Computers in Industry 68 (2015) 105–115

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

An image-based system to preliminary assess the quality of grape harvest batches on arrival at the winery

Cristina Portalés *, Emilio Ribes-Gómez

Instituto Tecnológico de Óptica, Color e Imagen (AIDO), C/ Nicolás Copérnico, 7-13, Parque Tecnológico, 46980 Valencia, Spain

ARTICLE INFO

Article history:
Received 18 June 2014
Received in revised form 29 October 2014
Accepted 23 December 2014
Available online 22 January 2015

Keywords:
Near-infrared
Grape
Detection
Classification
Image processing
Quality control

ABSTRACT

In this paper we present a hardware system and related computer processes to assess a preliminary quality control of grape harvest batches by automatically detecting, classifying and quantifying grape stems and other objects from images acquired on arrival at the winery, from which a quality grading is given. A non-invasive methodology based on computer vision is implemented, and the developed approach is based on the combination of a spectral and spatial analysis, where the inspection is performed in a small region of the near infrared (from 1000 to 1100 nm range). A non-expensive optical system was designed, which is composed of two high resolution CCD cameras, a long pass filter, some halogen light sources, related electronics and a standard PC. The performance of the optical system and implemented computer vision-based algorithms were tested in a laboratory setup for repeatability and overall accuracy while operating outdoors and over a whole working day, with varying illumination conditions. The system response presented small variations when estimating the occurrences of grape stems or other objects in the scene under analysis. The best results – lowest standard deviations and lowest root mean square errors – were obtained for the system working with added artificial lights and for the analysis being performed in the green channel. The system was also installed at a winery, where operators tested it for its good performance in a real scenario. The system worked as expected and the outcomes show that it is a robust and intuitive inspection system.

1. Introduction

Non-invasive-based technologies for food inspection, such as infrared and/or multispectral spectroscopy or imaging, are increasingly being used in the food industry, providing the basis for characterization, identification, quantification, classification and quality control of different products [1–10]. In the viticulture field, many works have been reported, especially in the last decade, being most of them based on near-infrared (NIR) spectroscopy or a combination of visible and NIR spectroscopy technology [11–20]. For instance, in Herrera et al. [12], a portable NIR spectrometer was used for the estimation of ripeness of Chilean wine grapes, where data was collected in the range of 650–1100 nm. In Roussel et al. [21] different technologies (aroma sensors and spectrometers) were successfully combined in order to classify musts of white grapes according to their variety. The fusion method was based on the Bayesian inference to combine the outputs of various sensors (aroma sensors, FT-IR and UV spectrometers). In Chauchard et al. [13] NIR spectra was used to predict the acidity of three different grape varieties by using the method of Least-Squared Support Vector Machine. A spectrometer which collected data in the 300–1160 nm range was used, with a 3.3 nm sampling interval, provided 256 point spectra. In Janik et al. [14] a study was carried out that compared the performance of different classification methods for the prediction of total anthocyanin concentration in red-grape homogenates from their visible (VIS) and NIR spectra (400–2500 nm). The VIS and NIR spectral range was also used by Le Moigne et al. [22] to characterize fifteen batches of Cabernet Franc grapes in order to investigate effects of ripening stages and parcel type on grapes. In Fernández-Novales et al. [15], the feasibility of NIR spectroscopy for predicting a reduction of sugar content during grape ripening, winemaking, and ageing was assessed. Samples were measured using a fibre spectrometer system collecting data in the 200–1100 nm range. In Naidu et al. [23] it is investigated the potential of leaf spectral reflectance changes between virus infected and uninfected grapevines in developing non-invasive techniques for field-based diagnosis of grapevine leafroll disease.

* Corresponding author. Present address: Instituto de Robótica y Tecnologías de la Información y las Comunicaciones (IRTIC), Universitat de València, Av. Blasco Ibáñez, 13, 46010 Valencia, Spain. Tel.: +34 963 54 35 57.
E-mail addresses: cristina.portales@uv.es (C. Portalés), eribes@aido.es (E. Ribes-Gómez).

http://dx.doi.org/10.1016/j.compind.2014.12.010
0166-3615/

The inspection was made from data collected with a portable spectrometer working in the 350–2500 nm range, which was used to obtain spectral reflectance measurements of the adaxial leaf surface. In Qin et al. [24] the relationship between the reflectance of grape leaves and their thickness was investigated by means of artificial intelligent techniques, where data was collected with a radiometer working in the spectral range of 350–1010 nm. Some other works that use VIS and/or NIR spectrometers to characterize grapes are found in [16,25–27].

