Chapter 4

Properties of Aerial Photography

4.1 Introduction

Aerial photography is the basic data source for making maps by photogrametric means. The photograph is the end result of the data acquisition process discussed in the previous chapter. Actually, the net result of any photographic mission are the photographic negatives. Of prime importance for measuring and interpretation are the positive reproductions from the negatives, called *diapositives*.

Many factors determine the quality of aerial photography, such as

- design and quality of lens system
- manufacturing the camera
- photographic material
- development process
- weather conditions and sun angle during photo flight

In this chapter we describe the types of aerial photographs, their geometrical properties and relationship to object space.

4.2 Classification of aerial photographs

Aerial photographs are usually classified according to the orientation of the camera axis, the focal length of the camera, and the type of emulsion.

4.2.1 Orientation of camera axis

Here, we introduce the terminology used for classifying aerial photographs according to the orientation of the camera axis. Fig. 4.1 illustrates the different cases.

true vertical photograph A photograph with the camera axis perfectly vertical (identical to plumb line through exposure center). Such photographs hardly exist in reality.

near vertical photograph A photograph with the camera axis nearly vertical. The deviation from the vertical is called tilt. It must not exceed mechanical limitations of stereoplotter to accomodate it. Gyroscopically controlled mounts provide stability of the camera so that the tilt is usually less than two to three degrees.

oblique photograph A photograph with the camera axis intentially tilted between the vertical and horizontal. A **high oblique photograph**, depicted in Fig. 4.1(c) is tilted so much that the horizon is visible on the photograph. A **low oblique** does not show the horizon (Fig. 4.1(b)).

The total area photographed with obliques is much larger than that of vertical photographs. The main application of oblique photographs is in reconnaissance.

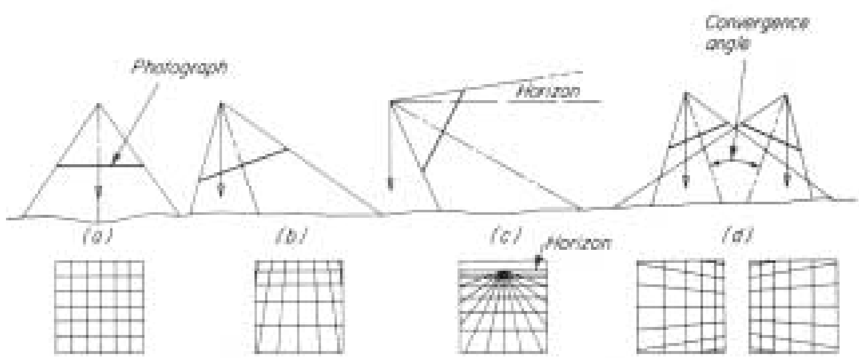

Figure 4.1: Classification of photographs according to camera orientation. In (a) the schematic diagram of a true vertical photograph is shown; (b) shows a low oblique and (c) depicts a high oblique photograph.

4.2.2 Angular coverage

The angular coverage is a function of focal length and format size. Since the format size is almost exclusively $9'' \times 9''$ the angular coverage depends on the focal length of the camera only. Standard focal lengths and associated angular coverages are summarized in Table 4.1.

Table 4.1: Summary of photographs with different angular coverage.

	super-wide	wide-angle	inter-mediate	normal-angle	narrow-angle
focal length [mm]	85.	157.	210.	305.	610.
angular coverage [o]	119.	82.	64.	46.	24.

4.2.3 Emulsion type

The sensitivity range of the emulsion is used to classify photography into

panchromatic black and white This is most widely used type of emulsion for photogrammetric mapping.

color Color photography is mainly used for interpretation purposes. Recently, color is increasingly being used for mapping applications.

infrared black and white Since infrared is less affected by haze it is used in applications where weather conditions may not be as favorable as for mapping missions (e.g. intelligence).

false color This is particular useful for interpretation, mainly for analyzing vegetation (e.g. crop desease) and water pollution.

4.3 Geometric properties of aerial photographs

We restrict the discussion about geometric properties to frame photography, that is, photographs exposed in one instant. Furthermore, we assume central projection.

