2006; Cubero et al., 2016; Hadimani and Mittal, 2019). he development of CVS involves statistical or heuristic data processing techniques, which are implemented in interactive programming languages facilitating the management and deployment of their functionalities (Narsaiah and Jha, 2012; Borji, 2018; Pira et al., 2018). Among which, Java has a wide use in the development of different applications because it is a free and multi-platform environment (Wang et al., 2019).

Lemon is one of the most commercially important citrus fruits in the world. Mexico, Turkey, South Africa, Argentina, and the United States are the main exporting countries (Tasteatlas, 2020). However, the classification of lemon by CVS was little studied (Rauf et al., 2019). Taking into account that the diameter is a fundamental parameter of quality of this fruit, the aim of the present work was the development of a CVS programmed in Java for the classification of lemons based on diameter.

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## 2. Material and methods

### 2.1. Samples

A total of 385 lemons (*Citrus aurantifolia*) from Olmos-Lambayeque (Peru) were used in this study. The number of samples was defined considering a random sampling for infinite populations (Salazar-Campos et al., 2019). Prior to classification by the CVS, the samples were washed with water, dried and stored in polyethylene bags. The measurement of the actual size of the lemons was carried out using a digital caliper (150 mm, Mitutoyo Co, Kanagawa, Japan). An actual caliber was assigned to each lemon using the actual size and the CODEX STAN 213 (Standard for Lime-Lemon) (FAO, 2005).

### 2.2. Image Capture System

The hardware architecture for the acquisition of images (Figure 1) consisted of a matte white box (length of 20 cm, height of 40 cm and width of 30 cm), a LED lighting lamp (4500K, 18W, 41cm, Philips Lighting Co, Somerset, NJ, USA), a digital camera (D-LUX 6 Edition 100: depth of 8 bits, spatial resolution of 2.4 megapixels - 2048 x 1152, Leica, Wetzlar, Germany) to capture images in "jpg" format, a computer (UX360UA laptop: 13.3", Intel Core i5, Asus, Taipei, Taiwan) for image analysis. The samples were placed 40 cm away in a vertical direction to the lamp and 40 cm away in a horizontal direction to the camera.

### 2.3. Development of the CVS

The software was developed in Java and included the following stages: image capture, preprocessing, segmentation, description, recognition and interpretation (Figures 2 and 3). The preprocessing consisted of: (1) the application of the contrast enhancement technique using equalization of histograms, (2) the transformation of the RGB color system to HSV channels in order to obtain a cleaner image, and (3) the use of Gaussian filters to eliminate noise. The segmentation of the region of interest (circular region of the lemon) of the background was carried out by binarization. The description of the region of interest was made using color and diameter descriptors. The recognition and interpretation included the determination of the size from the region of interest and its comparison with the calibers of the CODEX STAN 213 (Standard for Lime-Lemon) (FAO, 2005). It is worth mentioning that the CVS was also designed to measure the color of the fruit for an eventual maturity classification. However, in the sampling, all the lemons presented a characteristic green color within the recommended range. Therefore, this work focused on studying the size classification as a frequent need of the fresh lemon industry.

