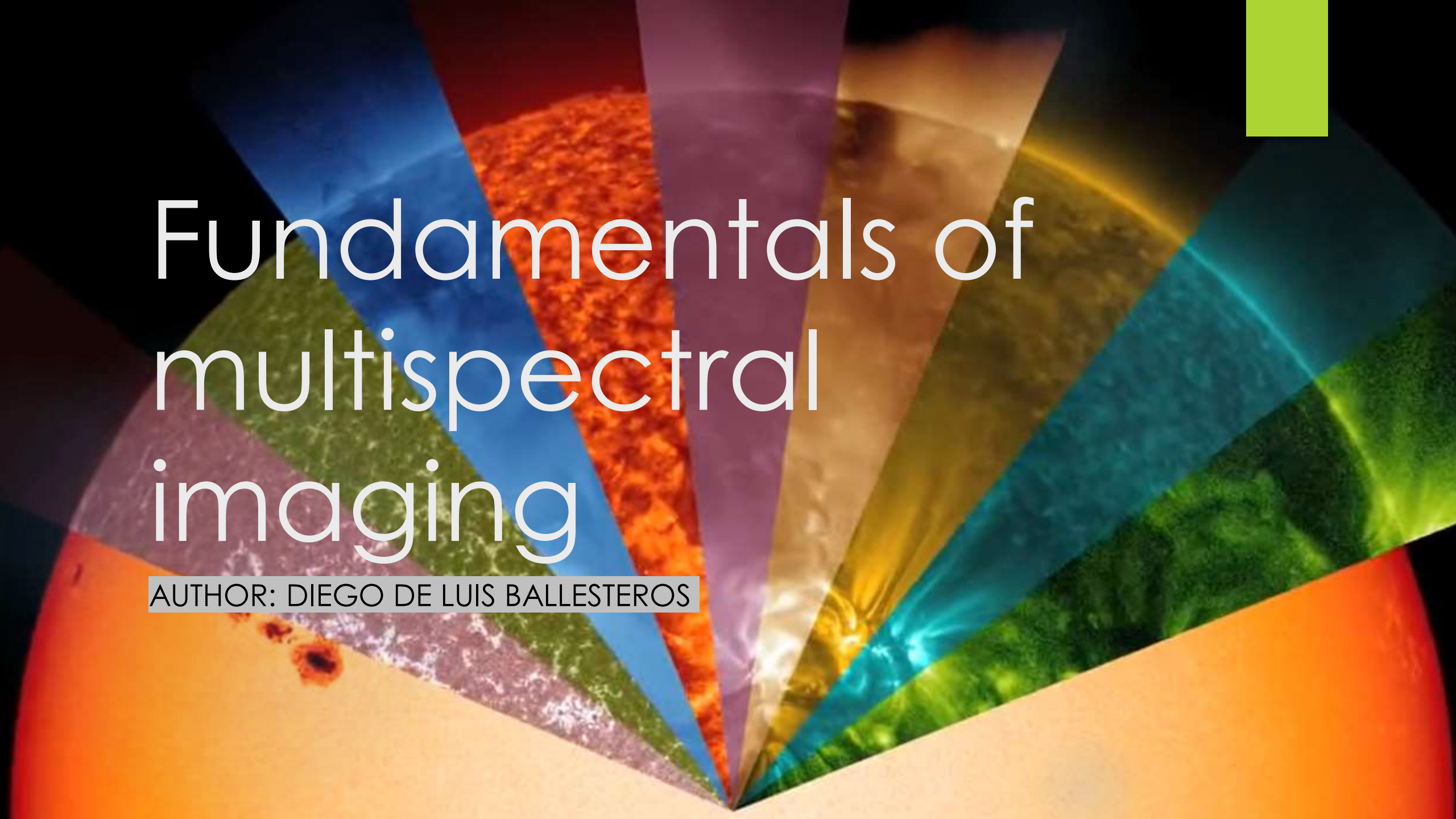

Fundamentals of multispectral imaging

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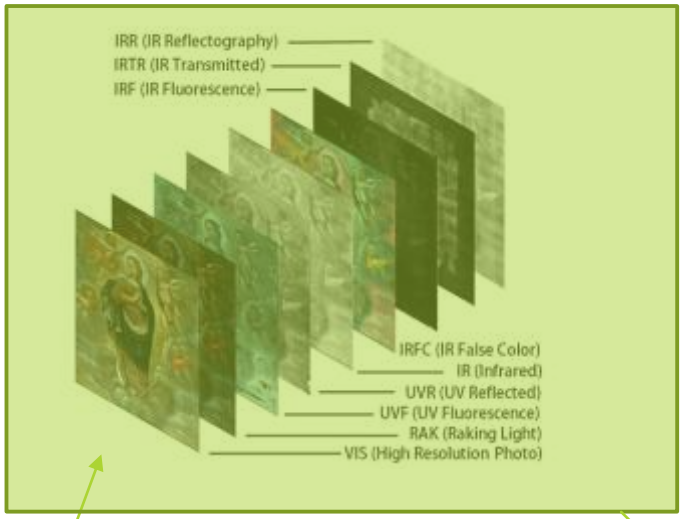
What's a multispectral image?

- Multispectral images are images that capture information at multiple wavelengths across the electromagnetic spectrum. Unlike a typical color image that consists of three-color channels (red, green, and blue), multispectral images have more than three bands, often covering a broader range of wavelengths.



One image

A couple of images in different spectrums

Applications of multispectral imaging

Agriculture:

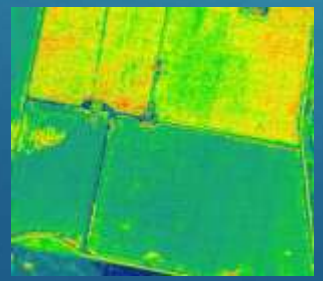
- Crop monitoring and management.
- Disease detection in plants.
- Precision agriculture for optimizing resource use.

For example, sometimes, plants has different radiation when they are not healthy

Medical Imaging:

- Differentiating between healthy and diseased tissues.
