
***Team Name: Archer***

**College: Indian Institute of Technology, Madras; Indian Institute of Technology, Bombay**

***Team Members Details:***

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3. **Atreem Das**

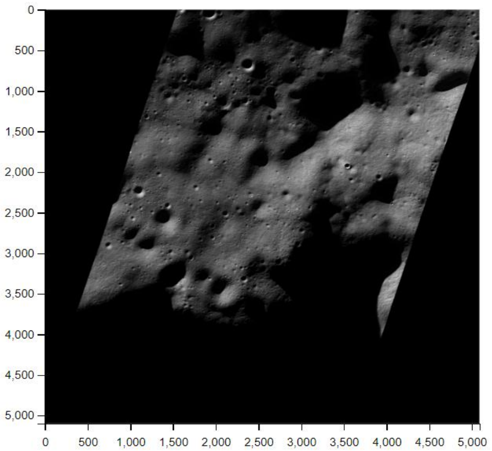
To tackle the challenge of identifying a safe navigation route on the Moon's south pole using Chandrayaan images, we adopted a systematic approach that began with the analysis of the landing site and concluded with the development of a navigable path incorporating scientific stops.

1. **Landing Site Selection and Initial Analysis:** We began by focusing on the landing coordinates at **85.28° S**, **31.20° E**. Using the Chandrayaan-2 **Terrain Mapping Camera (TMC)** and **Digital Terrain Model (DTM),** we meticulously analyzed the topography and terrain surrounding this location. This preliminary analysis enabled us to identify potential hazards such as boulders, craters, and steep slopes using **Hazard mapping** using **Computer Vision** and **Python**.
2. **Path Development and Scientific Stops:** We generated a traverse path extending **at least 100 meters** from the landing site. Our goal was to ensure the path was free from obstacles and incorporated scientifically valuable stops. The **Optical High Resolution Camera (OHRC)** data was crucial for identifying detailed surface features, while the **Imaging Infrared Spectrometer (IIRS)** provided insights into **material composition**. We used **QGIS** to overlay the datasets and delineate a path that avoided large shadows and extreme slopes. The path was designed to be partially in sunlit regions to **maximize solar power efficiency** for the rover. We identified and marked ten scientifically interesting stops along the route. This process was done with **hyperspectral analysis of CH2 IIRS data**. These stops included potential sites for **mineralogical analysis** and observations of unique geological formations.
3. **Path Justification and Detailed Explanation:** The chosen path was selected based on the presence of scientifically intriguing features, such as **unusual mineral deposits** and geological formations, while **avoiding hazardous regions**. We ensured that the rover's **ground clearance** was sufficient to navigate the path without encountering obstacles. The path’s alignment was adjusted to **optimize solar exposure**, preventing the rover from traversing long periods in permanent shadow.
4. **Annotated Map Preparation:** An annotated map was created using QGIS, clearly marking the 100-meter traverse path, landing site, and ten stops. The map highlighted major features and ensured that the path adhered to safety and scientific requirements.

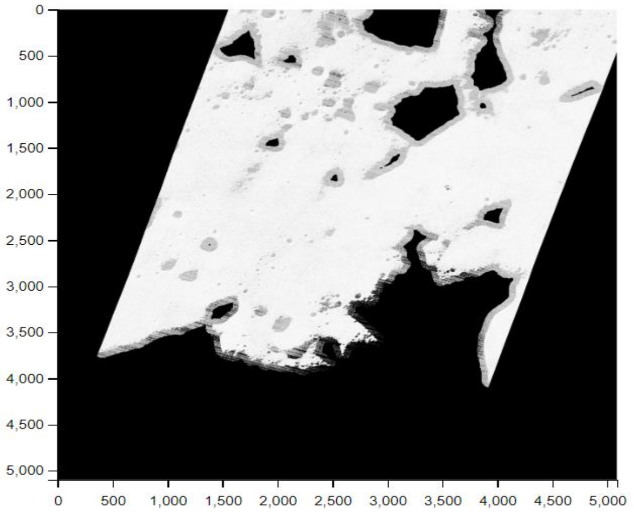
## **HAZARD MAPPING** - COMPUTER VISION BASED APPROACH USING PYTHON, QGIS AND OPENCV

