GE 119 – PHOTOGRAMMETRY 2

Topic 4. Orientation of Stereopairs

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Outline

• Review of Previous Lessons
  – Review of Photogrammetry Workflows
  – Review of Orientation of Single Aerial Photographs

• Orientation of Stereopairs
  – Why it is needed?
  – Orientation through Space Intersection
  – Model Space and Model Coordinate Systems
  – Different ways of orienting a stereopair
Intended Learning Outcomes

• After this lecture and hands-on exercises, the students must have:
  – Understood the mathematical concepts behind the orientation of stereopairs
  – Performed orientation of stereopair using the LISA photogrammetric software
  – Explained the processes involved in the orientation of stereopairs using the LISA photogrammetric software
REVIEW OF PREVIOUS LESSONS
Let’s recall:

- Typical Workflow in Photogrammetry
A Typical Workflow in Photogrammetry

Generally:
- Begins with the capture of the images
- Calculation of the orientation parameters of all images that will be used
- Measure co-ordinates
- Create several image products
- Use of results in cartographic or GIS software

Recall..

- Orientation of Single Aerial Photographs
Recall: the Orientation Process in Photogrammetry

**Orientation** → the process of establishing the relation between two coordinate systems of an aerial photograph or image
For single aerial photographs, there are 2 kinds of orientation procedures:

- **Interior Orientation**
  - establishing the relation between the camera-internal co-ordinate system and the pixel (image) co-ordinate system

- **Exterior Orientation**
  - establishing the relation between the pixel co-ordinate system and the ground coordinate system
Interior Orientation of Single Photographs

- establishing the relation between the **camera-internal co-ordinate system** and the **pixel co-ordinate system**

![Diagram showing the relationship between camera-internal CS and pixel CS]
Interior Orientation of Single Photographs through Affine Transformation

• If \((x, y)\) is the camera-internal coordinates of an object in an aerial photograph, we wish to find its corresponding pixel coordinates \((X', Y')\)

• Using Affine Transformation, the pixel coordinates can be determined as:

\[
\begin{align*}
X' &= a_0 + a_1 x + a_2 y \\
Y' &= b_0 + b_1 x + b_2 y
\end{align*}
\]

• Note: \(a_0, a_1, a_2, b_0, b_1\) and \(b_2\) are called the ‘affine transformation parameters’
Exterior Orientation of Single Photographs

- establishing the relation between the pixel (or image) coordinate system and the ground coordinate system

Exterior Orientation

- When we do exterior orientation, we define the **geometric relationship** between an object and its image.

- Exterior orientation is based on the condition of **collinearity**
The Collinearity Condition

• **Collinearity** is the condition in which:
  – the exposure station of any photograph (or image),
  – any object point in the ground coordinate system, and
  – its photographic image

all lie on a straight line.
The Collinearity Condition

- **Collinearity** is the condition in which:
  - the exposure station \( (L) \) of any photograph (or image),
  - any object point \( (P) \) in the ground coordinate system, and
  - its photographic image \( (p) \)

  all lie on a straight line.

The Collinearity Condition

- The collinearity condition holds irrespective of the angular tilt of the photograph.

- The possible *angular rotations* from that of an equivalent vertical photograph are:
  - $\omega$ ("pitch")
  - $\phi$ ("roll")
  - $\kappa$ ("yaw")

ω, φ, κ ....
The Collinearity Equations

• The collinearity equations are the equations that express the collinearity condition

• They describe the relationships among pixel/image coordinates, ground coordinates, the exposure station position, and angular orientation of a photograph/image.
The Collinearity Equations

\[ x_p = -f \left[ \frac{m_{11}(X_p - X_L) + m_{12}(Y_p - Y_L) + m_{13}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right] \]

\[ y_p = -f \left[ \frac{m_{21}(X_p - X_L) + m_{22}(Y_p - Y_L) + m_{23}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right] \]

where

- \( x_p, y_p \) = image coordinates of any point \( p \)
- \( f \) = focal length
- \( X_p, Y_p, Z_p \) = ground coordinates of point \( P \)
- \( X_L, Y_L, Z_L \) = ground coordinates of exposure station \( L \)
- \( m_{11}, \ldots, m_{33} \) = coefficients of a 3 \( \times \) 3 rotation matrix defined by the angles \( \omega, \phi, \kappa \) that transforms the ground coordinate system to the image coordinate system

