We are IntechOpen,
the world's leading publisher of
Open Access books
Built by scientists, for scientists

4,800

Open access books available

122,000

International authors and editors

135M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Introductory Chapter: Trends on Hyperspectral Imaging Development

Alejandro Isabel Luna Maldonado,
Humberto Rodríguez Fuentes and
Juan Antonio Vidales Contreras

Additional information is available at the end of the chapter

1. Introduction

Hyperspectral imaging (HSI) is the set of activities by which images are captured and spectral radiance values assigned to each pixel through the range of wavelengths of the electromagnetic spectrum under visible and infrared regions. HSI sensors provide information on hundreds of narrow wavelength bands of composite. The pixels are sorted and characterized using statistical analysis and software to classify among groups of pixels. The data from each wavelength band are connecting into a three-dimensional hyperspectral (data hypercube) for processing and analysis. Hypercube is composed of layers, and each layer represents data at a specific wavelength. HSI is quite important in food quality and assurance, agricultural practices and environmental quality.

2. HSI in assurance of food quality

Nowadays, consumers are interested in food quality and safety assurance. Fruits and vegetables can be inspected in-line by HSI for increasing the quality and safety of food products but also to offer significant earnings to food processors [1]. Spectral variations due to morphological changes of most fruits and vegetables decrease the prediction of models; in addition, the interferences that specimens possess might affect the classification accuracy, therefore imaging techniques in dealing with morphological effects are needed. Another demand is the automatic recognition of representative region of interest based on computer software to improve model

efficiency. HSI systems with low-cost and fast-detecting properties are provided [2]. An effective pixel-based apple bruise region extraction method has been proposed to obtain the complete bruise region. The hyperspectral images of 60 apples were obtained at 0, 12, and 18 h during an experiment. Principal component analysis (PCA) eliminates repetitious data of hypercubes. Random Forest (RF) model obtained high and steady classification accuracy. The mean accuracy of bruise extraction models reached 99.9 [3]. Color parameters (L*, a* and b*), firmness, and soluble solid content (SSC) have been quantified by HSI in the visible and near infrared (VNIR) regions between 600 and 975 nm and the short wave near infrared (SWIR) region between 865 and 1610 nm. SSC can be exactly predicted by SWIR hyperspectral imaging with than 0.8, while L* and a* adjusted better with VNIR hyperspectral imaging displayed correlation coefficients greater than 0.7 for [4]. Near infrared (NIR) hyperspectral imaging can classify among maize kernels of varying hardness and between fungal infected and sound kernels [5].

For the quick and nondestructive detection of microbial decay in muscle of beef, pork, poultry, fish, and so on, techniques have been used such as visible and near-infrared spectroscopy, Fourier transform infrared spectroscopy, fluorescence spectroscopy, Raman spectroscopy, and hyperspectral imaging. When those techniques are combined with chemometric analysis, spectral preprocessing and modeling methods are successfully developed for the determination of total viable count, aerobic plate count, *Enterobacteriaceae*, *Pseudomonas*, *Escherichia coli*, and lactic acid bacteria loads in muscle [6].

Starch content in adulterated fresh cheese has been measured using HSI. In a research, adulterated fresh cheese was prepared using concentrations of starch of 0.055–12.705 mg g^{-1}; afterwards, HSI images in the range of 200–1000 nm, distributed in 101 bands were acquired. A partial least square regression (PLSR) model of starch content was obtained with a determination coefficient (R^2) of 0.9915 and a root mean square error of cross-validation (RMSECV) of 0.3979. With five variables, a correlation coefficient of validation (r) of 0.8321 and a mean square error prediction (RMSEP) of 1.3515 was found for a reduced model [7].

Haugh unit (HU) index is a measure of the quality of the albumen in various studies on egg quality. HU is a destructive test of specimen and correctly reflects the batch of eggs being processed. In a study, fresh eggs were stored at 25°C and measured after storage for 0, 4, 7, 10, 14, 18 and 21 days by HSI system in the wavelength range of 900–1700 nm and compared to HU for each egg. A calibration model for HU initially used PLSR and then cross-validation was performed and a coefficient of determination (R^2) of 0.91 and root mean square error of calibration (RMSEC) of 4.58 was obtained; however, displayed colors of acquired image of eggs were different correspond to the freshness of the eggs based on HU [8].

Dairy product companies are demanding systems for quantifying and qualifying differences between milk powders. Hyperspectral imaging (HSI) has been used to distinguish between milk powders manufactured in factories and of differing practical and useful qualities, for instance, dispersibility. HSI and multivariate analysis techniques such as principal component analysis (PCA) and partial least squares (PLS) regression were performed. The PCA results exhibited differences in the first and second principal components. The PLS technique showed that HSI information could be used to forecast the dispersibility parameter and then establish significant correlations between hyperspectral images and crucial quality attributes of milk powder either on, or at line in close to real time [9].

