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Study on Hyper Spectral Imaging

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Abstract— Spectroscopy deals with how light behave in the target and recognize materials bases on their different spectral signatures. Spectrum describes the amount and range of radiation that is emitted, reflected or transmitted from the target. Hyper spectral data acquisition and exploitation by providing imaging sensors and software solutions covering hundreds of spectral bands from UV-VIS to SWIS is used to observe Earth, atmospheric science, space situation awareness etc. The work focuses primarily on hyper spectral imaging, data acquisition methods, Image resolution improvement strategies.
Keywords—Spectrum, Hyper spectral Imaging, Data cube, Resolution, Spectroscopy.

I. INTRODUCTION

Eyes are those sense organs which have 2/3rd interaction with this world. When light is reflected from an object, the photoreceptors which are more sensitive to red, blue, and green in our eye detect the color of the object. Humans can view 400-700nm range wavelength by which they can differentiate 10 million set of color shades. We cannot see the left and right side of the visible band that is the ultraviolet and infrared range of radiation. Interestingly, there are many animals which have wide range of vision; one of them is Mantis Shrimp which has 12 different photoreceptors in its eyes but, it cannot visualize due to its small brain size.

Light is a wave which has some frequency while oscillating. This frequency gives us enormous information of light/color that we are going to visualize. Color cameras which we use in our daily life actually detect a low frequency red, a mid-frequency green and a high frequency blue. A camera has a sensor which takes in light, converts it into an electrical signal which is further sent to a computer where image is processed. The sensor of a camera is of grid pattern where each grid is termed as a pixel. Each pixel forms a single point of the image, the color information is obtained by the filters which are red, blue and green. In this paper, we discuss about hyper spectral imaging, various data acquisition methods and also methods to improve the resolution of acquired hyper spectral image.

A. Hyper Spectral Imaging

Hyper spectral imaging is combining photoreceptor capacity of detecting light at different wavelengths and the huge processing power for analyzing the spectrum. In hyper spectral imaging we wish to detect many colors of vast frequency ranges which give more information of the object from which the light is thrown to camera. When a picture is clicked on a hyper spectral camera, lot of filters change quickly thereby, obtaining us images where each pixel is shot in the entire spectrum. These images are combined to form a three-dimensional (x, y, λ) data cube, as shown if fig 1.1, where x and y represent two spatial dimensions of the scene, and λ represents the spectral dimension (comprising a range of wavelengths).

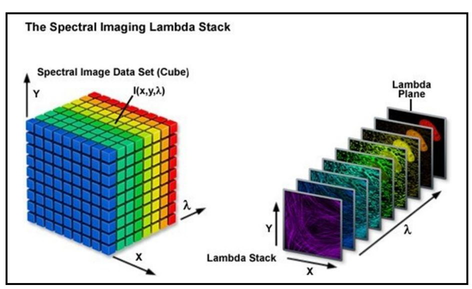

Fig 1.1: Data cube of hyper spectral images

II. METHODS FOR HYPER SPECTRAL DATA ACQUISTION

A. Spatial Scanning

This method is also called as line scanning where the two dimensional sensor output represents a full split spectrum. When an object is projected onto the slit it is dispersed through a prism or a grating where imaging is performed. Using whisk broom scanner we can perform point scanning which is the special case of line scanning shown in Fig 2.1.

B. Spectral Scanning

In this scanning technique the two dimensional output comes out to be as a single colored that is a monochromatic spatial map of the object. The devices used for this type of scanning use band pass filters which are either tunable or are fixed. The platform is kept stationary whereas the filters keep exchanging after the object is scanned. We can choose between the spectral bands having a direct representation of two spatial dimensions of the object shown in Fig 2.1.

C. Non Scanning

It is snap shot hyper spectral imaging which uses a staring beam to generate an image at an instance. In this technique a single two dimensional sensor output contains all spatial and spectral data. A three dimensional structure is constructed from a single snap shot data cube. All the spectral and spatial data is obtained in a single frame with low acquisition time. This method is also known as n perspective projection of hyper spectral cube shown in Fig 2.1.

D. Spatio-Spectral Scanning

It has the advantage of both spectral and spatial scanning. Each two dimensional sensor output represents a rainbow colored spatial map of the object. This method gives out a series of narrow diagonal slices of data cube. Wavelength coded image is obtained. This method yields high spatial and spectral resolution for objects in motion or which are irregular as shown in the Fig 2.1.