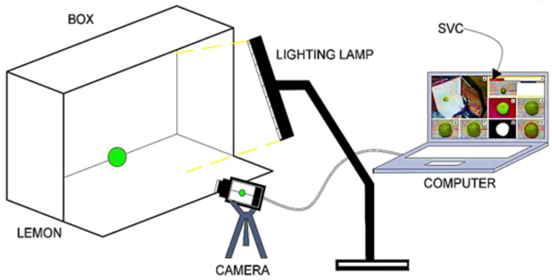


**Figure 1.** Methodology of capture of images of lemon fruits.

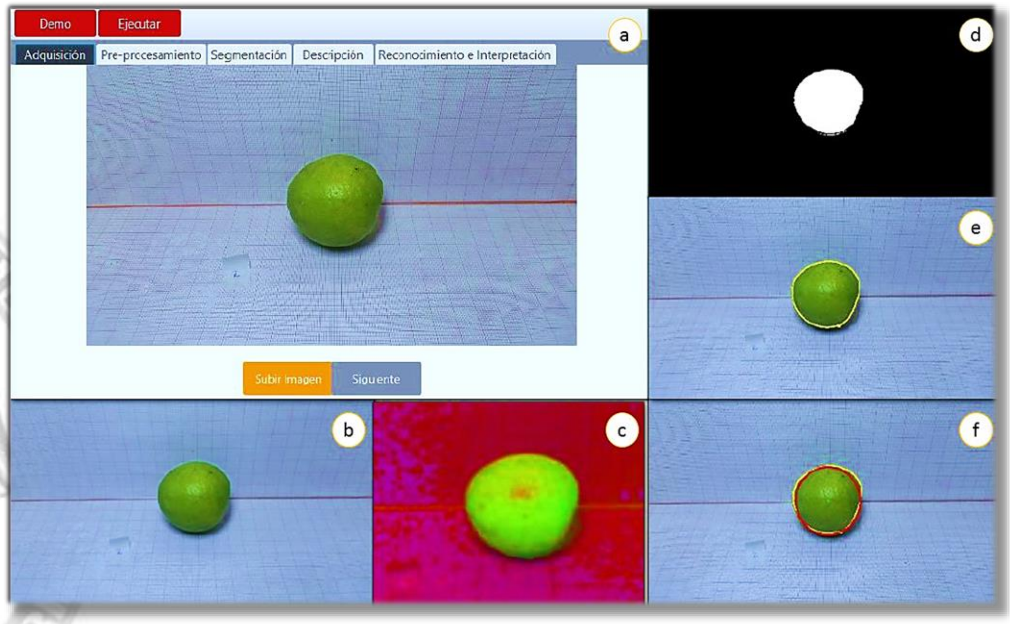


**Figure 2.** Processing of images to classify the fruit of the lemon: a) graphic interface of the image capture in CVS, b and c) pre-processing, d) segmentation, e) description, f) Recognition and interpretation.

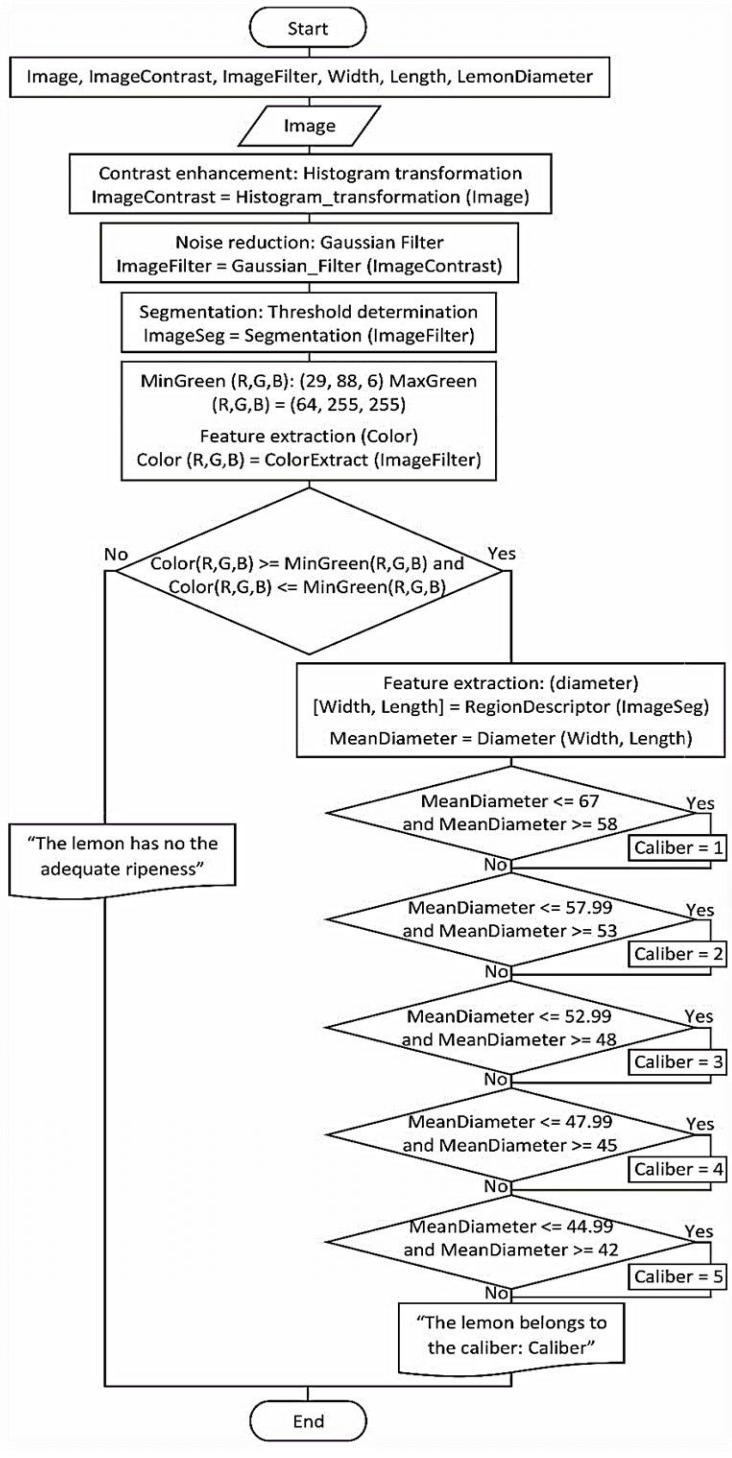


**Figure 3.** Algorithm of the CVS for classifying lemon fruit

## 2.4. Evaluation of CVS performance

The performance of the CVS was evaluated using the unit time (s) and the classification error (%). The unit time (s) is the time required for the CVS to analyze the image of a lemon, it was calculated by dividing the total operating time of the system over the total number of samples. The classification error (%) included the underestimation and overestimation error, it is the percentage of the samples to which the CVS assigned a lower or higher caliber than the actual caliber, respectively.