Herbal tea demand is increasing because of consumers coming to know of its health benefits. Chromatographical techniques require destructive sample preparation using solvents; therefore, HSI could be a nondestructive alternative method. In a research, HSI pushbroom system captured images of the raw material and tea blends by SisuChema SWIR (short wave infrared). Subsequently, the images were analyzed using multivariate analysis software. PCA revealed 54.2% chemical variation between *S. tortuosum* and *C. genistoides* raw materials. A partial least squares-discriminant analysis (PLS-DA) model had confidence prediction of 95.8% and it was possible to visualize the tea blend constituents (based on pixel classification) as *S. tortuosum* and *C. genistoides* and quantitatively predicted *C. genistoides* as the major constituent (>97%) while *S. tortuosum* was existent in lower amounts (<3%) [10].

Advanced preprocessing methods for denoising that possess high efficiency and high exactitude are appearing to improve the predicting accuracy for using hyperspectral images in food quality evaluation and analysis. Adaptive filters have been developed for applications since they can steadily adjust itself to the changing imaging environment [11]. Hyperspectral pan-sharpening method has been used with high frequency layer of each band of the hyperspectral image as the guidance image of the guided filter for extraction of spatial details from both the panchromatic image and the hyperspectral image. The total spatial attributes are added in the end into each band of the HS image low frequency layer to generate the last image [12].

On the other hand, hyperspectral fluorescence imaging (HSFI) method has been used to evaluate quality and safety of food since it combines the advantages of both hyperspectral imaging and fluorescence spectroscopy. However, it cannot be said that HSFI is very effective for measuring quality attributes. The potential of this technology for food and agricultural product quality and safety in online inspection will improve rapidly with advances in optical sensing and computer systems [13].

3. HSI in assurance of agricultural practices

The development of hyperspectral imaging systems, both aerial and ground, has been very important in crop monitoring for nutrients, water stress, disease, insect attack and estimation of crop yield in smart agriculture.

The remote perception of water stress in a citrus orchard have been researched using leaf measurements of chlorophyll fluorescence and Photochemical Reflectance Index (PRI) data, seasonal time-series of crown temperature and PRI, and high-resolution airborne imagery [14]. The miniaturization technology has supplied markets with hyperspectral imagers operating on frame format, which is highly attractive for unmanned aerial vehicle (UAV) based remote sensing, because it provides better stability and the likelihood to grab stereoscopic data sets, bringing in a possibility for three dimensional hyperspectral object reconstruction [15]. In some studies, UAV has been performed to acquire RGB images for vegetation analysis [16]. Liquid crystal tunable filter (LCTF)-based hyperspectral imaging system transmitted selected wavelengths without the requirement to exchange optical filters from UAV and measured 14 different ground objects in vegetative areas. Additionally, the machine learning (ML) approach using a support vector machine (SVM) model reached a classification accuracy of 94.5% in vegetated areas [17].

In recent research, automated remote sensing procedures have been developed, assessed, and compared based on novel, low-cost HSI system for the identification of beetle infestations in barks at the individual tree level in urban forests achieving an overall accuracy of 81% (kappa: 0.70), compared to the aircraft results of 73% (kappa: 0.56) in a smaller sub-area [18].

4. HSI in assurance of environmental quality

HSI is rapidly becoming a key tool for pollution tracking changes in the environment. Hyperspectral microscopy (HM) has been explored for nanotoxicity studies of materials in a more native state and truer to conditions of biomedical pertinence. Additionally, HM had potential and found its earliest macroscopic applications in geologic surveying. However, analysis of air or water samples is constrained by the challenge of immobilizing particles [19]. A study based on Hyperspectral Imaging (HSI), was developed to establish an efficient method to characterize marine microplastic litter. Reliable information on abundance, size, shape and polymer type for the whole ensemble of plastic particles in each sample was retrieved from hyperspectral images [20]. A new algorithm has been evaluated using the Hyperspectral Imager for Coastal Ocean (HICO). The hyperspectral vicarious calibration was applied to HICO, showing the validity and consistency of HICO's ocean color products [21]. HSI can arrange pixel providing a lot of potential for material characterization. A study demonstrated that HSI is possible for recognition of pigments [22]. Modern studies of heavy metal pollution of soils have been focused on the hyperspectral reflectance of typical metals in soils and in plants measured either *in situ* or in the laboratory. Most of these studies used wavebands lie within the visible near infrared range of the spectrum, especially the red edge. Metals detection must rely on their co-variation with the spectrally responsive metals or organic matter in the soils [23].

Acknowledgements

Author details

Alejandro Isabel Luna Maldonado*, Humberto Rodríguez Fuentes* and Juan Antonio Vidales Contreras*

*Address all correspondence to: alejandro.lunaml@uanl.edu.mx, juan.vidalescn@uanl.edu.mx and humberto.rodriguezfn@uanl.edu.mx

Faculty of Agriculture, Food and Agricultural Engineering, Autonomous University of Nuevo Leon, General Escobedo, Mexico

References

[1] Gallagher MS, Mahajan PV. The stability and shelf life of fruit and vegetables. In: Food and Beverage Stability and Shelf Life. Woodhead Publishing Ltd.; 2011. pp. 641-656

[2] Pu YY, Feng YZ, Sun DW. Recent progress of hyperspectral imaging on quality and safety inspection of fruits and vegetables: A review. Comprehensive Reviews in Food Science and Food Safety. 2015;**14**(2):176-188