- The equations are non-linear
- Contain 9 unknowns:
  - The exposure station position \( (X_L, Y_L, Z_L) \)
  - The three rotation angles \( (\omega, \phi, \kappa) \) which are embedded in the \( m \) coefficients
  - The object point coordinates \( (X_p, Y_p, Z_p) \)
The Collinearity Equations

\[ x_p = -f \left[ \frac{m_{11}(X_p - X_L) + m_{12}(Y_p - Y_L) + m_{13}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right] \]

\[ y_p = -f \left[ \frac{m_{21}(X_p - X_L) + m_{22}(Y_p - Y_L) + m_{23}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right] \]

where

- \( x_p, y_p \) = image coordinates of any point \( p \)
- \( f \) = focal length
- \( X_p, Y_p, Z_p \) = ground coordinates of point \( P \)
- \( X_L, Y_L, Z_L \) = ground coordinates of exposure station \( L \)
- \( m_{11}, \ldots, m_{33} \) = coefficients of a 3 \times 3 rotation matrix defined by the angles \( \omega, \phi, \) and \( \kappa \) that transforms the ground coordinate system to the image coordinate system

- The parameters \((X_L, Y_L, Z_L)\) and \((\omega, \phi, K)\) are commonly referred to as the “Exterior Orientation Parameters”
The Collinearity Equations

- The “m” coefficients are elements of a 3x3 rotation matrix

\[
\mathbf{m} = \begin{bmatrix}
\cos \varphi \cos \kappa & -\cos \varphi \sin \kappa & \sin \varphi \\
\cos \omega \sin \kappa + \sin \omega \sin \varphi \cos \kappa & \cos \omega \cos \kappa - \sin \omega \sin \varphi \sin \kappa & -\sin \omega \cos \varphi \\
\sin \omega \sin \kappa - \cos \omega \sin \varphi \cos \kappa & \sin \omega \cos \kappa + \cos \omega \sin \varphi \sin \kappa & \cos \omega \cos \varphi
\end{bmatrix}
\]

- \( \mathbf{m} \) is obtained by getting the product of matrices of rotation around the first (\( \omega \)), second (\( \varphi \)) and third (\( \kappa \)) axis (i.e., \( \mathbf{m} = \mathbf{R}_3^*\mathbf{R}_2^*\mathbf{R}_1^* \))

\[
\mathbf{R}_1(\omega) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \omega & \sin \omega \\ 0 & -\sin \omega & \cos \omega \end{bmatrix}, \quad \mathbf{R}_2(\varphi) = \begin{bmatrix} \cos \varphi & 0 & -\sin \varphi \\ 0 & 1 & 0 \\ \sin \varphi & 0 & \cos \varphi \end{bmatrix}, \quad \mathbf{R}_3(\kappa) = \begin{bmatrix} \cos \kappa & \sin \kappa & 0 \\ -\sin \kappa & \cos \kappa & 0 \\ 0 & 0 & 1 \end{bmatrix}
\]
### m values

\[
m = \begin{pmatrix}
    \cos \varphi \cos \kappa & -\cos \varphi \sin \kappa & \sin \varphi \\
    \cos \omega \sin \kappa + \sin \omega \sin \varphi \cos \kappa & \cos \omega \cos \kappa - \sin \omega \sin \varphi \sin \kappa & -\sin \omega \cos \varphi \\
    \sin \omega \sin \kappa - \cos \omega \sin \varphi \cos \kappa & \sin \omega \cos \kappa + \cos \omega \sin \varphi \sin \kappa & \cos \omega \cos \varphi
\end{pmatrix}
\]

