A

Project Report

On

"Digital Image Processing & Analysis of Planetary Datasets"

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ABSTRACT

Science and Technology have shaped human life and culture in unimaginable ways. Men have always been intrigued by the various planetary bodies like Sun, Moon and Mars. Planetary Science deals with studying various planets to increase the understanding of the universe, solar system and how it all started. The project “Digital Image Processing & Analysis of Planetary Datasets” is a research-based project which contributes to mineral exploration, crater detection and various features of planetary bodies.

To aid this task an easy to use tool “Hyper Image Analyser” is developed for viewing hyperspectral images and plotting various reflectance spectrum for mineral and crater study. Hyperspectral images are obtained from various space agencies like NASA, ISRO, etc. These images contain more information than a normal photograph which is helpful for the study. This tool also gives various mathematical and statistical outputs to help scientists and analysts. It also comes with an in-built spectral library which contains reflectance spectrums of various minerals found on earth and other planetary bodies.

This way Hyper Image Analyser will help our scientists and in turn our nation to flourish even more and increase human understanding of the universe. This is my way to give something useful and powerful back to the hard-working government, nation and universe.

ACKNOWLEDGEMENT

No project or an innovative step to solving a real-life problem can stand without any support and guidance, and same is the case with this one. It is not a single-handedly completed project but it is a cooperative and correlative teamwork of many hands together.

We would first thank from the core of our heart to the Dean of Physical Research Laboratory **Prof. Janardhan Padmanabhan** and also Head, Academic Services **Dr. Bhushit Vaishnav** for giving us an opportunity for doing the project training at Physical Research Laboratory one of the top government research institutes and allowed us to contribute something back to the society. It is our honour to acknowledge the sincere help and guidance which we received.

We joint handed bow and gratify our Project Guide **Dr. Neeraj Srivastava** for his support, input and sincere guidance. His all-time readiness to understanding the problems faced by us and solving it is truly unforgettable. The confidence which he has poured confidence in the project has not only enhanced our professional and technical skills but also enabled us to become more competitive in this field. He was always inspiring us to try new things and experimenting with it to perform new possibilities. He has provided a constant and valuable guidance to represent our ability when we face any kind of problem at each and every stage of the project.

TABLE OF CONTENT

List of Figures

List of Abbreviations

DIP	Digital Image Processing
NASA	National Aeronautics and Space Administration
ISRO	Indian Space Research Organization
PRL	Physical Research Laboratory
JPL	Jet Propulsion Laboratory
ENVI	Environment for Visualizing Images
IDL	Interactive Data Language
GIS	Geographic Information System
EMR	Electromagnetic Radiation
GRAIL	Gravity Recovery and Interior Laboratory
MRO	Mars Reconnaissance Orbiter
MOM	Mars Orbiter Mission
PDS	Planetary Data System
VIS	Visible
NIR	Near Infrared
PCA	Principal Component Analysis
MNF	Minimum Noise Fraction
MGM	Modified Gaussian Method
ROI	Region of Interest
ASCII	American Standard Code for Information Interchange
RGB	Red, Green & Blue Color Model
DN	Digital Number
GUIDE	GUI Development Environment
CRISM	Compact Reconnaissance Imaging Spectrometer
M3	Moon Mineralogy Mapper
HiRISE	High Resolution Imaging Science Experiment
Mg	Magnesium
Fe	Iron
Ca	Calcium

CHAPTER 1

INTRODUCTION

1.1 PROJECT OVERVIEW

The project "Digital Image Processing and Analysis of Planetary Datasets" comprises of multiple fields of application and research like Digital Image Processing, Planetary Remote Sensing and Data Analysis & Interpretation.

Remote sensing, in the simplest words, means obtaining information about an object without being in contact with the object itself. It has two facets: the technology of acquiring data through a device which is located at a distance from the object, and analysis of the data for interpreting the physical attributes of the object, both these aspects being intimately linked with each other. Remote sensing has evolved primarily from the techniques of aerial photography and photo interpretation. It is a relatively young scientific discipline and is an area of emerging technology that has undergone phenomenal growth during the last nearly five decades. It has dramatically enhanced man’s capability for resource exploration, mapping and monitoring of various planetary bodies. For planetary science, remote sensing seeks to acquire data remotely, to develop information about planets and moons in our solar system. A variety of sensors onboard satellites and spacecraft gather data about the planets. Remote sensing has allowed us to see through the clouds of Venus, minerals and elements on Mars and through the oceans of Earth.

Digital image processing deals with the manipulation of digital images through a digital computer. It is a subfield of signals and systems but focuses particularly on images. DIP focuses on developing a computer system that is able to perform processing on an image. The input of that system is a digital image and the system process that image using efficient algorithms, and gives an image as an output. The most common example is Adobe Photoshop. It is one of the widely used applications for processing digital images. In this project, we will be working on hyperspectral images acquired from various space missions of NASA and ISRO.

A normal photograph is acquired using a single wavelength whereas a Hyperspectral image is acquired in hundreds of narrow, contiguous band passes on a regular spatial grid over a target area. They have long been utilized in planetary science astronomy for remote geochemical analyses. Typical hyperspectral imagery spans the visible to near-and-thermal-infrared wavelengths, sufficient to resolve the discriminating spectral features of the surface, near-surface compounds and sub-surface chemistry.

Like humans have a unique fingerprint, every mineral has its own unique hyperspectral signature. This signature is helpful in mineral exploration remotely. Also, we will be able to study various craters on the surface of the moon, to study its size, age and composition. This information will be helpful for future space mission and understanding geology and morphological features.

To sum it up, we will analyze and process hyperspectral images obtained from various space missions to acquire information about craters and minerals, which will be helpful to understand planetary bodies and universe better.

1.2 MOTIVATION

Trillions of images of planetary surfaces are captured daily by optical cameras onboard various planetary missions. Extractions of the necessitate information from images require an application of suitable image processing techniques. The future of planetary science depends highly on availability and interpretation of these images. The quality of the images is dependent on the instrument that was being been used for the mission. We can increase efficiency by applying certain image processing techniques and logically defining the system to make the best out of the available data. Therefore, detection of craters and finding correct minerals from these craters is essential for well-informed and reliable decision-making. With the constant advancement of software engineering and innovation, image preparing and investigation progressively framed the logical framework, thus do the computerized picture handling. Advanced media picture is broadly utilized as a part of the general public, for example, instruction, ad, video, film, etc. [3].

Some recent work proposed different techniques but most of them have a limitation about detecting fresh craters and identify correct minerals from these craters. So proposed technique tries to increase the capacity of detecting mineral mixtures and crater information from hyperspectral images of a planetary body and modify the existing techniques for mineral detection.

1.3 SCOPE & OBJECTIVE OF RESEARCH

Digital Image Processing can be applied to any type of digital image data set and help in deriving relevant knowledge from it. The scope of the remote sensing is quite wide. It can be used to form a geographic information system. Hyper Image Analyser is easy to use and can help in analyzing the images and generating spectrum on one click. The findings can further be used for research and mission in future. It will be a major contribution to the human pool of knowledge.

Mineral exploration is an important agenda for the study of any planetary body. It can be achieved using a conglomerate of various image processing and data interpretation techniques. Hyperspectral image processing for planetary surfaces is the main focus of this project. Many minerals can be detected using the spectrum generated from the hyperspectral images captured by the various instruments used on space missions. Also, we will be detecting craters on the surface of a planetary body and study its properties. Hence, for accurate detection of minerals and craters, improving the image quality is necessary. For higher accuracy, we will not use raw data, rather we use calibrated and corrected data provided by agencies.

Studies inside craters provide a clear window to study the deeper crustal regions and exposed mantle rocks e.g. on the central peaks and rims of the craters. So these hyperspectral images and results interpreted form these are now the only possible source to study geomorphology as well as the mineralogical studies on the moon. The study of moon and mars can be very helpful in understanding the evolution of Earth and its chemical composition.

CHAPTER 2

LITERATURE REVIEW & ANALYSIS

2.1 STUDY OF EXISTING SYSTEM

There are various industry level tools which we learned to get a proper understanding of the functionalities and features they provide. Existing software studied are ENVI, ERDAS and ArcGIS.

2.2 REVIEW OF LITERATURE & FINDINGS

2.2.1 Planetary Geology

Planetary geology is the study of surface and interior processes on solid objects in the solar system: planets, satellites, asteroids, comets, and rings. It is a particularly appropriate subject for inclusion in a text on remote sensing, as the vast majority of our current knowledge on the geology of solar system objects has been derived from remote sensing measurements. These measurements have been obtained either using ground-based or Earth-orbital telescopes or robotic space probes equipped with sophisticated cameras or spectrometers. The exceptions are our detailed knowledge of several regions of the Moon from the samples returned by the Apollo and Luna missions and the inferences gleaned on the composition and evolution of the early solar system provided by meteorites and cosmic dust samples.[4]

2.2.2 Relevance of Planetary Geology

Why is it important to study the geology and surface processes of other objects in the solar system? There are several important reasons. The first reason involves the quest for knowledge. The hallmark of human nature is to explore the unknown and to push the limits of the available technology in this quest. The exploration of the solar system, including the important task of characterizing the current physical, chemical, and morphologic state of planets, satellites, etc. (hereafter simply referred to as "planetary surfaces"), is an extension of humanity's exploration of the Earth and represents an exciting, educational, and fulfilling endeavour in which everyone can participate.

The second reason involves evolution, not necessarily in the biologic sense but in the sense of the physical and chemical evolution of the solar system over time. How did planets form? What was the early solar system like? Why have some objects changed dramatically over time? Planetary geology includes an assessment of the past state of the solar system, for example as preserved in the ancient, scarred surfaces of objects like the Moon and asteroids, or in the enigmatic polar layered deposits on Mars.

The third, and perhaps most important, a reason to study planetary geology is comparative planetology, or the ability to understand processes on or the evolution of one solar system object, frequently the Earth, through comparisons to others. The solar system encompasses a wide diversity of objects, and these objects often allow for very informative "control experiments" to be carried out. For example, in terms of bulk size and density, Earth and Venus are very similar planets, yet the current and past evolution of the surfaces of these two bodies are vastly different. Studies of the physical and radiative properties of dust in the Martian atmosphere formed the basis of initial calculations on the effects of impact- or nuclear-generated dust and smoke in the Earth's atmosphere. Understanding of the processes involved in the formation of the lunar crust is routinely applied to try to understand the surface composition of Mercury. Many such examples demonstrate the often unexpected utility of comparative planetology toward understanding processes and landforms in the solar system that are often a strong function of environmental conditions (gravity, temperature, atmospheric pressure, etc.).[4]

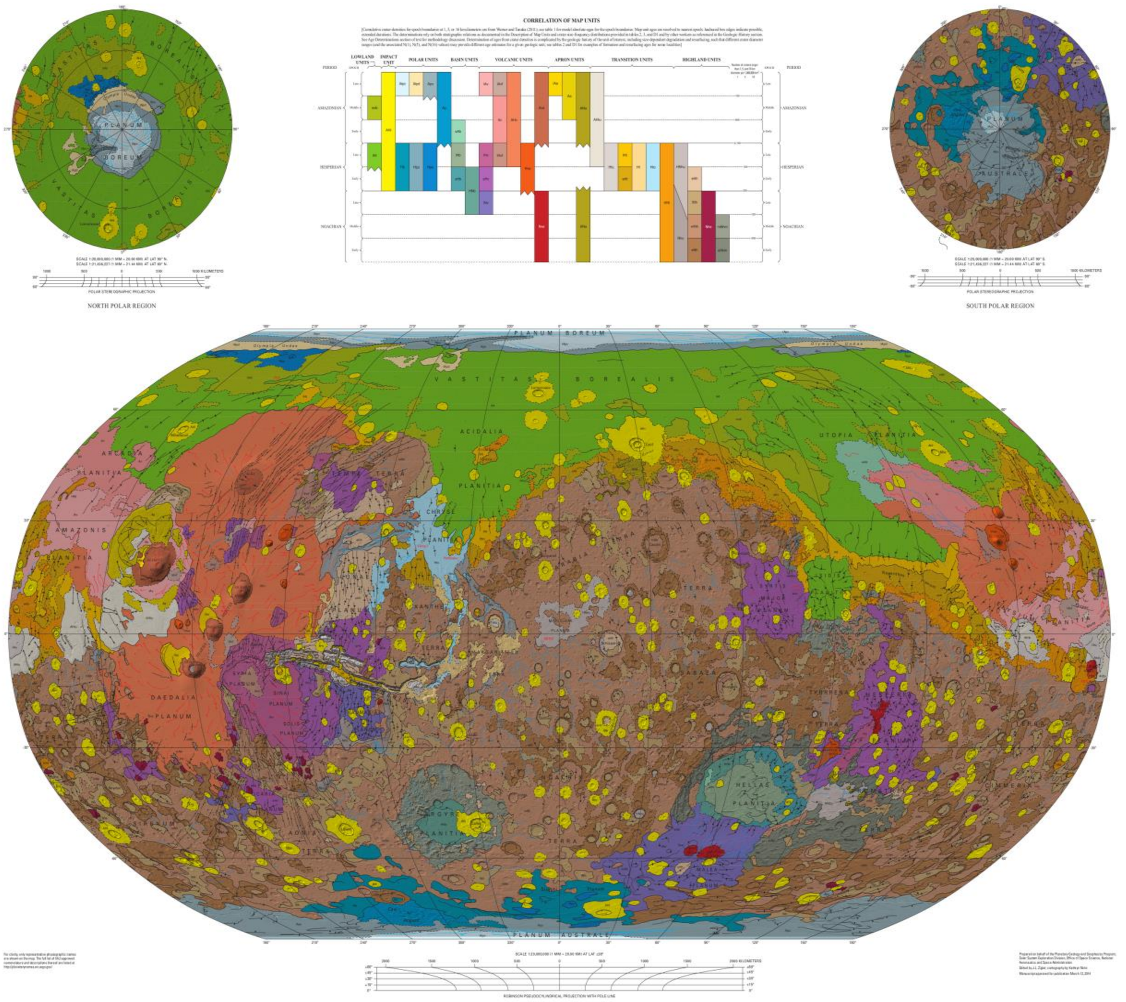


Fig 2. 1 Geologic Map of Mars

2.2.3 Planetary Remote Sensing System

Remote sensing is the process of obtaining information about an object without actually coming in contact with that object. The human eye is a remote-sensing device, and so is the ear. In planetary science, a variety of sensors onboard satellites and spacecraft gather data about the planets. Visible light, a particular wavelength range of electromagnetic radiation, passes over a distance until it encounters and is captured by sensors — your eyes — which then send a signal to a processor — your brain. The human sensory organs gather their awareness of the external world by perceiving signals. You hear disturbances in the atmosphere carried as sound waves, experience the sensation of heat, react to chemical signals from food through smell, and recognize the shape, colour, size, and position of objects by means of the visible light coming from them. Sensations that are not received through direct contact are remotely sensed.

For the study of planetary geology, remote sensing seeks to acquire data remotely, to develop information about planets and moons in our solar system. [6]

Different objects in the universe reflect or emit different amounts of energy in different bands of the electromagnetic spectrum. The amount of energy reflected or emitted depends on the properties of both the material and the incident energy (angle of incidence, intensity and wavelength). Detection and discrimination of objects or surface features are done through the uniqueness of the reflected or emitted electromagnetic radiation from the object. A device to detect this reflected or emitted electromagnetic radiation from an object is called a “sensor” (e.g., cameras and scanners). A vehicle used to carry the sensor is called a “platform” (e.g., aircraft and satellites).

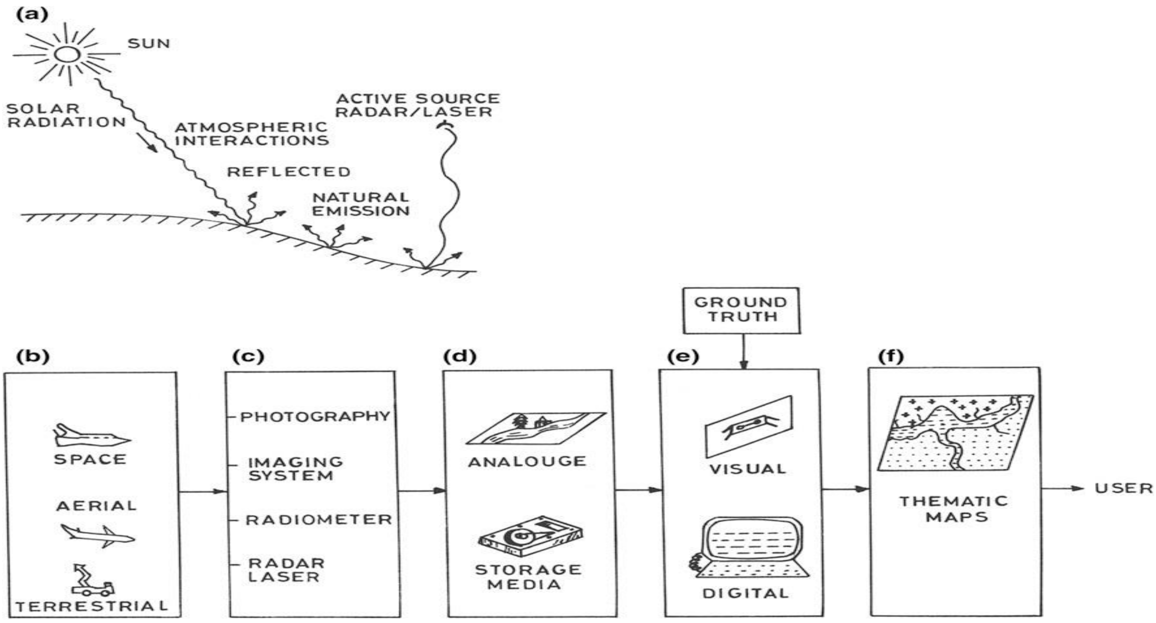


Fig 2. 2 Typical Remote Sensing Programme

(a) Sources of radiation and interaction (b) Platforms (c) Sensors (d) Data products

(e) Interpretation and analysis (f) Output

[2]

Main stages of remote sensing are the following.

A. Emission of electromagnetic radiation.

B. Transmission of energy from the source to the object.

C. Interaction of EMR with the object and subsequent reflection and emission.

D. Transmission of energy from the object to the sensor.

E. Recording of energy by the sensor.

F. Transmission of the recorded information to the ground station.

G. Processing of the data into digital or hard copy image.

H. Analysis of data.

Remote-sensing satellites collect data either "actively" or "passively" depending on the source of electromagnetic energy. In the case of passive remote sensing, the source of energy is naturally available such as the Sun. Most of the remote sensing systems work in passive mode using solar energy as the source of EMR. Solar energy reflected by the targets at specific wavelength bands are recorded using sensors onboard air-borne or spaceborne platforms. In the case of active remote sensing, energy is generated and sent from the remote sensing platform towards the targets. The energy reflected back from the targets are recorded using sensors onboard the remote sensing platform. Most of the microwave remote sensing is done through active remote sensing. As a simple analogy, passive remote sensing is similar to taking a picture with an ordinary camera whereas active remote sensing is analogous to taking a picture with a camera having a built-in flash. (7)

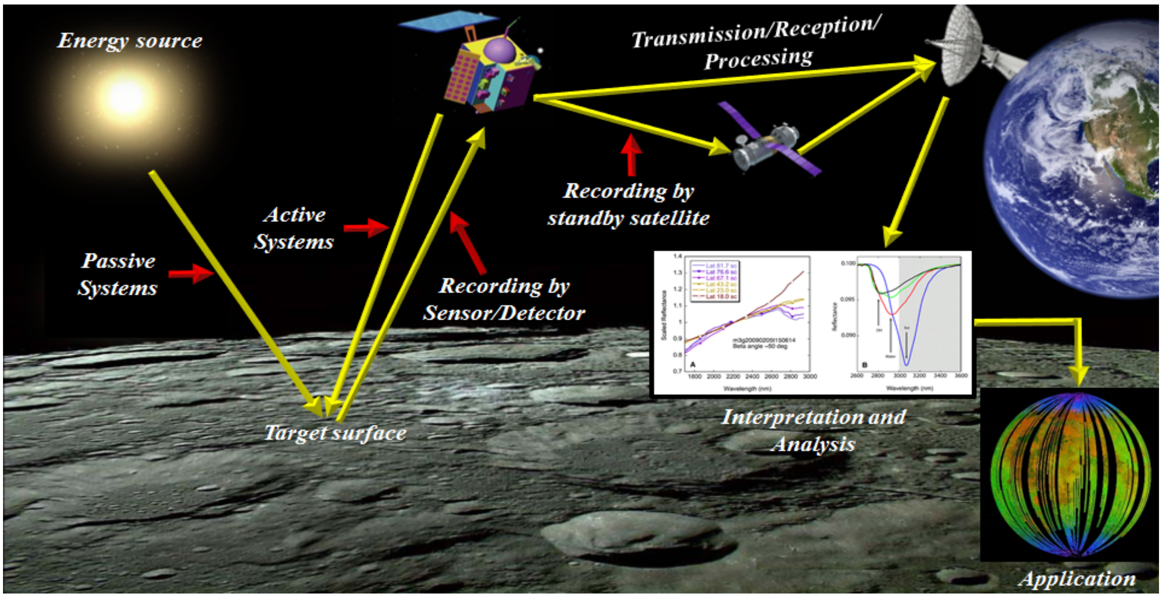


Fig 2. 3 Planetary Remote Sensing System

2.2.4 Planetary Remote Sensing Techniques

I. **Choice of Wavelength Regions for Planetary Applications**:

Remote sensing observations for the study of planetary geology span a wide variety of interests and applications. The specific object being observed or goal being addressed drives the choice of which region of the electromagnetic spectrum is appropriate. For example, surface mineralogy can be investigated using spectroscopy from the visible to infrared, because many minerals exhibit diagnostic absorption and emission features at these wavelengths. Geomorphologic information can result from broadband visible orbital imaging in the case of planets with thin to non-existent atmospheres.