[3] Che W, Sun L, Zhang Q, Tan W, Ye D, Zhang D, Liu Y. Pixel based bruise region extraction of apple using Vis-NIR hyperspectral imaging. Computers and Electronics in Agriculture. 2018;**146**:12-21

[4] Li B, Cobo-Medina M, Lecourt J, Harrison NB, Harrison RJ, Cross JV. Application of hyperspectral imaging for nondestructive measurement of plum quality attributes. Postharvest Biology and Technology. 2018;**141**:8-15

[5] Williams PJ. Near infrared (NIR) hyperspectral imaging for evaluation of whole maize kernels: Chemometrics for exploration and classification [Doctoral dissertation]. Stellenbosch: University of Stellenbosch; 2009

[6] Cheng JH, Sun DW. Recent applications of spectroscopic and hyperspectral imaging techniques with chemometric analysis for rapid inspection of microbial spoilage in muscle foods. Comprehensive Reviews in Food Science and Food Safety. 2015;**14**(4):478-490

[7] Barreto A, Cruz-Tirado JP, Siche R, Quevedo R. Determination of starch content in adulterated fresh cheese using hyperspectral imaging. Food Bioscience. 2018;**21**:14-19

[8] Suktanarak S, Teerachaichayut S. Non-destructive quality assessment of hens' eggs using hyperspectral images. Journal of Food Engineering. 2017;**215**:97-103

[9] Munir MT, Wilson DI, Yu W, Young BR. An evaluation of hyperspectral imaging for characterising milk powders. Journal of Food Engineering. 2018;**221**:1-10

[10] Sandasi M, Chen W, Vermaak I, Viljoen A. Non-destructive quality assessment of herbal tea blends using hyperspectral imaging. Phytochemistry Letters. 2018;**24**:94-101

[11] Dai Q, Sun DW, Cheng JH, Pu H, Zeng XA, Xiong Z. Recent advances in de-noising methods and their applications in hyperspectral image processing for the food industry. Comprehensive Reviews in Food Science and Food Safety. 2014;**13**(6):1207-1218

[12] Dong W, Xiao S, Li Y. Hyperspectral pansharpening based on guided filter and Gaussian filter. Journal of Visual Communication Image Representation. 2018;**52**:151-158

[13] Zhang R, Ying Y, Rao X, Li J. Quality and safety assessment of food and agricultural products by hyperspectral fluorescence imaging. Journal of the Science of Food and Agriculture. 2012;**92**(12):2397-2408

[14] Honkavaara E, Rosnell T, Oliveira R, Tommaselli A. Band registration of tuneable frame format hyperspectral UAV imagers in complex scenes. ISPRS Journal of Photogrammetry and Remote Sensing. 2017;**134**:96-109

[15] Zarco-Tejada PJ, González-Dugo V, Berni JA. Fluorescence, temperature and narrow-band indices acquired from a UAV platform for water stress detection using a micro-hyperspectral imager and a thermal camera. Remote Sensing of Environment. 2012;**117**:322-337

[16] Senthilnath J, Kandukuri M, Dokania A, Ramesh KN. Application of UAV imaging platform for vegetation analysis based on spectral-spatial methods. Computers and Electronics in Agriculture. 2017;**140**:8-24

[17] Ishida T, Kurihara J, Viray FA, Namuco SB, Paringit EC, Perez GJ, Takahashi Y, Marciano JJ. A novel approach for vegetation classification using UAV-based hyperspectral imaging. Computers and Electronics in Agriculture. 2018;**144**:80-85

[18] Näsi R, Honkavaara E, Blomqvist M, Lyytikäinen-Saarenmaa P, Hakala T, Viljanen N, Kantola T, Holopainen M. Remote sensing of bark beetle damage in urban forests at individual tree level using a novel hyperspectral camera from UAV and aircraft. Urban Forestry & Urban Greening. 2018;**30**:72-83

[19] Roth GA, Tahiliani S, Neu-Baker NM, Brenner SA. Hyperspectral microscopy as an analytical tool for nanomaterials. Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology. 2015;**7**(4):565-579

[20] Serranti S, Palmieri R, Bonifazi G, Cózar A. Characterization of microplastic litter from oceans by an innovative approach based on hyperspectral imaging. Waste Management. 2018. In Press

[21] Ibrahim A, Franz B, Ahmad Z, Healy R, Knobelspiesse K, Gao BC, Proctror C, Zhai PW. Atmospheric correction for hyperspectral ocean color retrieval with application to the hyperspectral imager for the coastal ocean (HICO). Remote Sensing of Environment. 2018;**204**:60-75

[22] Grabowski B, Masarczyk W, Głomb P, Mendys A. Automatic pigment identification from hyperspectral data. Journal of Cultural Heritage. 2018;**31**:1-12

[23] Wang F, Gao J, Zha Y. Hyperspectral sensing of heavy metals in soil and vegetation: Feasibility and challenges. ISPRS Journal of Photogrammetry and Remote Sensing. 2018;**136**:73-84