- \( m_{11} = \cos \varphi \cos \kappa \)
- \( m_{21} = \cos \omega \sin \kappa + \sin \omega \sin \varphi \cos \kappa \)
- \( m_{31} = \sin \omega \sin \kappa - \cos \omega \sin \varphi \cos \kappa \)
- \( m_{12} = -\cos \varphi \sin \kappa \)
- \( m_{22} = \cos \omega \cos \kappa - \sin \omega \sin \varphi \sin \kappa \)
- \( m_{32} = \sin \omega \cos \kappa + \cos \omega \sin \varphi \sin \kappa \)
- \( m_{13} = \sin \varphi \)
- \( m_{23} = -\sin \omega \cos \varphi \)
- \( m_{33} = \cos \omega \cos \varphi \)
Space resection (or photo-resection) to solve the Collinearity Equation

- Similar to the “resection” method in Surveying

- Use of Ground Control Points (GCPs)

- In this process, known Ground Control Points are located in the image, and the image coordinates are determined

- This means, for each GCP we know the following variables of the collinearity equations:
  - $X_p, Y_p, Z_p$
  - $x_p, y_p$

- We are left with the following unknowns:
  - $X_L, Y_L, Z_L$
  - $\omega, \varphi, K$ (or the rotation matrix coefficients)

\[
x_p = -f \left[ \frac{m_{11}(X_p - X_L) + m_{12}(Y_p - Y_L) + m_{13}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right]
\]

\[
y_p = -f \left[ \frac{m_{21}(X_p - X_L) + m_{22}(Y_p - Y_L) + m_{23}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right]
\]
Some Notes to Remember:

- Exterior orientation of single photographs by solving the **Collinearity Equation** basically informs us of the **position and orientation** of the camera when the photograph was taken
  
  - i.e., by knowing the values of \((X_L, Y_L, Z_L)\) and \((\omega, \phi, K)\)

\[
x_p = -f \left[ \frac{m_{11}(X_p - X_L) + m_{12}(Y_p - Y_L) + m_{13}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right]
\]

\[
y_p = -f \left[ \frac{m_{21}(X_p - X_L) + m_{22}(Y_p - Y_L) + m_{23}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right]
\]
Some Important Notes to Remember

• If the location of the exposure station is known as well as the angular rotations (i.e., after doing an exterior orientation), then any position on the ground can be located in the photo or image.

\[
x_p = -f \left[ \frac{m_{11}(X_p - X_L) + m_{12}(Y_p - Y_L) + m_{13}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right]
\]

\[
y_p = -f \left[ \frac{m_{21}(X_p - X_L) + m_{22}(Y_p - Y_L) + m_{23}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right]
\]
Some Important Notes to Remember

- If the location of the exposure station is known as well as the angular rotations (i.e., after doing an exterior orientation), then any position on the ground can be located in the photo or image.
  - But not the other way around!
  - Exterior orientation just relates the ground coordinates with the image coordinates
  - Exterior orientation cannot provide \((X_p, Y_p, Z_p)\) values!

\[
x_p = -f \frac{m_{11}(X_p - X_L) + m_{12}(Y_p - Y_L) + m_{13}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)}
\]

\[
y_p = -f \frac{m_{21}(X_p - X_L) + m_{22}(Y_p - Y_L) + m_{23}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)}
\]
• Illustration:
  – We pick a point in a photograph and determine its camera-internal coordinates
  – By interior orientation, we would be able to find its pixel or image coordinates \((x_p, y_p)\)
  – After exterior orientation, we know the values of \((X_L, Y_L, Z_L)\) and \((\omega, \phi, K)\)
  – Using \((\omega, \phi, K)\) we can solve for the \(m\) values
  – Even if we know the \((x_p, y_p)\), \((X_L, Y_L, Z_L)\) and the \(m\) values, there is no way we can compute for the 3D ground coordinates of that point!