Visible and NIR spectroscopy is becoming a more attractive analytical technique for measuring quality parameters in food and is ideally suited to the requirements of the wine industry in terms of both quality control and traceability, though still more can be done to optimize the use of such technique in the wine industry [27]. Additionally, it has to be taken into account that, although radiometers and/or spectrometers give rich spectral data, they work basically on limited areas, deriving results only for specific locations. If for instance an inspection needed to be done on a batch covering an area of 3 m $\times$ 1.5 m, only some sample data would be collected to perform inspection under a reasonable period of time. Despite the natural limitations arising from such punctual-based technologies, still few studies can be found which are based on collecting spectral data from spatial imaging sensors, e.g. CCD or CMOS cameras. In Baiano et al. [28] a hyperspectral imaging system in the VIS–NIR range was used for prediction of some physico-chemical and sensory indices of table grapes. Hyperspectral images were acquired using a hyperspectral imaging system consisting in a charge-coupled device (CCD) 12 bit camera connected to a spectrograph, allowing the inspection in the spectral range 400–1000 nm. Each collected spectral image was stored as a three-dimensional image (x, y, k), where the spatial components (x, y) included 1000 $\times$ 1000 pixels, and the spectral component (k) included 121 bands. In Rodríguez-Pulido et al. [29] a hyperspectral imaging system was used to characterize the grape seeds according to their chemical attributes to estimate the variety and stage of maturation. NIR spectral images were acquired in the reflectance mode using a pushbroom hyperspectral imaging system. The system comprised a spectrograph, a CCD camera, a translation stage, two tungsten-halogen lamps, data acquisition software, and a computer. The spectral range recorded was 897–1752 nm at an increment of 3.34 nm, producing 256 bands.

The objective of this research was to develop a device and related software to assess a preliminary quality control of grape harvest batches on arrival at the winery, thus speeding up decision-making at that stage and enabling separate processing of batches depending on the assessed quality of the raw material. Additionally, the analysis had to cover the entire area of the batch and be performed under a reasonable inspection time. To that purpose, a dedicated inspection device was designed, integrating (between others) a non-expensive RGB non-specialist camera working in the range of 400–1100 nm to which a long pass filter was added, limiting the study to the interest region of 1000–1100 nm – which was determined after an evaluation of different spectral regions. In this way, instead of having several bands (as is the case of hyperspectral images), we focus our attention to a single band (either R, G or B), which on the other hand contains all the relevant information we need, avoiding the use of expensive hardware and considerably reducing acquisition times. We present a processing methodology which makes use of computer vision techniques by analysing the acquired images to differentiate between grapes, grape stems and other foreign, undesired objects (mainly leaves) present in a harvest batch, identifying and giving a quantification of non-grapes elements. Instead of focusing our research only in the spectral dimension, we also work in the spatial domain, using areal and shape-based dedicated image processing algorithms to discern between different objects. All the procedure (from the image acquisition to the results of classification) is controlled with a dedicated software which provides an intuitive Graphical User Interface (GUI) and stores data in a standard database that can be accessible through the GUI.

2. Materials and methods

2.1. Hardware components

The inspection is performed with an own made device, a system that basically consists of a pair of non-expensive non-specialist cameras with 12 MP resolution each. One of the cameras acquires images in the visible range, while the other covers the visible and part of the near infrared region (from 400 to 1100 nm). The inspection presented in this paper is performed with the images acquired with the second camera, while the images from the first camera are stored for documentation purposes and may serve to do further quality control analysis (see Section 5). Both cameras and related electronics are kept inside a sealed box suited for outdoors use and are connected to a PC via cables. In Fig. 1 a laboratory setup of the system is depicted.

A filter was added to the second camera lens in order to limit the spectral region to that optimal for the inspection (see Section 2.2).

The acquisition time depends on the amount of available ambient light, as the integration time of the camera is set to automatic mode. On the other hand, if artificial light was available, acquisition times would remain constant.

2.2. Assessment of the optimal spectral region

Different filter configurations were tested in order to identify the one spectral region which produced optimal images with sufficient contrast between grapes and other undesired elements. The filter selections were made up of three band-pass filters at 550 nm, 800 nm and 880 nm and four high long-pass filters from 780 nm, 850 nm, 920 nm and 1000 nm. As an example, images acquired with the band-pass filter of 880 nm and with the long-pass filter of 1000 nm are shown (Fig. 2a and b) together with their

Fig. 1. System mounted on a movable structure (laboratory setup).