Advanced processing: PC/DCS Analysis; Filtering
Advanced visualizations: Google Earth, DEM's & LIDAR
November 29, 2023

I. General Class Schedule Reminders

- lab #3 reports are due by the start of tonight's class **(Nov. 29th)**

- next week (**Dec 6th**): *last class of the semester*
  - I will lecture for the first hour or so
  - then, the graduate student project presentation begins @ ~ 7:15 pm
  - you are required to stay for this, pay attention and ***ask questions!***
    - *this will count toward your class participation*

- also, next week (**Dec. 9th**): *all final projects reports are due by 5:00pm!*
  - *this is two extra days for everyone if you need it*
  - please email the 1-page written report to **Poushalee**
    - *fyi, you can have a second page with a key/important figure only!*

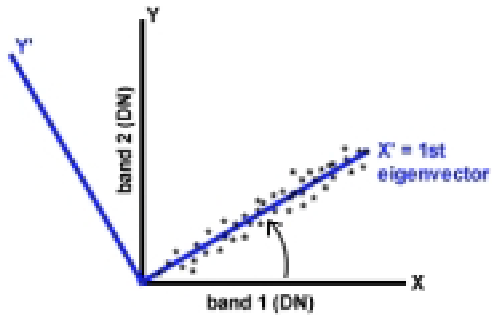
  - please email the 5-slide PowerPoint file **and** the written report to **me**
    - do **not** be late with these!
    - I will take a percentage off if you send this late

  - use the following naming convention:
    - *lastname-firstname_geol1460.docx*, *lastname-firstname_geol1460.pptx*

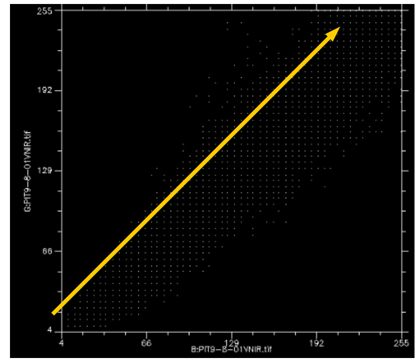
- finally, please remember to fill out the OMET course review for the class
  - these help with improving future classes

II. Advanced Image Processing

- Principal Component [PC] analysis
  - Performed to enhance highly correlated raster data *(like TIR data)*
    - data where the DN values vary in a systematic way from band to band as a function of the same parameter
    - parameter can be brightness/shadowing in the VNIR or temperature in the TIR (both the result of topography)
    - highly correlated data in two image bands will lie along a line/trend
      - known as the principal component or eigenvector
      - if this plotting is carried out for each band of an n-banded image, the results will vary from the most correlated in PC band 1 (topography/temperature) to less correlated (mineralogy) to the least correlated in PC band n (noise)
      - *benefits include removal of noise and better composition discrimination*