• 3 unknowns, 2 equations \(\implies\) no solution!

\[
x_p = -f \left[ \frac{m_{11}(X_p - X_L) + m_{12}(Y_p - Y_L) + m_{13}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right]
\]

\[
y_p = -f \left[ \frac{m_{21}(X_p - X_L) + m_{22}(Y_p - Y_L) + m_{23}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right]
\]
How do we solve this problem of not being able to get 3D coordinates from a single photograph?

• We need another set of collinearity equations which we can relate to the first set of the collinearity equations!
  – That means, the 2\textsuperscript{nd} set of the collinearity equations must be set-up for the same point!
  
  – Where do we get this second point which is the same as the first point?
    • In another photograph that contains the same point!
    • Basically, we need two photographs that contains the same point
    • These photographs is called a stereopair!
Recall (Topic 3)...

• We can **visualize 3D** information in aerial photographs through the use of a “**stereoscopic pair**” or “**stereopair**” of aerial photographs

  – If digital, we call it “model”, “stereo model”, or “image pair”

• This pair of aerial photographs consists of two adjacent, overlapping photos in the same flight line
Example of a Stereopair
Another Example of a Stereopair
Another Example of a Stereopair

Another Example of a Stereopair

Source: http://www.seos-project.eu/modules/3d-models/images/stereopair_overlap.png
• To set-up two sets of **collinearity equations** that can be related to each other, we need to do both **interior and exterior orientations** of a stereopair!
ORIENTATION OF A STEREOPAIR
Orientation of a Stereopair

• Why it is needed?
  – The application of single photographs in photogrammetry is **limited** because they **cannot** be used for reconstructing the object space (i.e., we cannot determine 3D coordinates of objects!)
  
  – This problem is solved by using a stereopair and exploiting **stereopsis**, that is by using a second photograph of the same scene, taken from a different position.

• This can be done through the process called “**Space Intersection**”
Orientation of Stereopair through Space Intersection

Orientation of Stereopair through Space Intersection

Space Intersection

- A procedure by which the ground coordinates (X, Y, Z) of any point in the overlap of a stereopair can be determined.

- Space intersection makes use of the fact that corresponding rays from overlapping photos intersect at a unique point
  - This unique point pertains to the location of a point on the ground!
The space where points intersect is called the “model space” (also called the “intersection space”)

Figure 5.9: The concept of model space (a) and model coordinate system (b).
Orientation of a stereopair through the process of the space intersection is based on the condition that for two photos, the two conjugate rays defined on each object point must be coplanar.

→ this is called as the “coplanarity condition”

Figure 5.9: The concept of model space (a) and model coordinate system (b).
Orientation of a stereopair through the process of the space intersection is based on the condition that for two photos, the two conjugate rays defined on each object point must be **coplanar.**

→ **this is called as the “coplanarity condition”**
Orientation of a stereopair through the process of the space intersection is based on the condition that for two photos, the two conjugate rays defined on each object point must be coplanar.

→ this is called as the “coplanarity condition”
Coplanarity Condition

• The coplanarity condition further implies that the two exposure stations, the two image points, and the object point are in a same plane, called the epipolar plane.

• The coplanarity condition is expressed by the “coplanarity equation” (not shown here due to complexity in the derivation)
Coplanarity Condition

- The coplanarity condition further implies that the two exposure stations, the two image points, and the object point are in a same plane, called the **epipolar plane**.

- The coplanarity condition is expressed by the "**coplanarity equation**" (not shown here due to complexity in the derivation)
Space Intersection can produce 4 collinearity equations

- If we subject the left photo to exterior orientation by space resection, we can determine the exterior orientation parameters of that photograph

- That means, we can set-up 2 equations
  - E.g.,:

\[
x_p = -f \left[ \frac{m_{11}(X_p - X_L) + m_{12}(Y_p - Y_L) + m_{13}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right]
\]

\[
y_p = -f \left[ \frac{m_{21}(X_p - X_L) + m_{22}(Y_p - Y_L) + m_{23}(Z_p - Z_L)}{m_{31}(X_p - X_L) + m_{32}(Y_p - Y_L) + m_{33}(Z_p - Z_L)} \right]
\]
Space Intersection can produce 4 collinearity equations

• Also, if we subject the **right** photo to exterior orientation by space resection, we can determine the exterior orientation parameters of that photograph.

