1. **Orthophoto or Orthoimage** is a photograph showing images of objects in their true orthographic position, and it is equivalent to a planimetric map.

The difference between maps and Orthophotos is, Orthophotos are composed of images of features, whereas maps utilize lines and symbols plotted to scale to depict features.

Orthophotos can be used as a map for making direct measurements of distances, angles, positions, and areas without making corrections for image displacement. This cannot be done with perspective photos. It is very widely used in a GIS as a reference for performing analysis

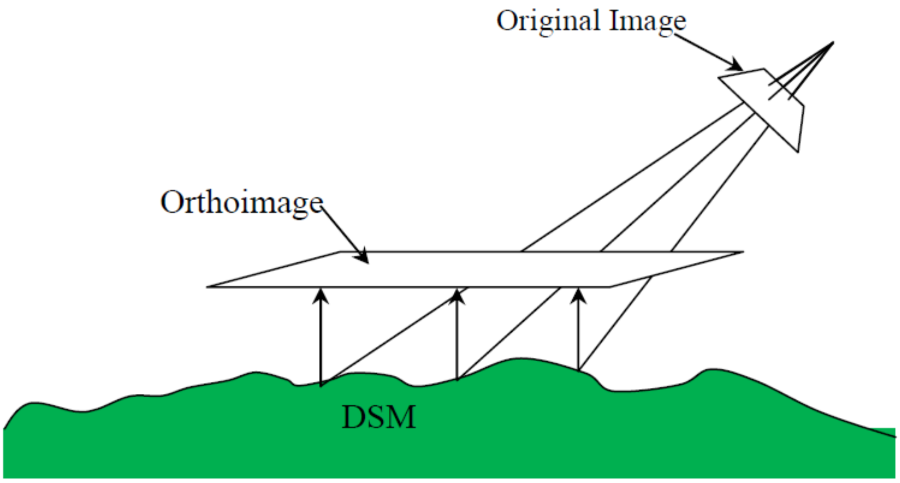
Orthoimage is based on perspective photos. The production procedure divides the entire image into small blocks and then rectifies the image block by block. Orthoimage production is also known as digital *differential rectification.*

The essential inputs for the process of differential rectification are a DEM and a digital aerial photo having known exterior orientation parameters (ω, ϕ, κ, X_{o1}, Y_{o2}, and Z_{o3}), image coordinate (rows and columns) to be used in the transformation to compute digital image coordinates.

1.1. <u>Differential rectification</u> or Orthorectification is the process of removing geometric errors inherent within photography and imagery. The variables contributing to geometric errors include, but are not limited to:

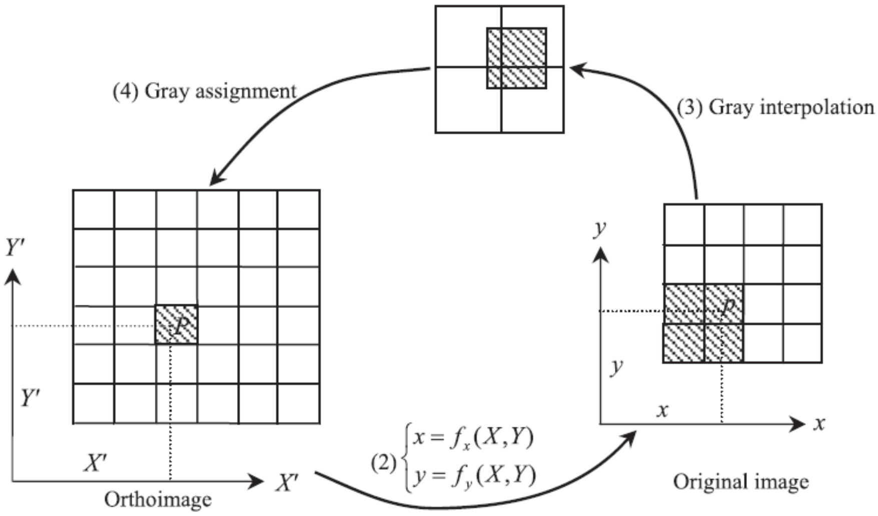
Source of error	**Treatment**
1. Camera and sensor orientation	accounted during performing block triangulation or single frame resection,
2. The systematic error associated with the camera or sensor	Accounted during using least square adjustment during block triangulation.
3. Topographic relief displacement	Accounted during the orthorectification process using DEM for the area.
4. Earth curvature	Accounted during block triangulation especially large photo block triangulation using the relevant option.

