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Comparative Analysis of RGB Imaging and Hyperspectral Imaging using Machine Learning Techniques

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***Abstract*— Image processing is the class of methods for face recognition, object detection, image compression, classification, etc. Hyperspectral imaging is the parallel acquisition of spatial and spectral information from an image, making it a useful tool for many applications. It is similar to an RGB color image, but it has a lot more channels and thereby making it challenging to visualize by the human eye. This paper discussed the fundamentals and components of RGB imaging and hyperspectral imaging. We also discussed the challenges of using a hyperspectral imaging system and some comparative study results of RGB imaging and hyperspectral imaging for various application areas. We also discussed the role of machine learning techniques in RGB imaging and hyperspectral image analysis. We also discussed future challenges and the scope of hyperspectral imaging. Though hyperspectral imaging has certain limitations, it can be a powerful image analysis tool for many applications in the future.**

***Index Terms*— Hyperspectral imaging (HSI), RGB imaging, machine learning (ML), deep learning (DL).**

I. Introduction

Image processing is the field that deals with handling the images through the use of various computer algorithms. There are various applications of image processing including image recognition, object identification, object classification, image enhancement, image restoration etc. Images are of various types including binary images, gray scale images, RGB images, multispectral images and hyperspectral images. To process these images, there are various machine learning algorithms. Machine learning focuses on the use of data and algorithms to learn and give accurate results for the given problem. This paper is organized as below. Section 2 focuses on basics of RGB imaging and HSI processing. Section 3 elaborates various ML methods available for processing of RGB and HIS imaging. Section 4 focuses on comparative analysis of RGB imaging and HIS analysis for different application areas. Section 5 presents research gap and future scope for RGB and HSI processing. Finally in section 6 we have concluded the research work discussed in this paper.

II. Basics Of Rgb Imaging And Hyperspectral Imaging

There are various types of images like binary images, gray scale images and color images etc. Binary images are having only two pixel values 0 and 1. Gray scale or 8-bit images are composed of 256 unique colors between black and white, where pixel intensity of 0 represents black color and pixel intensity of 255 represents white color. The RGB images consist

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of three different channels representing ‘Red’, ’Green’ and ‘blue’ color. Total 65,536 different colors are possible for each pixel.

The human vision is limited to only visible light which contain RGB bands only. Spectral imaging divides the spectrum into multiple bands. Recent years, HSI processing technique is evolved which is considered as a powerful tool for research in various application areas including remote sensing, agriculture, horticulture, medical imaging, forensic science etc. HSI has many more channels than RGB image which are beyond the human vision. A HSI contains reflections in infrared (infrared, IR) band and near-infrared (near-infrared, NIR) band which are not seen by human vision. Fig 1 represents electromagnetic spectrum with different wavelengths for different bands.

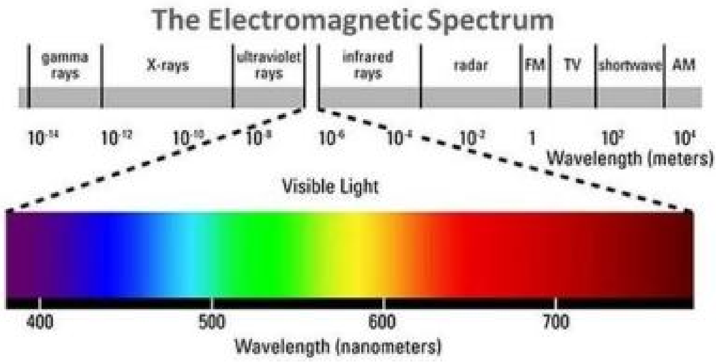

Figure 1: Electromagnetic spectrum representing different spectral bands.

A. Structure of Hyperspectral Imaging System

HSI processing is a method that integrates digital spectroscopy and imaging to generate information in special and spectral dimensions. HIS data consist of a number of spectral channels which are unique in each pixel [1]. A standard RGB image comprises of three bands including red, green, and blue. However, hyperspectral images consist of hundreds of wavelengths. After the image is acquired using the hyperspectral camera, a hypercube is formed which contains information in special as well as spectral domain. Fig 2 [2] illustrates the basic structure of a HSI and RGB image. Here, the x and y axis represent the spatial dimension of the image and λ represents the spectral dimension i.e. the number of bands for which the image is captured.

