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UNRAVELING THE COMPLEXITIES AND VERSATILITY OF HYPERSPECTRAL IMAGING APPLICATIONS

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Abstract

Hyperspectral Imaging (HSI) is a sophisticated technique that has emerged as a valuable tool in providing rich data on spectral, spatial, and temporal aspects of various subjects. By fusing the principles of spectroscopy and imaging, HSI excels in segmenting and recognizing regions of interest through the analysis of spectral values. Over the years, its appeal has grown exponentially, finding applications in diverse areas such as remote sensing, agriculture, medicine, astronomy, surveillance, food quality evaluation, and pollution monitoring. This growth is primarily driven by the ability of HSI to extract valuable information from spectral signatures present in complex scenes. In this article, we aim to provide a comprehensive overview of hyperspectral imaging, its underlying concepts, and its increasing influence across different application domains, emphasizing the immense potential of this cutting-edge technology.

I. Introduction

Spectroscopy is one of the foremost techniques in identification and in quality evaluation. In the beginning of 1980's, airborne imaging spectrometer (AIS) developed at NASA's Jet Propulsion Visible/Infrared Imaging Spectrometer (AVIRIS) to enhance the spectrometers into air and mobile platforms. AVIRIS measured spectral images within 400nm to 2500nm. It has shown the improved. Digital imaging provides data about the objects in the scene in terms of shape, texture, color, Spectral imaging extracts and identifies the objects with the help of radiance. The joined nature of imaging and spectroscopy in a hyperspectral imaging allowed to concurrently offer physical and geometrical features of the object interms of shape, size, appearance, and color as well as the chemical composition of the product through spectral analysis (Beaulieu et al, 2018). The hyperspectral imaging is one partition of three classes of spectral imaging, the other two classes are multispectral and ultraspectral imaging. In all kinds of imaging, a spectral image results spectral signature at a different spectral narrowband. These three classes can be distinguished based on the number of bands and the form of the spectrum achieved. Multipsectral imaging does not provide enough information of data in the image whereas hyperspectral contains extremely précised information about a pixel in the image. But the difficulty exists to process the data with

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hyperspectral algorithms (Fabelo et al , 2018). Hyperspectral imaging are broadly used to measure the radiance of materials present in the scene at hundreds of bands. This acquires increased performance when it is compared with multispectral imaging where it can measure radiance only at very less bands. Hyperspectral system collects quite a lot of hundred spectral bands over a narrow, contiguous spectral bands. Each pixel emits radiation at wide array of spectral bands which are measured by imaging spectrometers. These qualitative and quantitative spectral values helps to distinguish and recognize the materials which is existing in the scene or in the object. Human vision are restricted only to considerable portion of electromagnetic spectrum from 400 to 700nm, whereas hyperspectral systems can reach from 400 to 2500nm. These spectral values gains more importance during the identification of the existence of substance in the material. Fig.1 presents the spectral values of crop and the ground of vegetation. The hyperspectral camera captures the spectral values at different spatial dimensional. The spectral values of crop are high in few areas whereas spectral values of ground are less than crop in same spectrum as it is shown in the Fig.1. This imaging technique is attracted towards many application such as remote sensing, agriculture, medicinal, food safety and quality etc (Kumar and mittal , 2010).

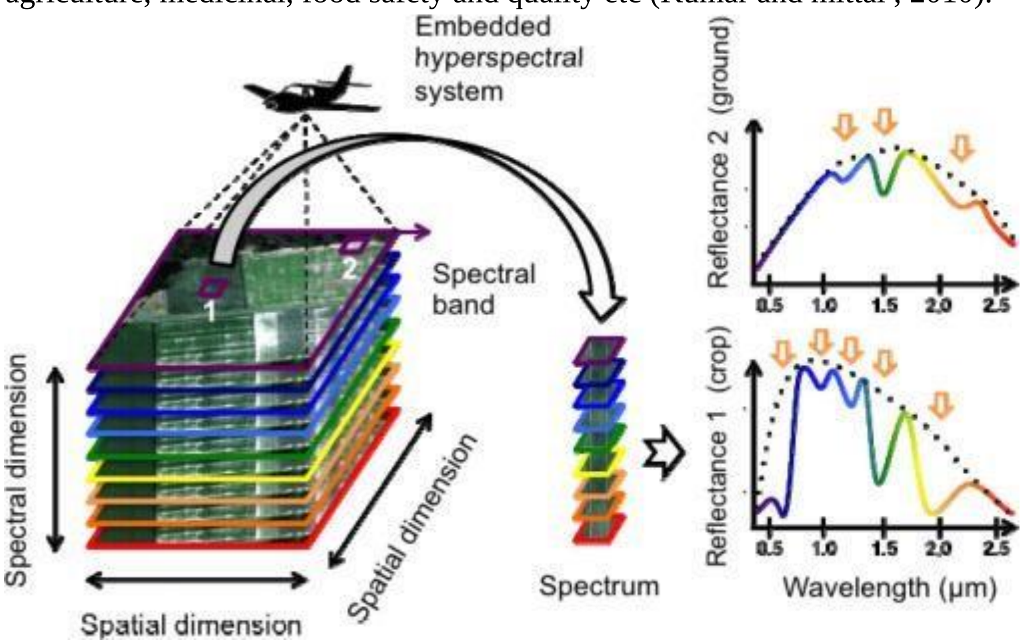

Fig 1 Spectral and Spatial dimension of Hyperspectral Imaging

II. Applications of Hyperspectral Imaging 1. In Water Resources

HIS is widely used for extracting in depth information about water resources. (Govender et al, 2007). It is well used for detecting flood quickly and reduces the time of deduction. The reflectance of hyperspectral signatures are widely used for assessing the quality of water in

open ecosystems. It includes of finding the algae and detecting ammonia dynamics for wetlands. It also helps to measure the concentration of chrolophyl1 in the solvents.

