5.4 SMART AGRICULTURE BASED ON CYBER-PHYSICAL SYSTEMS

Diego Francisco Larios Marín and Francisco Javier Molina Cantero

ABSTRACT

The general objective of the project is to develop a cyber-physical system based on low-cost portable multispectral IoT nodes and Artificial Intelligence that allows the most relevant parameters that influence olive quality to be measured in a simple and economical way, with the benefit of assisting the farmer in making a decision about when to collect the olive from the olive tree and its processing for production in both table olives and olive oil.

INTRODUCTION

This project proposes the creation of a monitoring system based on artificial vision techniques, using multispectral images and AI algorithms applied to crops of products derived from the olive tree. The aim is to obtain precise information on those organoleptic variables of olives that have an impact on the quality parameters of the olive oil obtained from them. The monitoring is carried out at two different moments in the process: in the field, during the last months of the campaign, and in the oil mill, when the harvested olives are received.

The system provides information on the level of maturity, the fat yield, and the acidity of the olives. These data, traditionally obtained through laboratory analysis, are obtained through IoT nodes. The nodes incorporate a processing system that analyzes the image and calculates the corresponding values of the quality parameters in real time.

Data from these samplings are integrated into a software platform that processes and combines them to offer the farmer precise information on the state of the crop that helps them make logistical decisions (i.e., optimal date of collection) and management (irrigation/fertilizers), in order to achieve a higher production while maintaining the quality of the oil.

STATE OF THE ART

The use of hyperspectral images in the field of support for decision-making in agriculture has been considered in the literature by different authors. In most practical applications, it is the infrared bands that provide the most relevant information for classification and pattern detection tasks. In the specific case of products derived from the olive tree, there are various proposals for the evaluation of characteristics, such as nitrogen and potassium in olive grove plots (Gómez-Casero, M.T. et al., 2007) or acidity, humidity, and peroxide value in olive oil samples (Martinez-Gila et al., 2015). The use of spectrometry techniques (Vis/NIR) directly in the fruit has been proposed by various authors (León et al., 2003), (Cayuela et al., 2009) for the generation of predictive models of quality parameters: moisture, dry matter, oil content, free acidity, and maturity index. These predictive models use different wavelength sets for each parameter.

Once the hyperspectral information has been acquired and calibrated, a system is needed for the execution of complex algorithms and the evaluation of the characteristics of the crops to be determined. For these algorithms to work properly, it is important to have a large number of samples that contain both positive and negative aspects, that is, as many objects that contain what is intended to be measured, as well as objects that do not, in order to define what are the characteristics of the reflection of the mentioned object. In order to achieve this, it is important to have a large collection of previous images, in a catalog that facilitates application development.

Solving this in traditional computing structures is expensive and complex since it generally requires oversizing above the expected demand. For this reason, the use of technologies based on the use of cyber-physical systems is proposed, which, as stated in the European Digital Strategy (Cyber-Physical European Roadmap & Strategy, 2013-21015), is a disruptive technology that allows controlling and coordinating processes, on both local and global scale, using communication and information technologies.

CONTRIBUTION

The project has been developed by the TIC150 research group of the University of Seville in collaboration with the company SOLTEL, an Andalusian ICT consultancy. The stages in which the project has been developed are briefly detailed below.

a) *Development of a cataloging and labeling tool*

Initially, the need to develop a tool for cataloging olive samples was identified, so that an adequate knowledge base could be built for the analysis and training of pattern detectors. Subsequently, integration, validation, preprocessing, and semi-automatic labeling functions were added.

b) *Automatic image validation*

It is a fundamental function for the creation of the knowledge database, for the algorithm training activities, and also for the effectiveness of the real-time detectors. The factors that most influence a correct interpretation of the scene are the lighting and the distance between the camera and the olive tree. The perspective from which the scene is captured also influences, although to a lesser extent.

For the validation process, a reference framework implemented in Teflon is used in the capture process. The developed algorithm looks for that frame within the scene. From the spectral analysis of the detected Teflon, it is possible to deduce the characteristics of the ambient light, in order to correct its influence on the rest of the scene. Using a fixed lens, the size of the frame in the scene allows us to ensure that the distance between the camera and the scene is similar in all captures. This aspect is very important for two reasons. The first reason is to guarantee that the size of the olives is sufficient to be detected, and the second one is to be able to compare the performance in terms of the number of fruits based on their density and not on their number within the scene.

c) *Generation of a hyperspectral signature database*

Having a database with the spectral characteristics of the different analysis objectives is essential to obtain efficient classifiers.

For this purpose, the project has implemented an algorithm that processes cataloged images in batches. The algorithm performs the validation of the scene for each image, as well as the extraction of spatial scales and lighting correction parameters. The corrected mean spectrum is calculated for the area marked as olive and it is associated with the labeled degree of maturation. The spectra of all olives with the same ripening index are averaged to obtain a base signature. The most frequent univocal spectral signatures present in the same degree of maturation are calculated.

Using this technique, the knowledge model will be based not on one but on a set of signatures. This method facilitates the interpretation of the models and increases the effectiveness and speed of detection of the classifiers.

d) *Classifier training*

In this work, the paradigm known as "Supervised Learning" has been chosen, where each example is associated with a discrete label that identifies its membership in a group or class. The set of examples is used both to train the algorithms and to validate the results of their learning. The learning objective may be the classification of new examples or predictive inference.

Once the algorithm has been trained, it is capable of performing several functionalities: olives detection, olives counting, maturity index estimation, pest detection, and pest growth.

e) *Integration*

Data integration has required coordination with the other partners to define the information format and the exchange mechanism between the applications involved in the capture, labeling, and analysis of the images. A distributed architecture based on REST services has been chosen for information exchange.

The intelligent analysis module executes the extraction of information and the classification and estimation algorithms in real time, that is, as users upload the images to the web platform. The algorithms for preprocessing, information extraction, classification, counting, and estimation of the maturity index have been integrated into the management and operation system by means of a dynamic link DLL library that is called from the host that supports the application.

The computational performance is high since in the worst-case scenario the execution time is less than 3 seconds, if we exclude the upload times of the images (with sizes of 200 MB). Therefore, the viability of the developed algorithms is concluded.

ACKNOWLEDGMENTS

This project has been carried out in collaboration with SOLTEL IT SOLUTIONS and with the support of the following researchers: C. León, J. Barbancho, and J. I. Guerrero.

WORKS CITED

Cayuela, J. A., García Martos, J. M., & Caliani, N. (2009). NIR prediction of fruit moisture, free acidity and oil content in intact olives. *Grasas y Aceites*, *60*, 194–202.

Cyber-physical European roadmap & strategy (2013–2015). https://cordis.europa.eu/project/id/611430/es

Gómez-Casero, M. T., López-Granados, F., Peña-Barragán, J. M., Jurado-Expósito, M., García Torres, L. & Fernández-Escobar, R. (2007). Assessing nitrogen and potassium deficiencies in olive orchards through discriminant analysis of hyperspectral data. *Journal of the American Society for Horticultural Science*, *132*(5), 611–618.

León, L., Rallo, L., & Garrido-Varo, A. (2003). Near-infrared spectroscopy (NIRS) analysis of intact olive fruit: An useful tool in olive breeding programs. *Grasas y Aceites 54*(1), 41–47.

Martinez-Gila, D. M., Cano Marchal P., Gámez García, J., & Gómez Ortega, J. (2015). On-line system based on hyperspectral information to estimate acidity, moisture and peroxides in olive oil samples. *Computers and Electronics in Agriculture*, *116*, 1–7.