DEVELOPMENT OF SPECTRAL LIBRARY FOR TRACE DETECTION OF EXPLOSIVES USING HYPERSPECTRAL SENSOR

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ABSTRACT

Determining the traces of chemicals is an important factor for identifying the explosive materials which are in the form of improvised explosive devices (IED). Due to the national security the research community has escalated the research in the field of detection of explosives. However, little information is known about identifying traces of chemicals using hyperspectral imaging. It is a combination of spectroscopy and imaging technique which gives information about the spatial distribution and chemical properties of the objects. The study provides a fast, non-contact and non-destructive method using visible and near infrared (400-1000nm) hyperspectral imaging (VNIR-HSI) for trace detection of chemicals used as a part of IED. The various explosives used in the research for this purpose are ANFO, C4 and TNT. A spectral library of these chemicals along with the background material is built. Identification of the chemicals ANFO, C4 and TNT is achieved using a high sensitive model developed in this study which leads to insitu detection of explosives using VNIR-HSI.
Keywords: *Trace explosives, Visible Near Infrared, Hyperspectral Imaging, Spectral Library*

1. INTRODUCTION

The threat of explosive is increasing due to the large number of conflicts taking place across the world due to which there is increase in number of warzones. This is a serious issue that is affecting socio-economy of many countries like public security, unused arable land, closing of trade routes, isolation of villages. Such problems act as a hindrance in the development of the country as discussed in [1]. These problems motivate the government and research community to develop a technique for fast and accurate detection of explosives.

To minimize the risk of destruction and contamination of traces Hyperspectral imaging (HSI) is most suitable as it provides non-contact identification of evidence. HSI is an integration of spectroscopy and digital imaging technique to create three-dimensional data set containing both spatial and spectral information of the target. HSI was initially used for remote sensing applications utilizing satellite imaging data of the earth [2] but has since found application in such diverse fields as food science [3], pharmaceuticals [4] and medical diagnostics [5]. Hyperspectral images are analogous to a stack of images, each acquired at a narrow spectral band. Like spectroscopy, HSI can be applied in different parts of the electromagnetic spectrum, e.g. ultraviolet (UV), visible (VIS), near infrared (NIR), mid infrared (IR) or even the thermal infrared range.

HSI is advantageous over other techniques due its speed of data acquisition, reduction of human error, no destruction of traces, no specimen preparation, and the ability to illustrate the results. Chemicals like ammonium nitrate, tri nitro toluene, C4 are used as explosive material. Ammonium nitrate is one of most common fertilizer used for agriculture but a mixture of ammonium nitrate and fuel oil in the ratio of 94:6 results in an explosive which is used widely [6].

2. OBJECTIVE

The main objective of the study was to develop a hyperspectral imaging technique to determine the traces of chemicals used in explosives because this system can give spatial and spectral information about the target. This objective was achieved by developing a spectral library for the chemicals and the background materials from the acquired hyperspectral images. Information was distributed in large number of bands and had data redundancy thus a suitable preprocessing technique was applied to reduce data redundancy and noise in the hyperspectral images. Specific objective of the system was:

- Acquire hyperspectral image
- Preprocessing of image for noise removal
- Acquire pure spectral response
- Build spectral library

3. METHODOLOGY

3.1. Chemical Samples

A total of 30 samples of pure chemical were used in this study which includes 10 samples each of Ammonium nitrate (AN), Trinitrotoluene (TNT) and Cyclotrimethylene trinitamine (C4). All the samples were collected by Foundation Innovation for Happiness and was stored safely in the laboratory.