- Identifying specific molecular markers.
- Imaging for diagnostic purposes.

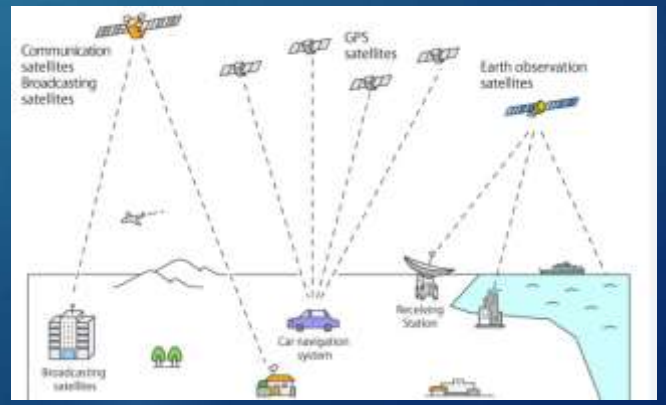
For example, multispectral imaging can capture information from different wavelengths, allowing for the characterization of tissues based on their spectral signatures.



Remote Sensing and Earth Observation:

- Monitoring and managing natural resources.
- Studying land cover and land use changes.
- Assessing environmental conditions and biodiversity.

For example, big forest surfaces usually has the infrared spectrum higher than other surfaces.



Which are the differents extensions we can represent our multispectral image?

TIFF (.tif):

- Tagged Image File Format is a versatile and widely used format for storing images. It supports lossless compression and can store multispectral data with multiple bands.
- It is the principal extension

How can I know how many bands has my .tif image?