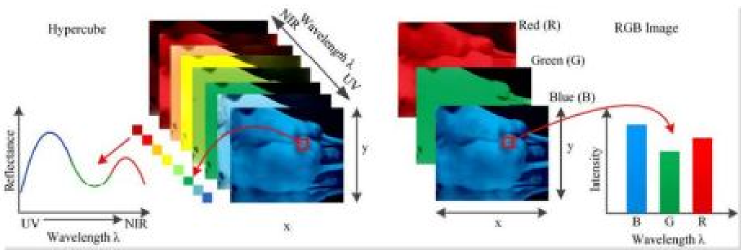

Figure 2. Comparison of structure of hyperspectral and RGB image

As shown in fig 3, a hypercube is formed for each acquired hyperspectal image. For each pixel in the image, a pixel vector is created which indicate a unique spectral signature of each pixel in the “hypercube”.

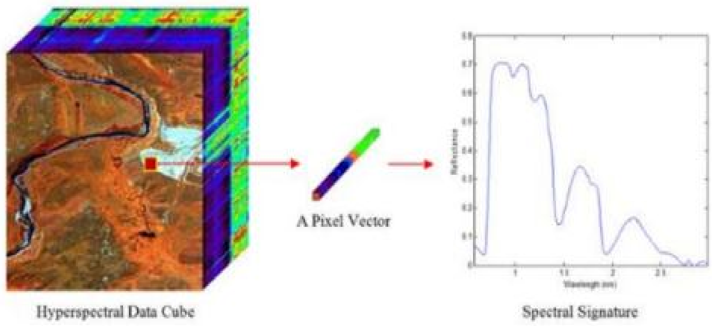

Figure 3. Hyperspectral data cube, pixel vector and spectral signature

B. Components of Hyperspectral Image Processing System

HSI system consists of a detector, a light source, a device for wavelength dispersion, and a computer system equipped with software for image acquisition like Unscrambler, ENVI, etc. Fig 4 illustrates the configuration of a HSI system [3].

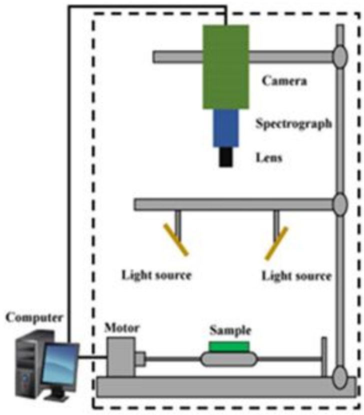

Figure 4: Components of hyperspectral imaging system

The HSI captured from different platforms and different sensors is a raw image and needs to be pre-processed to extract relevant information and to get precise output [4]. The acquired HSI undergoes several steps before it is used for classification such as calibration, spectral/spatial pre-processing, and dimensionality reduction. The basic HSI pre-processing procedure is depicted in Fig 5 [5] as shown below:

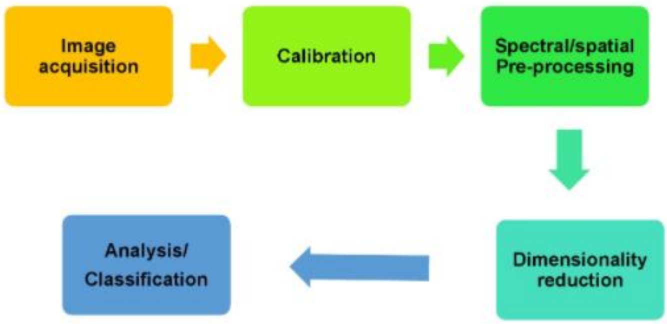

Figure 5: Basic hyperspectral image pre-processing procedure

III. Machine Learning For Rgb And Hyperspectral Image Processing

ML is a technique which allows computers to learn from the past data using mathematical models and make predictions from the historical data. It is classified into three types. Supervised, unsupervised and reinforcement learning. The following block diagram represent working of ML algorithms.