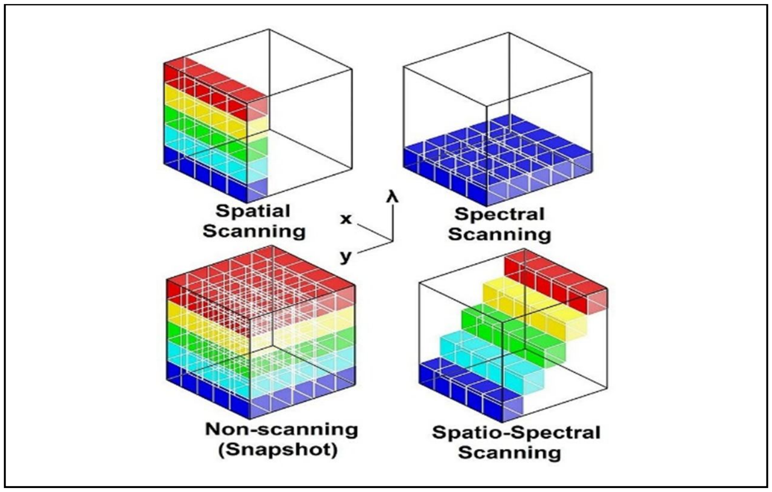

Fig 2.1: Methods for hyper spectral data acquisition

III. HYPER SPECTRAL CAMERAS

We require different hyper spectral cameras to capture different spectral ranges based on our purpose like VNIR, SWIR, MWIR and LWIR. Line scanning that is spatial scanning is adequate to use for a cube satellite where there is relative motion. Objective, Spectrograph and Grayscale camera are the three important components of a hyper spectral camera. By just using objective and grayscale camera we obtain a black and white image. HSI happens through spectrograph. Imaging spectrograph contains input slit, accommodating optics, a dispersive unit and a focusing lens. The narrower the slit the more accurate the image is obtained. Now we have the spectral information; every row contains intensity information from different wavelengths together providing the whole spectra, columns contain the spectra location. The image of whole object is recorded line by line obtaining a data cube.

IV. LITERATURE SURVEY

The images acquired from hyper spectral image often have low resolution. Enhancing the resolution from hardware side is very expensive. So improvising the resolution of the hyper spectral images through software is very much necessary. Here are few methods which improve the resolution using various software algorithms by various authors.

Jin Wang et al., in the year 2014 [8] proposed Super Resolution Using Advanced Non-local Means Filter and Iterative Back Projection: Hyper spectral images have high resolution in spectral domain but their resolution in special domain is limited due to scattering, secondary illusion, noise and etc. IBP is a very popular method to improve resolution over blurred images. It is an iterative error correction method. Due to this iteration jagging and ringing artifacts occurs in the detail region. ANLM filter is introduced to counteract this effect. NLM had been used for de-noising and deblurring in imaging. NLM computes on all the neighborhood similarities in the whole image where as in ANLM the missing pixels are smoothened as the weighted average of all other pixels that have Gaussian neighborhood and close path distance. This method is to restore the desired high resolution image from a down sampled and blurred low resolution image. Degradation model is applied on the down sample and then error is estimated. The estimated error is interpolated using ANLM and the process is iterated till a HR image is obtained. (Jin Wang et al., 2014).

Chiman Kwan in the year 2018 [6] discussed on Remote Sensing Performance Enhancement in Hyper spectral Images: One popular approach to improve spatial resolution is pan sharpening. Pan sharpening is a process of merging high resolution panchromatic and low resolution multispectral imagery to create a single high resolution image. The key difference between hyper spectral imaging and multispectral imaging is that HIS uses continuous and contiguous range of wavelengths whereas MSI uses a set of targeted and chosen wavelengths or narrow bands. There are several methods like bi-cubic interpolation, bilinear interpolation to improve the spatial resolution of a single HS image cube. The new method is to improve the resolution by injecting information of missing or blurred pixels from high resolution color images acquired by other imagers such as satellites or airborne hyper spectral image sensors. (Chiman Kwan, 2018).

Anna Rissanen in the year 2017 [7] has proposed miniaturized hyper spectral imagers for VNIR and SWIR interferometer for hyperspectral imaging and mobile sensing. It was developed using FPI tunable pass-band filter combined with image sensor. This sensor had high spatial resolution and spectral resolution with huge decrement in size of the hyper spectral imaging camera which can be equipped into a mobile unit or a cube sat.

V. APPLICATIONS

A. Medical diagnosis
B. In agricultural sector for monitoring the health of crops and detection of pests.
C. In food processing Industries for checking the quality of using chemical imaging technique.
D. In Mineralogy, to identify the oil fields and other minerals.
E. Atmospheric gas monitoring to detect hazards gases and emissions.
F. Hazardous waste monitoring.

VI. ADVANTAGES

A. Traceability
B. Chemical and physical properties of materials.
C. Google maps and etc services relay upon this method for imaging and tracking.
D. Efficient Pollution monitoring.
E. Remote Sensing.
F. Ease of Mineral differentiation in mining.
G. Ocean monitoring.
H. Environment forecasting.
I. Natural disasters can be predicted before they cause damage.

