Photogrammetry Notes and Observations

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Contents

Common Variables

- H - Height of the camera above ground, *Flying Height*
- B - Distance between two image, *Air Base*

Common Programs and Usage Notes

This section is dedicated to solving easy problems using common programs.

GDAL Binaries

Many of the included gdal programs can be installed using a package manager.

Ubuntu sudo apt-get install gdal-bin

gdalinfo

Description

gdalinfo is an application bundled with GDAL which provides the user with the ability to extract information about a particular geographic file to the console.

This application works on elevation information, vector files (KML, KMZ), imagery (NITF), and many more.

Information Provided

- Corner Coordinates
- Geographic Projection Used
- Image Raster Datatype
- Date Taken
- more Metadata and image info

Usage

```
./gdalinfo  data/dted/w119/n036.dt2

Driver: DTED/DTED Elevation Raster
Files: data/dted/w119/n036.dt2
Size is 3601, 3601
Coordinate System is:
GEOGCS["WGS 84",
    DATUM["WGS_1984",
        SPHEROID["WGS 84",6378137,298.257223563]],
    PRIMEM["Greenwich",0],
    UNIT["degree",0.0174532925199433],
```

```
    AUTHORITY["EPSG","4326"]]
Origin = (-119.000138888888884,37.000138888888884)
Pixel Size = (0.000277777777777778,-0.000277777777777778)
Metadata:
  DTED_VerticalAccuracy_UHL=0007
  DTED_VerticalAccuracy_ACC=0007
  DTED_SecurityCode_UHL=U
  DTED_SecurityCode_DSI=U
  DTED_UniqueRef_UHL=G18 063
  DTED_UniqueRef_DSI=G18 063
  DTED_DataEdition=02
  DTED_MatchMergeVersion=A
  DTED_MaintenanceDate=0000
  DTED_MatchMergeDate=0000
  DTED_MaintenanceDescription=0000
  DTED_Producer=USCNIMA
  DTED_VerticalDatum=E96
  DTED_HorizontalDatum=WGS84
  DTED_DigitizingSystem=SRTM
  DTED_CompilationDate=0002
  DTED_HorizontalAccuracy=0013
  DTED_RelHorizontalAccuracy=NA
  DTED_RelVerticalAccuracy=0009
  AREA_OR_POINT=Point
Corner Coordinates:
Upper Left  (-119.0001389,  37.0001389) (119d 0'0.50"W, 37d 0'0.50"N)
Lower Left  (-119.0001389,  35.9998611) (119d 0'0.50"W, 35d59'59.50"N)
Upper Right (-117.9998611,  37.0001389) (117d59'59.50"W, 37d 0'0.50"N)
Lower Right (-117.9998611,  35.9998611) (117d59'59.50"W, 35d59'59.50"N)
Center      (-118.5000000,  36.5000000) (118d30'0.00"W, 36d30'0.00"N)
Band 1 Block=1x3601 Type=Int16, ColorInterp=Undefined
  NoData Value=-32767
  Unit Type: m
```

gdaldem

Description

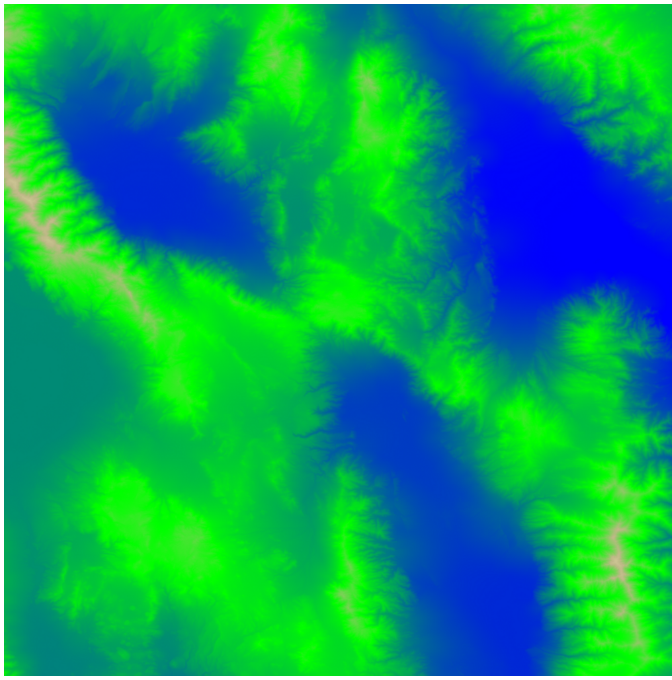
gdaldem is an application bundled with GDAL which provides the user with the ability to construct shaded relief and color maps for digital elevation models.