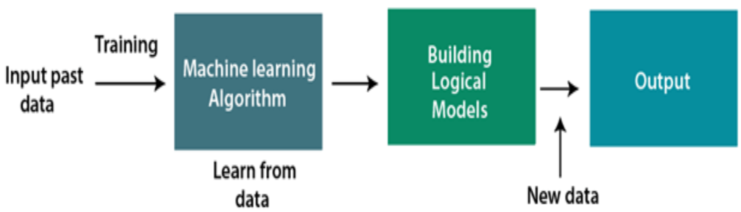

Figure 6: Block diagram of machine learning model

Supervised learning requires labelled data for classification whereas unsupervised learning does not require any prior information for classification [6]. Some of the supervised learning tools are Artificial Neural Networks, Decision Trees, Random Forests, Support Vector Machines, k-Nearest Neighbour, Logistic Regression, Naïve Bayes, and Linear Discriminant Analysis. Clustering and dimensionality reduction are a subcategory of unsupervised learning [7]. Some of the unsupervised learning tools are k-means clustering, Independent Component Analysis (ICA), and Principle Component Analysis (PCA). However, reinforcement learning refers to the application of specific task-oriented algorithms in a manner to learn achieving a complex goal by using the concept of interaction of agents with the environment [8]. It can be used for teaching and training robots for agriculture and food industry applications [9]. ANNs were developed to imitate the working of the human brain [10]. The simplest ANN is a multi-layer perceptron composed of an input layer, hidden layer, and output layer [11]. In the last years, deep learning was widely used and improved the state of the art in many different application areas.

IV. Comparative Analysis Of RGB And Hyperspectral Imaging

There are various application areas where the results show that HSI outperformed RGB imaging using machine learning techniques. Some of the comparative results are discussed below.

- Crop growth monitoring is an important research problem in remote sensing. Feng et al. [12] performed monitoring of winter wheat growth using unmanned aerial vehicles equipped with RGB and hyperspectral cameras to acquire high resolution remote sensing images. It was observed that UAV hyperspectral imagery gives better results as compared to UAV RGB images.
- Detection of diseases in fruits and leaves can be effectively performed with RGB and Hyperspectral imaging. Wen Sha et al. [13] combined RGB imaging and HSI to detect black root mould infection in apples. RGB and HSI images of healthy, slightly infected, moderately infected and highly infected apple fruits were considered for this study. Several machine learning algorithms are used out of which random forest outperformed other methods and gives 100 % accurate results for training and 96 % accuracy for prediction using network and statistic features of two types of images.
- Liao et al. [14] performed detection of diseases in banana using combination of close range HSI images and RGB images with high resolution. Experimental results shows that, instead of using only morphological features, use of special as well as spectral features in combination gives better accuracy.
- Detecting foreign object in given food product is also an important research area. Jaokim Nyman [15] detected contamination of sugar using RGB and hyperspectral imagery. Spectral range of 400-1000 nm was used. SVM and ANN models were trained and pixel based classification was performed. Pixels were labeled as sugar and other contamination material. Results showed that accuracy is slightly better for HSI camera as compared to RGB camera and SVM performed better as compared to ANN.
- S. D. Fabiyi *et al.* [16] performed classification of various types of rice seed varieties using RGB and HSI. The experimental results show that proposed algorithm is very effective in classifying rice seed varieties with high resolution spatial features and spectral features extracted from HSI data.

High information content and excellent feature extraction capability makes HSI processing a suitable and powerful tool for many applications.

Some of the advantages of HSI over RGB imaging are discusses as below:

- No sample preparation is requires for food and agricultural applications.
- This technique does not involves chemicals for testing the quality of food and agricultural products including fruits, vegetables, meat, dairy and bakery products which makes it an environment friendly technique.
- After calibration model is developed and validated, image analysis can be simple.
- This technique is economic as compared to other available techniques as it does not damage the food product which is to be tested, hence reusability of product can be done.
- This method provides flexible ROI selection which can be stored in a spectral library for future use.

HSI system has several dis-advantages over RGB imaging which are discussed as below:

- HSI generate huge amount of data. Hence it needs a lot of storage space and computational cost.
- Selection of effective wavelengths from the captured wavelengths is a big challenge.
- The hardware required for capturing HSI data which is based on the type of application is very costly and not suitable for real time applications.
- HSI pre-processing software’s are very costly to be used for real time applications.
- This process takes large time for acquiring and processing image. This method need to prepare a standard calibration model. Hence, this method is not suitable for online quality evaluation.