graphical representation

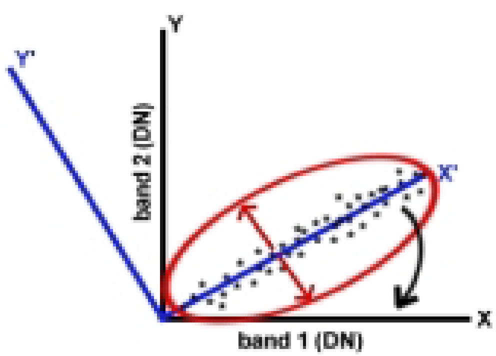


Pittsburgh ASTER example

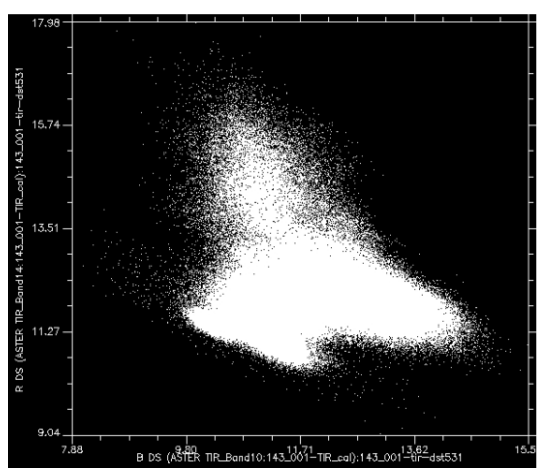
Pittsburgh ASTER: PC band 1

Pittsburgh ASTER: PC band 3

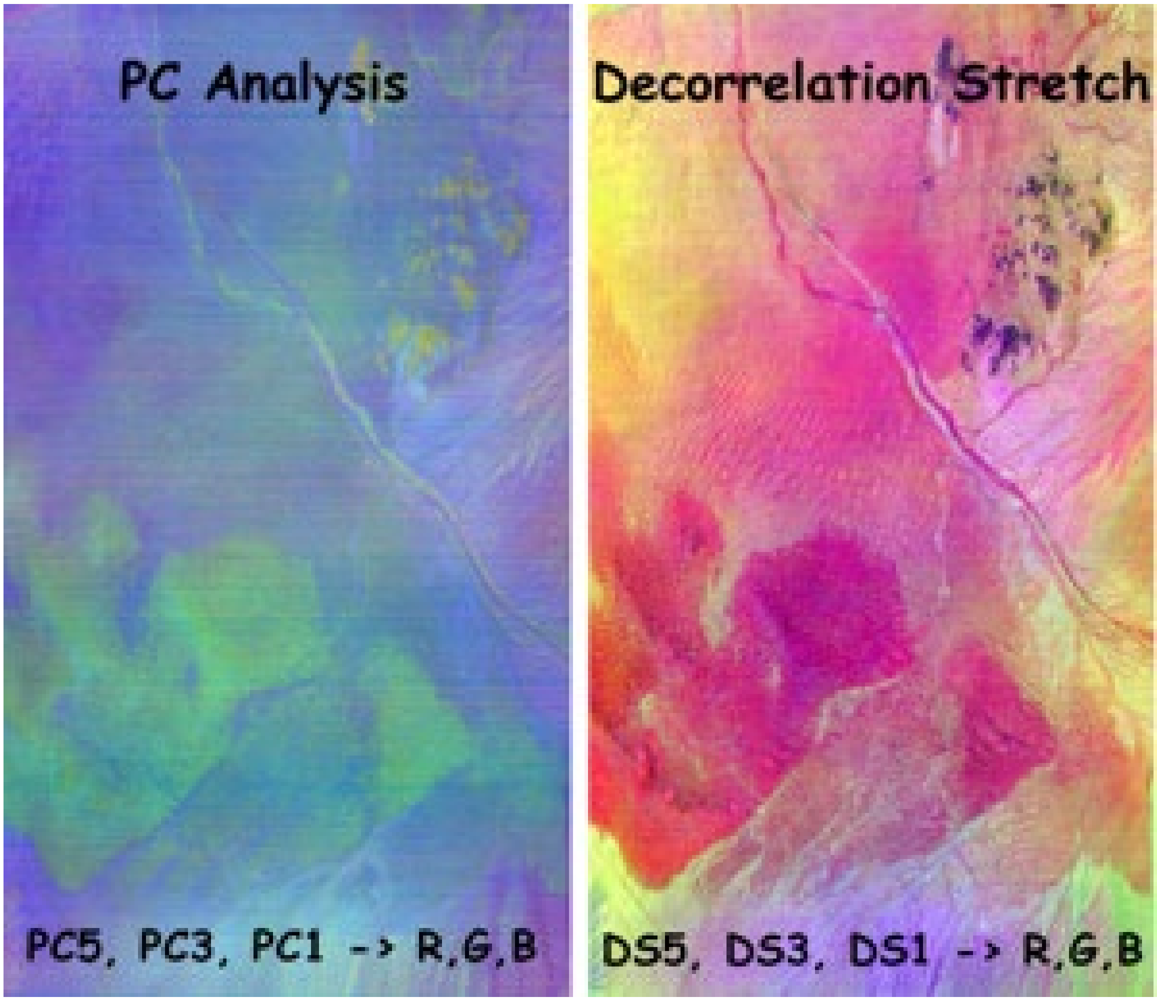
- Decorrelation Stretch [DCS]
  - a technique following a PC analysis that enhances the variation in the PC images
    - unlike the PC Analysis, DCS only uses 3 bands to make an R,G,B image
    - band axes are rotated into the plane of the eigenvector
    - stretch is performed perpendicular to the eigenvector
    - stretched data are rotated _back_ to the original axis producing colors that are once again meaningful and interpretable



graphical representation



UAE ASTER example



- spatial data filtering *(ENVI: "convolution filtering")*
    - spatial enhancement
        - directional and non-directional filters
        - both involve the creation of a "kernel" that is passed over the image data
            - this alters the final values

    - can be used to:
        - perform image restoration/correction
            - remove random noise, line dropouts, etc.