Download: ImageMagick Display

```
(base) C:\Users\diego\OneDrive\Escritorio>magick identify -verbose img11.tif
Image:
  Filename: img11.tif
  Permissions: rw-rw-rw-
  Format: TIFF (Tagged Image File Format)
  Mime type: image/tiff
  Class: DirectClass
  Geometry: 1748x1819+0+0
  Resolution: 72x72
  Print size: 24.2778x25.2639
  Units: PixelsPerInch
  Colorspace: sRGB
  Type: TrueColorAlpha
  Base type: TrueColor
  Endianness: LSB
  Depth: 8-bit
  Channels: 4.0
```

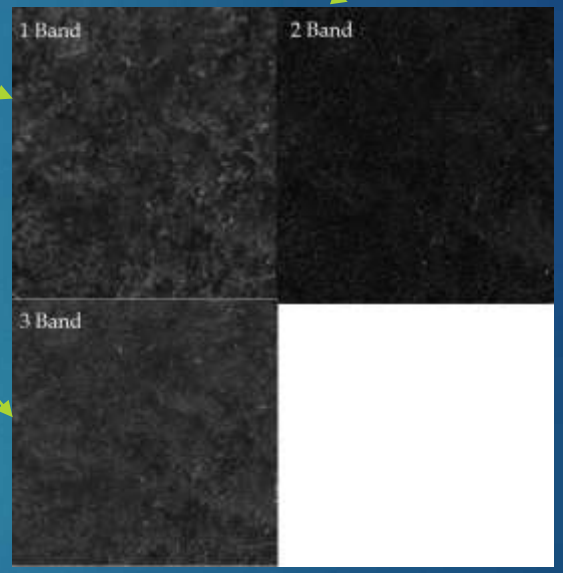
This image has 4 bands

JPEG (.jpg, .jpeg):
•**Compression:** Uses lossy compression.
•**Consideration:** May result in a loss of information, suitable for general images.

GeoTIFF (.tif):
•**Special Feature:** Contains additional georeferencing information.
•**Purpose:** Used when spatial referencing is essential for geographic data.

More about ImageMagick Display

- You can also use it to merge images into a multispectral image



- You can also use itto separate images in their different bands

```
>magick convert img11.tif -separate band%d.tif
```

Separated images ar in black and White spectrum

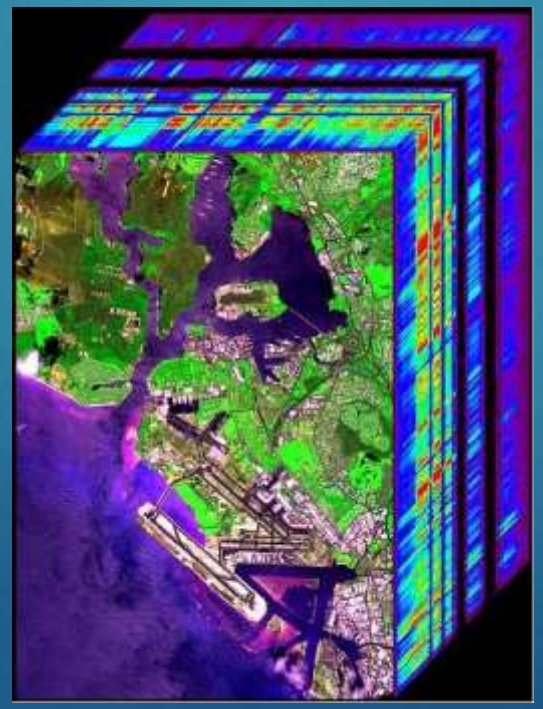
Some principles of multispectral imaging

Spectral and spatial resolution

Spectral resolution refers to the ability of the sensor to distinguish between different wavelengths

Spatial resolution pertains to the level of detail in the images and is determined by the size of the pixels on the ground

For example, the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) captures information in 224 spectral channels



This represent what AVRIS can do

Data Fusion:

Data fusion involves integrating multispectral data with information from other sensor types.