V. Research Gap And Future Scope

Out of the various available imaging techniques including RGB, multispectral and HSI, HSI is a powerful technique, but it has some limitations. The major limitation is the production of huge amount of data which lead to increase in the computational time for extracting main features from the spectral images. Hence, it is difficult to use HSI for real time applications. Moreover, HSI cameras, sensors and software like ENVI are very costly for real time applications. Development of fast, reliable and efficient algorithms for HSI data analysis is very important. Researchers should focus more on developing efficient techniques to reduce time complexity and achieve high accuracy of classification. More significant work can be done in combining RGB and HIS for various application areas.

VI. Conclusion

It can be concluded that RGB imaging and HSI can be used in combination of different machine learning algorithms for classification and analysis in various application areas. Although there are still many challenges to overcome including high computational cost, over fitting, and dependence on data quality, several studies shows that HSI outperform RGB imaging as it provides more information in spatial and spectral dimension. Some studies show that, combination of RGB and HSI for image classification and analysis prove to be a great choice depending upon type of application and availability of resources for researchers in near future.

References

[1] Johannes D Pallua, Andrea Brunner, and Bettina Zelger," New perspectives of hyperspectral imaging for clinical research." SAGE Journals, Volume 32, Issue 3-4, 5-13, (2021).

[2] Akin Ozdemir, Kemal Polat,," Deep Learning Applications for Hyperspectral Imaging: A Systematic Review." Journal of the Institute of Electronics and Computer, 2, 39-56 (2020).

[3] Chuanqi Xie, Xiaoli Li1, Yongni Shao, Yong He1.,"Color Measurement of Tea Leaves at Different Drying Periods Using Hyperspectral Imaging Technique," PLoS ONE, 9(12), e113422, (2014).

[4] Lu, B.; Dao, P.; Liu, J.; He, Y.; Shang.," J.,Recent Advances of Hyperspectral Imaging Technology and Applications in Agriculture." Remote Sens., 12, 2659, (2020).

[5] Park, B.; Lu, R. (Eds.).," Hyperspectral Imaging Technology in Food and Agriculture,"Springer: New York, NY, USA, (2015).

[6] Sawant, S.S.; Prabukumar, M., "Semi-supervised techniques based hyper-spectral image classification: A survey." In Proceedings of the 2017 Innovations in Power and Advanced Computing Technologies (i-PACT), Vellore, India, 21–22; pp. 1–8 (2017).

[7] Raschka, S., Mirjalili, V.," Python Machine Learning.", Packt Publishing Ltd, Birmingham, UK (2017).

[8] Aljaafreh, A.," Agitation and mixing processes automation using current sensing and reinforcement learning," J. Food Eng. 203, 53–57 (2017).

[9] Bechar, A., Vigneault, C.: Agricultural robots for field operations: concepts and components. Biosyst. Eng. 149, 94–111 (2016).

[10] Jamshidi, M.," Tools for intelligent control: Fuzzy controllers, neural networks and genetic algorithms." Phil. Trans. Math. Phys. Eng. Sci. 361, 1781–1808 (2003).

[11] Sanz, J.A., Fernandes, A.M., Barrenechea, E., Silva, S., Santos, V., Gonçalves, N., Paternain, D., Jurio, A., Melo-Pinto, P.," Lamb muscle discrimination using hyperspectral imaging: comparison of various machine learning algorithms." J. Food Eng. 174, 92–100., (2016).

[12] Feng, H.; Tao, H.; Li, Z.; Yang, G.; Zhao, C.," Comparison of UAV RGB Imagery and Hyperspectral Remote-Sensing Data for Monitoring Winter Wheat Growth," Remote Sens., 14, 3811 (2022).

[13] Sha, W.; Hu, K.; Weng, S.," Statistic and Network Features of RGB and Hyperspectral Imaging for Determination of Black Root Mold Infection in Apples." Foods ,12, 1608(2023).

[14] Liao, W.; Ochoa, D.; Zhao, Y.; Rugel, G.M.V.; Philips, W.," Banana Disease Detection by Fusion of Close Range Hyperspectral Image and High-Resolution Rgb Image." In Proceedings of the IGARSS (2018)—2018 IEEE International Geoscience and Remote Sensing Symposium, Valencia, Spain, 22–27 July 2018; pp. 1744–1747.

[15] Jaokim Nyman, "Pixel classification of hyperspectral images", UPTEC IT 18 003, (April 2018).

[16] S. D. Fabiyi et al., "Varietal Classification of Rice Seeds Using RGB and Hyperspectral Images," in IEEE Access, vol. 8, pp. 22493-22505, (2020).