        - highlight certain high or low frequency patterns in the image
            - e.g., linear features

    - **a null kernel (averaging)**
        - used for noise/line removal
        - kernel is passed over the image
        - center pixel values which exceed the average threshold value *(either high or low)* are replaced
        - works with random noise pixels and bad lines

40	60	50			40	60	50
40	0	40	⇨		40	43	40
40	60	60			40	60	60

- **low-pass (or box car) filter**
  - kernel averages the 8 (new) DN vales
    - which is substituted for the middle pixel value
  - removes “high frequency” features

0.11	0.11	0.11
0.11	0.11	0.11
0.11	0.11	0.11

→ = **1/9** *(number of elements in filter)*

ENVI default for a low-pass filter kernel

40	60	50		4.4	6.6	5.5		40	60	50
40	55	40	⇨	4.4	6.1	4.4	⇨	40	49	40
40	60	60		4.4	6.6	6.6		40	60	60

- **high-pass filter *(non-directional)***
  - all feature edges are enhanced
  - opposite effect of a low-pass filter
    - removes all low frequency features and accentuates linear features
  - kernel values sum to zero
    - kernel is multiplied by the underlying DN vales
    - the output is added to the original DN values to become the new image

-1	-1	-1
-1	8	-1
-1	-1	-1

ENVI default for a high-pass filter kernel

40	60	50		-40	-60	-50		40	60	50
40	55	40	⇨	-40	440	-40	⇨	40	50	40
40	60	60		-40	-60	-60		40	60	60

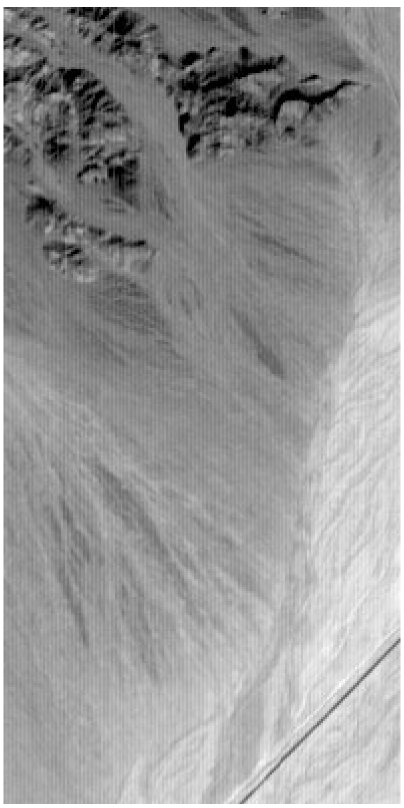
- **high-pass filter *(directional)***
  - enhances directional features
  - choice of kernel determines which features
  - removes all low frequency features and accentuates linear features in the direction of the kernel

-1.4	**-0.7**	**0**
-0.7	**0**	**0.7**
0	**0.7**	**1.4**

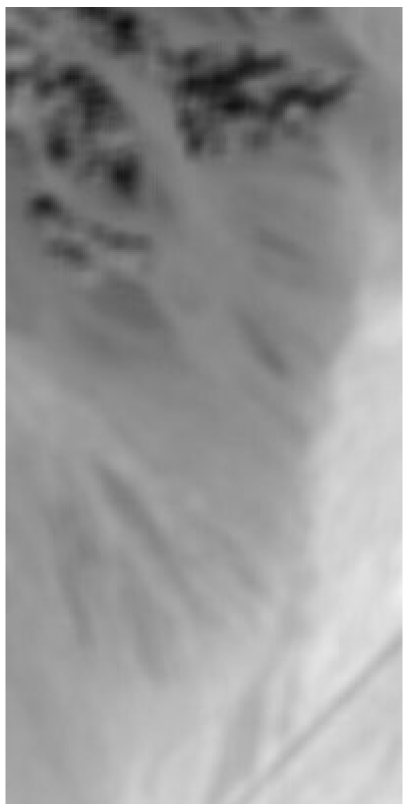
enhance _______ edges
?