### 1. Load raster and Extract Region of Interest (ROI)

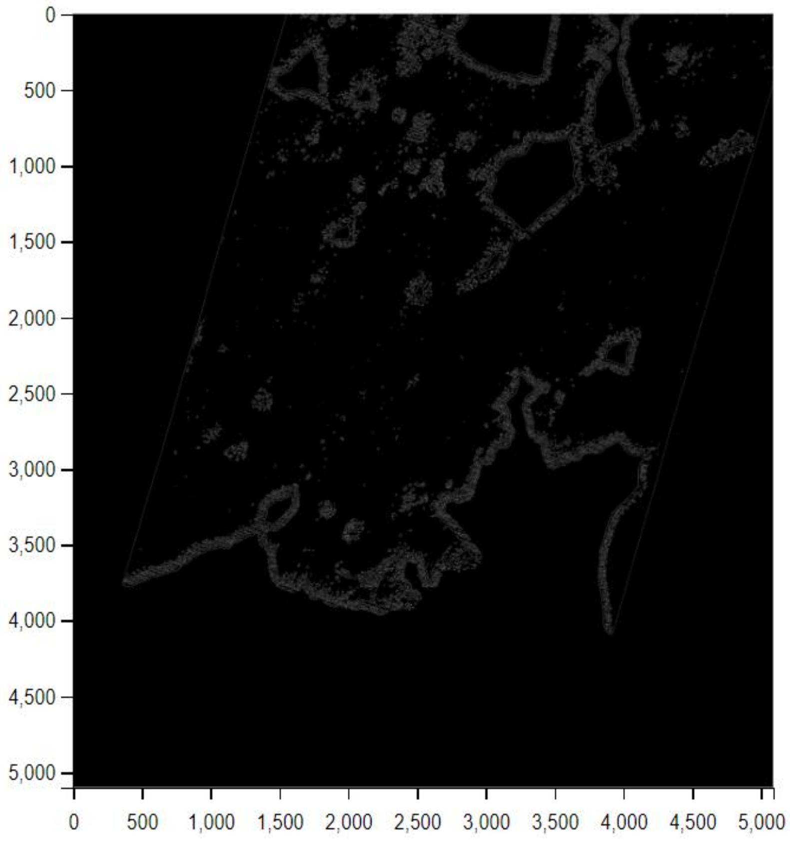
a)Python-opencv and rasterio was used to read tmc data exported as **.tif file** from **qgis** after **cropping ROI** in qgis using raster-extract tool.




b)A **slope map** of same ROI was extracted from qgis in .tif format by using the raster terrain analysis tool “Slope”. This was read in using rasterio. (**z-factor** was **set to 20.00** to extract **only high slope** areas)




c)The read data was reshaped to **(x, y, bands) shape** and stored as **numpy nd-arrays**




## 2.Identify High Slope areas

a)Slope map was converted to **grayscale** and **high slope gradient** was figured out by identifying values in the np array in the high slope gradient range using **cv2.inRange()** function.

