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Grape maturity estimation based on seed images and neural networks

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ABSTRACT

The grape phenolic maturity is one of the most important parameters to determine the optimal time for harvest. In this paper we propose an innovative methodology for the problem of how this task is performed today. In particular, the method consists in analyzing seed images using pattern recognition methodology, and classifying them in immature, mature and over mature states through a supervised learning neural network. The methodology presented gives objective information about maturity, which is useful for deciding the moment when the harvest should be performed.

1. Introduction

The wine market is very dynamic; therefore, it is relevant to develop applied research in this field in order to improve the level of competitiveness in a demanding market. To obtain a good quality wine, it is necessary to harvest the grapes at an optimal level of maturity. Traditionally, the maturity estimation is performed through chemical analysis in a laboratory, which entails a high cost. Moreover, it is possible to count on the judgment of an expert (oenologist), but this alternative has a high subjectivity degree and low representativity.

The resulting wine quality is related to the timing of the grape harvest. In particular, it is the Oenologist who must determine, by a quantitative or qualitative method, if grapes from a vineyard are at its harvest point. From a technical point of view the time of harvest is estimated by studying the degree of Phenolic Maturity of the grapes. The optimal Phenolic Maturity for the harvest is when the seed tannins are at a minimum and the skin phenols at a maximum, resulting in minimal bitterness.

To determine the Phenolic Maturity degree objective methods exist, corresponding to chemical analysis, that relate to the measurement of indicators such as pH, acidity, soluble solids, among others (Gil and Pszczólkowski, 2007). These methods are generally very accurate, but involve laboratory analysis.

There are also subjective methods, which are based on the experience of the Oenologist, and Phenolic Maturity is estimated by inspecting the aroma, flavor and appearance of both fruit and wine. These types of analyses are called Organoleptic analysis.

Traditionally, organoleptic analyses are performed on the fruit of the grape, or the wine. Unlike previous work, a very recent line of research explores the seed of the fruit to determine the Phenolic Maturity. Such indicators as color, shape and texture of the seeds were studied, finding a high correlation between appearance indicators and the taste of wines (Ristic and Iland, 2005; Fredes et al., 2010).

The subjective methods for determining grape Phenolic Maturity depend on the experience of a human expert, and they are known to be subject to errors of consistency in the evaluation (Gawel and Godden, 2008). When the seed appearance method is used, the expert visually compares the seed surface color with a color chart. The disadvantages of analyzing seeds through its appearance and organoleptic methods generally include the following: first, the visual determination of color is very subjective, and can easily incur into misjudgments. Second, it is not possible to infer information regarding the totality of the site with a small group of seeds, which forces the expert to analyze a large volume of seeds to obtain representative information of the entire property. Finally, a subjective analysis requires a highly trained expert aware of recent progress in this field, an expert who is not always available.

As mentioned above, the subjective methods have certain disadvantages, but due to their low cost, they are possible to implement in small vineyards.

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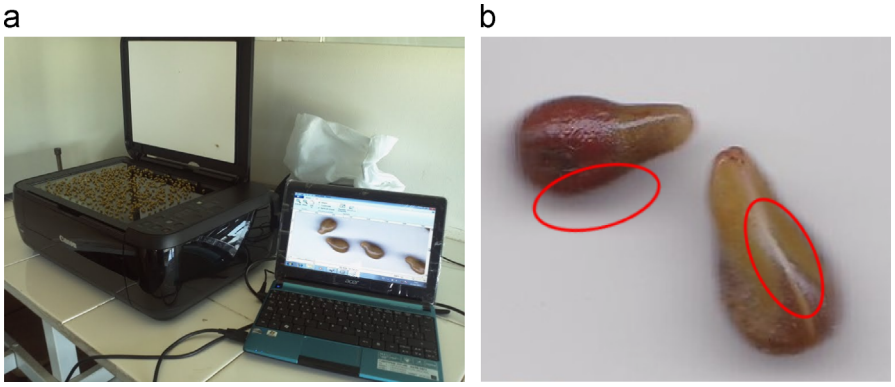

Fig. 1. Scanner and problems identified in the acquired images: (a) scanner and (b) shadows and highlights.