The orthorectification process takes the raw digital imagery and applies a DEM and triangulation results to create an orthorectified image. Once an orthorectified image is created, each pixel within the image possesses geometric fidelity. Thus, measurements taken off an orthorectified image represent the corresponding measurements as if they were taken on the Earth's surface:



Relief displacement is corrected by taking each pixel of a DEM and finding the equivalent position in the satellite or aerial image. A brightness value is determined for this location based on the resampling of the surrounding pixels. The brightness value, elevation, and exterior orientation information are used to calculate the equivalent location in the Orthoimage file.

1.2. The process of DIFFERENTIAL RECTIFICATION is illustrated below diagram:



1- Calculate the object space coordinate of point P(X,Y) which is P(X',Y')

2- The image-space coordinates are calculated based on the rectification equation of the inverse method

$$\begin{cases} x = f_x(X,Y) \\ y = f_y(X,Y) \end{cases}$$

The corresponding image-space coordinates of point P in the original image can be calculated, the collinearity equation gives the used rectification formula of the inverse method, and the Z value of the point P is obtained from DEM:

$$x_p - x_o = -f.\left[\frac{m_{11}(X_p - X_{o1}) + m_{12}(Y_p - Y_{o1}) + m_{13}(Z_p - Z_{o1})}{m_{31}(X_p - X_{o1}) + m_{32}(Y_p - Y_{o1}) + m_{33}(Z_p - Z_{o1})}\right] - (1)$$

$$y_p - y_o = -f.\left[\frac{m_{21}(X_p - X_{o1}) + m_{22}(Y_p - Y_{o1}) + m_{23}(Z_p - Z_{o1})}{m_{31}(X_p - X_{o1}) + m_{32}(Y_p - Y_{o1}) + m_{33}(Z_p - Z_{o1})}\right]$$

3- The greys values are resampled
The obtained image-space coordinate of point P will be transformed into image coordinates according to the interior orientation parameters.
The image coordinate doesn't need to be located at the centre of the pixel. Therefore, it can be interpolated.

4- The grey value is reassigned, and the grey value of image point p is assigned to the corresponding pixel P(X',Y') in the Orthoimage as follows:

$$G(x,y) = g(x,y)$$

1.3. True Orthophoto:

The true Orthophoto is an advanced type of the regular Orthoimage(left photo). In the regular Orthophoto, the refile displacement of the terrain has been treated using DTM. In contrast, the relief in the building still has not been removed, which can be removed using DSM leading to a true Orthophoto (right photo).

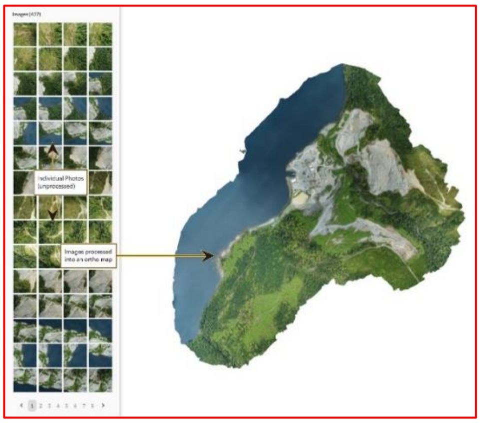
The process of producing a true Orthoimage is illustrated in the below figure. In addition to the differential rectification, the following process is applied first is digitizing the buildings that the removing the relief displacement, as illustrated in the below figures:

Regular Orthophoto showing the relief of the building.