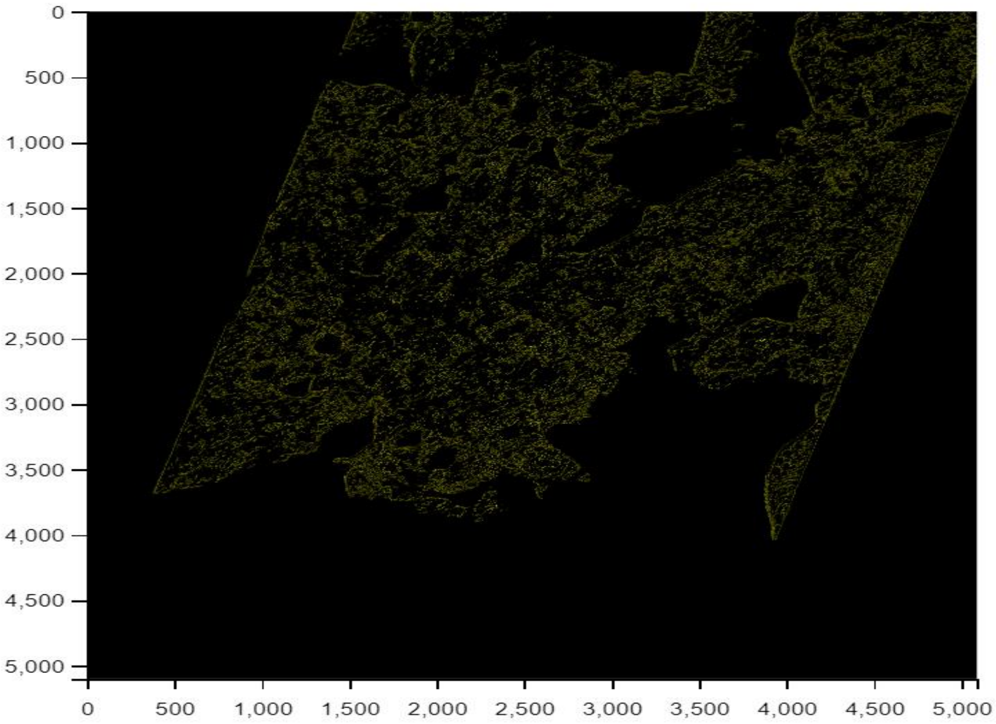
b)A **mask** was created using the above function and superimposed on the tmc roi data to identify high slope regions.

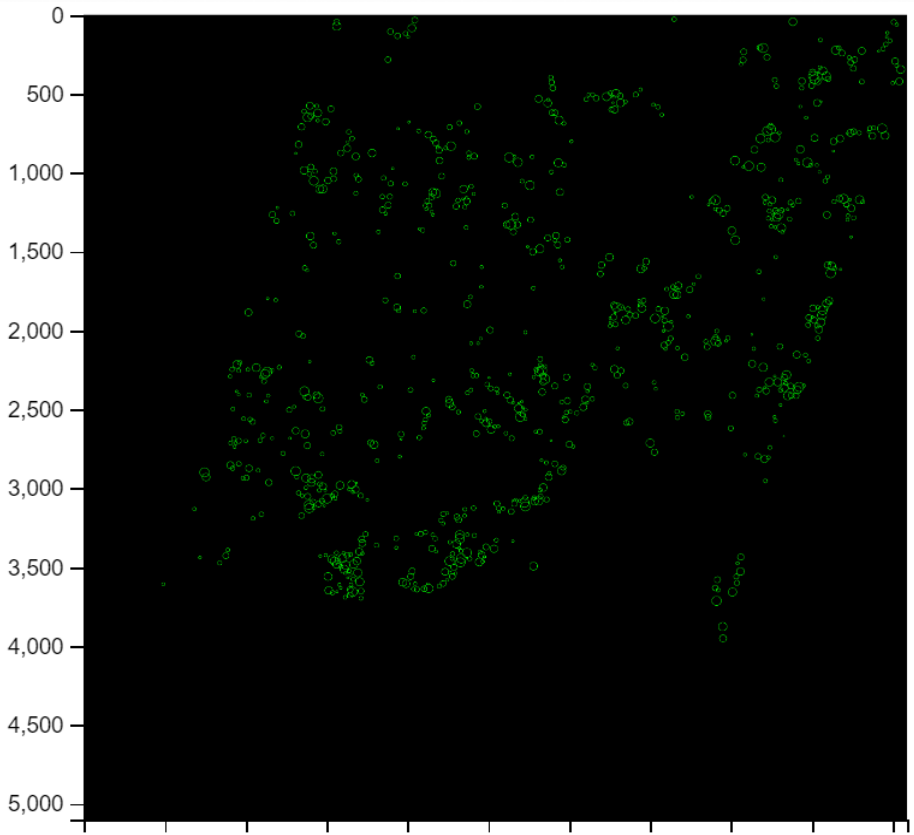
**3.Ridge Detection with Canny Edge**

a)A copy of the **initial ROI** was extensively blurred using the **gaussian blur method** for identification of **high risk ridges**.

