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Research Paper

Application for the estimation of the standard citrus colour index (CCI) using image processing in mobile devices

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The collection of oranges normally begins before they have reached the typical orange colour. Moreover, citrus fruits are subjected to certain degreening treatments that depend on the standard citrus colour index (CCI) at harvest. In order to facilitate the measure of this index, a free application that uses image processing techniques has been developed for Android-based mobile devices using the built-in camera of the device. The image analysis process is performed on all the images from the live input of the camera to obtain the CCI of such fruit using the open source OpenCV library. For this purpose, the RGB (red, green and blue colour coordinates) average value of a pre-selected area of the input image is calculated and then converted to HunterLab colour space to finally calculate the CCI. Several tests were carried out in the field with the fruit on the trees and under laboratory conditions with different varieties of oranges (Navel, Bonanza, Cram and Navelina) at different stages of maturity, and using different Android devices. The results were obtained for each device and condition in relation to the colour measured by a camera and compared with the performance of a panel of workers who evaluated the colour using the traditional methods. Best R^2 values obtained were 0.854 for outdoors conditions and 0.881 when measurements were done indoors.

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1. Introduction. State of the art

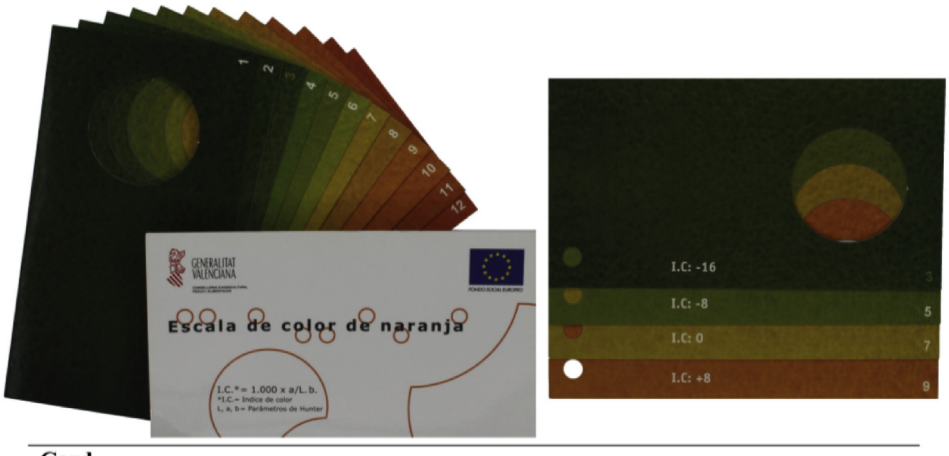
Colour is one of the main attributes that consumers associate directly with the freshness or maturity of agricultural food products, so it is a key factor in their preferences over other products (Campbell et al., 2004). A practical application where the inspection of the colour is also needed is the marketing of citrus fruits. Fruits are harvested manually, loaded in boxes and transported to packing houses, where they are sorted in batches. In the early season, when the citrus fruit is received in the packinghouse, this sorting focuses on classifying by colour because it normally needs a degreening treatment using ethylene, whose duration depends on the colour they present at harvest (Porat, 2008, pp. 71–76). The standard parameter used to determine the colour of citrus fruits is the citrus colour index (CCI), being used in the citrus industry to determine the harvesting date and to decide which fruit should undergo a degreening treatment and the type of the treatment (Jiménez-Cuesta, Cuquerella, & Martínez-Jávega, 1981).

The common way to determine the CCI in the industry is by using colorimeters, which are specific electronic devices for colour measurement that express colours as numerical coordinates. However, although colorimeters give accurate colour measures and are small handy devices, they are expensive and only provide information about a very small area of the fruit surface (Gardner, 2007), which may not be representative of the colour information of the whole fruit surface, especially when the fruit does not have a uniform colour. In this sense, calibrated colour cameras can achieve similar results to colorimeters (Vidal et al., 2013). Another extended way to estimate the CCI is the set of cards simulating the colour and texture of the fruit at different stages of maturity developed by the Centro de Tecnología Postcosecha of the Instituto Valenciano de Investigaciones Agrarias (IVIA) and provided by the Consellería de Agricultura Pesca y Alimentación of the Generalitat Valenciana for oranges (Fig. 1) and mandarins, which allows a visual comparison of the citrus surface to the printed colour inside a circular window in order to estimate the CCI of such fruit from the value printed on each colour card (DOGV, 2006).

A way to automate this measurement is to acquire images of the fruit using digital cameras and then analyse the colour using image processing software. This method allows the colour of a bigger region or even the entire fruit to be estimated, being especially suitable in those cases where the surface has a heterogeneous colour since the colours of the pixels are determined individually (Cubero, Aleixos, Moltó, Gómez-Sanchis, & Blasco, 2011; Lorente et al., 2012). Automated estimation of colour using image processing presents several advantages regarding visual inspection, such as accuracy, objectivity and repeatability. However, one of the major drawbacks when measuring colour using images is that, normally, the colour is provided in red, green and blue colour coordinates (RGB) since this is the native colour space for most image acquisition devices. However, this colour space is device-dependent, and it is not a perceptual colour model. By contrast, other colour models like CIELAB or HunterLab are defined in such a way that the distances among colours in the colour space are related to the differences in human perception, regardless of the position of the colours, so they are very well suited for colour comparison and appropriate for measuring or representing the colour of fruits (Arzate-Vázquez et al., 2011; Lang & Hübert, 2012; Mendoza, Dejmek, & Aguilera, 2006).

In most cases, it is necessary to obtain comparable measurements of the colour by using colour indices, which combine the colour coordinates in one single ratio that is easier for operators to handle and understand (Cavazza et al., 2013; Cárdenas-Pérez et al., 2017; Quevedo, Valencia, Alvarado, Ronceros, & Bastias, 2013). The CCI is estimated using a ratio whose definition is based on HunterLab colour coordinates and the colour of application ranges from green to orange. This index determines the need for degreening treatments and the commercial maturity stage, two important issues, that differ and depend on the variety (Lado, Rodrigo, & Zacarías, 2014).

However, a vision system generally needs an external acquisition device (the camera) and image processing



Card number	1	2	3	4	5	6	7	8	9	10	11	12
CCI	-24	-20	-16	-12	-8	-4	0	+4	+8	+12	+16	+22

Fig. 1 – Set of coloured texture cards used to estimate visually the CCI of oranges. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)