Stereoscopy and 3-D measurement

There are a number of methods for measuring the height of objects using aerial photography. The measurements can be done from a single photo, as well as from parallax differences.

I. Shadow Height Method:

Basically, if the shadow cast by an object can be measured and the sun angle causing the shadow is known or can be derived (from latitude, date and time) then the height of the object can be calculated using simple trigonometry, as follows:

\[ h = L \times \tan \alpha \]

Where: \( \tan \alpha \) is the tangent of the sun angle from the ground surface; \( L \) is the length of the shadow.
II. Height Measurement Based on Relief Displacement:

The amount of relief displacement, $d$, is directly proportional to the difference in elevation, $h$, between the top of the object whose image is displaced and the local datum. Therefore the height can be measured.
II. Height Measurement Based on Relief Displacement:

The greater the height of the object above the local datum, the greater its displacement.

The farther the object is from the principal point, the greater the displacement.
For height determination from a single aerial photo:

- Accept the principle point as the photo nadir (assuming a true vertical photo);
- Must precisely know or be able to determine the altitude from which the photo was acquired (H).
- Both the top and the bottom of the object to be measured should be clearly visible.
- The degree of image displacement must be great enough to be accurately measured with available equipment.
Each vertical aerial photograph overlaps the next photograph in the flight-line by approximately 60% which refers to as **stereoscopic overlap**.

**Flight-line of Vertical Aerial Photograph**

This overlap is very important because it provides at least two and sometimes three photographic views of each object on the ground along the flight-line.

**Figure 8-1**  A single flightline of vertical aerial photography with 60 percent overlap obtained at three exposure stations $H$ meters above-ground-level.
Most aerial photography projects require multiple flightlines of photography to cover the geographic area of interest.

Multiple flightlines with 20-30% sidelap (overlap between the flightlines) are commonly referred to as block of aerial photography.

It is common to combine several vertical photographs in the block of photography to create a photomosaic.
It is common to combine several vertical photographs in the block of photography to create a *photomosaic*.

**Fiducial Marks, Principal Points, and Conjugate Principal Points**
Fiducial Marks, Principal Points, and Conjugate Principal Points

Fiducial marks are photographed each time aerial photograph is recorded.

These marks are of varying shape or form and may appear in the corners or the middle of each side of the photo or in all eight locations.

These marks allow users to locate the precise center of a photograph, i.e., the principal point (PP). Drawing a line between opposite fiducial marks locates the principal point of the photograph.

Conjugate Principal Points

By carefully examining the vicinity of the principal point on a photograph, its location can be visually transferred to each of the two adjacent photos in the flightline. The transferred principal point is commonly called conjugate principal point (CPP).
Stereoscopic Parallax and Parallax Height Measurement

If we acquire multiple photographs along a flight line, we record images of the landscape from different vantage points.

The change in position of an object with height, from one photograph to the next relative to its background, caused by the aircraft's motion, is called stereoscopic parallax.

Parallax Height Measurement

Parallax is the apparent displacement in the position of an object, with respect to a frame of reference, caused by a shift in the position of observation. The differences in the parallax of various objects of interest (called differential parallax) can be used to measure the heights of objects and to extract topographic information.
Measurement of Absolute and Differential Parallax

\[ h = (H) \frac{dP}{P + dP} \]

where:
\[ dP \] = differential parallax, which can be determined by the measurement between the base of the building and the top of the building.

\[ P \] = absolute stereoscopic parallax at the base of the object. 
\[ P \] can be determined by measuring the distance between the PP and the CPP on each of the stereo airphotos and calculate the mean which is the average photo air base (\( P \)) between the two exposure stations (i.e., absolute stereoscopic parallax).
**Fundamentals of Human Stereoscopy**

Stereoscopy is the science of perceiving depth using two eyes. When a human being's two eyes (binocular vision) are focused on a certain point, the optical axes of the eyes converge on that point, forming *parallactic angle* ($\phi$). The nearer the object, the greater the parallactic angle.

The brain has learned to associate distance with corresponding parallactic angles and give the viewer the visual and mental impression which object is closer. This is the basis of depth perception.

\[ h = (H) \frac{dP}{P + dP} \]

Note: $dP$ and $P$ must be measured in the same units.
If both objects were exactly the same distance from the viewer, then the parallactic angles will be the same and the viewer would perceive them as being the same distance away.

The maximum distance at which distinct stereoscopic depth perception is possible is approximately 1000 meters for the average adult.

---

**Stereo Viewing without Instruments.**

People with normal or corrected vision in both eyes can often develop a facility for stereoscopic vision without the use of a stereoscope.

Seeing stereoscopically with unaided eyes can be practiced with the “sausage-link” exercise.

The eyes are focused on a distant background as the forefingers at arm’s length and horizontal to each other are brought slowly together into the line of vision. As the spacing closes, a point will be reached where a “sausage link” is seen between the fingertips.
Proper Use of Stereoscopes

The following are some guidelines that will help you use your stereoscopes properly. They are important and should be kept in mind when performing stereo based interpretations:

1. Be sure that the photos are properly aligned, preferably with the shadows toward the viewer. (Having the shadows away from the viewer can cause terrain reversal or "false stereo").
2. Be sure to keep the eye base and the long axis of the stereoscope parallel to the flight line.
3. Try to maintain an even glare free illumination of the images and make yourself comfortable.
4. Do not attempt stereoviewing for long periods in the beginning.
Lens and Mirror Stereoscopes

A stereoscope is a binocular viewing system specially developed to analyze terrestrial stereoscopic photographs.

Viewing Stereoscopic Aerial Photographs

- Principal Point and Conjugate Principal Point are located on each photograph. Drawn a line through them on each photograph can identify the flight line.
- Slides one of the photographs left or right so that a portion of the stereoscopic overlap area is visible.
- The stereoscope is placed above the overlap area and stereoscopic viewing takes place. The common overlap area of a pair of 9x9 in aerial photographs taken 60 percent overlap is about 5.4 in. that can be viewed in stereo.