II. **Spectroscopy:** Spectroscopic remote sensing observations can provide substantially more diagnostic compositional and mineralogical information on planetary surfaces than imaging alone. Essentially three types of spectroscopic observations can be obtained: X-ray and gamma-ray spectra, reflectance spectra, and thermal emission spectra.

Reflectance spectroscopy provides diagnostic information on the mineralogy and degree of crystallinity of the uppermost few microns of a planetary surface. This technique involves measuring the spectrum of sunlight reflected from a planetary surface, and is thus restricted to the wavelength range where the Sun's flux is highest and where the amount of energy reflected from the object is greater than the amount that is thermally emitted (the typical wavelength range is from 0.3 to 3.5 um). Reflectance spectra reveal absorption features that are characteristic of certain minerals and ices and/or indicate the presence of certain cations. For example, the mineral pyroxene, a common component of basaltic rocks on the Earth, can be detected remotely by the measurement of diagnostic absorption features near 1.0 and 2.0 um. Variations in the abundances of Fe and Ca in the pyroxene also be inferred based on subtle shifts in the positions of these bands. Reflectance spectroscopy is currently the most useful technique for remotely measuring the mineralogy of planetary surfaces, and specific minerals have been identified on the Moon, Mars, and a number of asteroids. [4]

2.2.5 Concept Of Signature

Electromagnetic radiation when incident on a surface, either gets reflected, absorbed, re-radiated or transmitted through the material depending upon the nature of the object and the wavelength of the incident radiation

Since the nature of the interaction of the electromagnetic radiation with an object depends on it cumulative properties, the study of these interactions can lead to an understanding of the objects under observation. In remote sensing, the basic property which allows identification of an object is called signature. In general parlance, the concept of signature in remote sensing is similar to how you are identified at the bank with your signature or fingerprint for transaction or identification purposes. In general, any set of observable characteristics, which directly or indirectly leads to the identification of an object and/or its condition is termed as a signature. Spectral, spatial, temporal and polarisation variation are four major characteristics of the targets which facilitate discrimination.

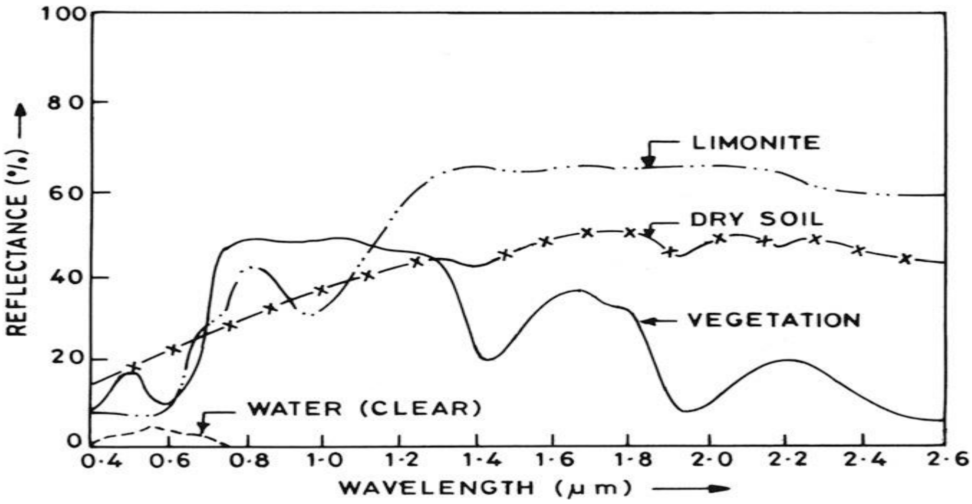


Fig 2. 4 Spectral Reflectance Curves of three different targets

Spectral variations are the changes in the reflectance or emittance of objects as a function of wavelength. Colour of objects is a manifestation of spectral variation in reflectance in the visible region. Spatial arrangements of terrain features providing attributes, such as shape, size and texture of objects which lead to their identification are termed as spatial variations. The reflectance of the object is different when it is hit by a different wavelength. Using this we can develop a hyperspectral signature based on reflectance value and use it to explore and identify minerals. [1][2]

2.2.6 Mission Studies

GRAIL

The Gravity Recovery and Interior Laboratory, or GRAIL, the mission was designed to create the most accurate gravitational map of the moon to date, which when combined with topographic data, can provide insight into the moon's internal structure, composition and evolution. It is a dual-spacecraft effort designed to determine the structure of the lunar interior and to advance understanding of the thermal evolution of the Moon.

By very precisely measuring the distance of one orbiter relative to the other, the orbital perturbations caused by the Moon could be observed. Combining this with the orbiter position as determined from Earth-based observations, the mass distribution on the Moon could be determined.

Launch Date: 10 September 2011 Both GRAIL spacecraft (GRAIL-A and GRAIL-B)

Launch Vehicle: Delta II

Launch Site: Cape Canaveral, United States

Mass: 132.6 kg

Accomplishments:

The twin GRAIL probes orbiting Earth's moon generated the highest resolution gravity field map of any celestial body. The gravity field map revealed an abundance of features never before seen in detail, such as tectonic structures, volcanic landforms, basin rings, crater central peaks and numerous simple, bowl-shaped craters. Data also show the moon's gravity field is unlike that of any terrestrial planet in our solar system. The map will provide a better understanding of how Earth and other rocky planets in the solar system formed and evolved.

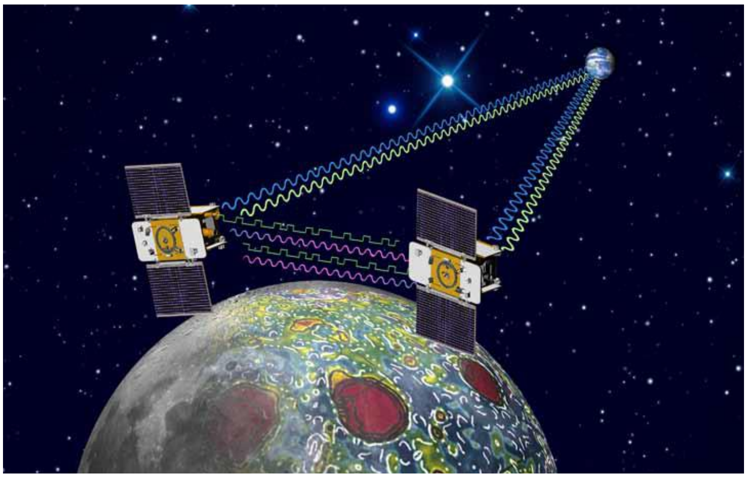


Fig 2. 5 GRAIL

Mars Reconnaissance Orbiter

NASA's Mars Reconnaissance Orbiter, launched August 12, 2005, is on a search for evidence that water persisted on the surface of Mars for a long period of time. While other Mars missions have shown that water flowed across the surface in Mars' history, it remains a mystery whether water was ever around long enough to provide a habitat for life. In its survey of the red planet, the MRO is increasing tenfold the number of spots surveyed close-up. One of the orbiter's cameras is the largest ever flown on a planetary mission. Though previous cameras on other Mars orbiters could identify objects no smaller than a school bus, this camera can spot something as small as a dinner table. That capability has allowed the orbiter to identify obstacles such as large rocks that could jeopardize the safety of landers and rovers, including the Phoenix mission and Mars Science Laboratory mission. Its imaging spectrometer looks at small-scale areas about five times smaller than a football field, a scale perfect for identifying any hot springs or other small water features.

Launch Date: August 12, 2005

Launch Vehicle: Atlas V

Launch Site: Cape Canaveral, United States

Mass: 2180 kg

Goals:

- Determine Whether Life Ever Arose on Mars
- Characterize the Climate of Mars
- Characterize the Geology of Mars
- Prepare for Human Exploration

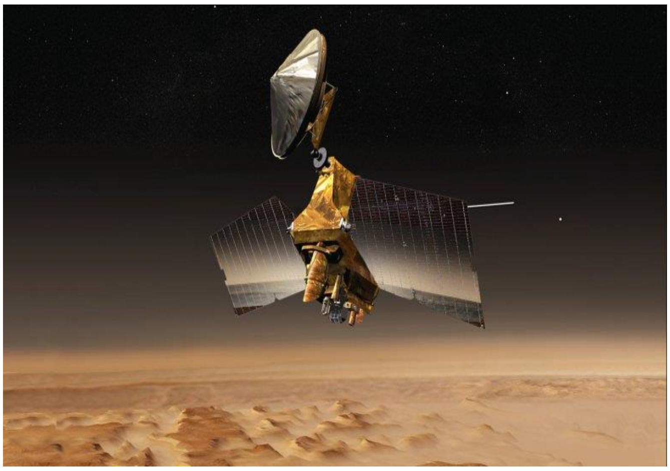


Fig 2. 6 MRO

Chandrayaan - 1

The idea of undertaking an Indian scientific mission to Moon was initially mooted in a meeting of the Indian Academy of Sciences in 1999 that was followed up by discussions in the Astronautical Society of India in 2000. Based on the recommendations made by the learned members of these forums, a National Lunar Mission Task Force was constituted by the Indian Space Research Organisation (ISRO). Leading Indian scientists and technologists participated in the deliberations of the Task Force that provided an assessment on the feasibility of an Indian Mission to the Moon as well as dwelt on the focus of such a mission and its possible configuration. Subsequently, Government of India approved ISRO's proposal for the first Indian Moon Mission, called Chandrayaan-1 in November 2003.

The Chandrayaan-1 mission performed high-resolution remote sensing of the moon in visible, near infrared (NIR), low energy X-rays and high-energy X-ray regions. One of the objectives was to prepare a three-dimensional atlas (with high spatial and altitude resolution) of both near and far side of the moon. It aimed at conducting chemical and mineralogical mapping of the entire lunar surface for distribution of mineral and chemical elements such as Magnesium, Aluminium, Silicon, Calcium, Iron and Titanium as well as high atomic number elements such as Radon, Uranium & Thorium with high spatial resolution.

Launch Date: 22 October 2008
Launch Vehicle: PSLV - C11
Launch Site: SDSC SHAR Centre, Sriharikota, India
Mass: 1380 kg

Fig 2. 7 Chandrayaan-1

Mars Orbiter Mission

Mars Orbiter Mission also called as "Mangalyaan" is India's first interplanetary mission and ISRO has also become the fourth space agency to reach Mars, after the Soviet space program, NASA, and the European Space Agency. It is the first Asian nation to reach Mars orbit, and the first nation in the world to do so in its first attempt. It has an orbiter craft designed to orbit Mars in an elliptical orbit. The Mission is primarily technological mission considering the critical mission operations and stringent requirements on propulsion and other bus systems of spacecraft. It has been configured to carry out observation of physical features of mars and carry out limited study of Martian atmosphere

The scientific objectives deal with the following major aspects:

- Exploration of Mars surface features by studying the morphology, topography and mineralogy
- Study the constituents of Martian atmosphere including methane and CO_2 using remote sensing techniques
- Study the dynamics of the upper atmosphere of Mars, effects of solar wind and radiation and the escape of volatiles to outer space

The mission would also provide multiple opportunities to observe the Martian moon Phobos and also offer an opportunity to identify and re-estimate the orbits of asteroids seen during the Martian Transfer Trajectory.

Launch Date: 5 November 2013

Launch Vehicle: PSLV - C25

Launch Site: SDSC SHAR Centre, Sriharikota, India

Mass: 1337 kg

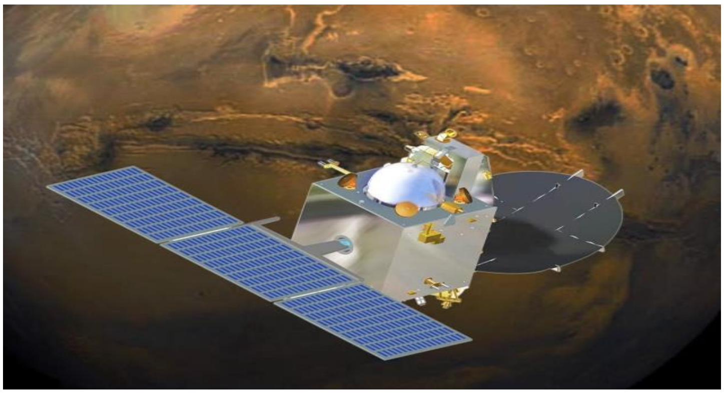


Fig 2. 8 Mangalyaan

2.2.7 Planetary Data System

NASA's Planetary Data System (PDS) is a federation of 'discipline nodes,' each specializing in a subset of planetary science such as geosciences, atmospheres, and planetary rings. PDS has been operational for more than two decades, most of that time in its version 3 (PDS3). A lot has changed since PDS3 was introduced; PDS version 4 (PDS4) has been developed to bring both the archiving process and use of the archived data into the modern era.

Standards lie at the heart of information transfer and interoperability. They provide the framework within which we browse the web, make online purchases, and even open and print this document. PDS standards ensure consistent description of planetary science data so that data providers1, programmers, and end-users all know what to expect when creating and working with PDS files. Standards also guarantee that the data collected and archived today will still be readable and usable generations from now — a long-term return on today's investments made in flying planetary spacecraft and funding ground-based planetary research.

Fig 2. 9 PDS4 Logo

When a data provider first contacts PDS, one of the discipline nodes will be assigned as the principal, or consulting, node for the mission, instrument, or project. A large mission may have different consulting nodes for different groups of instruments; when this happens, one discipline node will be designated as the lead node.

The consulting node provides basic training, copies of standards documents and tutorials, development materials, and advice throughout the archive development effort. As the archive is being designed, the consulting node recommends additional information, over and above the observational data, which should be included — calibrations, documentation, etc. When data production starts, the consulting node provides validation support for standards compliance and conducts an external peer review of data submitted; it then monitors archive quality through final delivery. [17]

2.2.8 Digital Image Processing

An image may be defined as a two-dimensional function, f(x, y), where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of coordinates (x, y) is called the intensity or gray level of the image at that point. When x, y, and the amplitude values of f are all finite, discrete quantities, we call the image a digital image. The field of digital image processing refers to processing digital images by means of a digital computer. Note that a digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are referred to as picture elements, image elements, pels, and pixels. Pixel is the term most widely used to denote the elements of a digital image. [8]

The digital image processing deals with developing a digital system that performs operations on an digital image. Digital image processing focuses on two major tasks – Improvement of pictorial information for human interpretation – Processing of image data for storage, transmission and representation for autonomous machine perception Some argument about where image processing ends and fields such as image analysis and computer vision start The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes

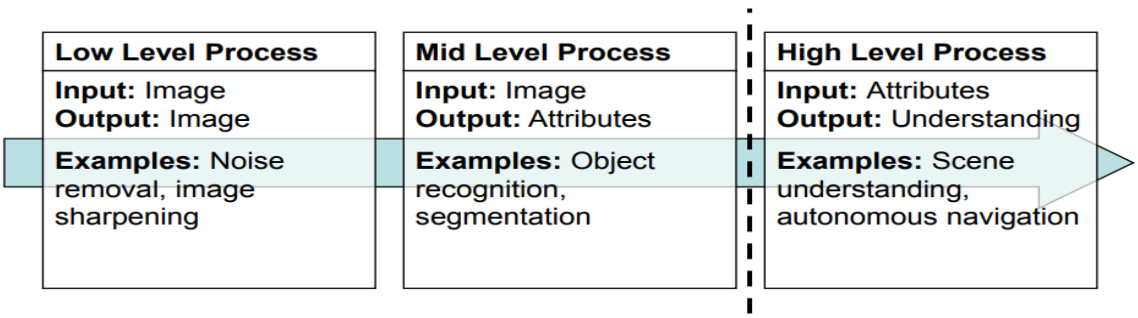


Fig 2. 10 Typical Digital Image Processing Processes

Some of the major fields in which digital image processing is widely used are mentioned below

- Image sharpening and restoration
- Medical field
- Remote sensing
- Transmission and encoding
- Machine/Robot vision
- Color processing
- Pattern recognition
- Video processing
- Microscopic Imaging

2.2.9 Principal Component Analysis

Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components.

In planetary remote sensing, we use the PCA to select the best bands for classification, analyse their contents, and evaluate the correctness of classification obtained by using PCA images. The principal component analysis has been used in remote sensing for different purposes. Most of the research explores ways of obtaining effective multispectral image classification, while the study of PCA performance and its improvement has been limited.

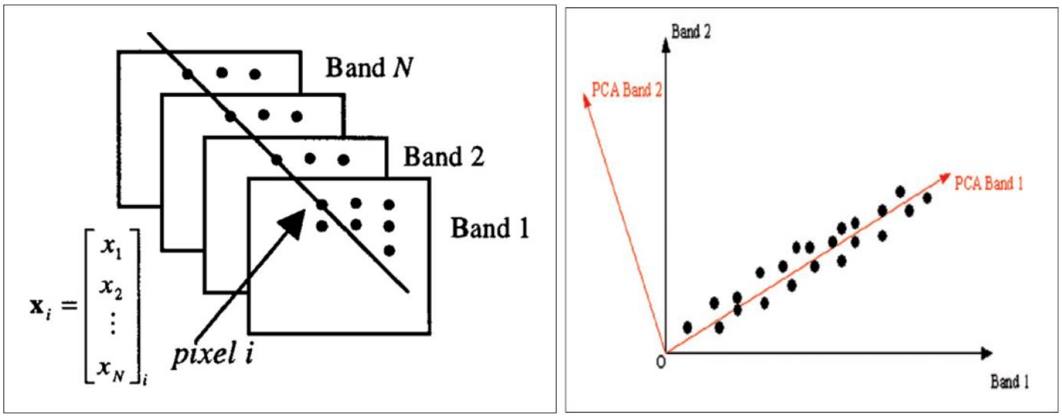


Fig 2. 11 Mathematical Representation of PCA

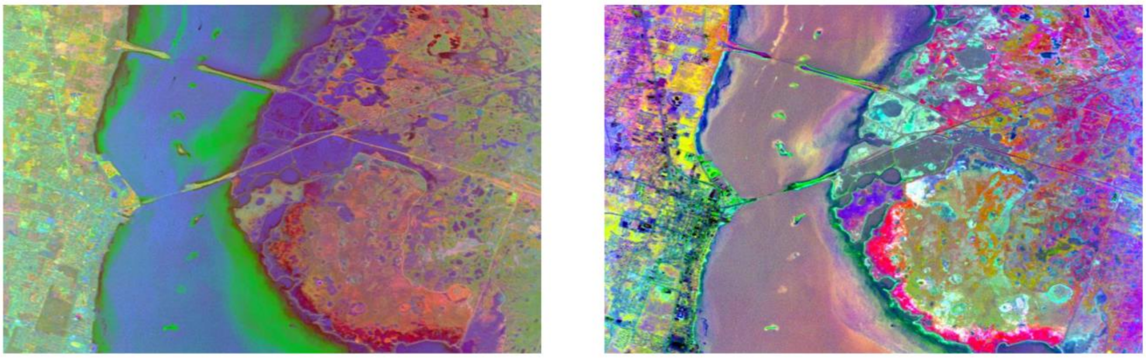
The principal component analysis is based on the fact that neighbouring bands of hyperspectral images are highly correlated and often convey almost the same information about the object. The analysis is used to transform the original data so to remove the correlation among the bands. In the process, the optimum linear combination of the original bands accounting for the variation of pixel values in an image is identified. The PCA employs the statistic properties of hyperspectral bands to examine band dependency or correlation. It is based on the mathematical principle known as eigenvalue decomposition of the covariance matrix of the hyperspectral image bands to be analysed.