b)OpenCV **Canny Edge** algorithm was executed on the blurred image to create **a mask of edges** found of high risk grayscale gradient. The higher the gradient, the faster neighboring pixels change grayscale values. This mask was superimposed on the tmc roi np array to identify ridges too risky for a rover to cross.

c)The **steepness** of the ridge was identified by the **grayscale intensity** of the canny edge mask lines. $\text{steepness} \propto \mathit{grayscale\ intensity}$






## 4.Crater Filtering with Hough-Circles Algorithm

a)Original tmc roi was converted to grayscale and blurred.

b)Hough Circles algorithm was **fine tuned** to identify different craters **fitting two category sizes.**

c)Both these categories had their own hough circle filter to **identify individual craters** and **dense small-sized crater areas** to avoid.

# Technologies Used

We utilized Python and Jupyter for data processing and analysis, employing OpenCV for feature detection using Hough Circles and image ROI algorithms. QGIS and ArcMap facilitated map creation and path planning. NumPy supported numerical operations, while the A*/dijkstra algorithm optimized the rover's traverse route, ensuring safety and efficiency.

## Differentiation from Existing Ideas:

Our approach stands out by **integrating multiple datasets** (TMC, DTM, OHRC, and IIRS) to create a comprehensive, **multi-layered analysis** of the lunar south pole. While traditional methods often rely on single-source data or simplistic path planning, our solution combines **advanced image processing** (using OpenCV’s Hough Circles and image ROI algorithms) with **sophisticated pathfinding techniques** (like A*), allowing for a more detailed and scientifically enriched navigation route.

## Problem Solving:

The solution addresses the challenge of navigating the Moon's south pole by providing a safe, obstacle-free path that incorporates scientifically valuable stops. By leveraging **high-resolution imagery** and **terrain models**, we ensure that the rover avoids hazardous **areas** such as craters and boulders while maximizing scientific exploration opportunities. The integration of solar considerations and the avoidance of permanent shadows optimize the **rover's power efficiency** and **operational capability**. The stop points are determined using **the concentrated ice-caps from terrain analysis** and **the hyperspectral analysis of IIRS.**

## Unique Selling Proposition (USP):

The USP of our solution lies in its holistic approach combining **diverse data sources** with advanced algorithms for **detailed path planning**. This method not only ensures safety by avoiding obstacles but also enhances scientific value by **strategically positioning stops** for in-depth analysis. The use of Python, Jupyter, OpenCV, Spectral Python and QGIS for integrated data processing and pathfinding ensures a robust, innovative solution that balances **practical navigation** needs with scientific exploration goals. The use of **Hyperspectral Analysis of CH2 IIRS Data** and **Computer vision based Geospatial Analysis** creates a efficient navigation path.

# Features Offered by the Solution

**1.High-Resolution Terrain Analysis:**

1. Utilizes data from Chandrayaan-2's Terrain Mapping Camera (TMC) and Optical High Resolution Camera (OHRC) for detailed terrain analysis.
2. Provides a clear view of the lunar surface, identifying potential hazards like craters and boulders.

**2.Advanced Feature Detection:**

1. Implements Hazard mapping, hyperspectral analysis and CV based Geospatial Analysis to extract specific features from the datasets
2. Uses image analysis to focus on specific areas of interest.

**3.Optimized Path Planning:**

1. Applies the A* algorithm to generate a safe, obstacle-free path for the rover.
2. Considers ground clearance and terrain challenges to ensure smooth navigation.

**4.Scientific Stops Identification:**

1. Integrates data from the Imaging Infrared Spectrometer (IIRS) to pinpoint scientifically significant sites.
2. Marks at least ten stops for detailed analysis and observations.

**5.Solar Exposure Analysis:**

1. Evaluates the solar exposure of the rover's path to optimize energy usage and prevent operation in permanently shadowed regions.