4.3.1 Definitions

Fig. 4.2 shows a diapositive in near vertical position. The following definitions apply:

perspective center *C* calibrated perspective center (see also camera calibration, interior orientation).

focal length *c* calibrated focal length (see also camera calibration, interior orientation).

principal point *PP* principal point of autocollimation (see also camera calibration, interior orienttion).

camera axis *C-PP* axis defined by the projection center C and the principal point *PP*. The camera axis represents the optical axis. It is perpendicular to the image plane

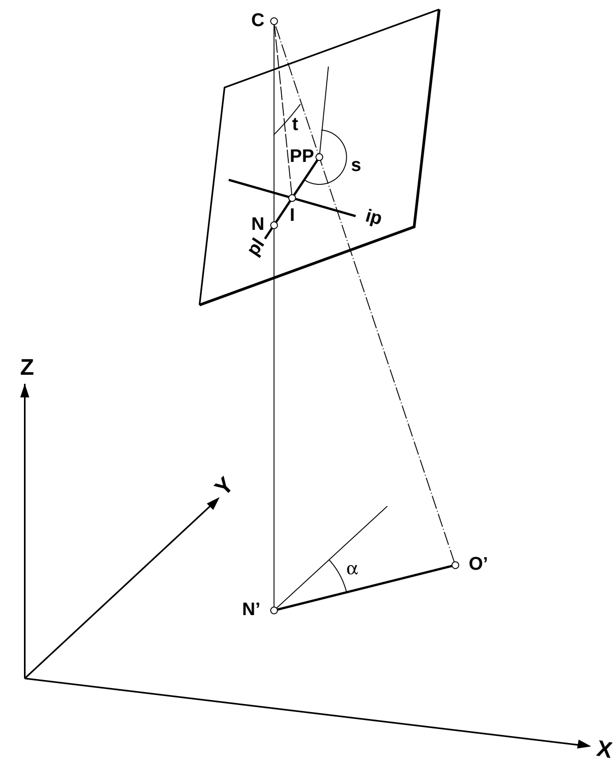

Figure 4.2: Tilted photograph in diapositive position and ground control coordinate system.

nadir point N' also called photo nadir point, is the intersection of vertical (plumb line) from perspective center with photograph.

ground nadir point N intersection of vertical from perspective center with the earth's surface.

tilt angle t angle between vertical and camera axis.

swing angle s is the angle at the principal point measured from the $+$*y-axis* counterclockwise to the nadir N.

azimut α is the angle at the ground nadir N measured from the $+$*Y-axis* in the ground system counterclockwise to the intersection O of the camera axis with the ground surface. It is the azimut of the trace of the principal plane in the XY-plane of the ground system.

principal line *pl* intersection of plane defined by the vertical through perspective center and camera axis with the photograph. Both, the nadir N and the principal point

PP are on the principal line. The principal line is oriented in the direction of steepest inclination of of the tilted photograph.

isocenter I is the intersection of the bisector of angle t with the photograph. It is on the principal line.

isometric parallel *ip* is in the plane of photograph and is perpendicular to the principal line at the isocenter.

true horizon line intersection of a horizontal plane through persepective center with photograph or its extension. The horizon line falls within the extent of the photograph only for high oblique photographs.

horizon point intersection of principal line with true horizon line.

4.3.2 Image and object space

The photograph is a *perspective (central) projection*. During the image formation process, the physical projection center object side is the center of the entrance pupil while the center of the exit pupil is the projection center image side (see also Fig. 4.3. The two projection centers are separated by the *nodal separation*. The two projection centers also separate the space into *image space* and *object space* as indicated in Fig. 4.3.

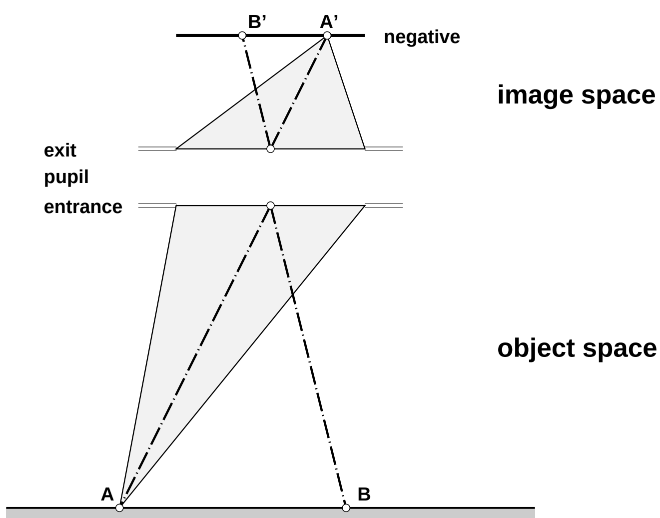

Figure 4.3: The concept of image and object space.

During the camera calibration process the projection center in image space is changed to a new position, called the calibrated projection center. As discussed in 2.6, this is necessary to achieve close similarity between the image and object bundle.

4.3.3 Photo scale

We use the representative fraction for scale expressions, in form of a ratio, e.g. 1 : 5,000. As illustrated in Fig. 4.4 the scale of a near vertical photograph can be approximated by

$$m_b = \frac{c}{H} \tag{4.1}$$

where m_b is the *photograph scale number*, c the calibrated focal length, and H the *flight height* above mean ground elevation. Note that the flight height H refers to the average ground elevation. If it is with respect to the datum, then it is called *flight altitude* H_A, with $H_A = H + h$.