3.2. Hyperspectral Imaging System

Images were acquired using hyperspectral camera manufactured by BaySpec. The instrument has two sensors visible and near infrared which provides images over 144 spectral bands with a spectral resolution of about 4.2 nm over the spectrum of 400-1000nm. The chemical samples prepared were placed on black color platform to reduce to the reflectance from the background. The movement of the platform was controlled using a potentiometer attached to the motor. Technical specification of the hyperspectral camera is described in Table 3.1 and laboratory setup is shown in Figure 3.1. Two artificial light sources one halogen lamp of 60 W and one IR lamp of 60 W was placed in opposite direction at angle of 45 covering the spectrum from 400-1000nm as shown in Figure 3.3. The light sources were arranged in such a way that light intensity was uniformly distributed around FOV shown in Figure 3.2. Light intensity was measured in Lux using a luxmeter at 13 different points in the field of view. SpecGrabber software was used to control and capture the raw images and CubeCreator was used to process the raw images to create hyperspectral image in 144 bands.

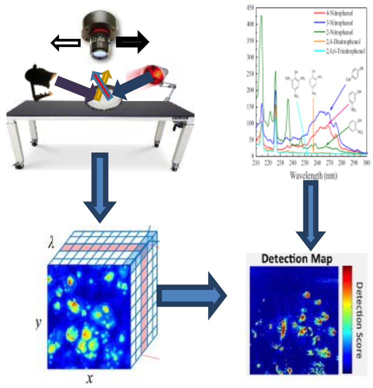

Figure 3.1: Graphical representation

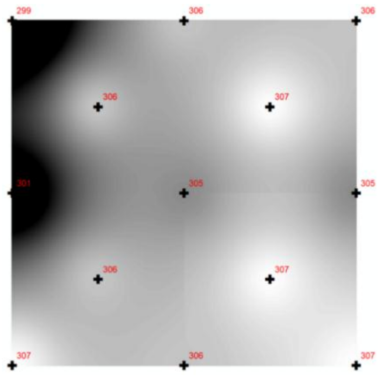

Figure 3.2: Distribution of light intensity

Scanning Technique	Push Broom
Field of View (FOV)	22°
Focal Length	16mm
Frame Per Second	45
Swath	15.4 cm*12.3 cm
Spatial Resolution	0.012 cm
Spectral Bands	144
Spectral Resolution	4.16
Height of Sensor	40 cm

Table 3.1: Sensor specifications

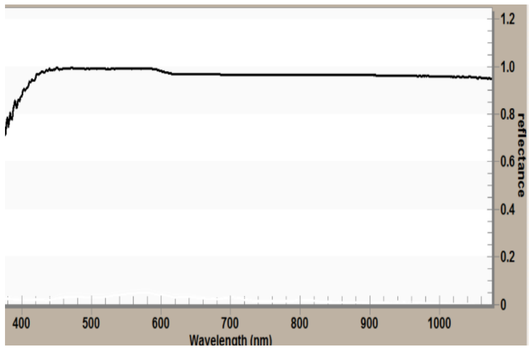

Figure 3.3: Spectrum of light source

3.2. Analysis of hyperspectral data and building spectral library

The hyperspectral cube created was analyzed on ENVI and IDL. To create the spectral reflectance and spectral library of various chemicals used in explosives following steps were carried out:

- Identification of chemicals on the platform
- Reflectance data was calculated
- Spikes or noises was removed by identifying the outliers
- Statistical analysis for each chemical sample

After processing the data spectral reflectance of each chemical samples and background material were calculated and saved as ASCII file format and *.lib format which was used as spectral library for explosives as shown in Figure 3.4. Such library will enable in prediction of spatial variation of traces of chemical in the scanned image.

4. RESULTS

All chemical samples were subjected to hyperspectral imaging. Raw spectrum was generated from the hyperspectral image which was later processed by removing the spikes and outliers to generate a processed spectrum as shown in Figure 4.1. The spectra of all three chemicals are different specially from 525nm – 975nm. The pure sample of TNT has lower reflectance throughout the spectrum as compared to pure ammonium nitrate and C4. TNT and C4 show similar peaks and falls in the spectral reflectance at 600nm, 725nm and 875nm due to the presence of NO_2. Whereas Ammonium nitrate can be distinguished between 600nm to 875nm as shown in Figure 4.2 because of constant rise in the spectral reflectance without any major peaks and falls as compared to C4 which also has lower reflectance. Ammonium nitrate can also be distinguished at 925 nm when there is a major fall in the reflectance. Further this library of explosives can be used for performing image classification and classifying the object in explosive and non-explosive.