**6.Interactive Visualization:**

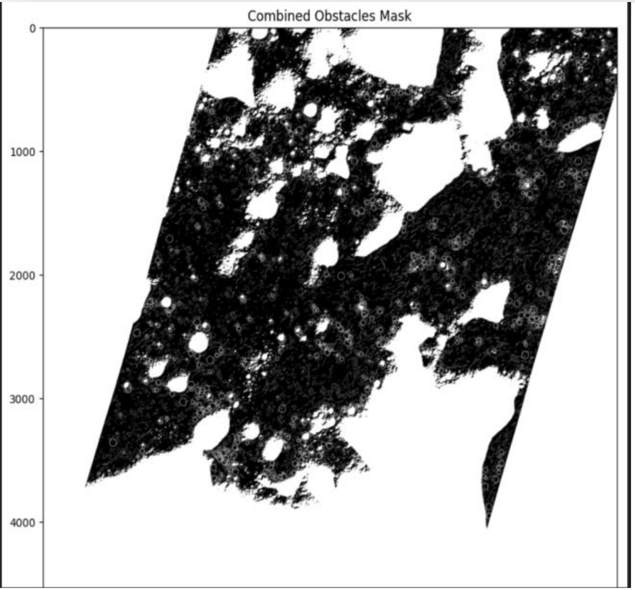
1. Provides an interactive map using QGIS and ArcMap for users to view and modify the rover's path and scientific stops.
2. Offers clear annotations of the traverse route and key features.

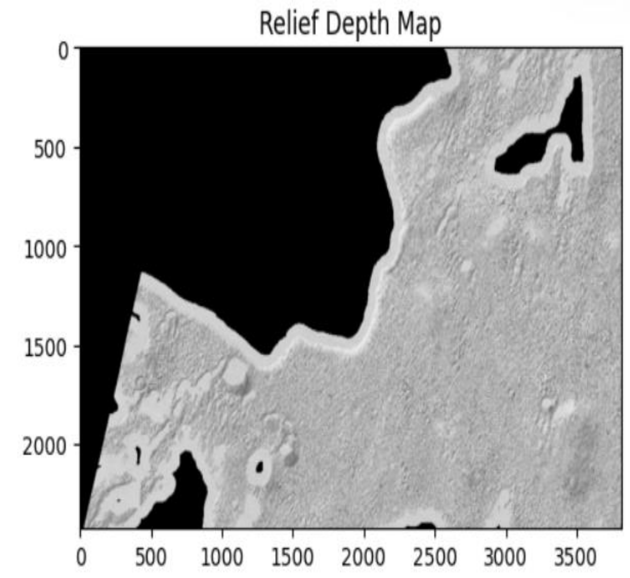
**7.Dynamic Path Adjustment:**

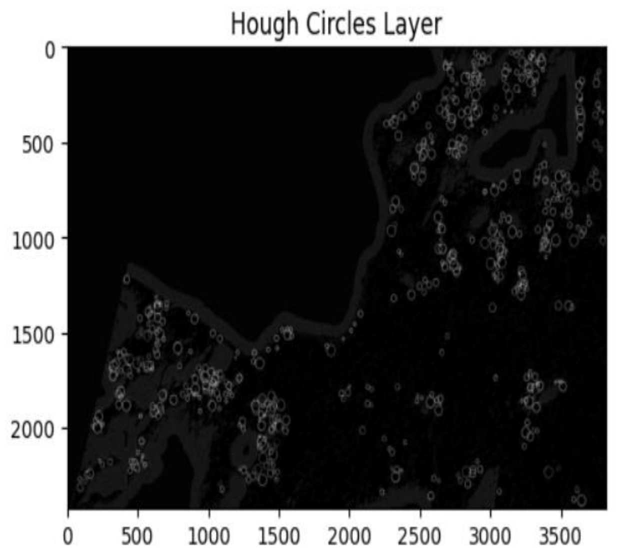
1. Allows users to adjust the path and stops based on real-time data and requirements.
2. Ensures flexibility and adaptability in mission planning.