Airborne Light Detection And Ranging (LiDAR) systems usually operate at a monochromatic wavelength measuring the range and the strength of the reflected energy (intensity) from objects. Recently, **multispectral LiDAR** sensors, which acquire data at different wavelengths, have emerged

Vegetation discrimination using the new Optech Titan multispectral lidar sensor

Continue of principles of multispectral imaging

Bands and Spectral Signatures

Each band in a multispectral image corresponds to a specific range of wavelengths.

Objects and materials exhibit unique spectral signatures, which are patterns of reflectance or emission at different wavelengths

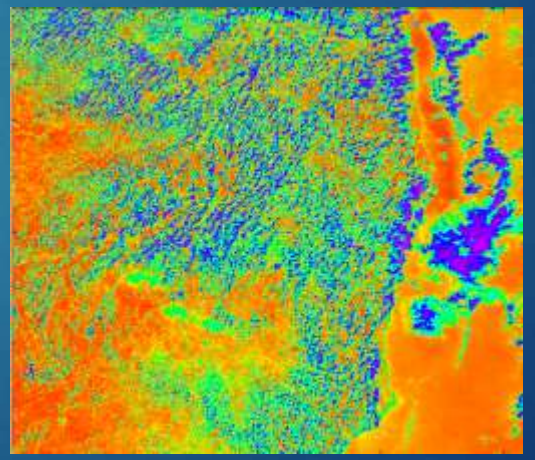
For example

1. Heating devices that generate heat emit infrared radiation as part of the thermal radiation spectrum. In general, all bodies can emit infrared radiation. More temperature, more infrared radiation.

2. **Snow-Covered and Glacial Surfaces:** Snow and ice have high reflectivity in the ultraviolet spectrum. They can reflect a significant amount of UV radiation, especially in snowy or high-altitude glacial areas.

3. **Sand and Light-Colored Surfaces:** Surfaces composed of sand and light materials tend to reflect more ultraviolet radiation. The reflectivity of sand can vary, but in general, lighter surfaces reflect UV radiation better.

Infrared emiting of a tree



In this image high radiation surfaces are represented with blue, in this case clouds, as we can see, are blue, more density in clouds means more near to purple so more UV reflection

Where can I find multiespectral images?

This is a difficult task because multispectral image is not a normal image that you can find easily in Google images. Let's explain 2 ways to find them

Earthdata

In earthdata will be easy take a lot of multispectral images. You can just take images from all of the world. The format of this images will be geotiff, represented as .tif

GeoTIFF is a public domain metadata standard that allows georeferenced information to be embebed in a tif format image file

Landsatlook

Is other map developed by USGS where you can obtain multispectral images in 12 bands. The inconvenet is that they only offer that bands separetly, so we can not get the full multispectral image.

Earthdata multispectral image representation

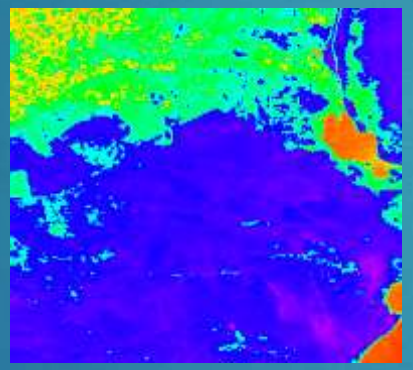
This image has 4 bands, we can only use 3 of them in this case.

- **Red Band:** Typically captures light in the red region of the spectrum. This band may be sensitive to healthy vegetation and some soil characteristics.
- **Green Band:** Captures light in the green region of the spectrum. It is sensitive to vegetation health and soil characteristics.
- **Blue Band:** Captures light in the blue region of the spectrum. It can provide information about surface reflectivity and the presence of water.