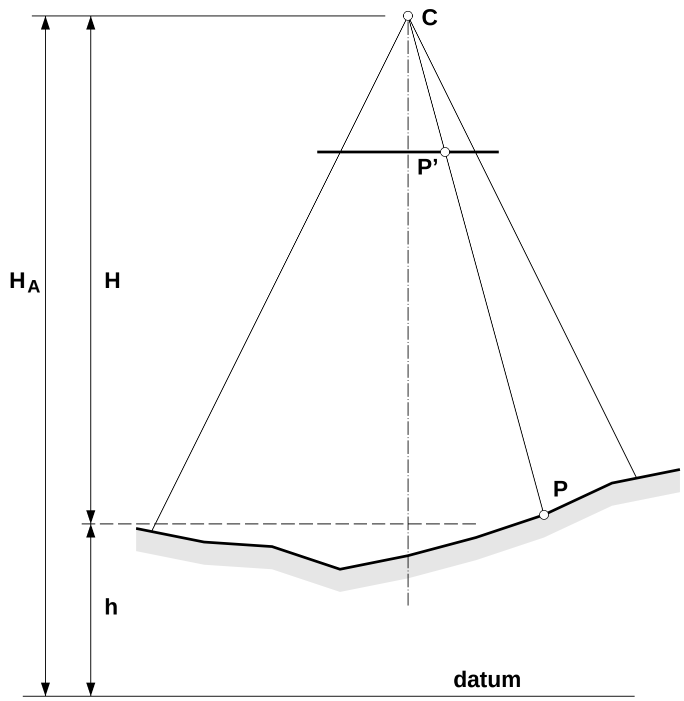

Figure 4.4: Flight height, flight altitude and scale of aerial photograph.

The photograph scale varies from point to point. For example, the scale for point P can easily be determined as the ratio of image distance CP' to object distance CP by

$$m_P = \frac{CP'}{CP} \tag{4.2}$$

$$CP\prime = \sqrt{x_P^2 + y_P^2 + c^2} \tag{4.3}$$

$$CP = \sqrt{(X_P - X_C)^2 + (Y_P - Y_C)^2 + (Z_P - Z_C)^2} \tag{4.4}$$

where x_P, y_P are the photo-coordinates, X_P, Y_P, Z_P the ground coordinates of point P, and X_C, Y_C, Z_C the coordinates of the projection center C in the ground coordinate system. Clearly, above equation takes into account any tilt and topographic variations of the surface *(relief)*.

4.3.4 Relief displacement

The effect of relief does not only cause a change in the scale but can also be considered as a component of image displacement. Fig. 4.5 illustrates this concept. Suppose point T is on top of a building and point B at the bottom. On a map, both points have identical X, Y coordinates; however, on the photograph they are imaged at different positions, namely in T' and B'. The distance d between the two photo points is called ***relief displacement*** because it is caused by the elevation difference Δh between T and B.

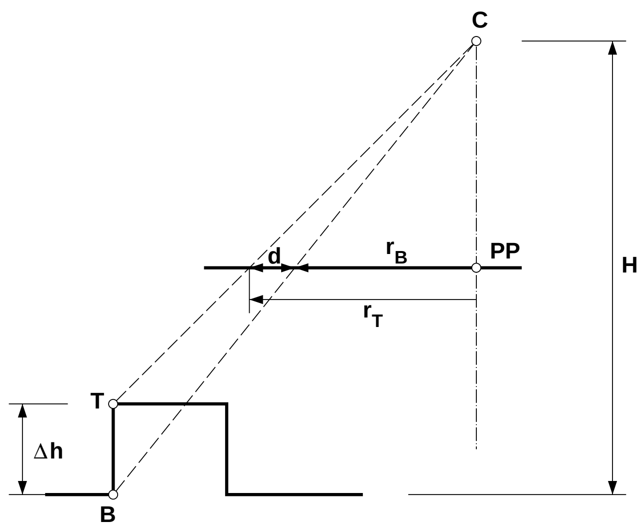

Figure 4.5: Relief displacement.

The magnitude of relief displacement for a true vertical photograph can be determined by the following equation

$$d = \frac{r\ \Delta h}{H} = \frac{r'\ \Delta h}{H - \Delta h} \tag{4.5}$$

where $r = \sqrt{x_T^2 + y_T^2}$, $r' = \sqrt{x_B^2 + y_B^2}$, and Δh the elevation difference of two points on a vertical. Eq. 4.5 can be used to determine the elevation Δh of a vertical object

$$h = \frac{d\ H}{r} \tag{4.6}$$

The direction of relief displacement is radial with respect to the nadir point N', independent of camera tilt.