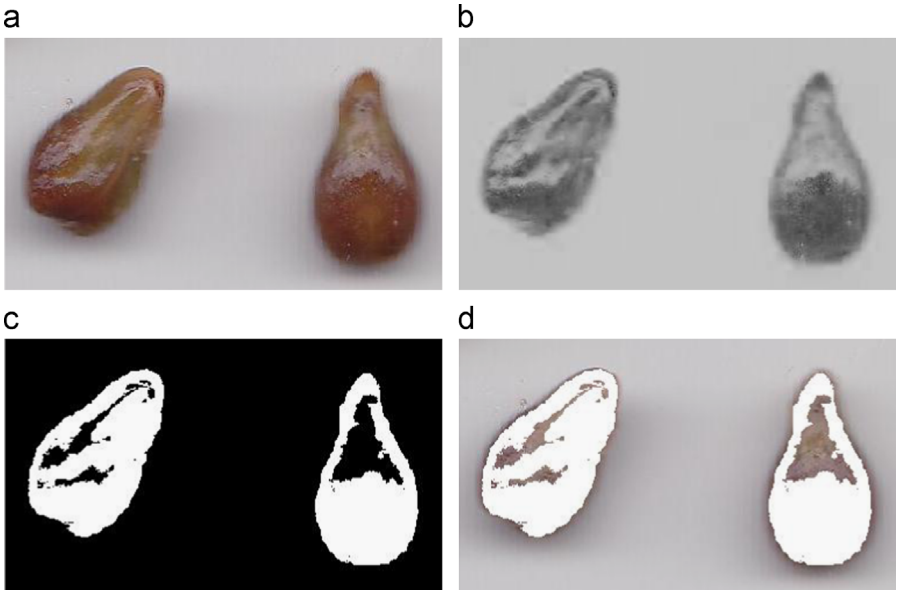

Fig. 2. Seed segmentation: (a) original image, (b) c_3 channel, (c) Otsu method and (d) resulting segmentation.

A recent line of research examines the seed of the fruit to estimate its level of maturity. In Ristic and Iland (2005) a study of the relationship between the development of the seed and berry of *Vitis vinifera* L. cv Shiraz is presented. Seed were removed to analyze their physical properties such as weight, color and moisture, in addition to its phenolic components. The study identified three phases of growth and development of the seed, which determined specific stages in the development of the berry. Also, changes in the phenolic composition of the seeds in relation to the different stages of development and maturity of the seeds and berries were studied. It provided evidence that changes in the phenolic composition of the seeds can be reflected by changes in color, and that this can be used as an indicator of maturity.

In Fredes et al. (2010) the relationship between seed appearance and its phenolic maturity in cv. Carmenere was studied. The objective of this research was to develop a simple neutral indicator of berry maturity based on the color of the seed, and to compare the evolution of form and color with berry phenolic maturity. It is determined that there is a high correlation ($R^2 = 0.96$) between the total polyphenol index and changes in the color of the seed.

In Rodríguez et al. (2012) one of the first studies that analyzes the seed using techniques of digital image processing and pattern recognition was presented. The relevance of some descriptors such as lightness ($L*$), chroma ($C*_{ab}$), seed length, roundness and aspect ratio, on the problem of seed maturity of the grapes of *Vitis vinifera* L. cv. Graciano was studied. Twenty-one phenolic compounds were identified to study their association with seed descriptors along the stages of grape ripening. The study concludes that in some cases there are good relationships between the data of appearance and chemical data, and that it is possible to estimate

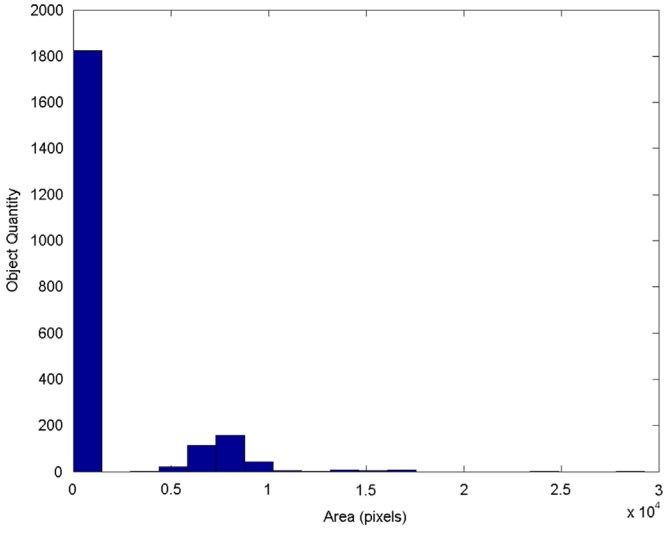

Fig. 3. Histogram of the area (pixels) of the seeds.