This application works on elevation information to include DTED and SRTM.

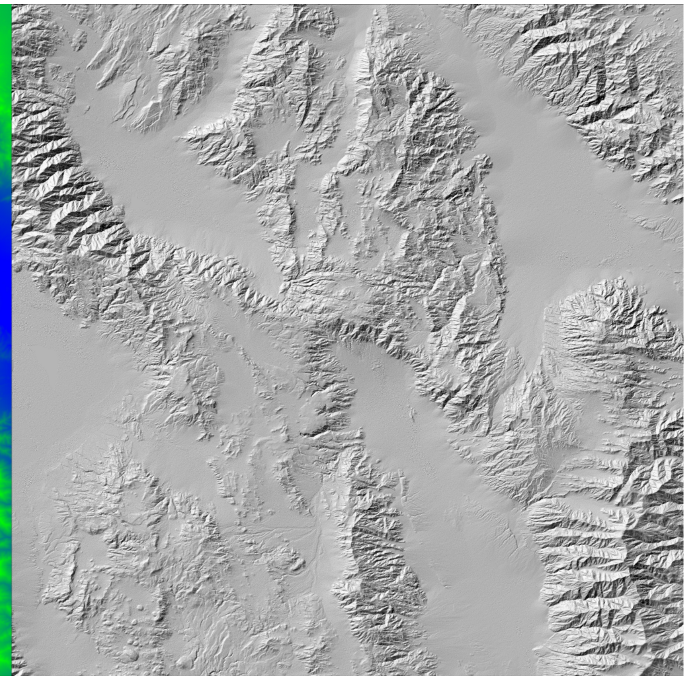
Usage

```
# For color relief maps
gdaldem color-relief data/dted/w118/n36.dt2 color_model.txt output.tif

# For shaded relief maps
gdaldem hillshade  data/dted/w118/n36.dt2 output.tif -s 100000 -z 5

# You can merge the images together with a t=0.7 such that  Out(x,y) = t*Color(x,y) + (1-t)*Hill(x,y)
# to get a great output image
```

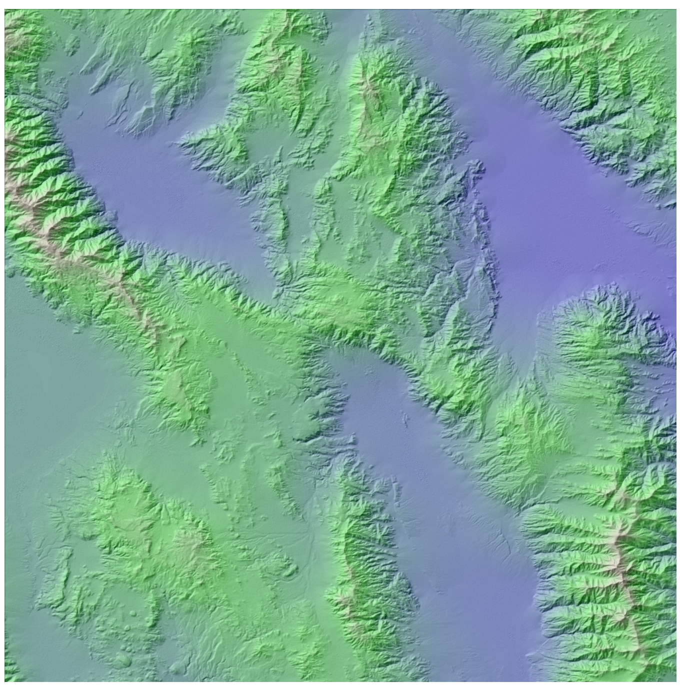
For more information, see manual pages and http://developmentseed.org/blog/2009/jul/30/using-open-source-tools