The vector map of the buildings

True Orthophoto produced by removing relief displacement by applying the vector data

2. Mosaic

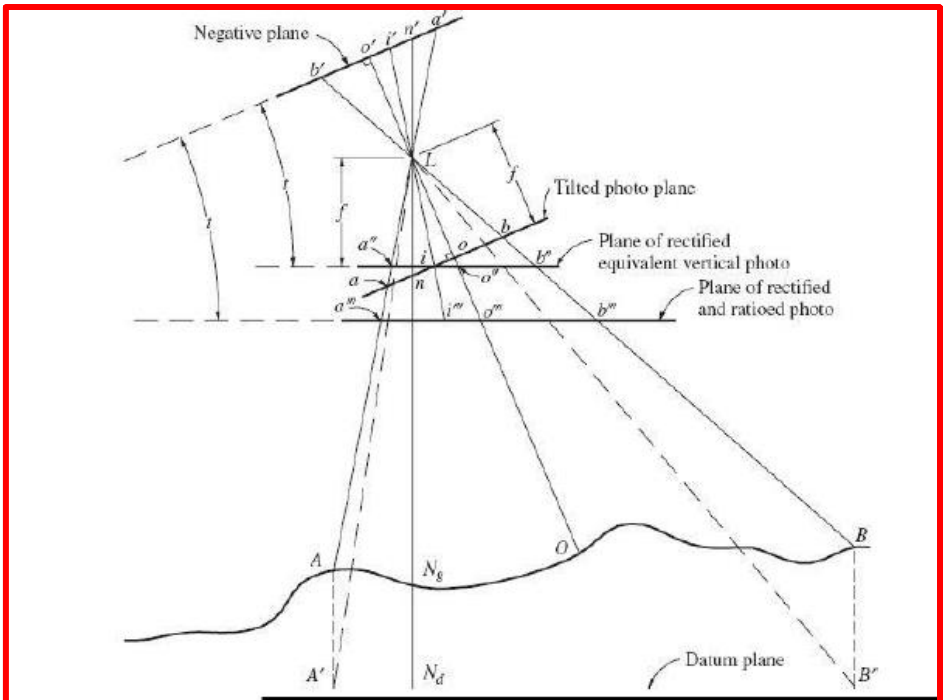


- If a single photo does not contain extensive enough coverage to serve as a photomap of an area, an aerial mosaic may be prepared.
- Mosaics are constructed from a block of overlapping photographs which are trimmed and joined, much as cloth patches are stitched together to form a quilt.
- A special type of digital mosaic, known as a composite orthophoto, provides the most geometrically accurate image product available; however, its production is far more complex than that of a simple mosaic.
- Aerial mosaics generally fall into three classes: controlled, semicontrolled, and uncontrolled.

3. **Photomaps:** are simply aerial photos that are used directly as planimetric map substitutes. The photos were traditionally brought to some desired average scale, be enlargement or reduction by projection printing.

The effect of tilt can be eliminated by rectifying the photograph.

Rectification is the process of making equivalent vertical photographs (rectified photographs) from tilted photo negatives. The geometry of Rectification is shown below:



RE 10-13 Principal plane of a tilted photograph showing the basic geometry of rectificat

Photomaps are similar to standard maps in many respects but have some definite advantages over maps.

- Photomaps show the relative planimetric location of a virtually unlimited number of objects, While features on maps, which are shown with lines and symbols, are limited by was produced by the mapmaker
- For large areas, photomaps can be prepared in much less time and considerably lower cost than maps.
- Features on Photomaps are easily understood and interpreted by people without a photogrammetry background, while they may be confused by maps.

However, the disadvantage of photomaps, they are not true planimetric representations. Rather, they are constructed from the perspective photograph, which is subject to image displacement and scale variation, which are considered to be most severe at the edge of the photographs.

Relief displacement can be minimized by increasing the flying height while at the same time using a longer focal length camera to compensate for the decreases in scale.

Due to image displacements, the scaled value will not be true. Therefore, they are used only for qualitative studies (e.g. planning, soil type, geological feature, growth of the cities (sprawls), drainage pattern and etc..)

3.1. Correction for relief of ground control points used in Rectification

Since the rectified and ratioed aerial photos retain the effect of relief, ground control points used in Rectification must be adjusted slightly to accommodate their relief displacement.

The relief displacement may be outward when GCP is higher than the average terrain.

Or, the relief displacement is inward when GCP is lower than the average terrain.