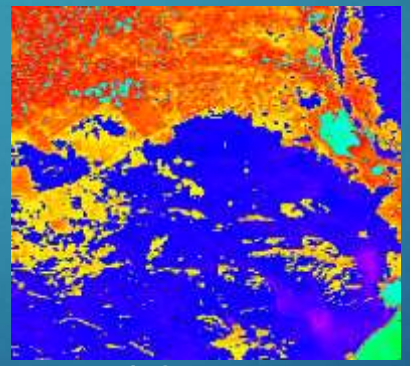
In the next slide I will explain how can we show the data in a multispectral divided image

Data representation of multispectral earthdata image

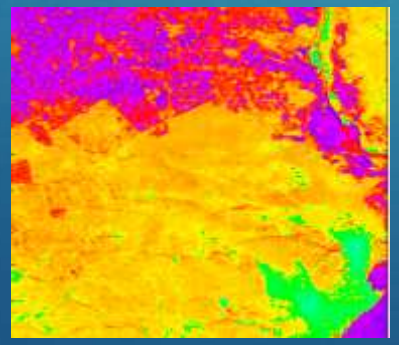
I used MATLAB to generate these images, creating them with a false-color composite. This portion depicts the Nile River Delta, allowing us to observe desert areas, swamps, and the Red Sea. For instance, as clarified in the previous slide, healthy vegetation is depicted in the first band where vegetation exhibits low reflectance, noticeable by the absence of red colors in the first image. The third band represents water, and the colors assigned to lower frequencies like water are blue and purple. As observed in the Nile Delta, there is some water present (purple in third band), but the vegetation doesn't show high reflectance (absence of red colors in first band).
Note: I used red colors for low frequencies in first band because as I mentioned, the first band shows the healthy vegetation, and it is taken on red spectrum. I used the same logic for the rest of bands.



Band 1:
Blue-purple: high reflectation
Green: medium reflectation
Red: low reflectation



Band 2:
Blue-purple: high reflectation
Green: low reflectation
Red: medium reflectation



Band 3:
Blue-purple: low reflectation
Green: High reflection
Red: medium reflectation

Multispectral imaging in MATLAB: Introduction

- 1.The path to the multispectral image is specified, indicating the file name ('our_image.tif'). You should replace it with the actual path of your file.
- 2. The 'imread' function is used to read the multispectral image from the specified path and store it in the variable 'our_multispectral'
- 3. Colormaps are defined for each band of the multispectral image. Each band is associated with a specific colormap that highlights certain features, such as vegetation reflection, water, and other elements.
- 4. For each band, the false-color composite is visualized using the imagesc function. The corresponding colormap is applied, a colorbar is added, and a descriptive title is displayed.

```
% Display the false-color composite
figure;
imagesc(falseColorComposite);
colormap(bandColormaps{band});
colorbar;
title(['False-Color Composite of Multispectral I
xlabel('Column Index');
ylabel('Row Index');
```

Image filtering

Linear Filtering:

- **Operation:**
  - Linear filtering involves convolving the original image with a linear kernel or mask.
- **Linear Kernels:**
  - Linear kernels are weighted matrices that define how the pixels of the original image are combined to obtain the value of the filtered pixel.
- **Properties:**
  - Linearity: The filtering operation is linear, meaning the result is a linear combination of the original pixels.
  - Translation Invariance: The same kernel is applied to all pixels in the image, making it translation invariant.
- **Examples:**
  - Smoothing filters (average, Gaussian).
  - Edge enhancement filters (Sobel, Prewitt).
  - Low-pass and high-pass filters.