The algorithm of PCA used in the project will be explained later in the report.

2.2.10 Minimum Noise Fraction

Multispectral and Hyper spectral remote sensing image consists of data in which vector components are arranged to form an image. The vector components do not contain completely independent information they are correlated to some extent. That means that variations in the brightness in one band may be mirrored by similar variations in another band (for example, when the brightness of a pixel in band 1 is high, it is also high in band 3)[14]. From a signal processing view, this correlation results in two undesirable effects. First, there is unnecessary redundancy which increases the data-processing cost without providing more information. Second, the data set includes both information and noise, and the noise content is relatively higher in these high-dimension data sets[14]. In remote sensing in order to increase the image quality main aim is to reduce the dimensionality of the data and remove the noise.

Minimum noise fraction (MNF) transformation is used to reduce the dimensionality of the hyperspectral data by segregating the noise in the data. The MNF transform is a linear transformation which is essentially two cascaded Principal Components Analysis (PCA) transformations. The first transformation decorrelates and rescales the noise in the data. This results in transformed data in which the noise has unit variance and no band to band correlations. The second transformation is a standard PCA of the noise-whitened data. The second rotation uses the principal components derived from the original image data after they have been noise-whitened by the first rotation and rescaled by the noise standard deviation. Since further spectral processing will occur, the inherent dimensionality of the data is determined by examining the final eigenvalues and the associated images. You can divide the data space into two parts: one part associated with large eigenvalues and coherent eigen images, and a complementary part with near-unity eigenvalues and noise-dominated images. Using only the coherent portions separates the noise from the data, thus improving spectral processing results.



Eigenvectors 1, 2, & 3 of MNF Transform Data *Eigenvectors 6, 9, & 12 of MNF Transform Data*

Fig 2. 12 MNF Transform Data

2.2.11 Curve Fitting

Curve Fitting is performed for the purpose of interpreting remote-sensing spectra of planetary bodies – though many of the methodological points are equally applicable to any other spectrum or curve one might want to fit. Curve fitting is necessary for finding out the band centres which are important for mineral identification. Finding the centres using the original dataset may be erroneous since the measured data points are discrete values. In order to successfully curve-fit spectra of solid minerals, a certain amount of a priori knowledge is required of spectroscopy, mineralogy, and the basics of curve fitting mathematics. Researchers use varying combinations of techniques to derive qualitative or quantitative information from spectra, e.g., curve matching, curve deconvolution, and empirical curve fitting. The following are the metrics which are used for understanding the nature of spectra.

Band Minima: Denotes the wavelength or energy of the position of lowest reflectance over a specified wavelength interval, derived from a spectrum that has not had its imposed continuum removed. The minimum wavelength position for any absorption or band minima is the most universally applicable metric as it is measured from existing spectra unaltered by removal of an imposed or apparent continuum.

Band Centre: Denotes the wavelength position of lowest reflectance over a specified interval after some kind of continuum removal for a band has been performed; e.g., apparent continuum removal by division. It is important that centres only be reported when an apparent continuum has been removed by division and the spectra have experienced the contrast stretch that is applied by this method of apparent continuum removal.

Band Depth: Band depth is always the depth to the minimum or centre along a straight line, which intersects the band minima or centre tangent to a fit straight-line continuum. Band Depth provides information of the composition of the spectra and nature of the absorption band in the spectra.

Pin points: Pin points are those points on which the straight line continuum is pinned on. Pin point are those points in the spectrum around the band minima of an absorption band where maximum reflectance has occurred.[12]

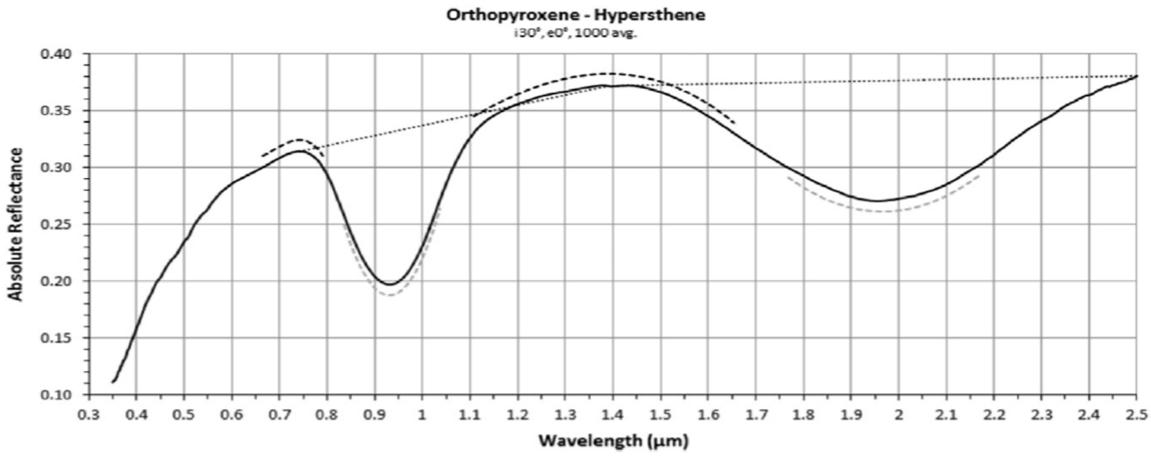


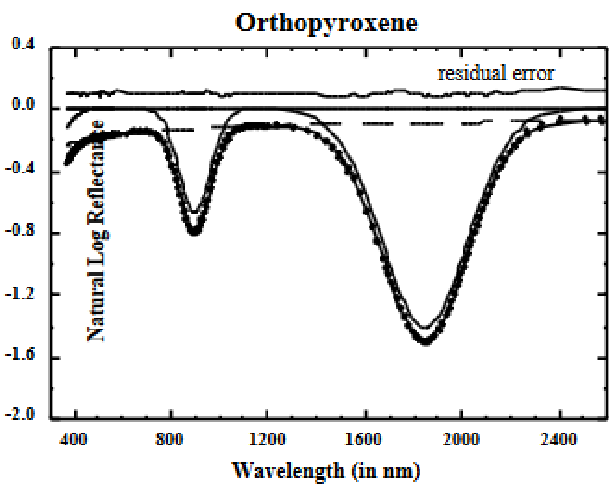
Fig 2. 13 Curve Fitting Explained

2.2.12 Modified Gaussian Method

The Modified Gaussian Model (MGM) is a method for accurately resolving spectra into their physical components, constituent absorption bands. The modelled absorption bands can then be used to infer compositions and amounts of co-existing phases. One of the major strengths of the MGM s that the derived absorption bands are determined directly from measured spectra. Unlike other methods, MGM modelling does not rely on pre-determined assumptions about the spectral constituents, nor does it require the direct use of terrestrial samples or meteorites as spectral analogues. The MGM approach is thus particularly well suited for analysis of remote spectra.

The MGM is a refinement of the Gaussian model used previously by many investigators [e.g. 2-6]. Modified Gaussian distributions, by adhering more closely to the physical processes involved in electronic transition absorptions, are the first accurate mathematical description for the shape of isolated absorption bands [1,7]. Under the MGM spectra are modelled as sums of absorption bands, each represented by a modified Gaussian distribution, superimposed onto baseline curves, or continua. Each absorption is described by three model parameters; a band centre, width and strength.

Since the MGM centres around an accurate model of electronic transition absorptions, it is not merely a mathematical description, but rather a physically based model of reflectance spectra. Thus, results derived with the MGM can confidently be used to infer composition. The MGM has been shown to accurately resolve individual absorption bands in laboratory spectra and has been used to quantify variations in absorption bands. One of the examples where MGM resolved individual bands is listed below. [9]



Starting Model Parameters for Orthopyroxene

Continuum (polynomial in energy):
Offset: 0.85 ± 10 Slope: -0.10E-05 ± 0.10E-3

Band	Center	FWHM	Strength
1	333 ± 10000	400 ±	-20. ± 100
2	1000 ± 200	250 ± 400	-1.0 ± 10
3	2000 ± 200	300 ± 400	-2.0 ± 10

Final Model Parameters for Orthopyroxene

Continuum (polynomial in energy):
Offset: 0.94 Slope: -5.57E-06

Band	Center	FWHM	Strength	Log Area
1	333.89	113.52	-0.15	-1.15
2	898.59	147.68	-0.66	-13.96
3	1845.36	416.05	-1.40	-46.18

Current RMS Error = 1.14 % after 8 iterations

Fig 2. 14 Deconvolution and Parameters used for Orthopyroxene

2.2.13 Crater Detection And Analysis

Craters are commonly found on the surface of planets, satellites, asteroids and other solar system bodies. The number and size of craters can establish the age of the surface or surface units and yield the relative ages between the surfaces of different bodies. Generally, the crater is a bowl shaped depression created by collision or volcanic activities. Younger craters may have sharper and regular rims while aged craters might have very vague rims. Therefore, the craters are a fundamental tool to determinate the geological age and history of a surface. [10]

The continuing exploration of the Solar System by automated probes leads to the acquisition of large numbers of images of the surfaces of planets and satellites. The amount of information contained in these images grows at a faster rate than the availability of human operators to analyze them and to extract from them the relevant data for the characterization of the planetary body under scrutiny. When it comes to understanding the geological history of a planet, the study of impact craters (their density, patterns and morphology) assumes a capital importance.

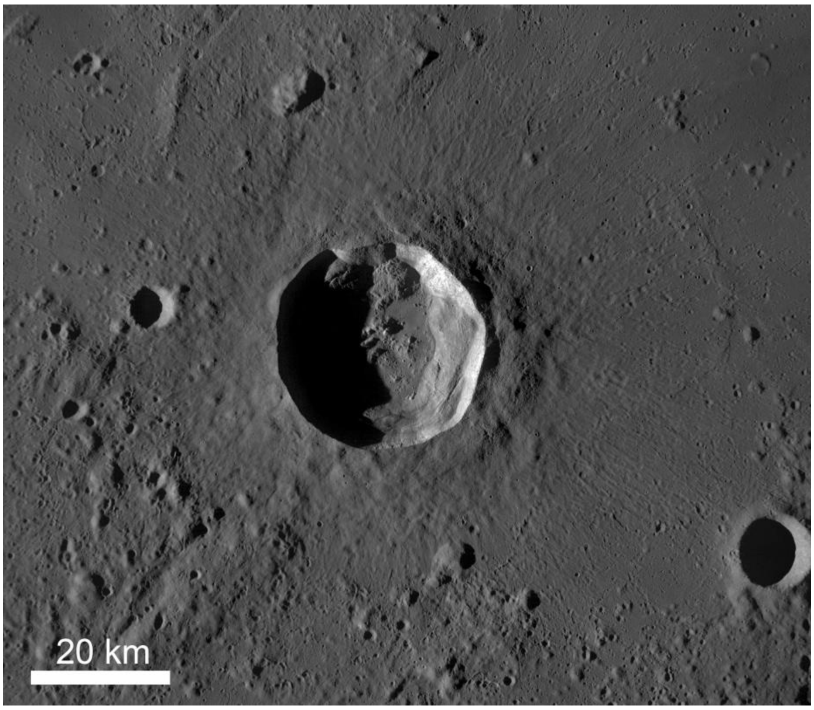


Fig 2. 15 Lunar Craters

These features come in all sizes, but their numbers generally increase as we probe smaller dimensions (as a result of the availability of images with better spacial resolution). Plus, their identification by human operators is a time-consuming endeavor, time that could be applied to the analysis and interpretation of data, if the detection of craters (their location and dimension) was achieved through a trustworthy automated procedure. The creation of such an automated method for impact crater detection in images of planetary surfaces is a goal that has been pursued by several teams in recent years. The size of the challenge posed by this problem can be evaluated by the fact that, as yet, there is no reliable methodology that can be applied to all situations and produce an acceptable result (that is, one that fits inside the margin of error associated to human analysis of images). [11]

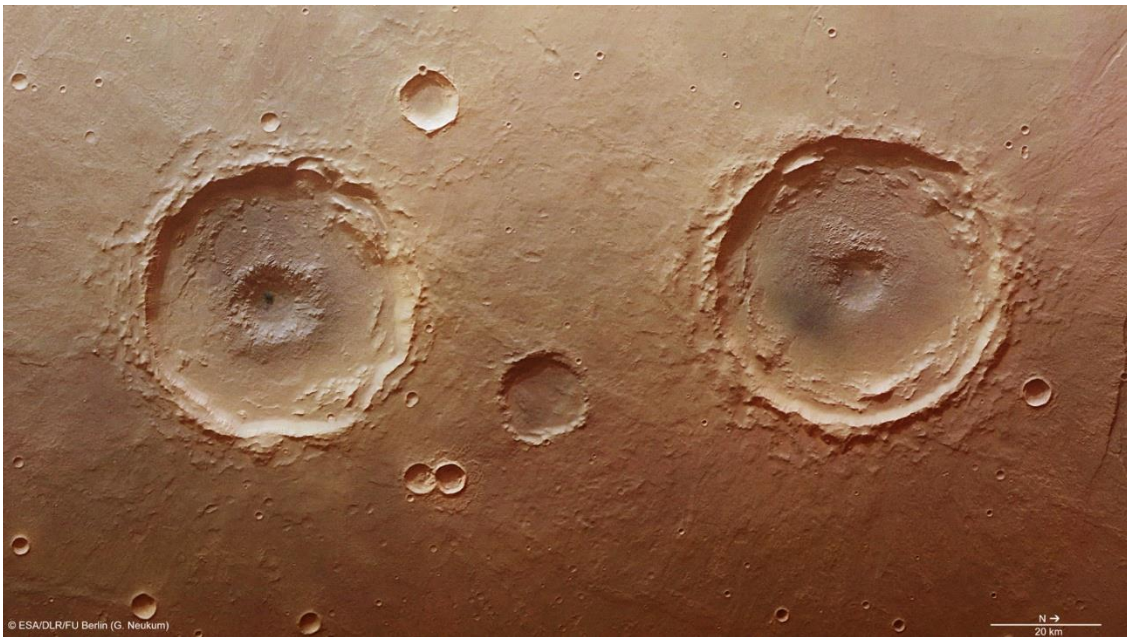


Fig 2. 16 Martian Craters

CHAPTER 3

ANALYSIS OF EXISTING WORK & LIMITATIONS

3.1 WORKING OF EXISTING SYSTEM

Fig 3. 1 ENVI

ENVI: Environment for Visualizing Images which is known as ENVI is a software application used to process and analyze geospatial imagery. It is commonly used by remote sensing professionals and image analysts. ENVI is a software which is used by GIS professionals, remote sensing scientists, and image analysts to extract meaningful information from imagery to make better decisions. It is designed to be used by anyone who relies on imagery and data to make decisions and delivers expert-level results across regardless of a user's prior experience with imagery. It supports different types of imagery from today’s newest and most popular satellite and airborne sensors, including multispectral, hyper spectral, panchromatic, LIDAR, infrared, thermal, radar, HDF5, full-motion video, LAZ, ASCII, and NET CDF-4.

ENVI modules perform highly specialized tasks such as extracting features, correcting for atmospheric conditions, and orthorectifying images etc. It helps the user to perform various takes and algorithms on hyper spectral data like Sub-pixel analysis, Feature extraction, Spectrum identification, Anomaly detection, Mapping of materials, Target finding. ENVI simplifies comprehensive interactive processing of large multiband data sets, screen-sized images, spectral plots and libraries, and image regions of interest (ROIs), while providing flexible display capabilities and geographic-based image browsing. ENVI has a unique approach to image processing which combines file-based and band-based techniques with interactive functions. When you open a data input file, its bands are stored in a list where you can access them from all system functions.

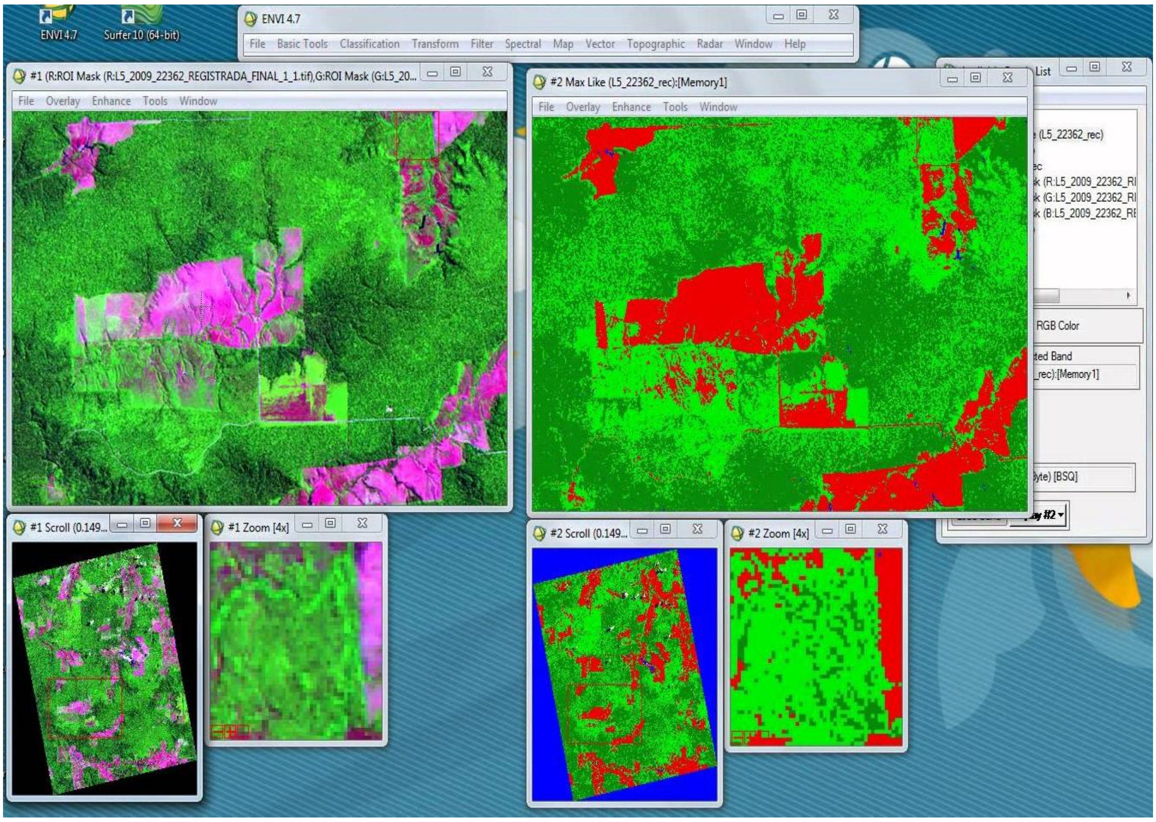


Fig 3. 2 ENVI Working Snapshot

3.2 LIMITATIONS OF EXISTING SYSTEM

1. In order to use the software for academic purposes the students can purchase its license but the costing for the purchase of student license is $195 and if the student needs any add-ons like Feature Extraction Module or Advanced Math and Stats it would cost additional to get those features.
2. The Student Licenses are valid for one year only, they are not eligible for renewal. To continue their use after the expiration they have to purchase new license for that they have to go through all the same procedures which are performed earlier to become eligible for requesting student license.
3. Network Licenses are not available in Student Licenses purchase.

CHAPTER 4

PROPOSED DESIGN

4.1 INTRODUCTION TO PROPOSED SYSTEM

The proposed system (i.e. Hyper spectral Analyser) will be able to read Hyperspectral Images of any domain related to planetary remote sensing. It is possible to manually provide the information about the image to the system or the system can automatically read widely used ENVI standard header file. The system will have the capabilities of displaying images for various spectral bands in both Gray-scale image and a combination of 3 bands generating RGB image.