(a) Color Relief Results



(b) Hillshade Relief Results



(c) Merged Results

Figure 1: Results from typical *gdaldem* usage.

Camera Calibration Notes

Intrinsic Parameters

Common Intrinsic Camera Parameters

- Focal Length (f)
- Radial Distortion

Orthorectification Notes

This section is divided into the following sections$\cdots$

Camera View Rectification

Camera View Rectification

1. Compute the geographic extents. AKA, find the min and max coordinates and construct an axis-aligned bounding box.
2. Given the bounding box, compute the Ground Sampling Distance. Multiply the GSD with the image to determine the output image size.
3. Iterate over every pixel in the output image.
4. For a pixel in the output image, compute its geographic world coordinate value.
5. Compute the vector which links the pixel's world position with the camera position of the original image.
6. Conduct an intelligent search of the space to look for pixels which occlude the original point.
7. Given the point in world coordinates, compute the pixel in the original image.
8. Set the output image pixel.

Computing the geographic bounding box.

For each corner $P_{\text{pix}}(X,Y)$, compute the world coordinate of the pixel on the surface of the image plane as $P_{\text{img}}(X,Y)$. This will enable you to compute the intersection of the point with the surface plane as P_{world}.

$$P_{\text{img}} = M_w M_c M_p \tag{1}$$

M_p is the transformation which transforms the pixel to the focal plane space. The focal plane space is the 2D image surface originating around the principle point P_o. This is often assumed to be the center of the image. In addition the unit of measure is in meters and the range of the image is the length and width of the CCD surface.

$$M_p = \begin{bmatrix} \frac{X_f}{X_\text{I}} & 0 & 0 & -\frac{X_f}{2} \\ 0 & -\frac{Y_f}{Y_\text{I}} & 0 & \frac{Y_f}{2} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{2}$$

Where X_f and Y_f are the dimensions of the focal plane and X_{I} and Y_{I} are the dimensions of the input image. It is important to note that the Y axis is scaled inversely as image coordinates must be converted from a top-left origin to a bottom-left one.

$$M_c = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -f & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

M_c converts the pixel space into the camera coordinate system. For convenience, this is merely a 3D coordinate system identical to the focal plane space, where the z axis is the negative focal length. This is important as this will be identical to the world coordinate system except that the camera is rotated into position and translated by the world coordinates of the camera.

$$M_w = \begin{bmatrix} 1 & 0 & 0 & T_{Cx} \\ 0 & 1 & 0 & T_{Cy} \\ 0 & 0 & 1 & T_{Cz} \\ 0 & 0 & 0 & 1 \end{bmatrix} \mathbf{M}_{\text{Quaternion}} \tag{4}$$

Where T_C is the position of the camera in the world coordinate system and $M_{Quaternion}$ is the matrix derived from the quaternion.

This will give you the 3D coordinate of the pixel on the focal plane. You still need to translate this into the actual location on the surface. In order to compute this, you need to compute the intersection between the ray connecting the camera origin and the point on the focal plane with the surface of the Earth.

$$\mu = \frac{N \cdot (P_n - P_c)}{N \cdot (P_p - P_c)} \tag{5}$$

$$P_{\text{gnd}} = P_c - \mu \cdot (P_p - P_c) \tag{6}$$

Where μ is the scale factor of the ray, P_n is the nadir point, P_c is the camera origin, P_p is the principle point, and N is the earth normal pointing $(0, 0, 1)$.