• That means, we can set-up 2 more equations
  – E.g.,:

\[
x_{p2} = -f \left[ \frac{m_{11}(X_p - X_{l2}) + m_{12}(Y_p - Y_{l2}) + m_{13}(Z_p - Z_{l2})}{m_{31}(X_p - X_{l2}) + m_{32}(Y_p - Y_{l2}) + m_{33}(Z_p - Z_{l2})} \right]
\]

\[
y_{p2} = -f \left[ \frac{m_{21}(X_p - X_{l2}) + m_{22}(Y_p - Y_{l2}) + m_{23}(Z_p - Z_{l2})}{m_{31}(X_p - X_{l2}) + m_{32}(Y_p - Y_{l2}) + m_{33}(Z_p - Z_{l2})} \right]
\]

Space Intersection can produce 4 collinearity equations

- Two of these equations relate to the point’s x and y coordinates on the left photo; two result from coordinates measured on the right photo.

- If the exterior orientation of both photos is known, then the only unknowns in each equation are X, Y, and Z for the point under analysis.

- Given 4 equations, 3 unknowns, a least square solution for the ground coordinates of a point can be performed.
Space Intersection can produce 4 collinearity equations

- The 4 equations can be related to each other to determine the value of \((X_P, Y_P, Z_P)\)!

\[
x_{p_1} = -f \left[ \frac{m_{11}(X_p - X_{l_1}) + m_{12}(Y_p - Y_{l_1}) + m_{13}(Z_p - Z_{l_1})}{m_{31}(X_p - X_{l_1}) + m_{32}(Y_p - Y_{l_1}) + m_{33}(Z_p - Z_{l_1})} \right]
\]

\[
y_{p_1} = -f \left[ \frac{m_{21}(X_p - X_{l_1}) + m_{22}(Y_p - Y_{l_1}) + m_{23}(Z_p - Z_{l_1})}{m_{31}(X_p - X_{l_1}) + m_{32}(Y_p - Y_{l_1}) + m_{33}(Z_p - Z_{l_1})} \right]
\]

\[
x_{p_2} = -f \left[ \frac{m_{11}(X_p - X_{l_2}) + m_{12}(Y_p - Y_{l_2}) + m_{13}(Z_p - Z_{l_2})}{m_{31}(X_p - X_{l_2}) + m_{32}(Y_p - Y_{l_2}) + m_{33}(Z_p - Z_{l_2})} \right]
\]

\[
y_{p_2} = -f \left[ \frac{m_{21}(X_p - X_{l_2}) + m_{22}(Y_p - Y_{l_2}) + m_{23}(Z_p - Z_{l_2})}{m_{31}(X_p - X_{l_2}) + m_{32}(Y_p - Y_{l_2}) + m_{33}(Z_p - Z_{l_2})} \right]
\]
Relating the 4 equations depends on the coordinate system to be used

\[
x_{p_1} = -f \frac{m_{11}(X_p - X_{l_1}) + m_{12}(Y_p - Y_{l_1}) + m_{13}(Z_p - Z_{l_1})}{m_{31}(X_p - X_{l_1}) + m_{32}(Y_p - Y_{l_1}) + m_{33}(Z_p - Z_{l_1})}
\]

\[
y_{p_1} = -f \frac{m_{21}(X_p - X_{l_1}) + m_{22}(Y_p - Y_{l_1}) + m_{23}(Z_p - Z_{l_1})}{m_{31}(X_p - X_{l_1}) + m_{32}(Y_p - Y_{l_1}) + m_{33}(Z_p - Z_{l_1})}
\]

\[
x_{p_2} = -f \frac{m_{11}(X_p - X_{l_2}) + m_{12}(Y_p - Y_{l_2}) + m_{13}(Z_p - Z_{l_2})}{m_{31}(X_p - X_{l_2}) + m_{32}(Y_p - Y_{l_2}) + m_{33}(Z_p - Z_{l_2})}
\]

\[
y_{p_2} = -f \frac{m_{21}(X_p - X_{l_2}) + m_{22}(Y_p - Y_{l_2}) + m_{23}(Z_p - Z_{l_2})}{m_{31}(X_p - X_{l_2}) + m_{32}(Y_p - Y_{l_2}) + m_{33}(Z_p - Z_{l_2})}
\]