It would also have the ability to generate spectrum based on selection of the pixel, where selection can be done either using a cursor or manually providing the xy coordinate of the pixel. The system will be enhanced with tools for generating basic statistics i.e. mean, median etc. It would also be able to perform PCA and generate it results again both in Gray scale image as well as RGB image. This would help scientist to a great extent analysing any surface area of planetary bodies.

It will also have a panel displaying Spectral Library which can be updated as and when new laboratory spectrum for minerals are generated. The system would not be able to quantify the mineral composition but would be able to help scientist identify the possible mineral composition using the comparison between spectrum of the spectral library and the spectrum generated through the hyperspectral data.

It will also have a module for crater detection which would help detecting craters on any planetary surface image to a great precision. This would be done using circular Hough transform. The results generated will be helpful to study the mineral composition at the centre of each craters.

4.2 ALGORITHMS USED IN PROPOSED SYSTEM

4.2.1 Principal Component Analysis

An image pixel vector is calculated as:

$$X_i = [x_1, x_2, \ldots . x_N]_i^T$$

with all pixel values x_1, $x_{2\ldots.}$, z_N at one corresponding pixel location of the hyperspectral image data. The dimension of that image vector is equal to the number of hyperspectral bands N. For a hyperspectral image with m rows and n columns there will be M=m*n such vectors, namely i=1,…., M. The mean vector of all image vectors is denoted and calculated as:

$$m = \frac{1}{M}\sum_{i=1}^{M}[x_1\ x_2\ \ldots\ \ldots\ x_N]_i^T$$

The covariance matrix of **x** is defined as:

$$Cov(x) = E\{(x - E(x))(x - E(x))\}^T$$

where:

E = expectation operator;

T superscript = transpose operation;

And,

Cov = notation for covariance matrix.

The covariance matrix is approximated via the following calculation:

$$C_x = \frac{1}{M}\sum_{i=1}^{M}(x_i - m)(x_i - m)^T$$

The PCA is based on the eigenvalue decomposition of the covariance matrix, which takes the form of:

$$C_x = ADA^T$$

where:

D = diag (λ_1, λ_2...λ_N)

is the diagonal matrix composed of the eigenvalues λ_1, λ_2...λ_N of the covariance matrix **C_X**, and **A** is the orthonormal matrix composed of the corresponding *N* dimension eigenvectors $\mathbf{a}_k$ *(k=1, 2, …., N)* of **C_X** as follows:

$$A = (a_1, a_2, \ldots . a_N)$$

The linear transformation defined by:

$$y_i = A^T X_i \quad (I = 1, 2, \ldots, M)$$

is the PCA pixel vector, and all these pixel vectors form the PCA (transformed) bands of the original images.

Let the eigenvalues and eigenvectors be arranged in descending order so that $\lambda_1 > \lambda_2 > \ldots > \lambda_N$, thus the first *K* (K < N, usually *K*<<*N*) rows of the matrix **A^T**, namely the first *K* eigenvectors, can be used to calculate an approximation of the original images in the following way:

$$x_i = \begin{bmatrix} z_1 \\ z_2 \\ . \\ . \\ z_k \end{bmatrix}_i = \begin{bmatrix} a_{11} & a_{12} & . & a_{1K} & . & a_{1N} \\ a_{21} & a_{22} & . & a_{2K} & . & a_{2N} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ a_{K1} & a_{K2} & . & a_{KK} & . & a_{KN} \end{bmatrix} . \begin{bmatrix} x_1 \\ x_2 \\ . \\ . \\ x_k \\ . \\ . \\ x_N \end{bmatrix}_i$$

where pixel vector $\mathbf{z}_i$ will form the first *K* bands of the PCA images.

Working Example of PCA :

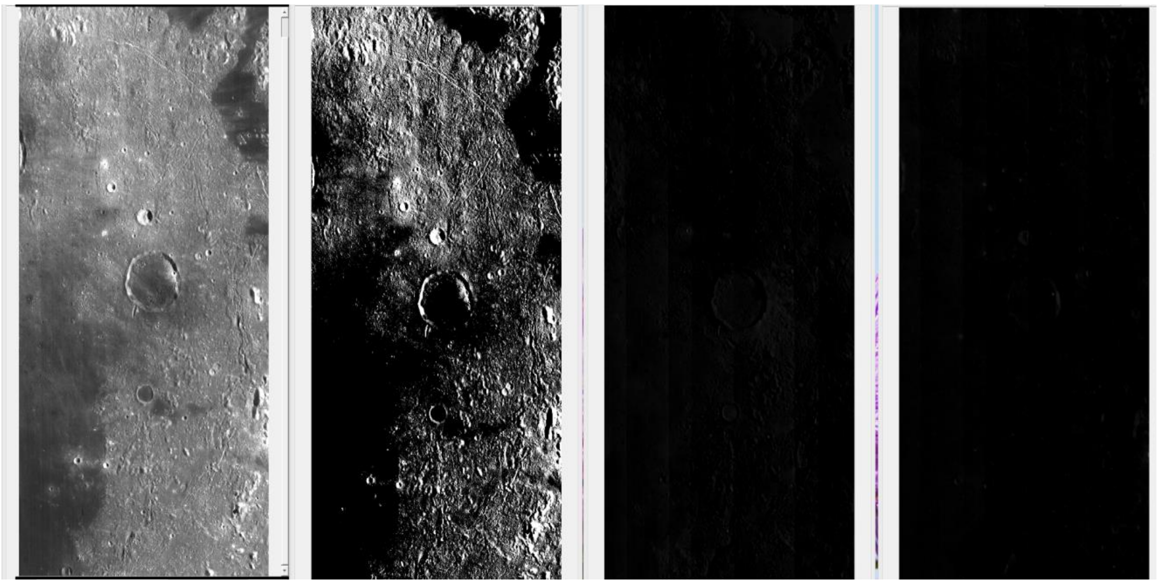


Fig 4. 1 Normal Image and PCA Band 1, PCA Band 2, PCA Band 3

4.2.2 Image Enhancement Techniques

Image enhancement is used to enhance the information available from an image for any specific purpose. The enhancement may be done either in the spatial domain or in the frequency domain. Here are some basics algorithms for image enhancement in the spatial domain.

Contrast Stretching:

Contrast stretching is used to increase the dynamic range of the gray levels in the image. For example, in an 8-bit system the image display can show a maximum of 256 gray levels. If the number of gray levels in the recorded image spread over a lesser range, the images can be enhanced by expanding the number of gray levels to a wider range. This process is called contrast stretching. The resulting image displays enhanced contrast between the features of interests.

Two types of contrast stretching are:

i. Linear Contrast Stretching
ii. Non-Linear Contrast Stretching

i. Linear Contrast Stretching:

When the values in the original image are expanded uniformly to fill the total range of the output device, the transformation is called linear contrast stretching. If DN is the Digital Number of the pixel, DNst is the corresponding DN in the enhanced output image, DNmax and DNmin are the maximum and minimum DN values in the original image, the linear contrast stretching can be graphically represented as shown below.

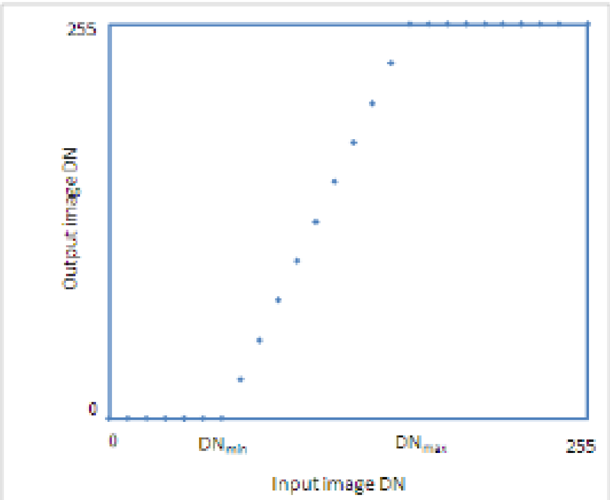


Fig 4. 2 Linear Contrast Stretching

For example, for an 8-bit display system, linear contrast stretching transformation can be achieved as given below.

$$DN_{st} = 255 \times \frac{(DN - DN_{min})}{(DN_{max} - DN_{min})}$$

where DN values in the range DNmin – Dnmax are rescaled to the ranges 0-255 in the output image.

ii. Non-linear Contrast Stretching:

In non-linear stretching, the DN values are not stretched linearly to uniformly occupy the entire display range. One of the many non-linear contrast stretching method is Histogram-Equalized stretching. In histogram equalized stretch the DN values are enhanced based on their frequency in the original image. Thus, DN values corresponding to the peaks of the histogram are assigned to a wider range.

For example, for an 8-bit display system, the histogram equalization function used for stretching the input image can be represented as follows.

$$DN_{st} = 255 \sum_{j=0}^{k} \frac{n_j}{N}$$

Where n_j is the number of pixels having DN values in the j^{th} range, k is the number of DN value ranges, and N is the total number of pixels in the input image. Here, while building the analyser in MATLAB, we used histogram equalization as a generic technique for all the hyperspectral data. There are other image enhancement techniques which can give better results for specific images.

Fig 4. 3 Normal Image

Fig 4. 4 Linear Contrast Stretched Image

Fig 4. 5 Histogram Equalized Image

4.2.3 Automatic Crater Detection

An **impact crater** is an approximately circular depression in the surface of a planet, moon, or other solid body in the Solar System or elsewhere, formed by the hypervelocity **impact** of a smaller body.

Fig 4. 4 Craters

For crater detection on planetary surfaces,the proposed algorithm to be used is circular hough transform.Its working is explained below

Circular Hough Transform:

The Hough transform can be described as a transformation of a point in the x,y-plane to the parameter space. The parameter space is defined according to the shape of the object of interest.A straight line passing through the points (x1,y1) and (x2,y2) can in the x,y-plan be described by:

$$y = ax + b$$

This is the equation for a straight line in the cartesian coordinate system, where a and b represent the parameters of the line. The Hough transform for lines does not using this representation of lines, since lines perpendicular to the x-axis will have an a -value of infinity. This will force the parameter space a , b to have infinite size. Instead a line is represented by its normal which can be represented by an angel θ and a length ρ .

$$\rho = x\cos(\theta) + y\sin(\theta)$$

The parameter space can now spanned by θ and ρ , where θ will have a finite size, depending on the resolution used for θ . The distance to the line ρ will have a maximum size of two times the diagonal length of the image.

The circle is actually simpler to represent in parameter space, compared to the line, since the parameters of the circle can be directly transfer to the parameter space. The equation of a circle is

$$r^2 = (x-a)^2 + (y-b)^2$$

As it can be seen the circle got three parameters, r ,a and b. Where a and b are the center of the circle in the x and y direction respectively and where r is the radius. The parametric representation of the circle is

$$x = a + r\cos(\theta)$$

$$y = b + r\sin(\theta)$$

Thus the parameter space for a circle will belong to R3 whereas the line only belonged to R2. As the number of parameters needed to describe the shape increases as well as the dimension of the parameter spaceR increases so do the complexity of the Hough transform. Therefor is the Hough transform in general only considered for simple shapes with parameters belonging to R2 or at most R3 . In order to simplify the parametric representation of the circle, the radius can be held as a constant or limited to number of known radii.

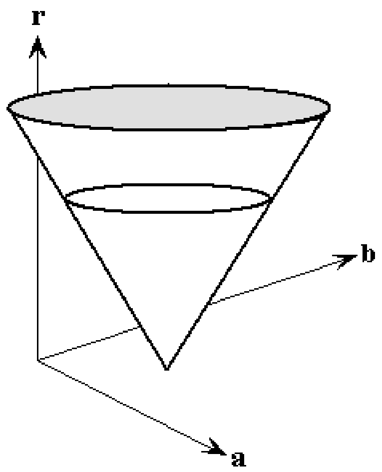


Fig 4. 5 Parameter space for circular Hough Transform

Pseudo-Algorithm:

The algorithm for Circular Hough Transformation can be summarized to :

1. Find edges(can be done using canny, sobel or morphological operators as per our desire)
2. //HOUGH BEGIN
3. For each edge point
   Draw a circle with center in the edge point with radius r and
   increment all coordinates that the perimeter of the circle passes
   through in the accumulator.
4. Find one or several maxima in the accumulator
5. //HOUGH END
6. Map the found parameters (r,a,b) corresponding to the maxima back to the original image

CHAPTER 5

SYSTEM IMPLEMENTATION

5.1 SYSTEM ENVIRONMENT

The environment used to develop the "Hyper Image Analyser" is MATLAB. It has an elementary GUI i.e. Graphical User Interface is a key for the scientists and analysts who will be using it. Making application fancy sometimes confuses users about its use. Hyper Image Analyser has pleasant GUI which is easy to use even for a layman. Its beauty lies in its simplicity and its features.

MATLAB supports developing applications with graphical user interface features. MATLAB includes GUIDE for graphically designing GUIs. It also has tightly integrated graph-plotting features.

MATLAB

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment. A proprietary programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

As of 2017, MATLAB has roughly 1 million users across industry and academia. MATLAB users come from various backgrounds of engineering, science, and economics.

Reasons for choosing MATLAB as the environment:

1. MATLAB Speaks Math

Engineers and scientists need a programming language that lets them express matrix and array mathematics directly. Linear algebra in MATLAB looks like linear algebra in a textbook. The same is true for data analytics, signal and image processing, control design, and other applications.

2. MATLAB Is Designed for Engineers and Scientists

Everything about MATLAB is designed specifically for engineers and scientists:
Function names and signatures are familiar and memorable.
The desktop environment is tuned for iterative engineering and scientific workflows.
Documentation is written for engineers and scientists, not computer scientists.

3. MATLAB Toolboxes Just Work

MATLAB toolboxes offer professionally developed, rigorously tested, field-hardened, and fully documented functionality for a wide range of scientific and engineering applications. Toolboxes are designed to work together, and they integrate with parallel computing environments, GPUs, and C code generation.

"Developing algorithms in MATLAB is 10 times faster and more robust than developing in Java. We need to filter our data, look at poles and zeroes, run nonlinear optimizations, and perform numerous other tasks. In MATLAB, those capabilities are all integrated, robust, and commercially validated."
-Borislav Savkovic, lead data scientist, BuildingIQ

4. MATLAB Has Apps

MATLAB apps are interactive applications that combine direct access to large collections of algorithms with immediate visual feedback. You can instantly see how different algorithms work with your data. Iterate until you’ve got the results you want, then automatically generate a MATLAB program to reproduce or automate your work.

5. MATLAB Integrates Workflows

Major engineering and scientific challenges require broad coordination across teams to take ideas to implementation. Every handoff along the way adds errors and delays. MATLAB helps automate the entire path from research to production.

- CONNECT
  Use MATLAB with over 1,000 common hardware devices.
- ANALYZE
  Integrate MATLAB into your production analytics applications.
- SCALE
  Run algorithms faster and with big data by scaling up to clusters, the cloud, and GPUs.
- SIMULATE
  Plug into Simulink and Stateflow for simulation and Model-Based Design.
- EMBED
  Convert MATLAB code to embeddable C and HDL code.

6. MATLAB Is Fast

MATLAB does the hard work of making your code fast. Math operations are distributed across your computer’s cores, library calls are heavily optimized, and all code is just-in-time compiled.

You can run your algorithms in parallel by simply changing for-loops into parallel for-loops or by changing standard arrays into GPU arrays. Run parallel algorithms in an infinitely scalable cloud with no code changes.

7. MATLAB Is Trusted

Engineers and scientists trust MATLAB to send a spacecraft to Pluto, match transplant patients with organ donors, or just compile a report for management. This trust is built on impeccable numerics stemming from the strong roots of MATLAB in the numerical analysis research community. A team of MathWorks engineers continuously verifies quality by running millions of tests on the MATLAB code base every day.

User Interface using GUIDE

GUIs (also known as graphical user interfaces or UIs) provide point-and-click control of software applications, eliminating the need to learn a language or type commands in order to run the application.

GUIDE (GUI development environment) provides tools to design user interfaces for custom apps. Using the GUIDE Layout Editor, you can graphically design your UI. GUIDE then automatically generates the MATLAB code for constructing the UI, which you can modify to program the behavior of your app. It extends MATLAB's support for rapid coding into the realm of building GUIs. Guide is a set of MATLAB tools designed to make building GUIs easier and faster. Just as writing math in MATLAB is much like writing it on paper, building a GUI with Guide is much like drawing one on paper. As a result, you can lay out a complex graphical tool in minutes. Once your buttons and plots are in place, the Guide Callback Editor lets you set up the MATLAB code that gets executed when a particular button is pressed.

Fig 5. 1 MathWorks Logo

5.2 SYSTEM MODULES

Hyper Image Analyser consists of 5 modules. Each of them performing a unique task that adds to the features of the toolbox.

They are:-

1. **Hyperspectral Image Reader Module**
   i) **Browse Header & Image File**
   ii) **Display image in the window**
   iii) **Cursor Module**
   iv) **Zoom Module**

2. **Spectrum Viewer Module**
   i) **Automatic cursor spectrum**
   ii) **Manual co-ordinates spectrum**

3. **Statistical Method Module**
   i) **Min-Max Calculation**
   ii) **Mean-Median Calculation**
   iii) **Standard Deviation Calculation**
   iv) **Principal Component Analysis**

4. **Spectrum Library Module**
   i) **Included CRISM spectrum library**

5. **Crater Detection Module**
   i) **Automatic Crater Detection using Hough**
   ii) **Manual Crater Detection using 3 point circle & 4 point circle**