Applying these equations to each of the 4 corners will determine the min and max values for the coordinate system.

Computing the GSD

The ground sampling distance is the distance per pixels, measured in this project as *meters per pixel*. This is computed using the bounding box of the image computed in the previous section. Incorporating the rotation into this would help, however I currently am not sure how to address this.

I currently compute the GSD for the x axis as the average between the span of the top row and bottom row. This span is then divided by the number of pixels. For example, if top row of a 1000 pixel wide image is 5000 meters wide and the bottom row is 1000 meters (the image is rotated), then the GSD is $(5000 + 1000)/1000 = 3$ meters per pixel. The GSD for the Y is the same except column heights. The final GSD is the smaller of the two. A smaller GSD is safer as you can scale the image down and not lose data.

Iterate over image

Once the parameters of the output image are determined, it is necessary to iterate every pixel and find the relationship between its position in the input image. Since we create a bounding box with is axis-aligned, we can easily find the ground position of the pixel in the output image.

$$\text{pos} = \begin{bmatrix} \frac{\text{bbox.max.}x}{I_{cols}} & 0 & \text{bbox.min.}x \\ 0 & \frac{\text{bbox.max.}y}{I_{rows}} & \text{bbox.min.}y \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} \tag{7}$$

Where bbox is the geographic bounding box of the image, I is the output image, and X, Y are the image coordinates you are iterating.

This equation will yield the ground coordinates of the output image pixel.

Geographic Coordinate to Image Pixel

Now that we know the geographic coordinate of the output pixel, we need to compute the input image coordinate. This will allow us to copy its pixel to the output image. Note that this current technique does zero interpolation, so this should be eventually implemented.

$$P_{\text{in}} = \tag{8}$$

Glossary

Aerotriangulation The process of assigning ground control values to points on a block of photographs by determining the relationship between the photographs and known ground control points.. 11

Boresight Boresight is the physical mounting angles between an IMU and a digital camera. Basically, if the IMU defines a flight axis, the Boresight defines the angles from the axis of which the camera is pointing.. 11

Bundle Adjustment The process of simulaneously refining 3D coordinates derived from multiple viewpoints. This requires that the user has multiple 3d coordinates measured from multiple image pairs. This is often solved with Levenberg-Marquardt.. 11

Camera Origin The center of the camera in world coordinates. In reality, this should be the latitude, longitude, and elevation of the camera if described in geodetic coordinates. symbol. 11

Focal Length The distance between the focal point and the image plane. This is relevant as the focal length determines attributes such as the clarity of the image and the depth of field. It is an essential part of camera calibration.. 11

Georectification A method of stretching and warping an image to align with another map projectin or spatial data in GIS. This is comparable to Google Earth and other systems which implement overlays. If an image is rectified, Ground Control Points (GCP) can be used to create a transformation which aligns one image to the GIS data. This is different from orthorectification as well because it is assumed that the image is already orthorectified. Georectification just changes the projection and/or coordinate system.. 11

Georeference Same as Georectification . 11

Orthorectification A method of correcting an image to align with real-world coordinates on a map. This involves measuring the exact location of the image center as well as the camera angle. This is followed by the computation of the camera calibration parameters to remove camera and lens distortions. Finally, you may terrain induced distortions using DEM data.. 11

Principle Ground Point Using the ray defined by the Camera Origin and the line $P_O P_P$, the intersection of this line with the surface of the Earth creates a coordinate on the surface which is located in the principle point of the image. This is relevant because images can only give you 3D information up to scale and depth. This will provide the depth attribute. symbol. 11

Principle Point The intersection of the ray which defines the center of the camera view with the image plane. This is the physical location in world coordinates of the center of the image view. This subtracted with the Camera Origin define the vector which points “straight ahead”.. 11

Bibliography

[1] Bon A. DeWitt and Paul R. Wolf. *Elements of Photogrammetry(with Applications in GIS)*. McGraw-Hill Higher Education, 3rd edition, 2000.

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