2. Abdominal organs differentiation

Hyperspectral imaging helps in organ differentiation. It collects the spectral signature of each pixel in all the organs. An open surgery on pig was experimented to identify the each organ. The generated spectral values are used to recognize small intestine, colon, peritoneum, bladder and spleen. Each organ is represented in different colors. This helps doctors to examine the disease in the larger portion of tissue and also reduces the surgical time. The accuracy of the diagnosis can be improved by HIS. Fig.2 shows the RGB image and segmented image by using HIS. From that image it is clear to visualize each organ separately with edges and region boundaries.(Ortega 2019).

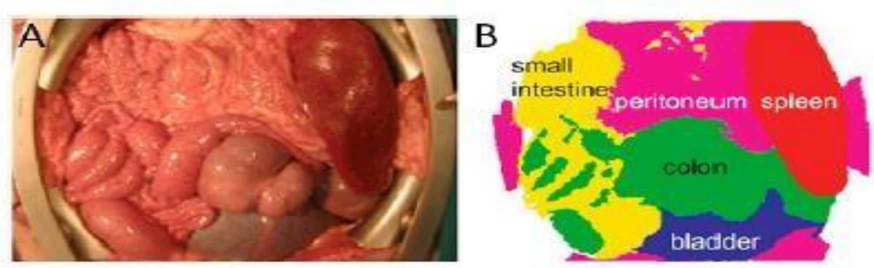

Fig.2 a) RGB image of organs b) Segmented HIS image of the organs

3. Seed damage detection

In general seeds will be damaged due to natural germination, diseases, insects, fungi. These serious hazards creates great loss of yield and quality (Feng et al). Hyperspectral imaging plays vital role in identifying the damaged seed effectively than other imaging systems. Xing et al. proposed a method to identify sprouted and severely sprouted wheat kernels by using hyperspectral imaging system at the spectral range of 400–1000 nm. Many studies were done on healthy and damaged kernels with varied angle. Mean, standard deviation of scores of each kernel are retrieved as features. From fig.3, it is clearly shown the difference between healthy and unhealthy seeds.

4. Quality assessment of Fruits and Vegetables

Although there are numerous methods are available in computer vision, they could not efficiently identify the defects of bruises, rottleness or chilling injury. But hyperspectral imaging tools are available to differentiate skin defects and color and texture. Few pressure points will not be visible on the fruits and vegetables.

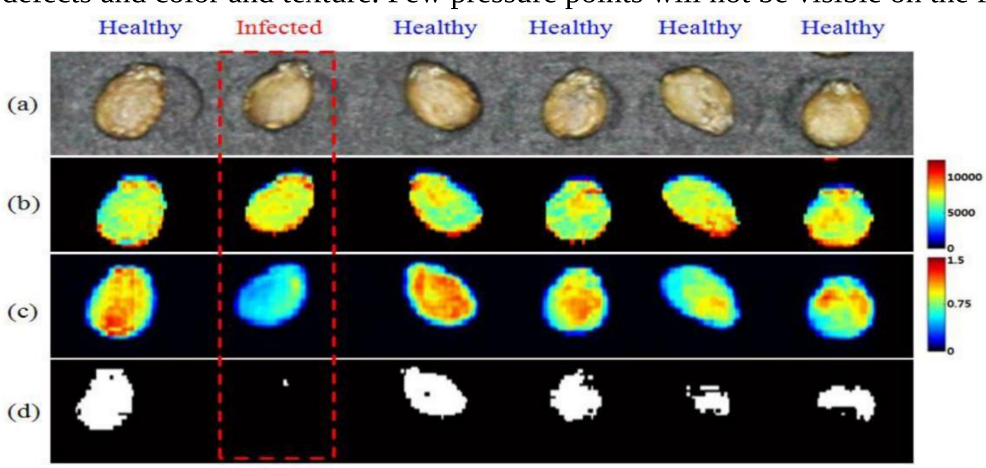

Fig.3 Seed damage detection

But HIS can efficiently identify the spots. It automatically improves the quality of recognition.(Lorente et al, 2011) and (Serranti et al, 2017). In apple the pressure points are spotted in hypsectral image but not in RGB image which is presented in figure.

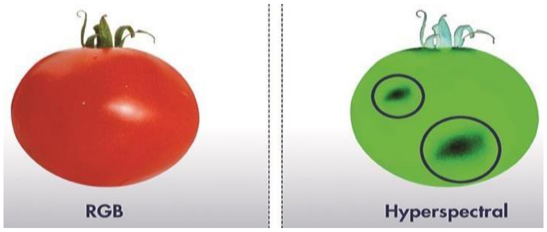

Fig. 4 Difference between RGB and Hyperspectral images

5. Surveillance

HSI is not only playing vital role in other application areas. It is attracted towards surveillance especially in military (Xing et al,2011). The spectral signatures are drawn from a large area of the light spectrum from different bands such as weapons, bombs, explosions, guns, chemical objects etc. Osama bin Laden was killed in may 2011 by using the hyperspectral technology. Traditionally thermal infrared hyperspectral imaging system which are commercial was used. But the major challenge faced in those systems are need for liquid nitrogen or helium cooling which has made difficult for practical solutions.

Conclusion

Hyperspectral imaging is a popular technique devised to incorporate both optical spectroscopy and traditional imaging. HSI is a multidisciplinary and complex technique aims to efficiently measuring both spatial and spectral values. In this paper a generic overview of HIS and its role in different areas are discussed. The performance measures of HIS beats up the results of other Image processing techniques. This technique will meet the requirements efficiently in near future.

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