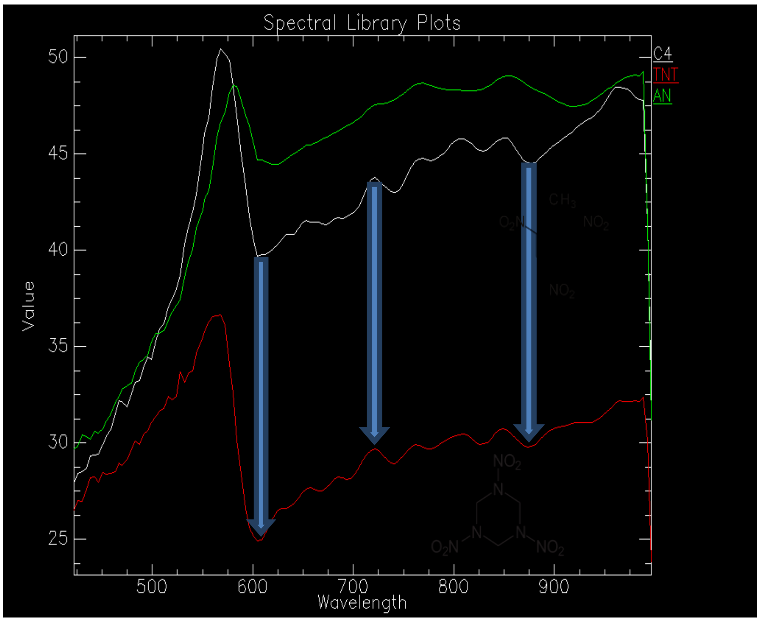

Figure 4.1: Processed spectral reflectance

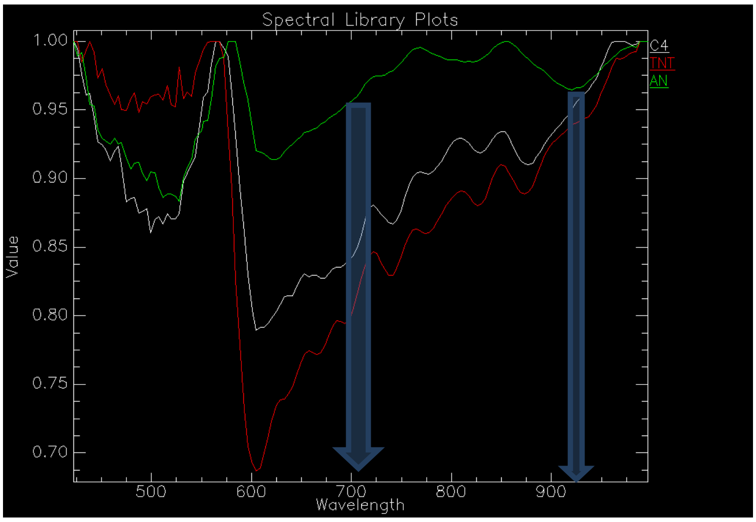

Figure 4.2: Normalized spectral reflectance

5. CONCLUSION AND DISCUSSION

The research was carried out to study the capability of the hyperspectral imaging system for trace detection of chemical by building a spectral library of the chemicals used in the explosives along with the background materials. Hyperspectral imaging system used in this study was a combination of digital imaging and spectroscopy which gives information regarding spatial distribution and properties of the chemicals. HSI is used increasingly in many applications but due to push broom scanning the system face a technical challenge like signal disturbance due to the relative movement between imaging platform and samples. But still the system is a promising tool for trace detection of chemicals because this technology is fast, non-contact nondestructive and presents advantage of remote and real-time measurements.

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