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A practical framework for automatic food products classification using computer vision and inductive characterization

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ABSTRACT

With the increasingly international regulatory demands for food products import and export, as well as with the increased awareness and sophistication of consumers, the food industry needs accurate, fast and efficient quality inspection means. Each producer seeks to ensure that their products satisfy all consumer's expectations and that the appropriate quality level of each product is offered and sold to each different socio-economic consumer group. This paper presents a framework that uses computer vision and inductive characterization with a reduced set of features, along with three cases where this framework has been successfully applied to improve the quality inspection process. Three different basic food products are studied: Hass Avocado, Manila Mango and Corn Tortillas. These products are very important in economical terms for the sheer volume of their production and marketing. Each product has particular characteristics that involve different ways of handling the quality inspection process, but this framework allows addressing common key points that allow automatizing this process. Experimental results of each case shows that the proposed technique is competitive with existing systems and has significantly lower costs in terms of the number of features required for classification.

1. Introduction

Nowadays, assessing the quality of food products involves mostly using physical methods. These methods can be nondestructive (produce compression, tactile testing) and destructives (*v. gr.* penetrometers); however, even traditional nondestructive methods may represent a quality dropping, because the produce is usually delicate and can be easily damaged [28]. For these reasons, newer noninvasive techniques have been proposed. Noninvasive methods such as acoustic, spectroscopic and digital image analysis, including multi- and hyper-spectral imaging techniques, have been widely applied to evaluate the food quality. However, acoustic and spectroscopic methods (near-infrared, nuclear magnetic resonance and magnetic resonance imaging) could be relatively expensive and laborious, and a large number of samples, as well as a large laboratory area, could be required; therefore, an interesting alternative to study the superficial features in produces is the computer vision systems that have been developed in the food sector. Physical characteristics, such as size, shape, morphology, color and texture properties can be measured using image processing [17,33].

Computer vision systems allow food quality evaluation by maintaining accuracy and consistency while eliminating the subjectivity of manual inspections. Image analysis has more advantages than other noninvasive techniques such as being cheap and easy to adapt to obtain online measurements. In addition, it allows achieving high accuracy and a good correlation with visual human inspection. In general, its versatility allows obtaining a widespread number of features from a simple digital image [6]. A comparative introduction, latest developments and applications of computer vision systems in the external quality inspection of fruits and vegetables are presented in [39]. They emphasize that the outer appearance of fruits and vegetables affects their point-of-sale value and consumer's buying behavior, thus causing great economic losses. In this comprehensive study, only mango is mentioned.

In the literature, there are only a few ideas in the establishment of a general framework for automatic classification of food products. In [35], where the hardware and software parts are explained separately; however the software steps are only established for volume measurement. A more general scheme is introduced in [7]; nevertheless a general set of features and an unique classifier for a diverse kinds of food products are missing. In other hand, a thorough survey about the use of machine vision system

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for the quality inspection of food and agricultural products is shown in [30].

Moreda et al. [23] present a review of some two-dimensional computer vision methods applied throughout the past 25 years for determining the shape of horticultural produces. The authors mentioned that the boundary signature is used to determine malformation or misshapenness. They present examples to show that is possible to detect two shape abnormalities in avocado or establish a maturity index for the Mango.

Careful image feature selection plays an important role for a successful classification. A common set of features to analyze food products is shown in Vanloot et al. [38], while some works as [18] extract as much as 2300 features to finally use only a few, 64. Zhang et al. [40] present a fruit classification of 18 different food products (Hass avocado included) with an overall classification accuracy of 89.1%. In order to achieve this result, they originally used 79 features that were in turn reduced via PCA to only 14 features; however the authors do not mention which these 14 items are; additionally, great amounts of preprocessing were necessary, including the use of the split-and merge algorithm used to remove the background of the images. Using a great amount of features represents a system overload and hinders automatic classification systems for real time applications, where very fast classification is needed due to the sheer volume of production. In this work we aim to find a reduced, but suitable set of features that allow automatic classification of different products, establishing a framework as simple as possible, while effective.