5.3 SYSTEM FLOW

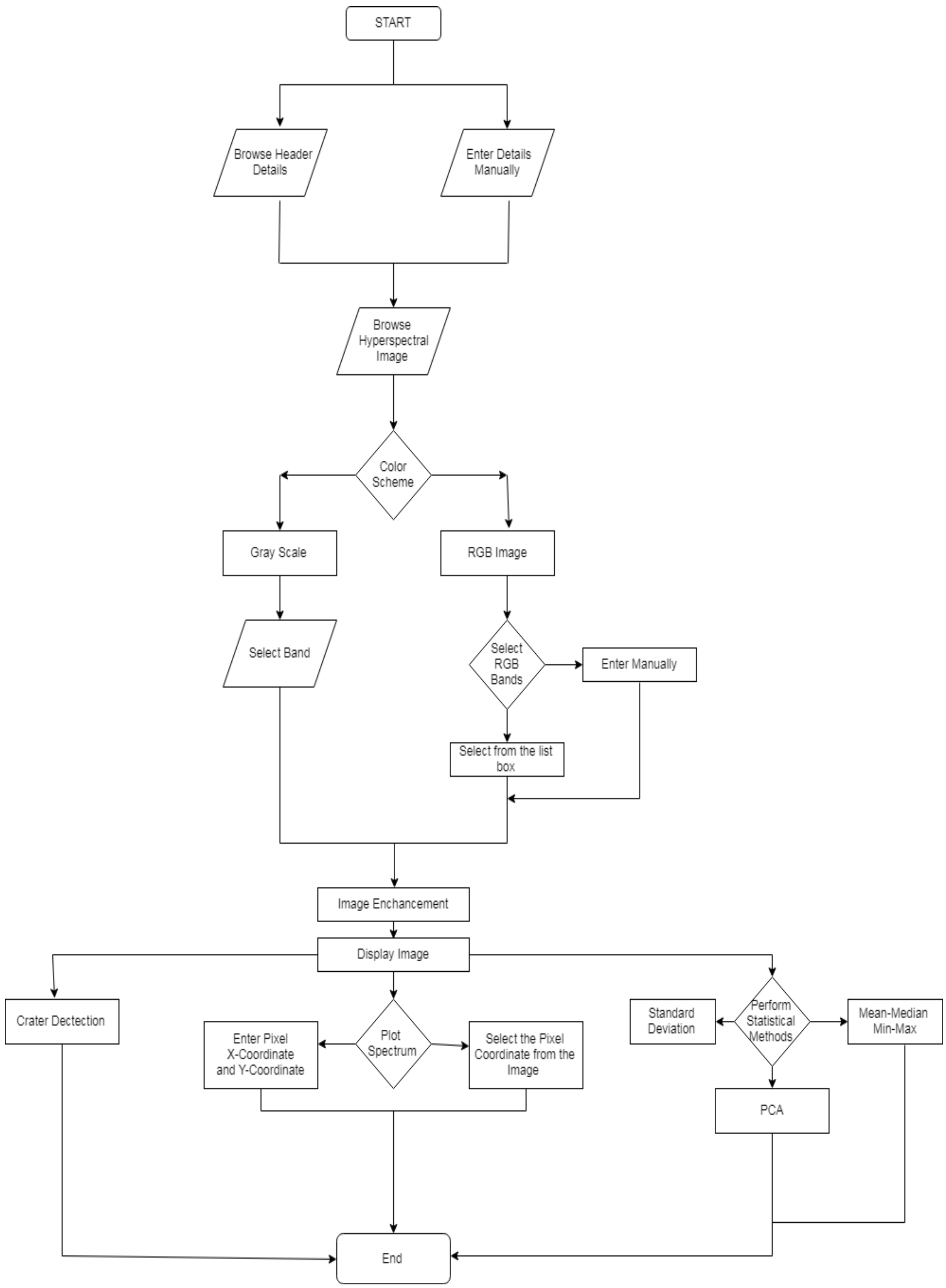


Fig 5. 2 Hyper Image Analyser System Flow

5.4 WORKING WITH SYSTEM

Snapshot 1: GUI of Hyper Image Analyser

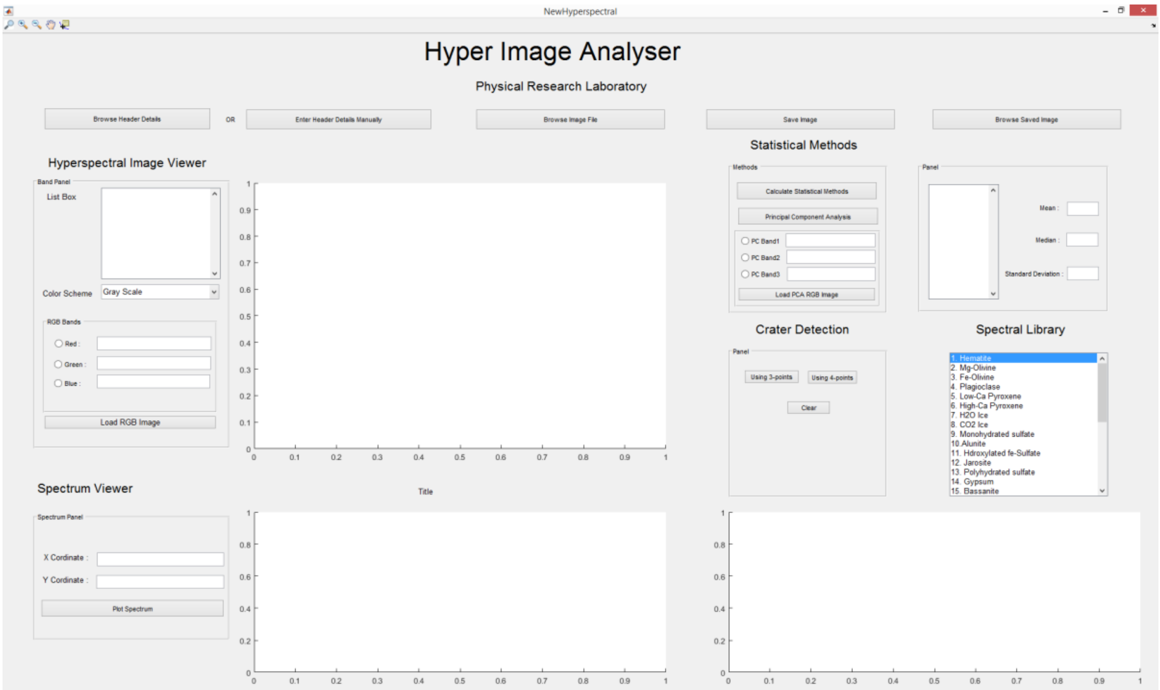


Fig 5. 3 Working Snap 1

Snapshot 2: Browsing Header File (.hdr)

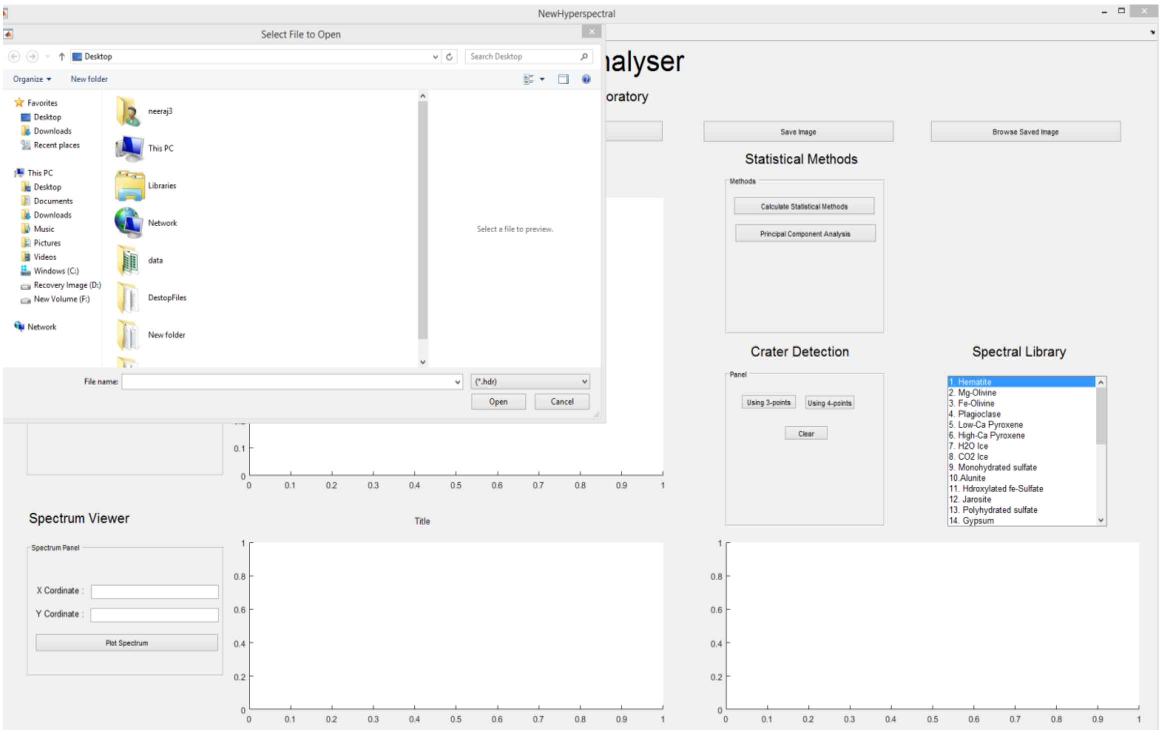


Fig 5. 4 Working Snap 2

Snapshot 3: Browsing Image File (.img)

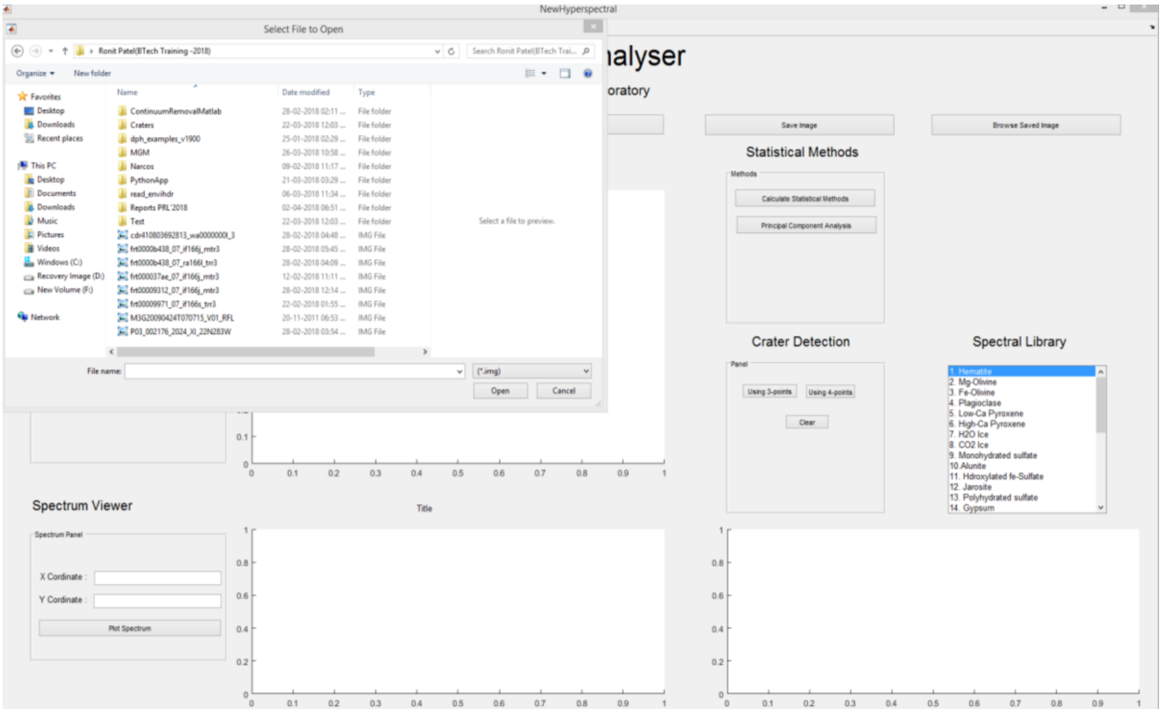


Fig 5. 5 Working Snap 3

Snapshot 4: Viewing Hyperspectral Image

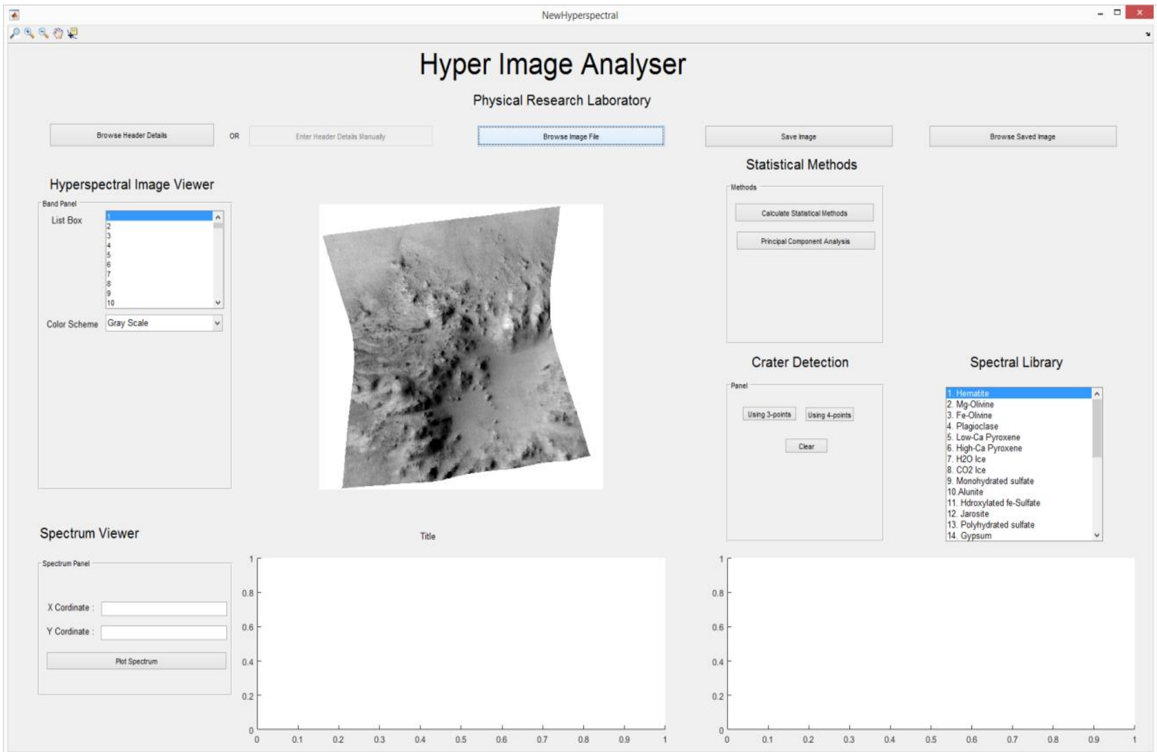


Fig 5. 6 Working Snap 4

Snapshot 5: Choosing RGB Color Scheme

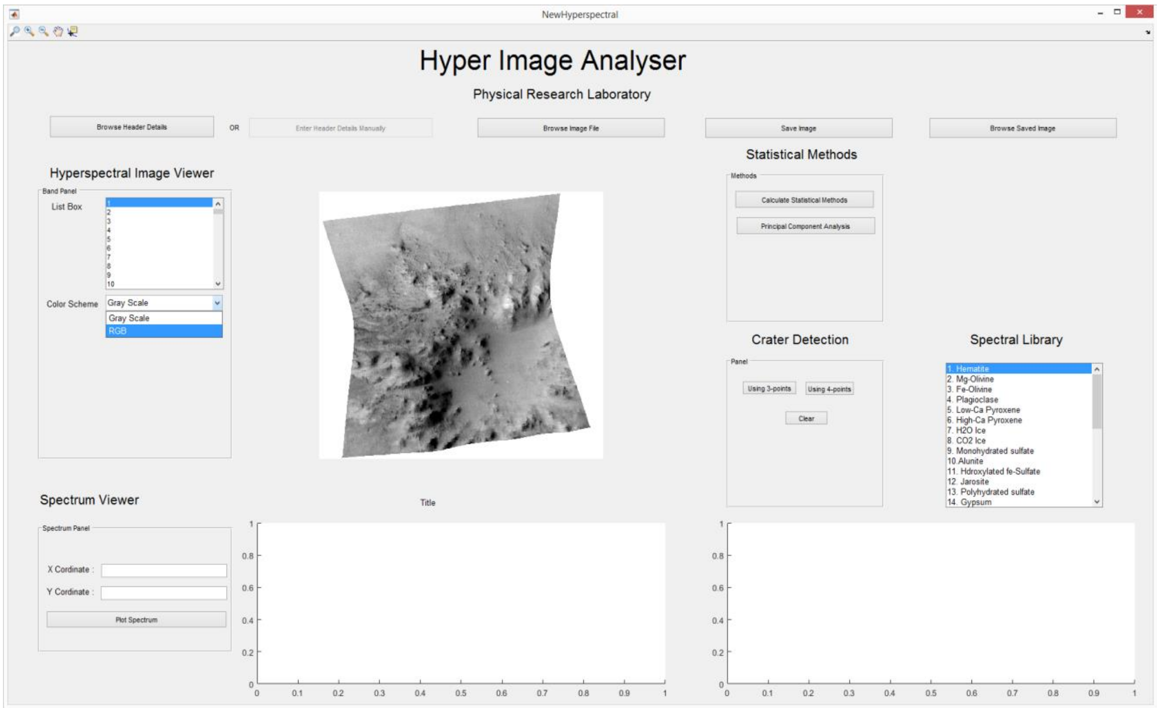


Fig 5. 7 Working Snap 5

Snapshot 6: Choosing Bands for Red Green & Blue

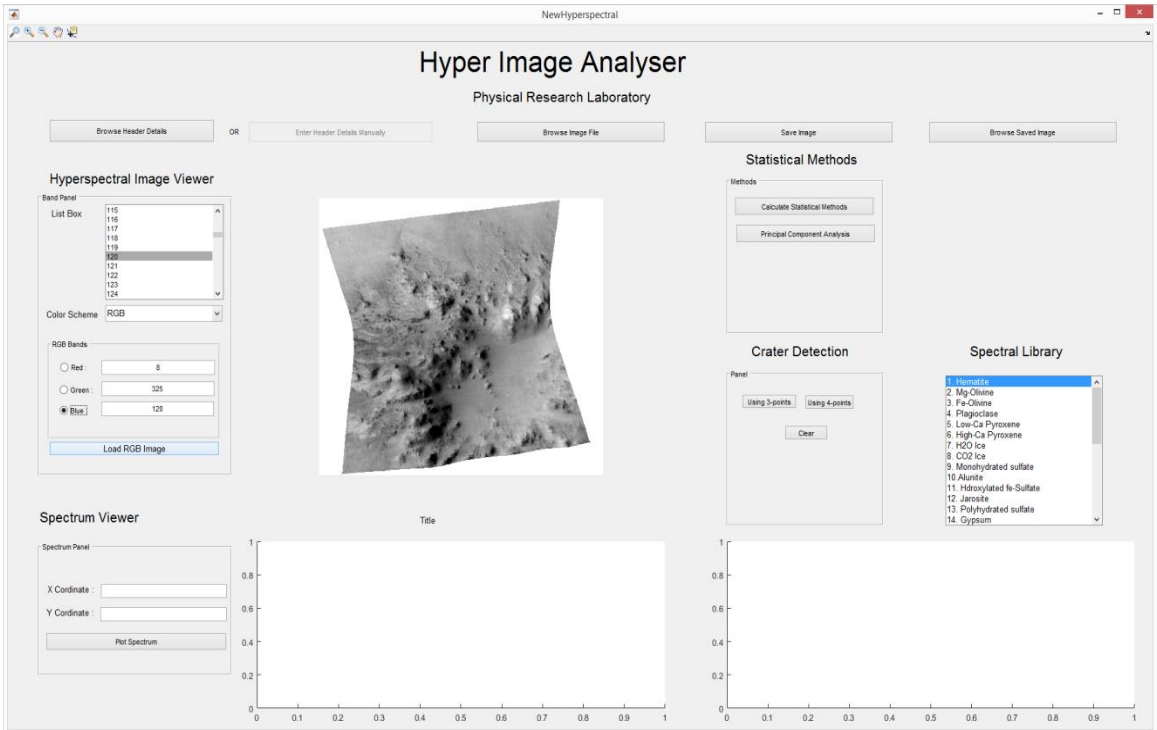


Fig 5. 8 Working Snap 6

Snapshot 7: Viewing hyperspectral image in RGB mode.