**8.Annotated Map Creation:**

1. Generates detailed annotated maps showing the rover's route, scientific stops, and major features.
2. Enhances mission planning and communication through clear visual representation.



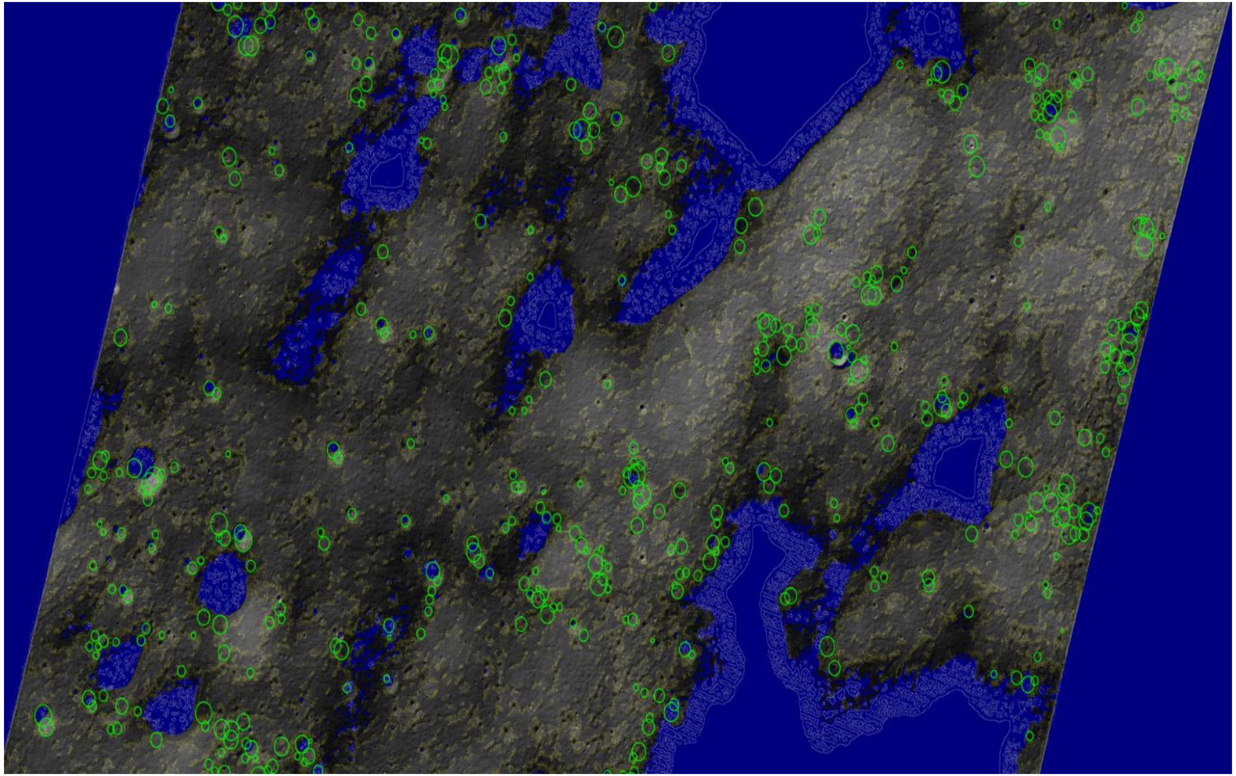



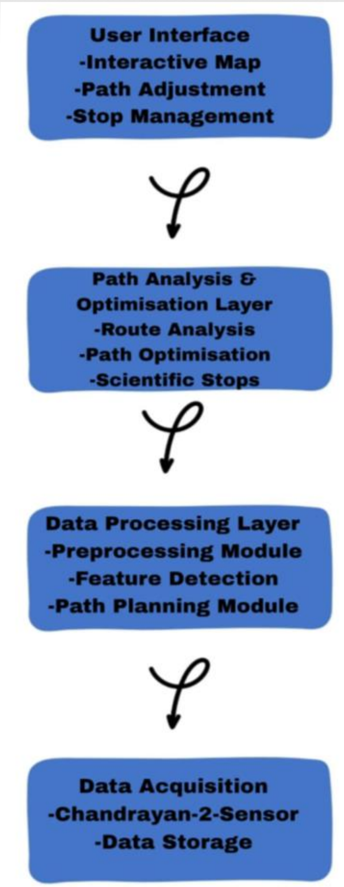




Obstacle Mask From Extracted Features

Relief Map Of OHRC Image

Hough Circles for crater detection

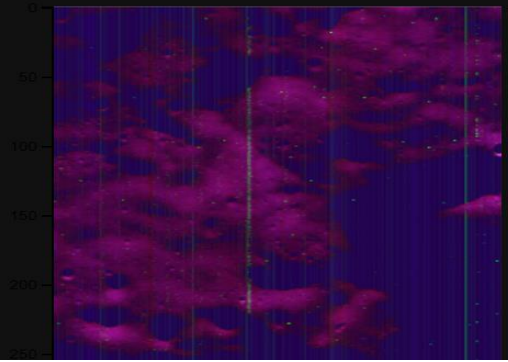



User Interface
-Interactive Map
-Path Adjustment
-Stop Management
Path Analysis &
Optimisation Layer
-Route Analysis
-Path Optimisation
-Scientific Stops
Data Processing Layer
-Preprocessing Module
-Feature Detection
-Path Planning Module
Data Acquisition
-Chandrayan-2-Sensor
-Data Storage

# Hyperspectral Analysis of CH2 IIRS Data

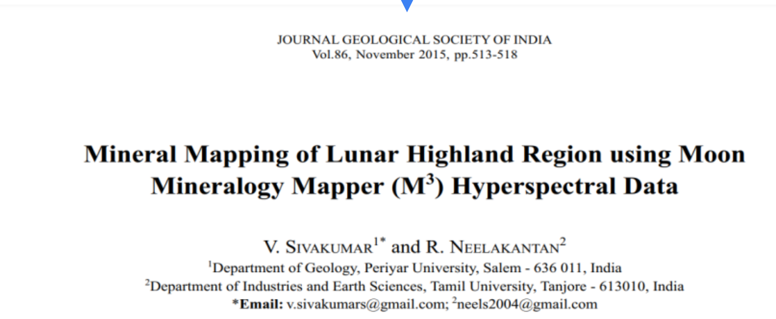
```
spectral.imshow(mnf_transformed_data, bands=[0,1,2])

[30]: ImageView object:
        Display bands       :   [0, 1, 2]
        Interpolation       :   <default>
        RGB data limits     :
          R: [-201.5746140223841, 773.377369107641]
          G: [-38.86877941665445, 1171.8502009164586]
          B: [-52.34703594829066, 125.09763142099663]
```




1. **MNF (Maximum Noise Fraction)** method applied to reduce dimensionality of original image.
2. Calculated **PPI (Pixel Purity Index)** to identify endmembers, extracted using **K-Means**. 7 endmembers were processed
3. **MSAM**, a modified version of **the SAM (Spectral Angle Mapper)** algorithm was used to identify **spatial distribution** of the endmembers on the region of interest. The endmembers extracted from **PPI** by **K-Means** was used as reference spectra for the MSAM method.

REFERENCE PAPER



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**Mineral Mapping of Lunar Highland Region using Moon Mineralogy Mapper ($M^3$) Hyperspectral Data**