0	**-0.7**	**-1.4**
0.7	**0**	**-0.7**
1.4	**0.7**	**0**

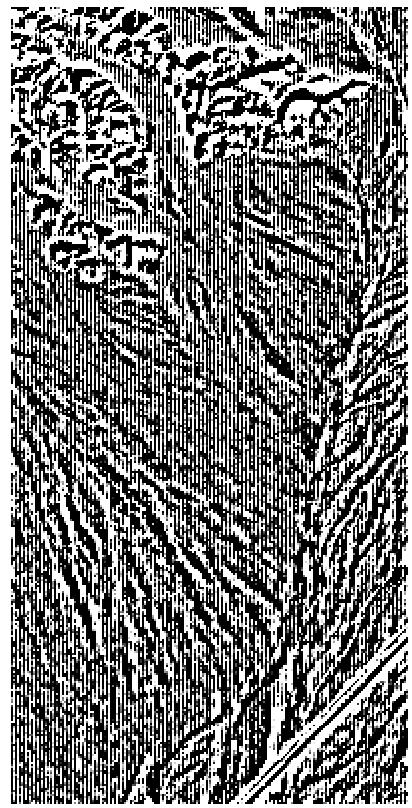
enhance _______ edges
?



airborne thermal IR image



9x9 low-pass filter



9x9 high-pass filter

- numerous other filters as well
  - median, Sobel, Roberts, Gaussian low pass/high pass, etc.
  - user-defined
  - choice of the filter depends on the image and the required analysis

III. Digital Elevation Models *(revisited)*

- stereo-pairs = successive overlapping air photos
  - because each photograph images each point on the ground from a slightly different angle, the offsets can be used to reproduce the vertical dimension
  - known as a DEM (digital elevation model)
  - what are used to produce the USGS topographic maps

- what they are
  - digital representation of ground surface topography or terrain
  - aka a digital terrain model (DTM)
  - can be done using a single pass of the satellite
    - if it equipped with two antennas (e.g., SRTM instrument)

  - double pass (e.g., SPOT or ASTER)
  - contour lines (older)

- types
  - shaded relief maps
    - different shades of gray assigned to slopes
    - shadowing to selected slopes depending on their orientation and the sun direction and azimuth

  - color density slices
    - color-code elevations

  - perspective views
    - similar to oblique photos

  - draped views
    - draped surface image, such as a Landsat scene, onto the DEM array

- ***ENVI DEM*** example using ASTER data
  - *your notes*

IV. LIght Detection And Ranging (LIDAR)

- uses the same principle the range finder we use
  - active transmission and timing of a laser pulse

- like RADAR – active form of remote sensing
  - transmitted light interacts with and is changed by the target
    - energy is reflected and/or scattered back to the instrument
    - timing is measured
      - determine the range to the target

    - change in the properties of the light analyzed
      - determine the roughness and scattering properties

- time to measurement range conversion
  - with the speed of light (c) = 3.0×10^8 m/s
    - 1 ns (1×10^{-9} sec) = 0.15 m = 5.9 inches
    - 1 microsecond (1×10^{-6} sec) = 150 m = 492 feet
    - 1 ms (1×10^{-3} sec) = 150 km = 93.2 miles

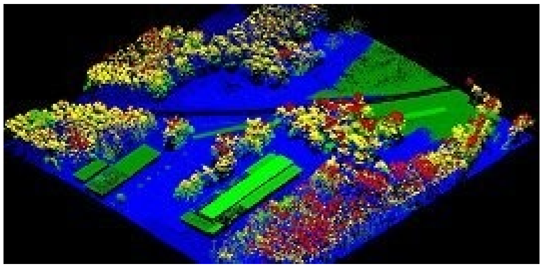
- three basic types of LIDAR:
  - range finders
    - used to measure the distance from the instrument to a target

  - DIAL (Differential Absorption Lidar)
    - used to measure chemical concentrations in the atmosphere