As shown in the right figure, The **Rectification** process involves plotting the ground control points at the location they will occupy in the rectified and ratioed photo.

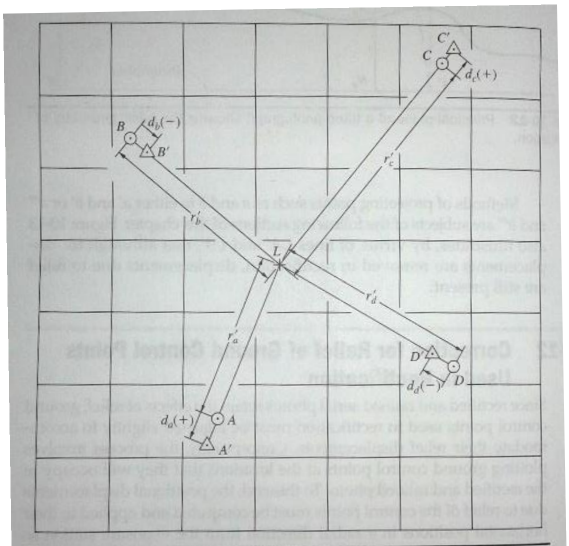


FIGURE 10-14 Plot of control points for rectification showing corrections made for relief displacements.

<u>The following data is required to achieve the needed process following data:</u>

- Coordinate X_L, Y_L and Z_L(or H) from space resection.
- X,Y, and Z for each GCP
- A plane which is the scale photo required to be computed, such as h_{avg}.

The following steps are followed to achieve the process:

1. Compute r'

$$r' = \sqrt{(X - X_L)^2 + (Y - Y_L)^2} \quad ---(2)$$

2. Calculate relief displacement (d)

$$d = \frac{r'(h - h_{avg})}{H - h} \quad ---(3)$$

Where:
h=height of the control point above the datum.
h_{avg}=the average terrain height in the tilted photo.
H=flying height above datum.

3. Calculate the location of the point using

$$r = r' + d \quad --- (4)$$

4. Compute the azimuth

$$\alpha = tan^{-1}\left(\frac{X - X_L}{Y - Y_L}\right) \quad --- (5)$$

5. Finally, calculate the X' and Y' the coordinate of the displaced (image) point are:

$$X' = X_L + rsin(\alpha) \quad --- (6)$$

$$Y' = Y_L + rcos(\alpha) \quad --- (7)$$

Example: a tilted aerial photograph is exposed at X_L=9274.2m, Y_L=8292.0m and Z_L=1500.1m. A rectified and ratioed photograph is to be produced. The following for GCP (8829.8m, 9590.4, 110.2m) coordinates will control the Rectification. If the plane of Rectification (average terrain) is 110.0m, compute the displaced image location X', Y' of the control point.

$$r' = \sqrt{(X - X_L)^2 + (Y - Y_L)^2} =$$

$$\sqrt{(8829.8 - 9274.2)^2 + (9590.4 - 8292.0)^2} = 1372.346\text{m}$$

$$d = \frac{r'(h - h_{avg})}{H - h} = \frac{1372.346(110.2 - 110)}{1500.1 - 110.2} = 0.1975m$$

Since $h > h_{avg}$ then d is-ve:

$$r = r' + (d) = 1372.346 - 0.197 = 1372.149m$$

$$\alpha = tan^{-1}\left(\frac{X - X_L}{Y - Y_L}\right) = tan^{-1}\left(\frac{8829.8 - 9274.2}{9590.4 - 8292.0}\right) = -18.8944037$$

$$X' = X_L + rsin(\alpha) = 9274.2 + 1372.149\, sin(-18.8944037) = 8829.86m$$

$$Y' = Y_L + rcos(\alpha) = 8292.0 + 1372.149\, cos(-18.8944037) = 9590.21m$$

References:

Liang, S., Li, X. and Wang, J. (2012) *Advanced Remote Sensing: Terrestrial Information Extraction and Applications*. Academic Press.

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Leica Geosystems (2013) *ERDAS Field Guide* TM. Leica Geosystems Geospatial Imaging, LLC.