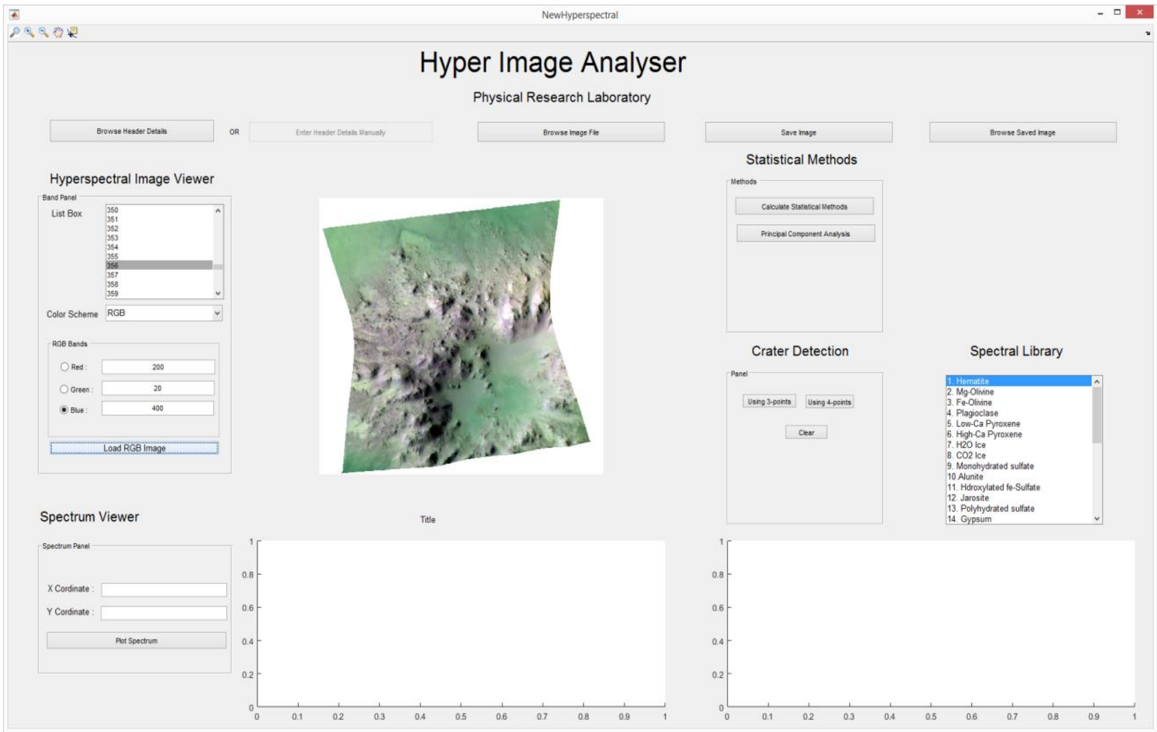


Fig 5. 9 Working Snap 7

Snapshot 8: Using Cursor to create Spectrum of any pixel

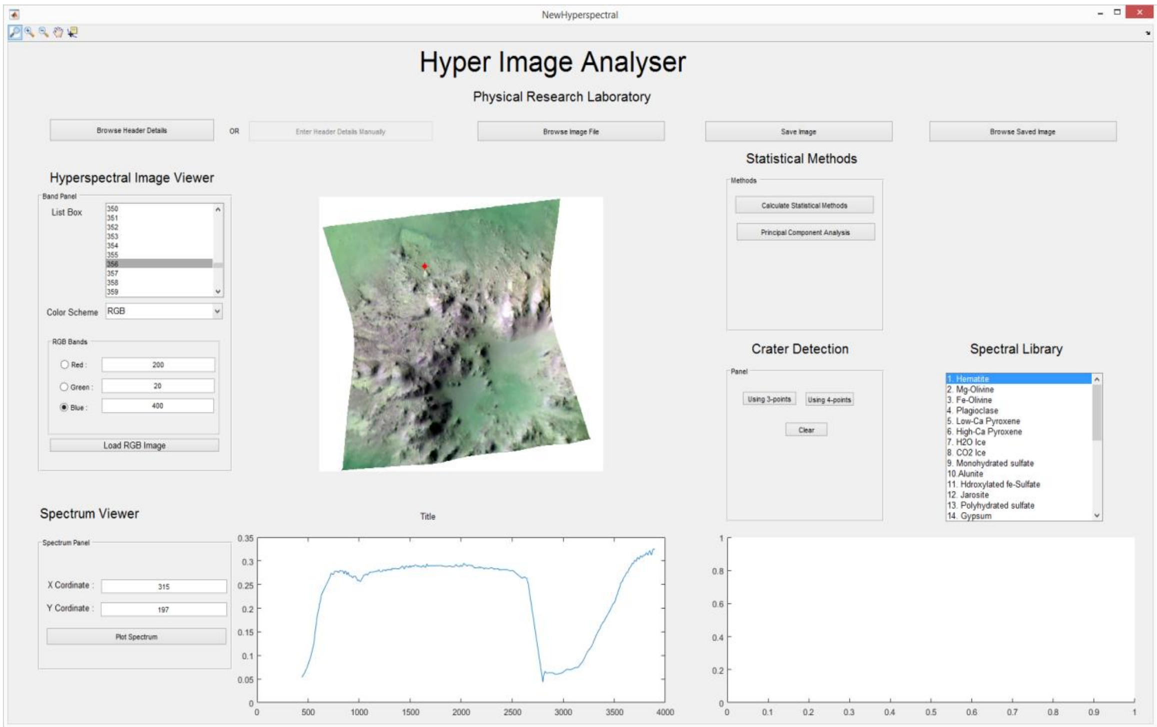


Fig 5. 10 Working Snap 8

Snapshot 9: Manually entering co-ordinates and plotting the spectrum.