For demonstration purposes, we present the feature extraction on three different food products:

i. *Tortilla* is a fundamental element in the diet of Mexican people. Since ancient times, tortillas have been hand-made, but as a result of the increasing demand of this product, even from other countries, there has been an increase in the necessity to update production methods and mass-produce tortillas. Thus, their quality must be assessed to comply with industrial production standards as well as import/export regulations (NOM-187-SSA1/SCFI-2002, 2002); however, there is an absence of standards and guides to evaluate the sensory impression of consumers, *i.e.*, color, shape, spots, etc., or some other kind of imperfections resulting from their elaboration process.

   It has been shown [13,18] that sensory characteristics are of great importance for consumers, however, for small and mid-size producers currently there is no system for quality control that can guarantee a high level of sensory quality; tortillas are evaluated manually so that the quality of the tortilla is not uniform.

ii. *Avocado* is a tree that belongs to the Lauracea family and to the Persea genus, where the best-known member is variety Hass (*Persea americana Mill.*) According to experts, there are about 500 varieties of avocados; however, only three strains are considered appropriate for commercial production: Mexican, Guatemalan and West Indian [1]. The Hass avocado fruit is part of the Guatemalan strain, and it is the most widely harvested and consumed around the world as a result of its good production yields, resistance to handling and transportation, the excellent quality of its pulp, its pleasant texture and its great taste [27].

   Avocado is a high metabolic fruit and completes its ripeness within 12 days at 15 °C after harvesting [5]. In [29] the authors comment that avocado maturity and picking time are determined according to external markers (color and size). However, [16] reported that determining the commercial maturity of the avocado is difficult because the start of ripening is not accompanied by visible external changes. These situations made the task of classification very challenging, indicating that an automatic sorting system would be very useful.

iii. The *mango* (*Manguifera Indica L.*) is one of the more important crops with a high demand in the market both national and international; this is mainly derived from the consumption in fresh, as well as its use of industrial processes for juice production, nectars and jams.

Mango fruit has high nutritional values, nice flavor, taste, etc. and hence is known as *king of fruits*. However, it faces a number of challenges such as the attack of microorganisms, having short shelf life, mismanagement during transportation and storage [3]. In [36], the authors indicated different postharvest damages due to harvesting fruit at improper maturity, mechanical damage during supply chain, sap burn, spongy tissue, lenticels discolouration, fruit softening, decay, chilling injury and disease and pest damage. The automatic detection of these damages via a machine vision system would help the producers to improve their postharvest treatment reducing its economic losses.

The remainder of the article is organized as follows: in Section 2 our proposed Framework is introduced, the difference between computer and machine vision is discussed. The designed features and a brief digital image analysis are explained in Section 3. The inductive characterization via the BOUNDSTAR algorithm is presented in Section 4. The results of applying our methodology to the previous mentioned food products are shown in Section 5, and finally we draw conclusions and future work in Section 6.

2. Proposed framework

In this section, based on [7], we present the proposed general methodology for non-destructive classification of diverse food products. Fig. 1 shows a simplified block diagram of the framework; it includes systems and sub-systems for different processes. The big rectangles represent the subsystems while the small ones indicate gathering information. Blocks 1–6 show the typical components of a computer vision system, and block 7 represents a machine vision system. Blocks 1–4 are very common steps and have been described in [7,9]. Block 5 will be explained in the next chapter of this paper. Section 4 refers to block 6 the inductive characterization and is where the main contribution of this paper is presented. Additionally, an example of a machine vision system (Block 7) will be shown in Section 5.3.

In [9] the differences between computer and machine vision are presented; namely, in Machine Vision design (in opposite to Computer Vision) a practical point of view pervades, *i.e.*, theoretical contribution is not required, cost is critical, a dedicated hardware for high-speed processing is desirable, designers are willing to use non-algorithmic solutions to solve problems. Additionally, *in situ* programming is possible, the most important criteria by which a vision system is judged is (a) ease to use, (b) cost-effectiveness, (c) consistent and reliable operation; free-standing operation is required, the nature of an acceptable solution is not an optimal performance—just a satisfactory performance, among others.

In the next two sections we will introduce three examples to illustrate the functionality of our framework presented in Fig. 1. The Tortilla and the Avocado are examples of computer vision systems and mango is an example of a machine vision system. For more details on block 7 please refer to [8].

3. Feature selection

In this section, we describe the feature selection of the selected food products: tortilla, avocado and mango for their latter