VII. LIMITATIONS

A. Different hyper spectral sensors are required to capture images in different wavelength.
B. Three dimensional cubes have high dimensionality which needs to be reduced
C. As lot many images are captured, processing such huge data is complex and slow.
D. Retrieving hyper spectral images with high resolution and high accuracy is a very important issue.
E. Generally, the size of cameras is huge which limits their usage in cube satellites.
F. Compression of lousy hyper spectral data.

VIII. CONCLUSION

Hyper spectral Imaging is an evolving vast technology which bears huge advantages over medical, military, ecological and etc sectors. With hyper spectral imaging we are able to look at the world in wide range of wavelengths by dividing the electromagnetic spectra into many more bands. The spectral imagers read images over time scan and process information. The key issue of Hyper spectral imaging is to enhance its resolution using various appropriate and adequate software algorithms such as super resolution as it is expensive to operate upon hardware of the hyper spectral device. As our main concern is to fit in the hyper spectral imager into a cube satellite, it is very much necessary to minimize the camera's size and power up the system well with a maximum accuracy.

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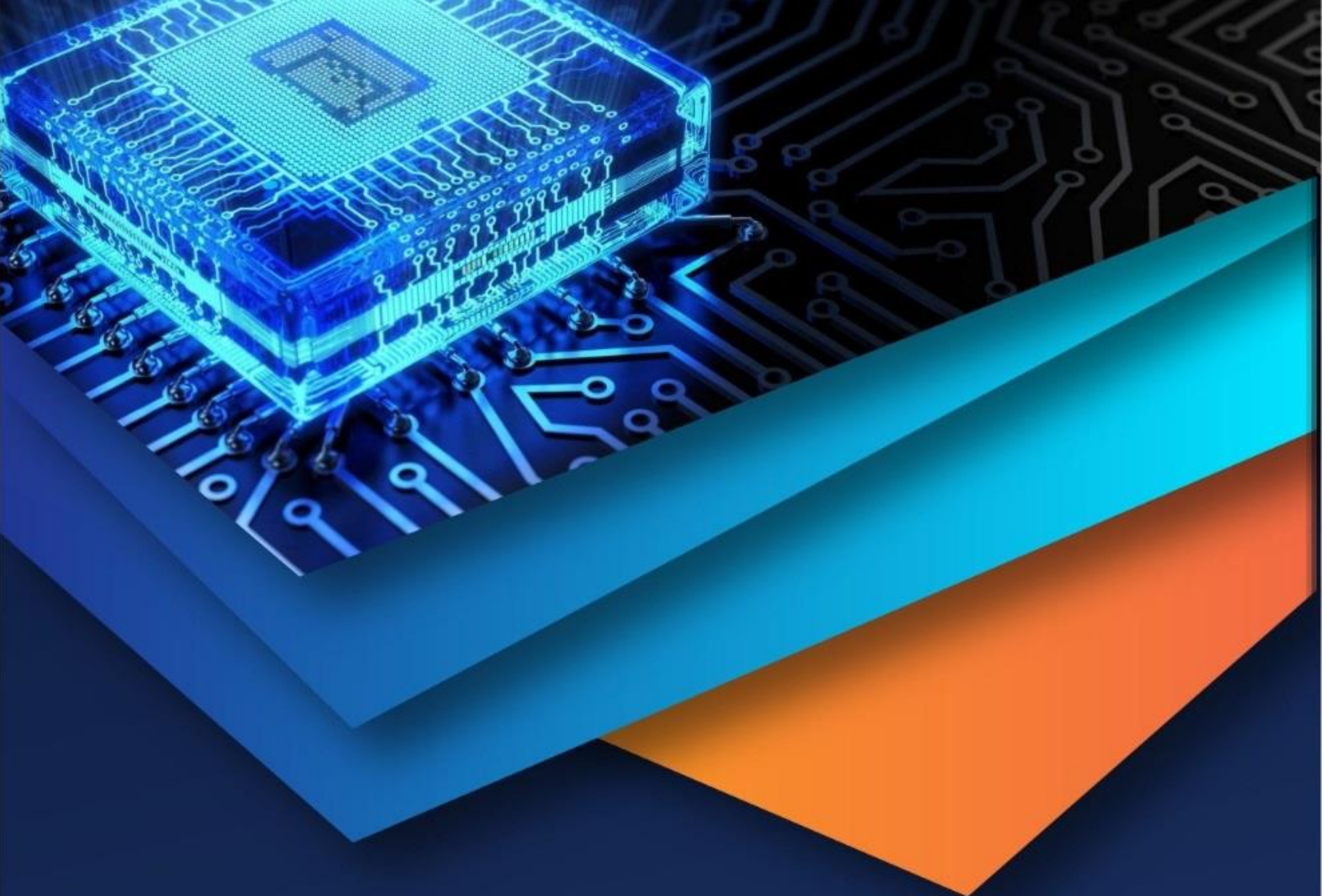

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