Non - Linear filter

Linear filter

Nonlinear Filtering:

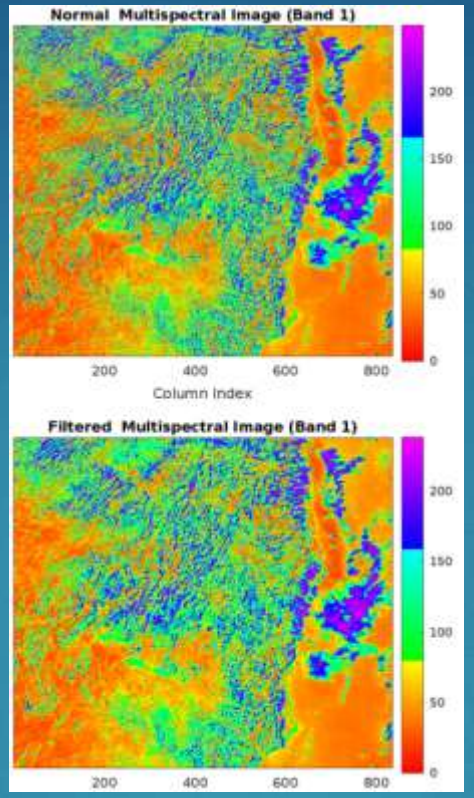
- **Operation:**
  - Nonlinear filtering does not use convolution with weighted masks. Instead, it relies on operations that are not linear combinations of input pixels.
- **Characteristics:**
  - Nonlinearity: The filtering operation does not follow the linearity property.
  - Sensitivity to Content: The filter response may depend nonlinearly on pixel values in the neighborhood.
- **Examples:**
  - Median filter.
  - Mode filter.
  - Nonlinear noise removal filters.

MATLAB: filters

Nonlinear filters

The last example of this kind of filters was **medfilt2(I)**.

The median filter is robust to impulsive noise due to the way it performs the filtering operation. This type of filter calculates the median value of pixels in a local neighborhood instead of using weighted averages as in some linear filters. It is particularly effective at reducing impulsive noise, such as "salt and pepper" noise. It is full white or black pixels in image. I will use it on my program.



Median filter

In multispectral imaging

In general, using filters in multispectral imaging is similar to using them in single images. However, since some multispectral images represent Earth's surfaces, edge preservation is crucial for these images, making it an advantage of median filters.

Linear filters

The last example of this kind of filters was 'motion':

```
h = fspecial('motion', 50, 45);
filteredRGB = imfilter(originalRGB, h);.
```

The 'motion' filter in MATLAB creates a kernel that simulates the effect of displacement or directional motion in an image. This filter is used to apply directional blur, mimicking the appearance of a moving object.

Edge Preservation

Unlike some linear filters that may smooth out edges, median filters tend to better preserve edges in multispectral images. This is important when working with data representing different elements of the landscape.

Enhacement techniques

Spacial filter: I already explained this in the last slide. For example, median filters is one of the spacial filter.

Histogram Equalization:

- *Contrast Enhancement:* Histogram equalization redistributes pixel intensities in the image, improving contrast and highlighting details that might not be visible in the original image. This is useful for enhancing important features in different spectral bands.
- *Increased Detail Visibility:* By extending the dynamic range of the image, histogram equalization can make details more visible, particularly beneficial when working with multispectral information covering different aspects of the landscape.
- *Improved Interpretation:* By enhancing contrast and visibility of details, histogram equalization facilitates visual interpretation of multispectral images and helps highlight regions of interest.

Supresión de Ruido:

- *Preservación de Información Importante:* En imágenes multiespectrales, donde la información específica de cada banda es crucial, la supresión de ruido es esencial para preservar la calidad de la información. Técnicas de supresión de ruido, como filtros adaptativos, pueden ayudar a eliminar el ruido sin comprometer la información relevante.
- *Mejora de la Calidad de la Imagen:* La reducción del ruido mejora la calidad general de la imagen, lo que es vital para aplicaciones que requieren una representación precisa de características específicas, como la detección de cambios en el uso del suelo o la identificación de objetos.
- *Facilita Análisis Cuantitativos:* La supresión de ruido permite realizar análisis cuantitativos más precisos al eliminar interferencias no deseadas en los datos multiespectrales, proporcionando resultados más confiables.