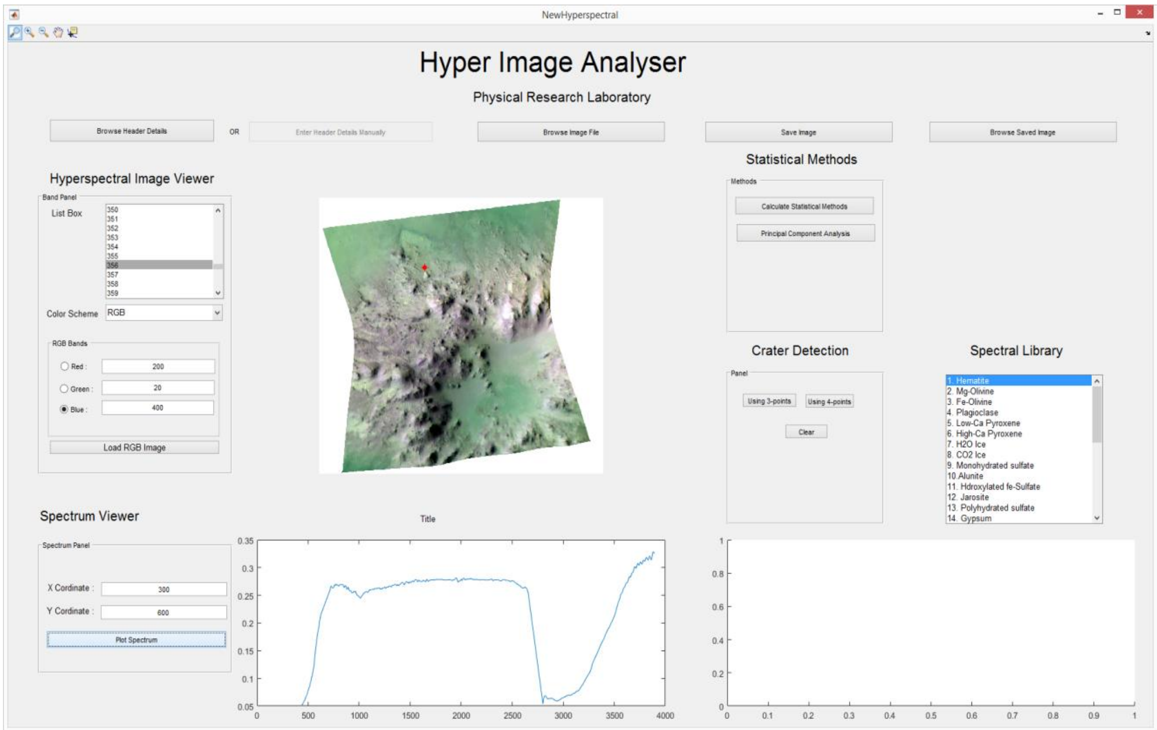


Fig 5. 11 Working Snap 9

Snapshot 10: Generating plot from spectral library for analysis

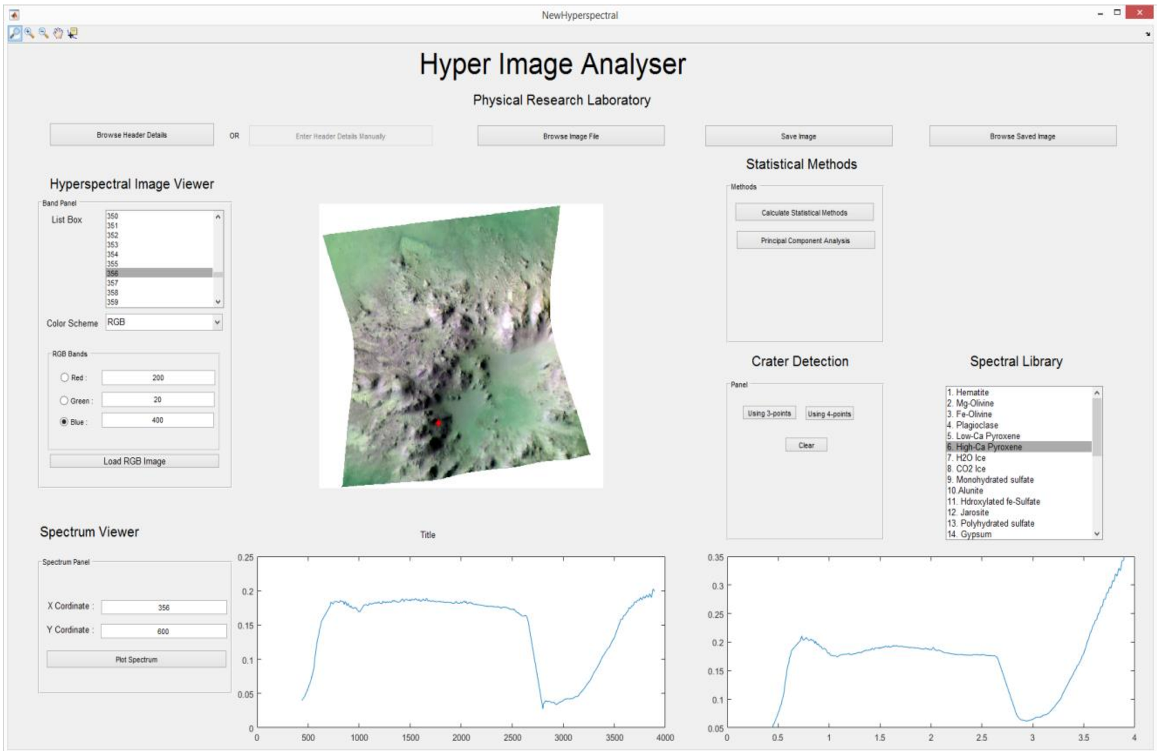


Fig 5. 12 Working Snap 10

Snapshot 11: Principal Component Analysis RGB Image

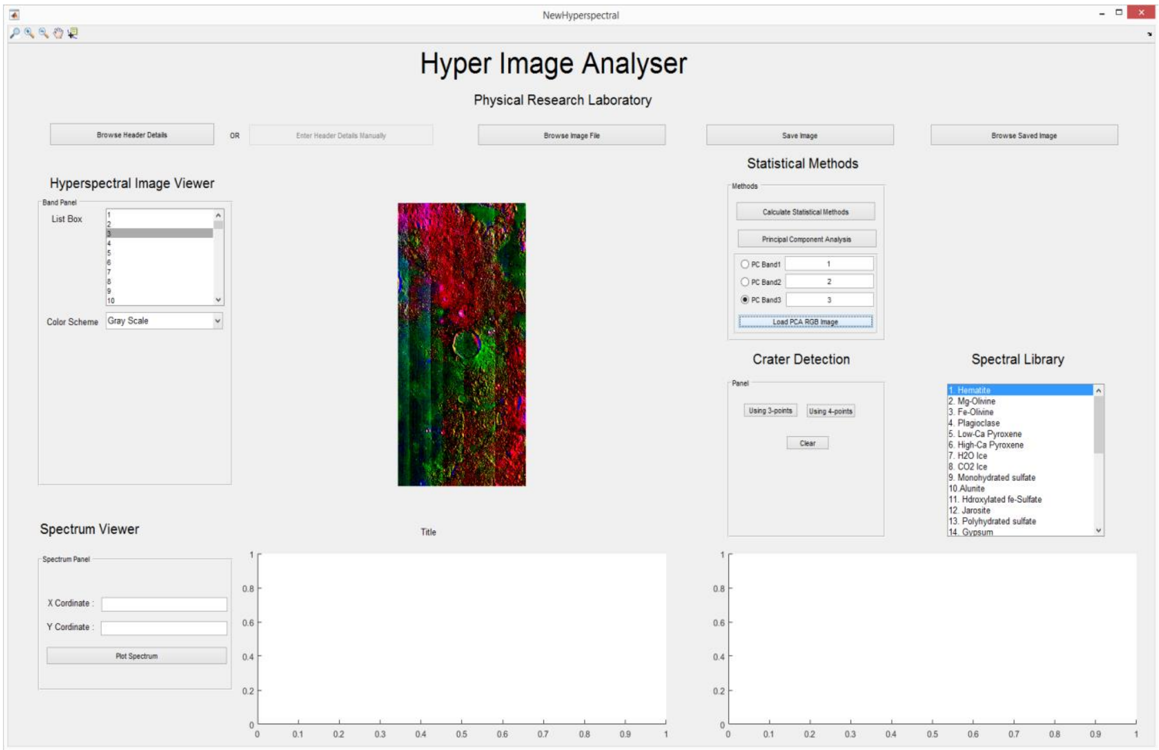


Fig 5. 13 Working Snap 11

Snapshot 12: Principal Component Analysis Grayscale Band 1

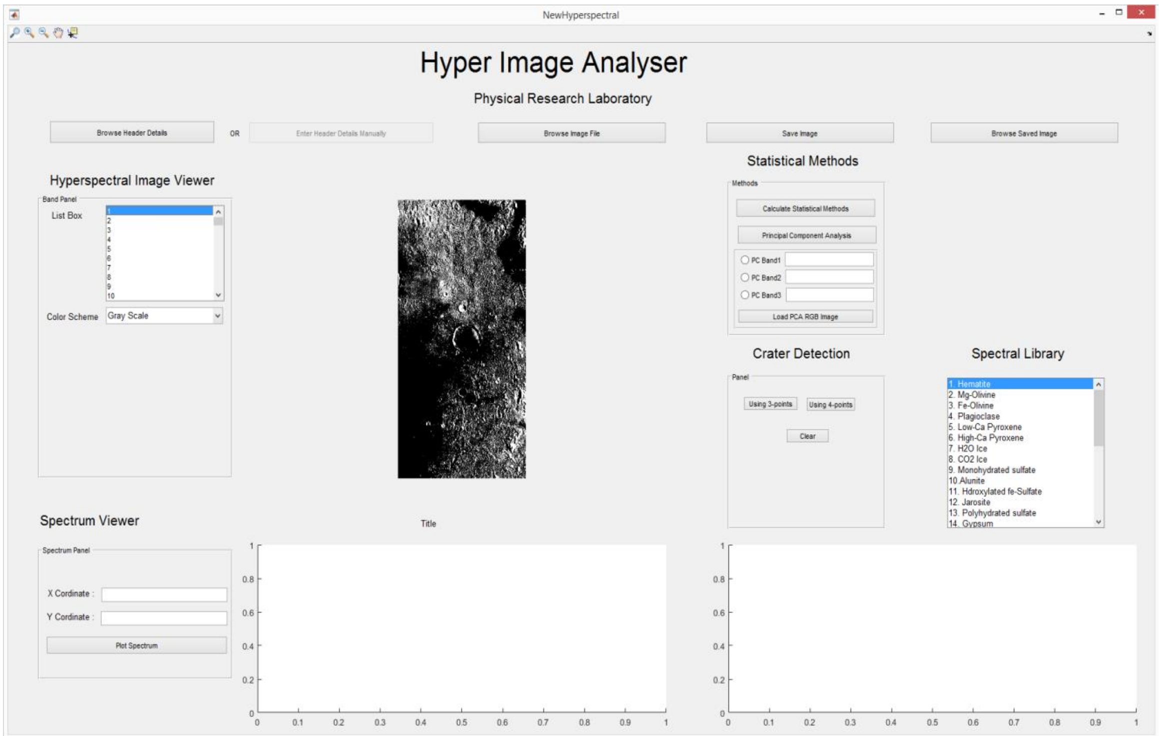


Fig 5. 14 Working Snap 12

Snapshot 13: Principal Component Analysis Grayscale Band 2

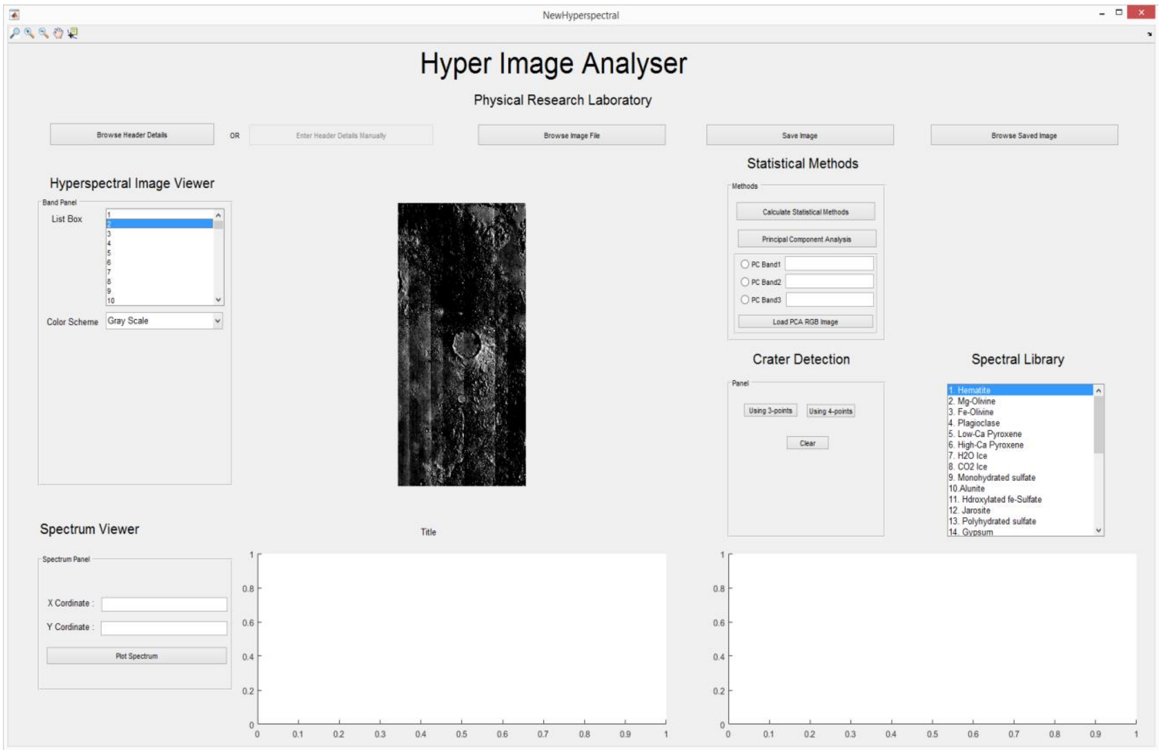


Fig 5. 15 Working Snap 13

Snapshot 14: Principal Component Analysis Grayscale Band 3

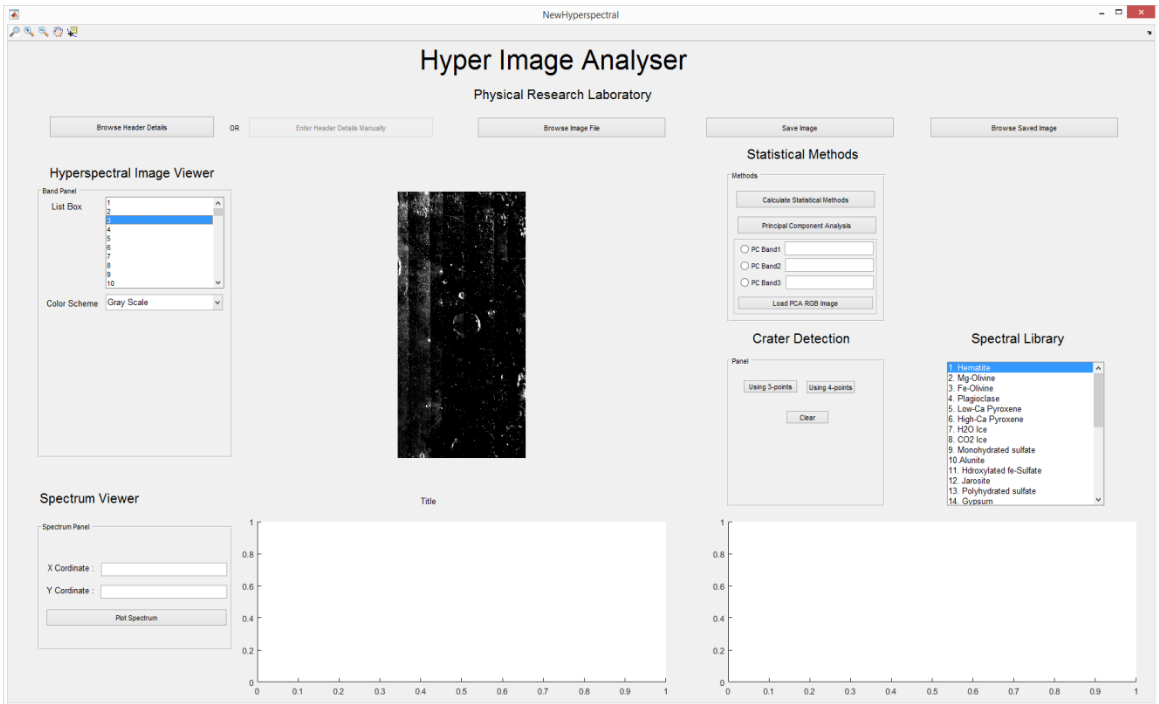


Fig 5. 16 Working Snap 14

Snapshot 15: Manual Crater Detection using 3-points

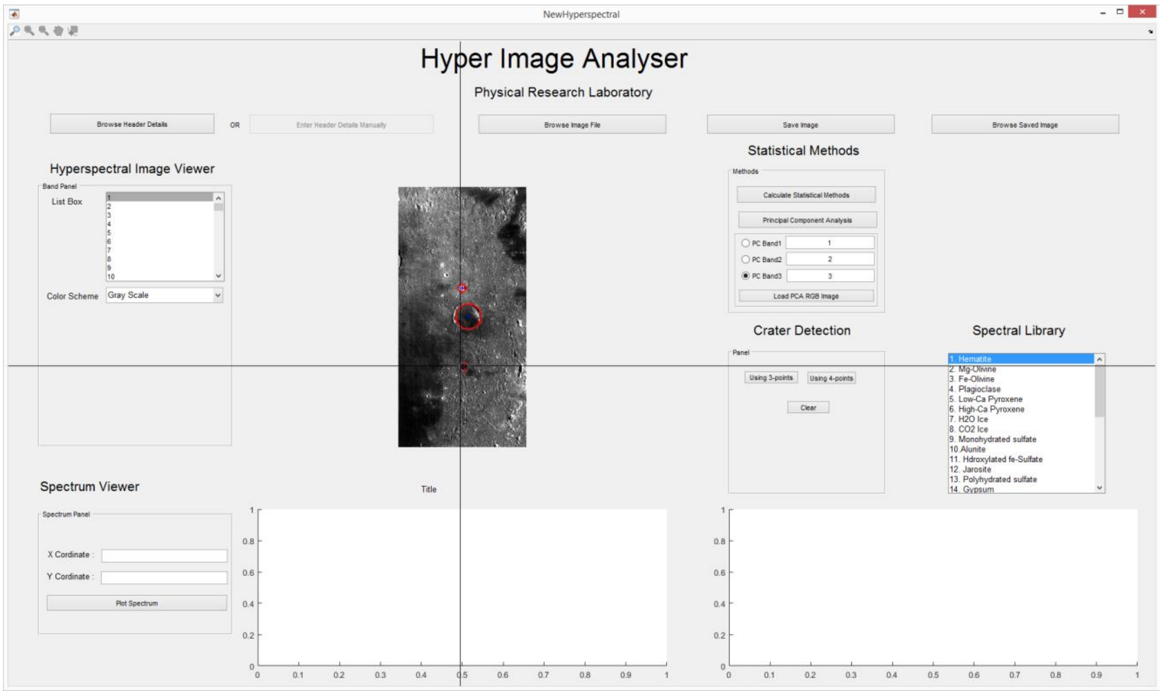


Fig 5. 17 Working Snap 15

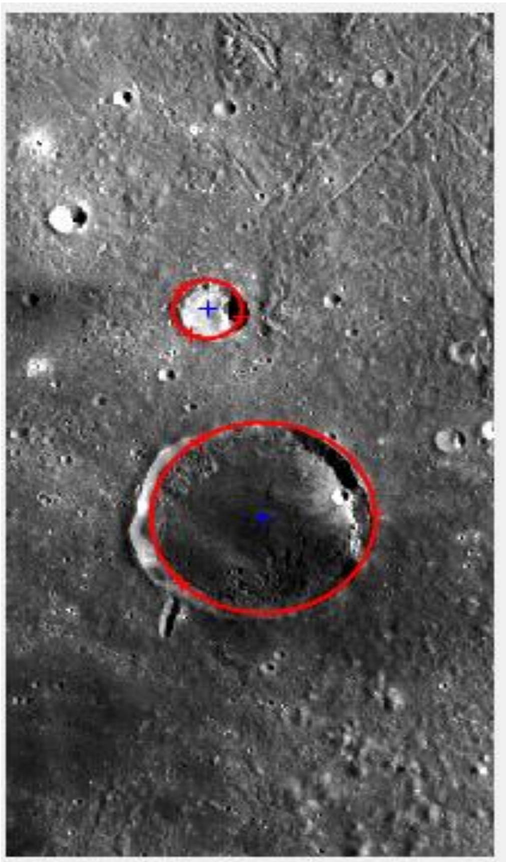


Fig 5. 18 Working Snap 16

Snapshot 16: Deleting the craters created

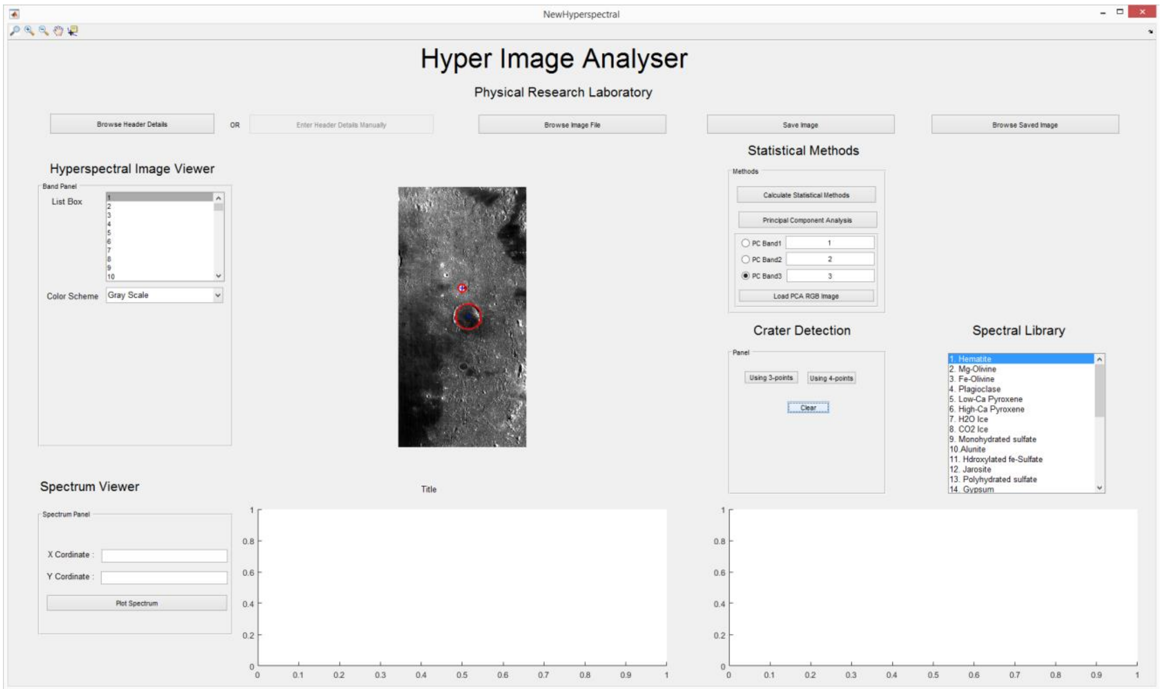


Fig 5. 19 Working Snap 17

Snapshot 17: Finding Statistical Results

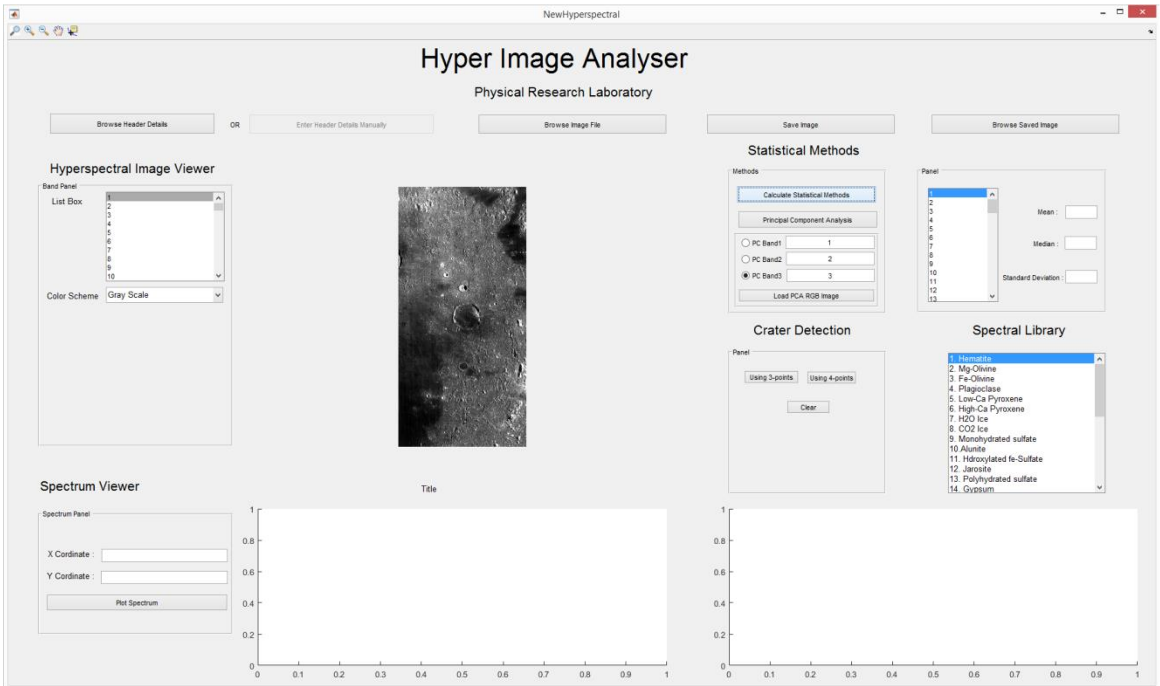


Fig 5. 20 Working Snap 18

Snapshot 18: Statistical Results of Band No. 4

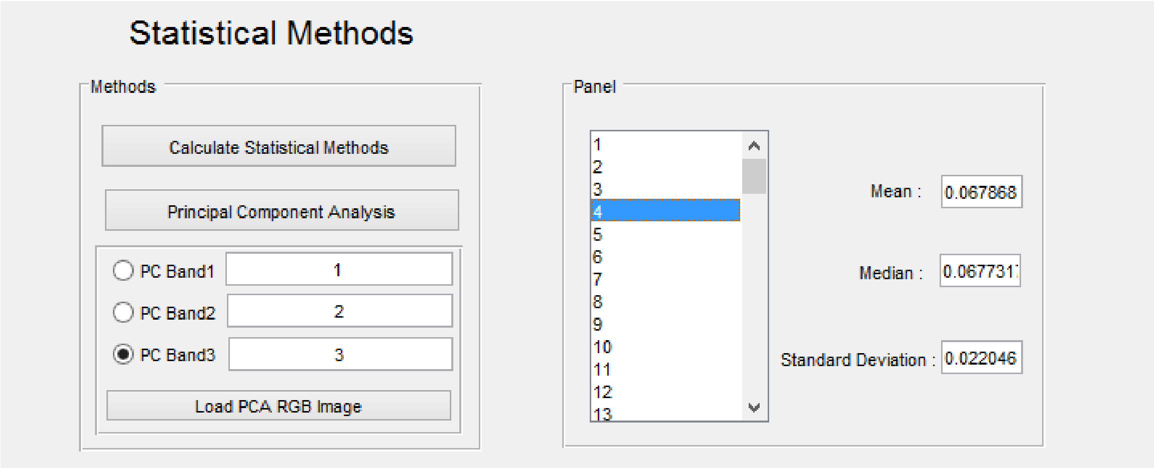


Fig 5. 21 Working Snap 19

CHAPTER 6

EXPERIMENTAL RESULTS

Nili Fossae is a group of large, concentric grabens on Mars, located in the Syrtis Major quadrangle. They have been eroded and partly filled in by sediments and clay-rich ejecta from a nearby giant impact crater, the Isidis basin.[23] It is located at approximately 22°N, 75°E, and has an elevation of −0.6 km (−0.37 mi). A large exposure of olivine is located in Nili Fossae.[23] In December 2008, NASA's Mars Reconnaissance Orbiter found that rocks at Nili Fossae contain carbonate minerals, a geologically significant discovery. Other minerals found by MRO are aluminum smectite, iron/magnesium smecite, hydrated silica, kaolinite group minerals, and iron oxides.

In this experiment we have used Nili Fossae Regions of the Mars to generate results which have been obtained in research paper [23]. The purpose behind conductance of this experiment was to check the results which were obtained by the application. In order to find out whether the results obtained by the application are validate or not the experiment was conducted. After the experiment was conducted same results were found which were obtained in research paper [23]. The following are the results which were found in research papers and those results were compared with the results obtained from the system designed.

Experimental Analysis

Aim: To compare the results of generated by the system with the existing work performed in the research paper [23] [24] in order to check the efficiency of the system.

Result:

To check the efficiency of the system three different regions of Nili Fossae region where selected whose minerals composition where already known and then compared them with the results generated by the system to check the accuracy. We will take 3 different analyzed planetary areas and try to replicate results.

Case 1

In Case 1 The Jezero Crater of Nili Fossae region was used to compare the result obtained by the system. As shown in Figure 6.1 which is a Hypersectral Image of Jezero Crater in Nili Fossae region represents the following:

(a) False Color CRISM image HRL000040FF with colors (red,2.38; green,1.80; blue,1.15μm).

(b) Parameter map(red,D2300;green,BD2500;blue,BD1900H). for each pixel, the red and blue channels are scaled by value of the green channel (($G_{scene\ max}$.-G)/$G_{scene\ max}$.) so that predominantly carbonate-bearing units appear green rather than white.

(c) Crism rationed spectra from regions of interest from light-toned deltaic sediments.

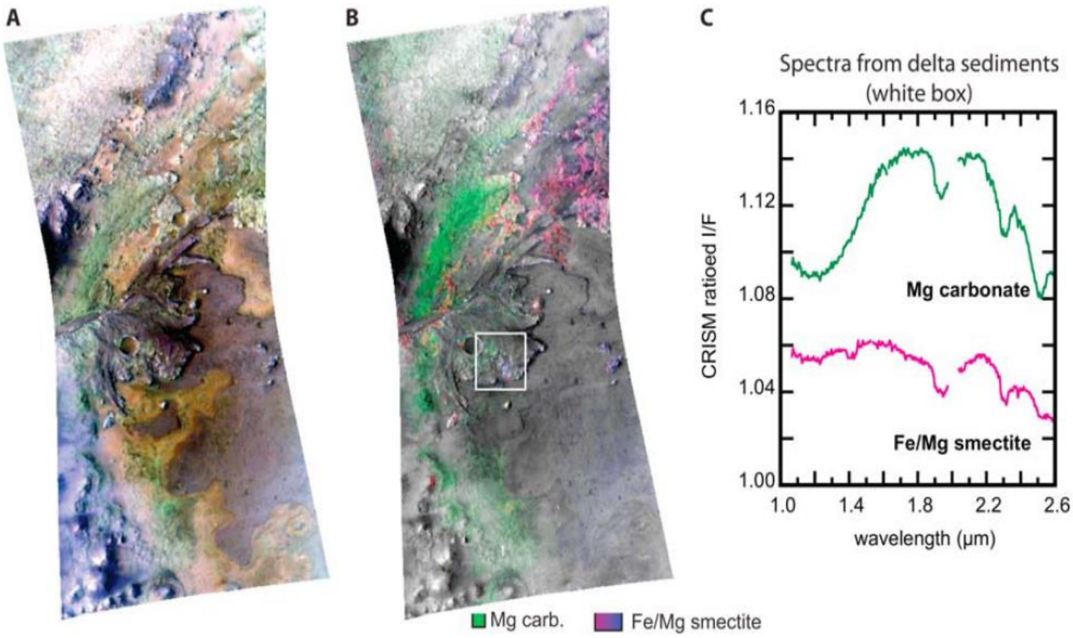


Fig 6. 1 Results from Research Paper

Fig 6.1 Demonstrate the results generated in research paper [23]. It shows the Magnesium – Carbonate deposits and Iron/Magnesium Smectite deposits in Jezero Crater in Nili Fossae region. Fig 6.2 shows the spectrum generated at the particular pixel which is a Magnesium – Carbonate rich region. Fig 6.3 shows the spectrum which is obtained at the laboratory for Magnesium – Carbonate mineral.

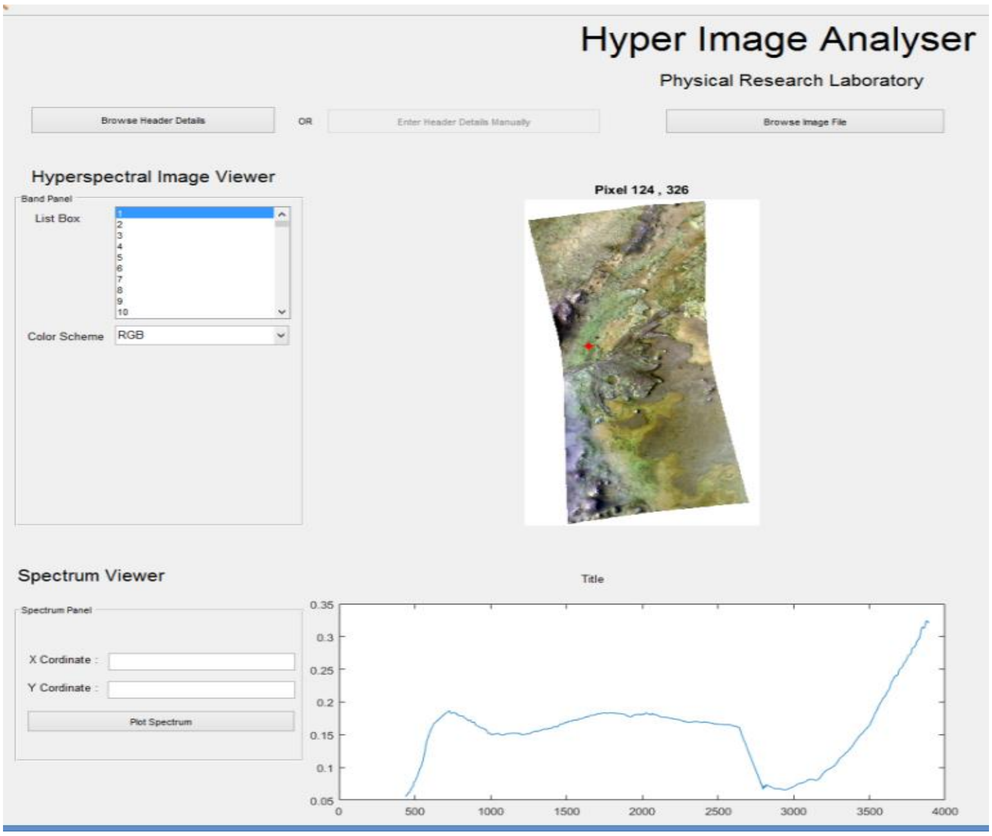


Fig 6. 2 Result generated by the system at Mg-carbonate rich region.