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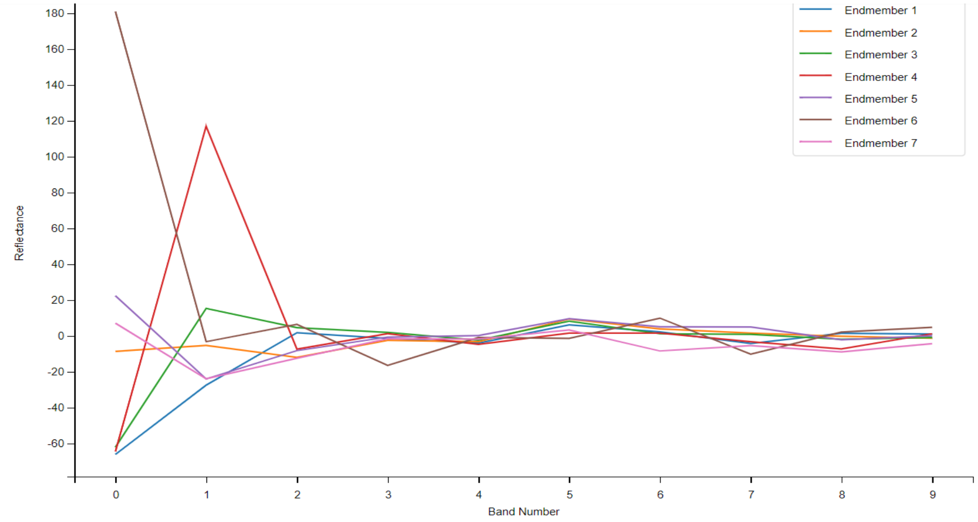
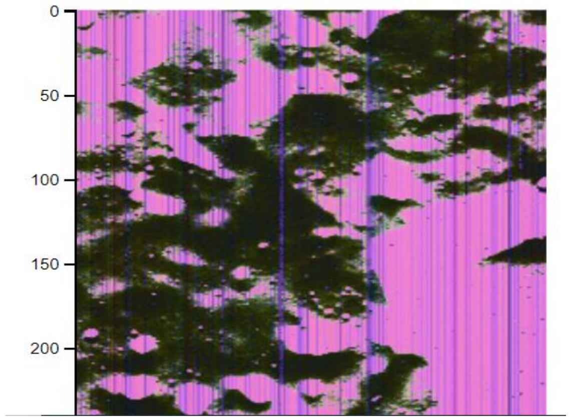
```
spectral.imshow(sam_result, bands=[0,1,2])
```

```
(330, 244, 7)
```

[76]:
```
ImageView object:
  Display bands       :  [0, 1, 2]
  Interpolation       :  <default>
  RGB data limits     :
    R: [-0.9383988649187354, 0.9999999865842415]
    G: [-0.462467600137316, 1.0]
    B: [-0.9629775269077836, 1.0]
```

## Spatial Distribution of Minerals




Diverse and concentrated groups of minerals like olivine, anorthosite, pyroxene etc.

## Solution Brief: Lunar Rover Navigation System

**Objective:** The goal of this project was to develop a robust and efficient navigation route for a lunar rover on the south pole region of the Moon using data from Chandrayaan-2 missions. The solution aimed to ensure safe and scientifically valuable exploration by integrating high-resolution imaging and terrain data, advanced feature detection, and optimized path planning.

**Key Components:**

**1.Data Acquisition:**

1. Utilized imagery and terrain models from Chandrayaan-2's Terrain Mapping Camera (TMC), Optical High Resolution Camera (OHRC), and Imaging Infrared Spectrometer (IIRS) to gather comprehensive surface and topographic data.

**2.Data Processing:**

1. Employed preprocessing techniques to enhance and prepare data for analysis.
2. Applied OpenCV algorithms, including Hough Circles, Canny Edges on ROI, to detect and map surface features such as craters and boulders.

**3.Path Planning:**

1. Used the A* and Dijkstra's algorithm to generate an obstacle-free path for the rover, ensuring it avoids hazardous areas while maintaining a minimum distance of 100 meters from the landing site.
2. Analyzed solar exposure to optimize energy efficiency and avoid long periods in permanently shadowed regions.

**4.Path Analysis and Optimization:**

1. Incorporated scientific data to identify and mark at least ten significant stops along the path for in-depth analysis and exploration.
2. Created an annotated map highlighting the rover's route and key features, facilitating mission planning and execution.

**5.Interactive Visualization:**

1. Developed interactive maps using QGIS to visualize the rover's path and scientific stops.
2. Enabled users to adjust and optimize the route based on real-time data and mission requirements.

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# THANK YOU