Bad techniques for multispectral images: segmentation

Image segmentation is the process of dividing an image into parts or regions. Often, the division into parts is based on the characteristics of the image pixels

Problems of image segmentation on multispectral images

High Dimensionality:

- Multispectral images can have multiple bands, resulting in high data dimensionality. Segmentation in a high-dimensional space may require more advanced methods and may be more susceptible to the curse of dimensionality.

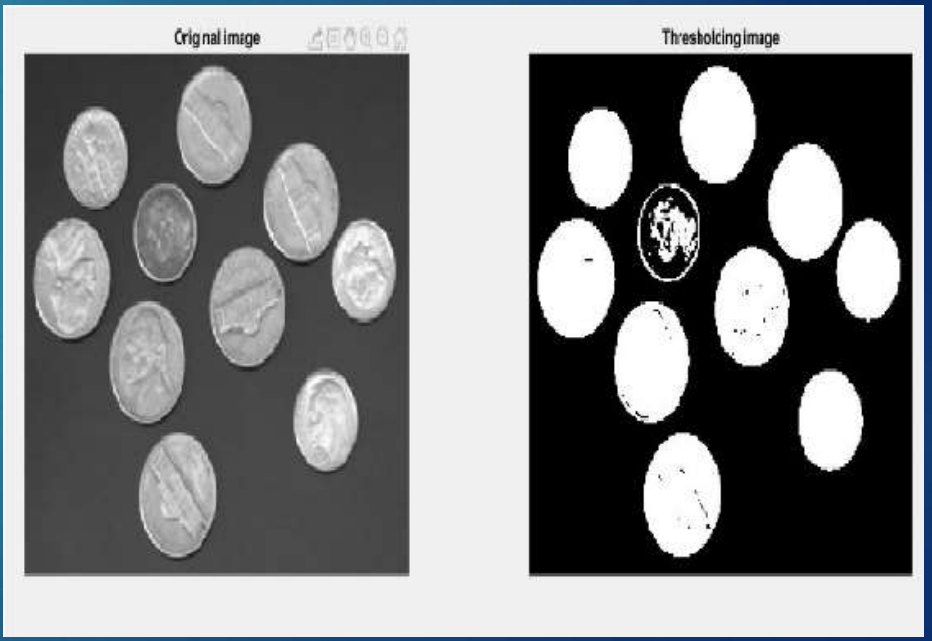
Correlation Between Bands:

- Different bands in multispectral images are often correlated due to the physical properties of the scene. This can affect the effectiveness of certain segmentation algorithms that assume independence between features.

Redundant Information:

- Some bands may contain redundant or highly correlated information, which may not contribute significantly to segmentation. Identifying which bands are more informative for the segmentation task may require detailed analysis.

Coins and background segmentation. This technique is good for this



MATLAB: histogram equalization and image segmentation

equalizedBand = histeq(multispectralImage(:, :, band));

This is the histogram equalization function in MATLAB. It enhances the contrast of an image by redistributing the intensity values of its pixels. It takes the specified band as input.

labeledImage = bwlabel(binaryImage);

This function in MATLAB is used for labeling connected components in a binary image. Connected components are regions of adjacent pixels with the same value (in this case, regions with a pixel value of 1, i.e., white regions). We should transform our image first into a binary image:

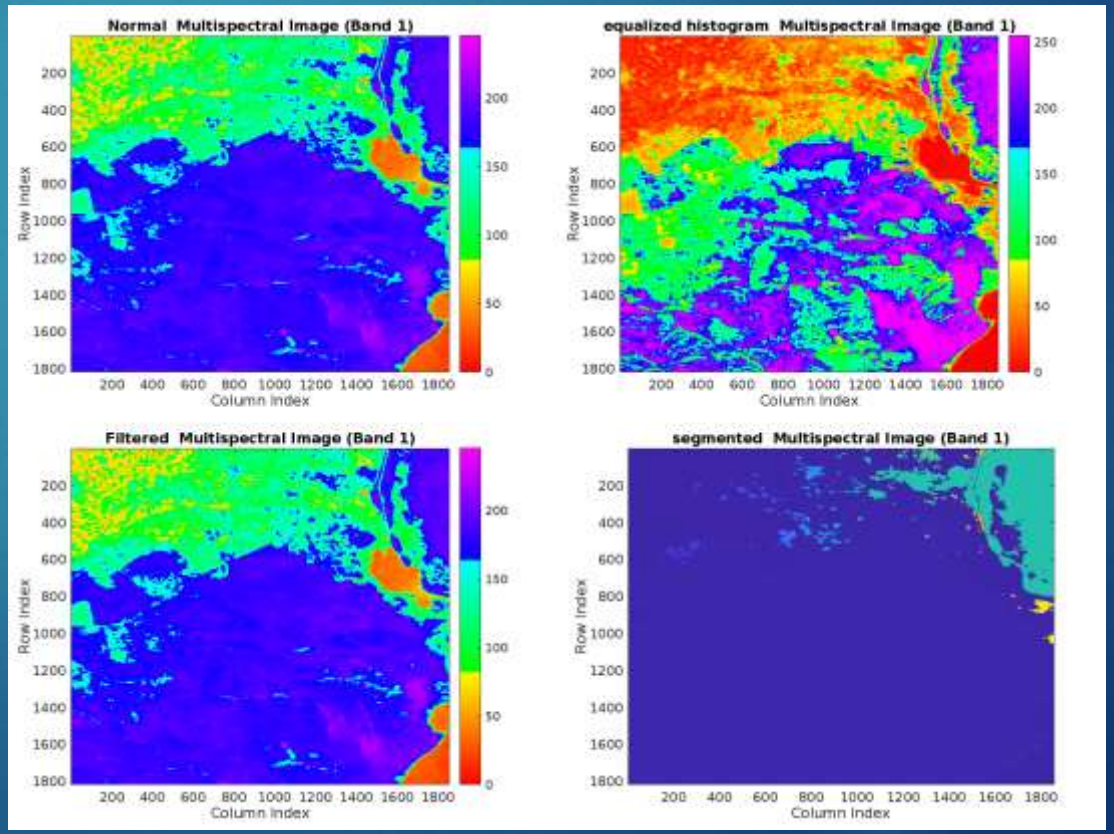
- threshold = graythresh(multispectralImage(:, :, band)
- binaryImage = imbinarize(multispectralImage(:, :, band), threshold);

Visualize differences between the different techniques

I explained in slide 10 and 11 how I processed the images in mathlab.

As we can see, segmentation is not working for us very good. It is dividing the same dessert in two different parts for example

Multispectral Image 1



Band 1 of the multispectral image 1

References

Earthdata: https://worldview.earthdata.nasa.gov/?v=21.40343674006271,34.4366612687906,43.282603923838685,44.450368645219314&t=2024-01-19-T10%3A58%3A56Z

Landsatlook: https://landsatlook.usgs.gov/explore

Geotiff:

http://www.aet.org.es/congresos/viii/alb87.pdf

https://es.wikipedia.org/wiki/GeoTIFF

Multispectral imagen general information: https://en.wikipedia.org/wiki/Multispectral_imaging

Spectral resolution:

https://www.earthdata.nasa.gov/learn/backgrounders/remote-sensing

https://www.eoportal.org/other-space-activities/aviris

Fusion liDAR and multiespectral imaging: https://www.mdpi.com/1424-8220/17/5/958

Linear filter:

https://es.mathworks.com/help/images/ref/imfilter.html

https://es.mathworks.com/help/images/what-is-image-filtering-in-the-spatial-domain.html

Non linear filter:

https://www.monografias.com/trabajos108/filtros-no-lineales-y-morfologia-matematica/filtros-no-lineales-y-morfologia-matematica

https://es.mathworks.com/help/images/ref/medfilt2.html

Segmentation:

https://es.mathworks.com/help/images/image-segmentation.html