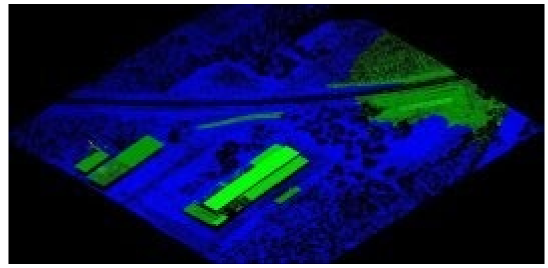
  - Doppler LIDAR
    - used to measure the velocity of a target

- all LIDAR systems utilizing electromagnetic radiation at optical frequencies
  - the wavelengths are 10,000 to 100,000 times shorter than that used by conventional radar

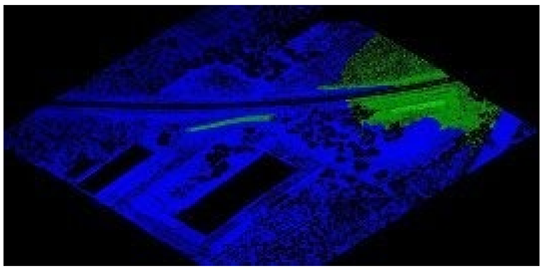
- photons scattered by the target
  - yield information about the target and/or the path to the target
  - modern LIDARs
    - observe intensity and time delay
    - PLUS, the phase of the scattered radiation
    - coherent laser radars (CLR's)
      - can be used to progressively strip height elements away from the high resolution DEM



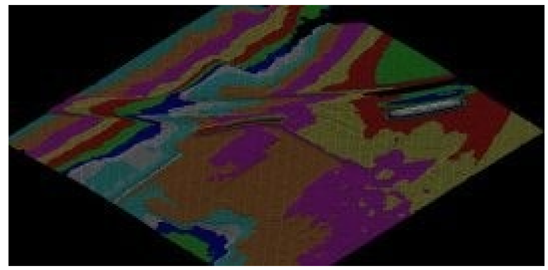
Lidar image in full



vegetation removed



buildings and vegetation removed



resultant “bare earth” model

V. Advanced Visualizations

- Google / Google Earth
  - Neogeography (new – Earth – study)
    - methodologies of neogeography tend toward the intuitive, personal, artistic, and generally don't confirm to traditional protocols and boundaries
    - mapping and spatial technologies such as Virtual Globes (e.g., Google Earth) are typical of the tools used
  - Evolution
    - Jan 2001: Keyhole Inc. founded
      - developed “EarthViewer” mainly for the CIA
    - Oct 2004: Acquired by Google
    - Jun 2005: Google Earth released (v3, PC only)
    - Jan 2006: Mac version released
    - Jun 2006 Google Earth v4 released (KML 2.1)
    - Apr 2008: Google Earth v4.3 released (KML 2.2)
      - Street view integrated
    - Apr 2008: KML ratified as OGC standard
    - May 2008: Google Earth plug-in
    - May 2009: Google Earth v5 released
      - addition of historical image data
      - addition of water and oceans
    - 2012: v7 released (and still current)
    - since added Google Sky, Moon, Mars

- The Globe
  - DEM
    - SRTM (30m, USA; 90m World)
    - added the Mountains “upgrade”
    - added high resolution in Switzerland (m’s), Canary Islands, W. USA (10m)
    - now many areas are rendered using LIDAR datasets *(especially over urban regions)*

  - Image Data
    - Earthsat: Global – 15 m
    - DigiGlobe, Spot Image, and other commercial sensors: High resolution
    - > 90% urban areas now at high res (m’s)
    - the initial highest resolution (<1m) was over the Googleplex (CA), Cambridge (MA), Glendale (CA)

- What is KML?
  - KML = Keyhole Markup Language
  - it is an eXtensible Markup Language (XML) used for managing 3D geospatial data
  - the format used in Google Earth, Google Maps and other geobrowsers
  - the KML 2.2 Reference is an Open Geospatial Consortium (OGC) standard

  - KML Elements
    - between the <kml></kml> designation tags are placed one or more elements
    - **Complex Element** = Element begins with a capital letter, e.g., <Placemark>
    - these can act as a parent element that can contain one or child elements
    - **Simple Element** = Element begins with a lowercase letter, e.g., <name>
    - can only contain character data

- Google in society
  - becoming ubiquitous
    - commercial applications
    - use by news media
    - military security
    - viewing in the future

Issues: Censorship

Issues: Border Disputes

- **Google Earth *(in-class demo)***
  - *your notes*