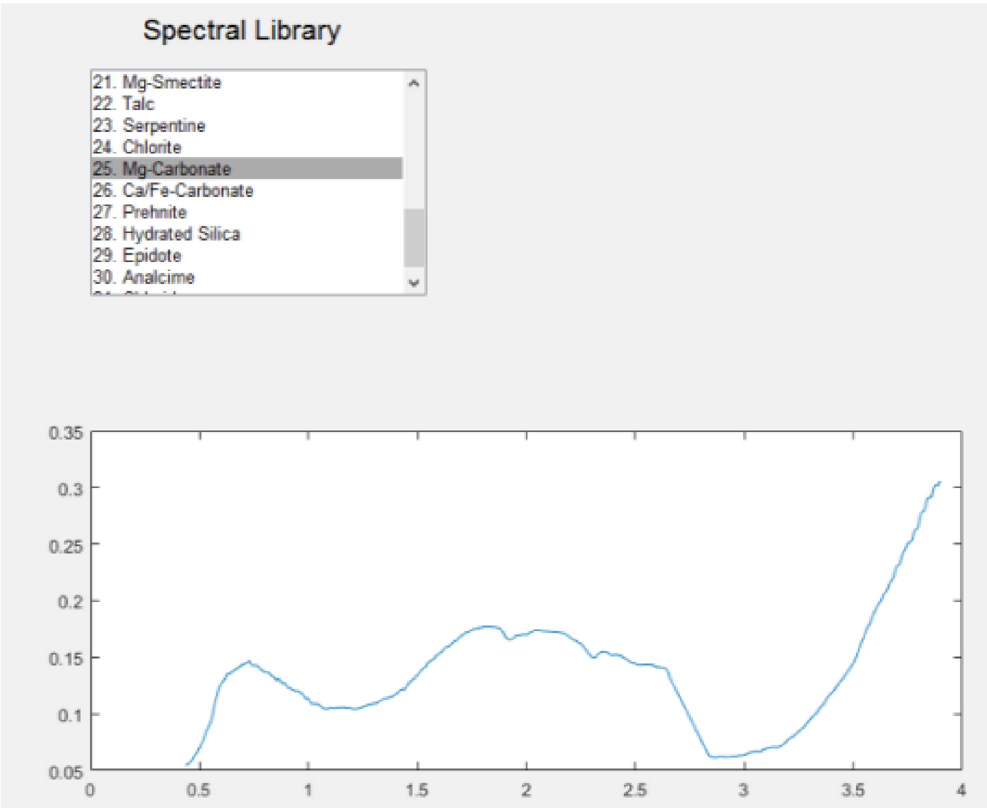


Fig 6. 3 Matching Result from Spectrum Library

Case 2

In Case 2 The rocks in eastern Nili Fossae region bearing Carbonate, Smectite, and olivine was used to compare the result obtained by the system. As shown in Figure 6.4 which is a Hyperspectral Image of Carbonate, Smectite, and olivine bearing rocks in eastern Nili Fossae region represents the following:

(a) False Color CRISM images of FRT00003E12, FRT0000B438, FRT0000A4FC, and FRT0000871C (red,2.38;green,1.80,blue,1.15µm). With this choice of bands olivine appears yellow.
(b) CRISM data from Figure 6.4a was used to colorize a subset of HiRISE.
(c) Same HiRISE subset colorized with a CRISM parameter map (red, OLINDEX; green, BD2500; blue, D2300). The red and blue channels are scaled by ((Gscene max.–G)/Gscence max.) so that carbonate-bearing units are green rather than white. Red is olivine, and blue is Fe/Mg smectite. Noncarbonate altered olivine is magenta.
(d) Unratioed CRISM spectra from the units labeled 1–4 in Figure 6.4c.
(e) Close-up view of Figure 6.3c.

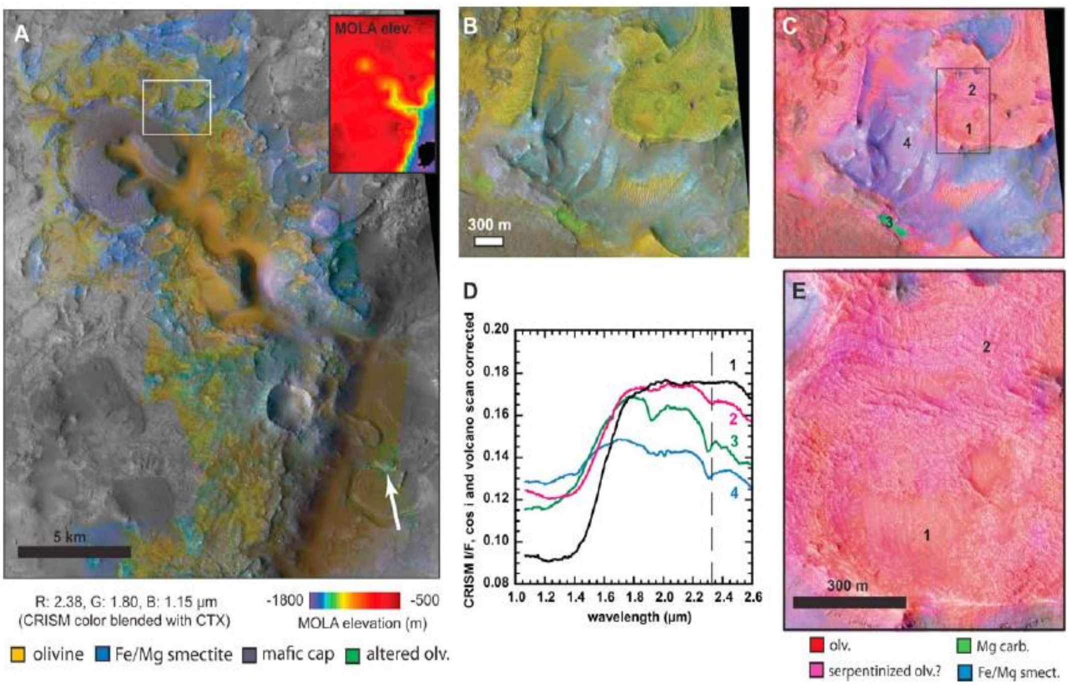


Fig 6. 4 Nilli Fosae Region containing Olivine

Fig 6.4 Demonstrate the results generated in research paper [23]. It shows the Magnesium – Carbonate deposits, Iron/Magnesium Smectite, Olivine deposits in eastern Nili Fossae region. Fig 6.5 shows the spectrum generated at the particular pixel which is a region that demonstrate the presence of olivine in that region. Fig 6.6 shows the spectrum which is obtained at the laboratory for Olivine mineral.

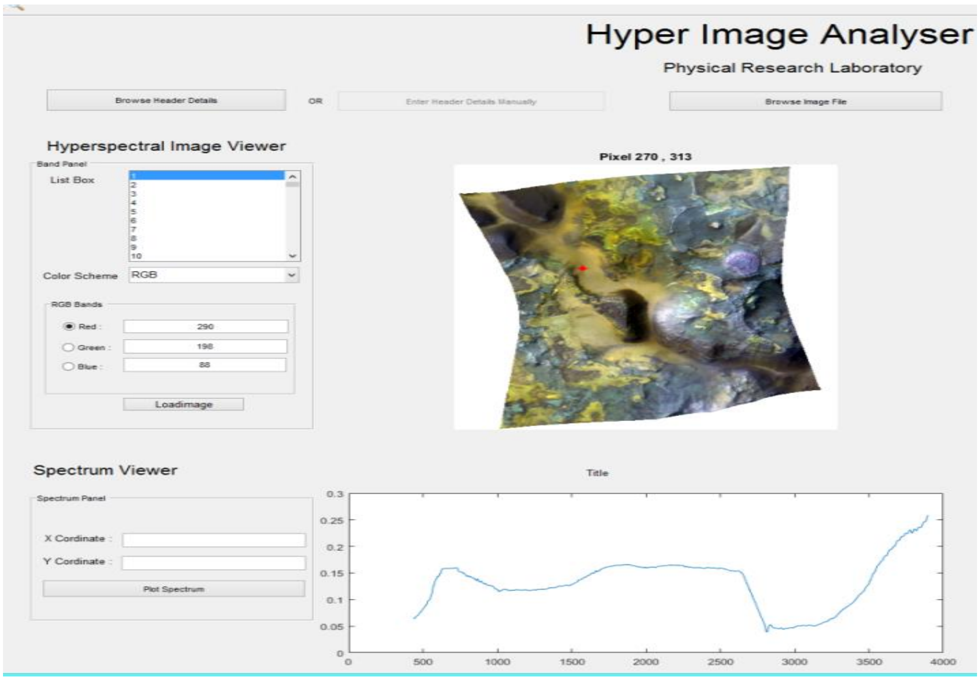


Fig 6. 5 Result generated by the system at olivine rich region.

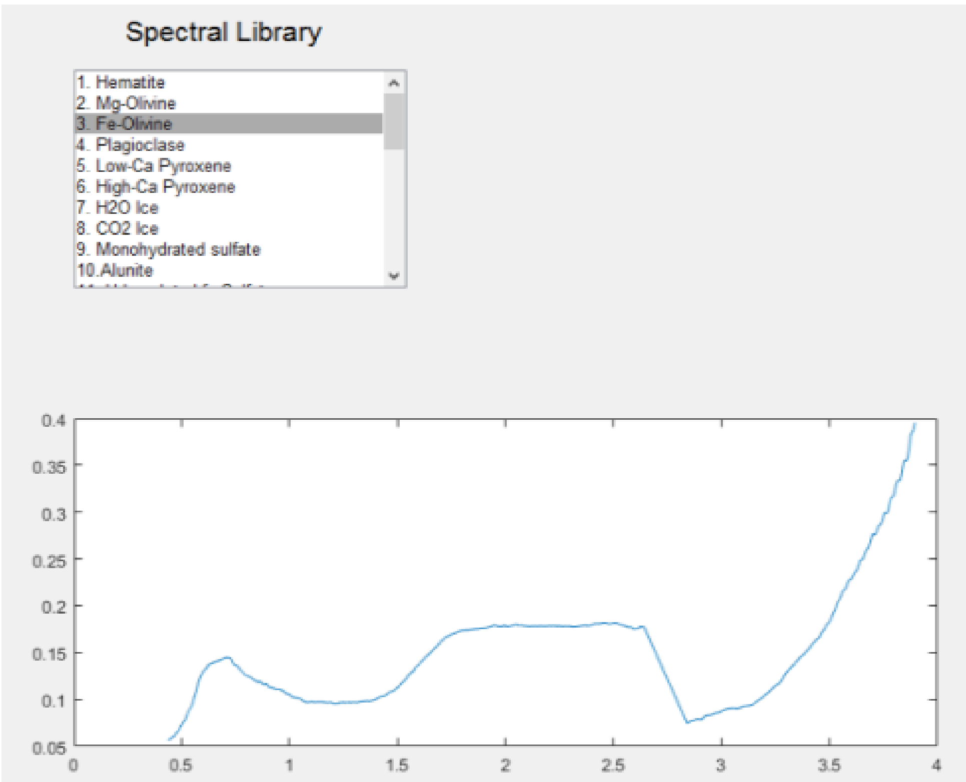


Fig 6. 6 Matching Fe-Olivine Result from Spectrum Library

Case 3

In Case 3 the Isidis Basin of Nili Fossae region was used to compare the result obtained by the system. As shown in Figure 6.5 which is a Hyper Spectral Image of Isidis Nili Fossae region represents the following:

(a) False Color Image of CRISM observation FRT00003E12.
(b) Zoomed CRISM view of a carbonate-bearing outcrop in green.
(c) The stratigraphic position of the carbonate-bearing layer. The numbering of the materials indicates the order of their deposition. The white box in figure 6.5a shows the location of figures 6.5b and 6.5c.

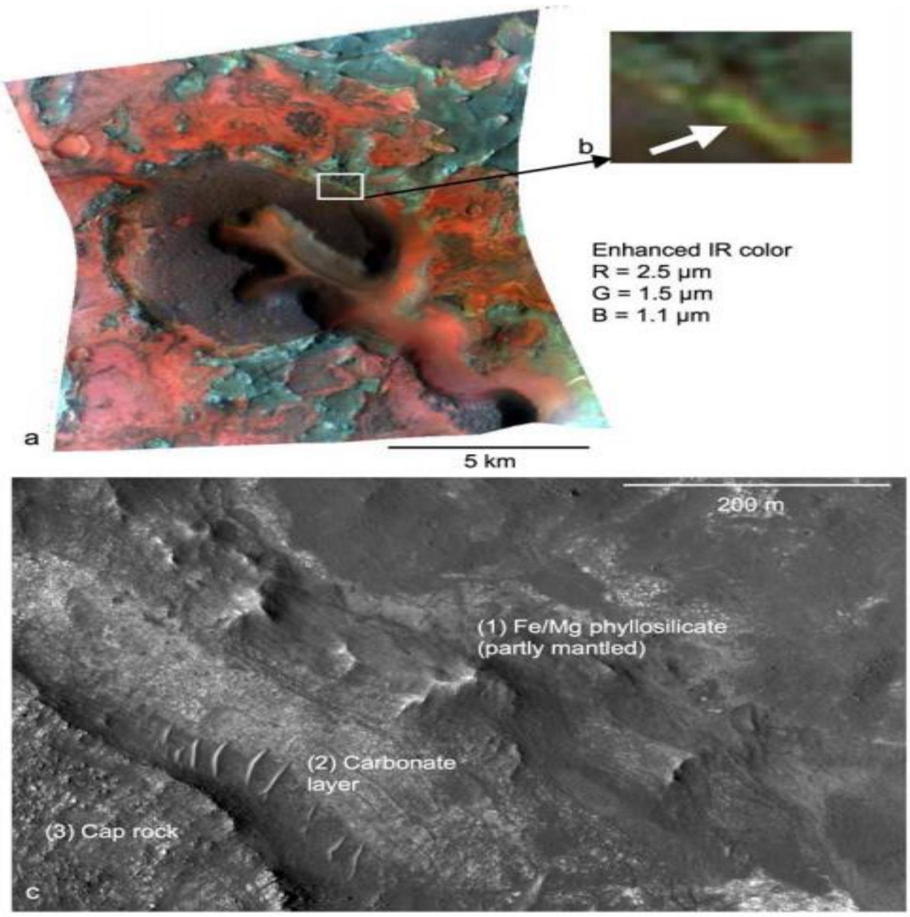


Fig 6. 7 Carbonate-bearing rock surrounding the Isidis Basin.

Figure 6.7 Demonstrate the results generated in research paper [24]. It shows the Iron/Magnesium phyliosilicate, Olivine, Cap rock deposits in the Isidis Basin. Fig 6.8 shows the spectrum generated at the particular pixel which is a region that shows the presence of olivine in that region. Fig 6.9 shows the spectrum which is obtained at the laboratory for Olivine mineral.

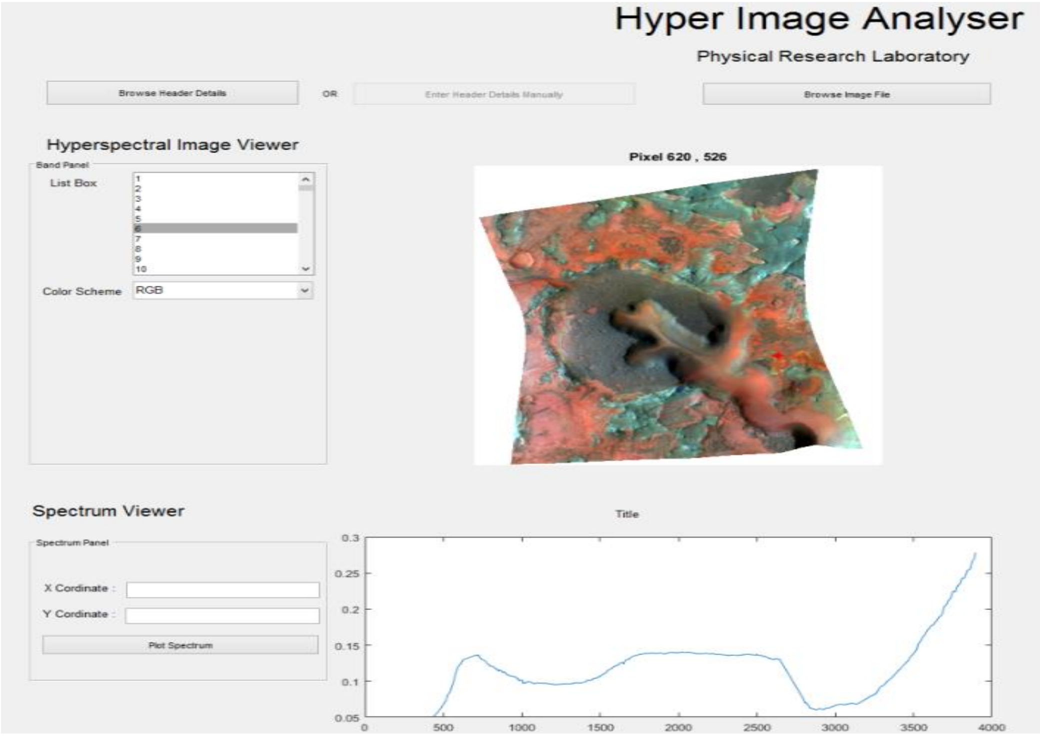


Fig 6. 8 Result generated by the system at olivine rich region in Isidis Basin

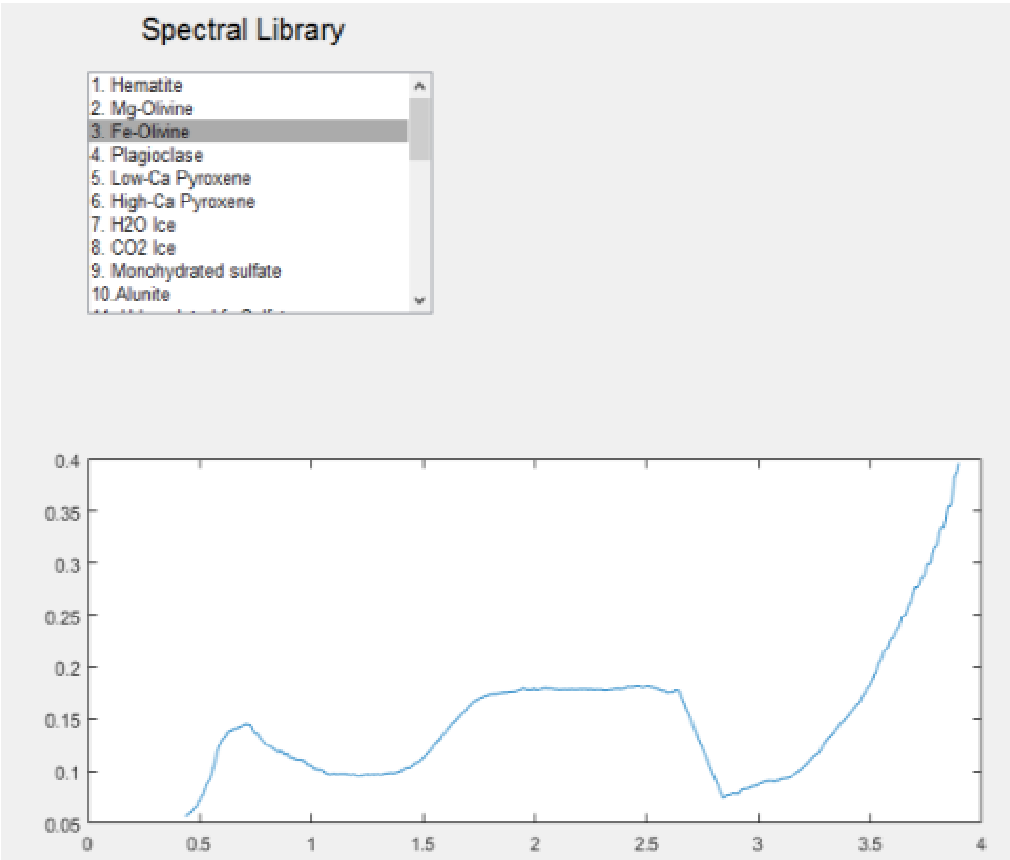


Fig 6. 9 Matching Result from Spectral Library

Experimental Conclusion:

The System was able to replicate the results of existing work done in research paper [23] [24]. By conducting this experiment, it can be concluded that the system was able to generate the same result of known region therefore it can be used to obtained results of any unknown region which would help to discover its mineral composition.

CHAPTER 7

CONCLUSION & FUTURE ENHANCEMENTS

7.1 CONCLUSION

This project has enlightened me with many aspects not only about technical aspects but also about the domains beyond computer science. We learned many tools in MATLAB and using various software used for analysis of data from different space agencies. Hyper Image Analyser, an easy to use analyser has been developed for reading multispectral and hyperspectral images, spectrum analysis and detection of craters and mineral identification from planetary data using MATLAB. We have replicated the results of known and published research work to know more about the efficiency of the system. We have performed automatic detection of craters using filtering and Circular Hough transformation. Another important part of this study is spectral analysis of any region of interests. Every mineral has a unique hyperspectral signature and band center combination and by analysing these, minerals can be identified. Here we analyse data from Moon Mineralogy Mapper aboard Chandrayaan-1 and CRISM data from Mars Reconnaissance Orbiter. The task was difficult in this short span of time but with great power comes great responsibilities. We successfully developed our system fulfilling the promises made at the start and made tasks of analysis easier for our scientists and analysts.

7.2 FUTURE ENHANCEMENTS

- In future as and when experiments are conducted and new spectral signatures are generated, they can be easily included in the spectral library.
- Techniques like Modified Gaussian Model, Curve Fitting etc. that have their basis on mathematics can be implemented and merged easily into this tool as MATLAB is a very powerful software.
- Hyper Image Analyser can advance to a level which would be a whole and sole tool for remote sensing scientists to read, analyse and process hyperspectral data.

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