- The values of \(x_{p_1}, y_{p_1}, x_{p_2}\) and \(y_{p_2}\) can be referenced to a single coordinate system
- The coordinate system is called the "model coordinate system"
Different Ways to Orient a Stereopair

• Orientation of stereopair can be done in several ways depending on how the model coordinate system is defined
Different Ways to Orient a Stereopair

- **Dependent Relative Orientation**
  - The position and the orientation is identical to one of the two photo-coordinate system
  - Rotation angles in the left photo is zero; rotation angles in the right photo needs to be determined.

\[
\begin{align*}
L_1 & \quad L_2 \\
zm & \quad ym \\
xm & \quad zm \\
bx & \quad by \\
bz & \quad bz \\
\phi & \quad \phi_0 \\
\kappa & \quad \kappa \\
\end{align*}
\]

Parameters:
- \(by\): y base component
- \(bz\): z base component
- \(\phi\): rotation angle about x
- \(\phi_0\): rotation angle about y
- \(\kappa\): rotation angle about z

Schenk, T., 2005. Introduction to Photogrammetry. Department of Civil and Environmental Engineering and Geodetic Science, The Ohio State University
• The **dependent relative orientation** leaves one of the photographs unchanged (i.e., the left photo is “fixed”)
  – The other one is oriented with respect to the unchanged system.

• This is of advantage for the conjunction of successive photographs in a strip.

• All photographs of a strip can be joined into the coordinate system of the first photograph.
Different Ways to Orient a Stereopair

- **Independent Relative Orientation**
  - The origin is identical to one of the two photo-coordinate system
  - The orientation is chosen such that the positive \textbf{xm-axis} passes through the perspective center (exposure station) of the other photo-coordinate system.
  - 2 rotation angles unknown in left photo; 3 rotation angles unknown in the right photo

\begin{itemize}
  \item \textbf{L}_1
  \item \textbf{L}_2
\end{itemize}
Different Ways in Orienting a Stereopair

• **Direct Orientation**
  – the model coordinate system becomes identical with a defined ground coordinate system (e.g., UTM Zone 51)
  – Ground control points (with known X, Y and Z) are used to determine the exterior orientation parameters of each photo
Different Ways in Orienting a Stereopair

• **Absolute Orientation**
  
  – the process of orienting a stereopair to the **ground coordinate system**
  
  – uses the 7-parameter transformation to establish the relationship between two 3-D Cartesian coordinate systems (which are the model and the ground coordinate systems)

  – Ground control points are used

Schenk, T., 2005. Introduction to Photogrammetry. Department of Civil and Environmental Engineering and Geodetic Science, The Ohio State University
Different Ways in Orienting a Stereopair

- **Absolute Orientation**
  - the 7-parameter transformation is also called the “Helmert Transformation”, a 3D transformation method
    - Includes rotation, translation, and scaling
  - Similar to Affine Transformation but Affine is a 2D transformation
Different Ways to Orient a Stereopair

• Dependent Relative Orientation
• Independent Relative Orientation
• Direct Orientation
• Absolute Orientation
Remarks

• Once a stereopair is oriented, 3D measurements is now possible
  – Also called “stereophotogrammetric measurements”

  – From the 3D measurements, we can generate a Digital Surface Model and a Digital Terrain Model from a stereopair!

  – Will be discussed in Topic 5
Laboratory Exercises

- Anaglygh 3D Glasses Preparation and Creation of Anaglyph 3D Images from Stereopairs
- Orientation of a Stereopair using LISA Software
Reading Assignments


(See Facebook page for the PDF link)