The linear relationship between the actual size of the samples and the size measured by the CVS was studied using the equation: size measured by the CVS (cm) = slope * actual size (cm) + intercept (cm). In which, it is desirable that the coefficient of determination ($R^2$) is similar to 1, the slope similar to 1, and the intercept similar to 0.

The distributions of the actual size and measured size by the CVS were analyzed. The cumulative distributions of the size were adjusted to the Rosin-Rammler function. This function describes cumulative distributions using two parameters: the "$X_R$", which is the 63.21% percentile and the "n", which is the narrowness of the distribution (Yan and Barbosa-Cánovas, 1997). Finally, distribution descriptors as the 10th percentile (D10), 50th percentile (D50) and 90th percentile (D90) were estimated.

## 3. Results and discussion

The CVS required 0.33 seconds to classify the caliber of each lemon. With the CVS, 79% of the samples were classified correctly. The 21% of classification error consisted of an under-estimation error of 4.1% and an overestimation error of 16.9%.

A high linear correlation ($R^2$ = 0.9549) was observed between the actual size and the size measured by the CVS. This resulted in the following expression: size measured by the CVS (cm) = 0.9771 * actual size (cm) + 0.2259 cm. The regression constants were used to adjust the size measured by the CVS as follows: size measured by the adjusted CVS (cm) = (size measured by the CVS (cm) - 2.2589 cm) / 0.9771. This adjustment caused the correct classification of all the samples without any type of error.

The size distribution of the samples (Figure 4) was successfully explained by the Rosin-Rammler function, yielding coefficient of determination values greater than 0.9975 (Table 1). The analysis of Rosin-Rammler parameters (n and $X_R$) and the estimated descriptors (D10, D50 and D90) evidenced that the actual size distribution of the samples presented a lower narrowness (n) and distribution values ($X_R$, D10, D50 and D90) slightly lower than that obtained by CVS. Nevertheless, the actual size distribution was very similar to that obtained by adjusted CVS. These results explain the high error of overestimation of the sample size when the CVS is not adjusted.

**Table 1**
Analysis of the distribution of the real lemon size and measured by CVS

| | n | $X_R$ (cm) | $R^2$ | D10 (cm) | D50 (cm) | D90 (cm) |
|---|---|---|---|---|---|---|
| Real | 15.40 | 5.0 | 0.9978 | 4.4 | 4.9 | 5.3 |
| CVS | 17.51 | 5.1 | 0.9976 | 4.5 | 5.0 | 5.4 |
| CVS adj. | 14.81 | 5.0 | 0.9980 | 4.3 | 4.9 | 5.3 |

The CVS classified each lemon in 0.33 seconds, which could be considered advantageous because manual classification is too time-consuming and mechanical classification, despite being as fast as a CVS, is not as accurate as a CVS. Other advantage is that this CVS could be modified to assess surface defects of the lemons, allowing a complete evaluation of this fruit.

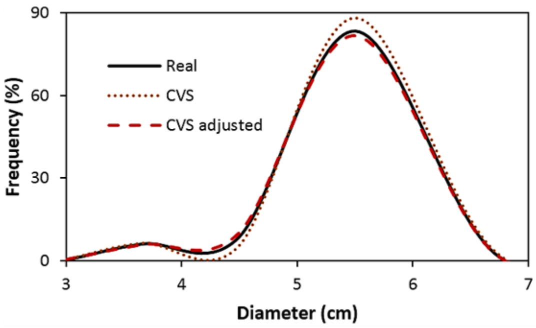


**Figure 4.** Distribution of the diameter values of the lemons obtained by manual measurement and CVS.

This CVS carried out the lemon size measurement and then the classification (Figure 3). The CVS was able to measure the lemon size with a high correlation with the actual size ($R^2$ = 0.9549) and after adjusting the CVS, the size distribution was very similar to the actual size (Figure 4, Table 1). This demonstrated that a simple step in CVS design, such as size adjusting, can improve the performance achieved. Even though size measurement with high precision does not have a practical application in the fresh lemon industry, it was necessary to achieve the perfect classification of the lemons (0% classification error) by this CVS.

## 4. Conclusions

A CVS was developed for the classification of lemon according to the size specified in CODEX STAN 213. The CVS achieved a classification error of 0% and required 0.33 seconds to classify each lemon, making the system an efficient and reliable option for the. of fresh lemon industry. This CVS can be adapted to classify different agricultural products in a unitary way due to the flexibility of its stages and the features of the Java programming language.

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