What is the principal point of aerial photography

 SECTION 8 Aerial photographs are an invaluable source of information for the study of the nature and characteristics of the coastal and terrestrial environment. Vertical aerial photographs can be used to update existing base maps and to produce new base maps in the form of individual photographs or several photographs in assembled format known as mosaics (refer to Section 8.9). Various simple transfer instruments (sketch master and zoom transfer-scope) are available for correcting the horizontal distortion (x and y) inherent in aerial photographs and may be used to transfer the necessary photo information to line maps with a reasonable degree of accuracy. The amount of information extracted from these aerial photos depends upon the skills of the photo interpreter. To correct for height displacement (z), a complex and expensive photogrammetric plotting instrument is required, e.g., Wild AIO. 8.1 Types of Aerial Photographs There are two major classes of aerial photographs: i) Verticals: the survey camera lens points vertically downwards producing a view resembling a plan of the ground; ii) Obliques: the survey camera lens axis points at an angle to the ground. If the horizon is included the photograph is defined as a high oblique; if not, it is a low oblique. Depending on the photo information required, more than one film type may be necessary. In this situation, the use of multiple survey camera installations will reduce flying costs. In Figure 8.1 the twinned and triple camera installations are indicated. 8.2 Acquisition of Aerial Photographs An aircraft taking systematic air photo coverage of an area does so by making successive passes back and forth across it, usually in an east-west direction. This flight line ensures consistency in orientation and sun angle, which aids in photo interpretation. The orientation of the prints is at 90° to that of the flight lines. To permit stereoscopic and photogrammetric analysis there is usually a 60% forward overlap between successive photographs in the same flight line and 20–40% lateral overlap between adjacent flight lines (Figure 8.2). Considerable variation in the format size of photographs exists, although the most common size is 23 × 23 cm (9 × 9"). Scales may vary from 1:1,000 to 1:80,000 depending on the photo interpretation requirements. For example, forest inventory photography is commonly at 1:10,000 whereas the analysis of geological features may only require photography at a scale of 1:50,000. An annotation, usually located along the southwest corner of the photographs, should contain all relevant information such as the roll number, print number, time and date of photography, etc. Figure 8.1 Twinned (a); and tripled (b) suvey camera installations. (After G.C. Dickinson, 1969) Figure 8.2 Lateral and forward overlap of aerial photographs. The top left-hand corner of each photograph is indicated. (After G.C. Dickinson, 1969) 8.3 Terminology of Aerial Photographs Basic terminology associated with aerial photographs includes the following: i) Format: the size of the photo; ii) Focal plane: the plane in which the film is held in the camera for photography (Figure 8.3); iii) Principal point (PP): the exact centre of the photo or focal point through which the optical axis passes. This is found by joining the fiducial or collimating marks which appear on every photo (Figure 8.4); iv) Conjugate principal point: image of the principal point on the overlapping photograph of a stereo pair; v) Optical axis: the line from the principal point through the centre of the lens. The optical axis is vertical to the focal plane (Figure 8.4); vi) Focal length (f): the distance from the lens along the optical axis to the focal point (Figure 8.3); vii) Plane of the equivalent positive: an imaginary plane at one focal length from the principal point, along the optical axis, on the opposite side of the lens from the focal plane (Figure 8.3); viii) Flying height (H): height of the lens above sea level at the instant of exposure. The height of a specified feature above sea level is designated "h" (Figure 8.3); ix) Plumb point (Nadir or vertical point): the point vertically beneath the lens at the instant of exposure (Figure 8.5); x) Angle of tilt: the angle subtended at the lens by rays to the principal point and the plumb point (Figure 8.5). 8.4 Properties of Aerial Photographs The majority of photogrammetric techniques are based on the three basic properties of aerial photographs: scale, displacement and radial property. 8.4.1 Scale The scale of a truly vertical photo of perfectly flat terrain would be nearly the same as an accurate line map (refer to Section 3). The occurrence of relief, however, causes variations in scale because of the perspective view of the camera lens (Figure 8.6). These differential variations in scale preclude the tracing of information from photographs directly to large-scale maps. The amount of displacement, however, can be measured. Figure 8.3 The focal length, focal plane, plane of the equivalent positive and flying height of aerial photographs. Figure 8.4 The principal point, fiducial marks and optical axis of aerial photographs. Figure 8.5 Plum point and angle of tilt of aerial photographs. Figure 8.6 The effect of topography on photo scale: photo scale increases with an increase in elevation of terrain. The overall scale is the ratio of the focal length of the camera lens to the elevation of the camera lens with respect to some specific features on the landscape; it follows that this ratio will not be correct for any other elevation, 8.4.2 Displacement Relative to one level of terrain, higher points are displaced away from the centre of the photograph and lower points towards the centre. The amount of displacement increases as the height of the object and the distance from the centre of the photograph increases. As the altitude of the camera increases, displacement is less. This is the reason why high altitude vertical photography is used for the construction of mosaics or as an effective and inexpensive base map substitute. The displacement of objects on aerial photographs produces parallax, which is the apparent change in position of an object due to a change in the point of observation. This apparent change in position is the principal reason for our ability to view two photographs to produce an illusion of a third dimension. The algebraic difference of the parallax on two overlapping photographs is used to determine elevations using stereoscopic plotting instruments. 8.4.3 Radial property In a vertical photograph the radial directions from the centre are true. Thus bearings measured from the principal point are true, whereas distances are not. 8.5 Scale of Aerial Photographs The scale of a photo affects its use in the revision of line maps, i.e. a photo with a nominal scale of 1:50,000 should not be used to revise a map with a scale of 1:10,000. Photos at the same scale or larger should be used to insure that the resolution of the photograph matches the degree of precision required for the revised information. 8.5.1 Determining the scale There are four basic methods of determining the scale of an aerial photograph which, in decreasing order of accuracy, are as follows: i) the relationship between two points on the ground of known distance, and the same two points on the photo. (Note that the scale may vary for other locations on the same photograph if there is significant relief variation); ii) the relationship between two points on the map and the same two points on the photo; iii) the relationship between an object on the ground, whose dimensions are known and the same object on the photograph; iv) the relationship between the focal length of the camera lens and the altitude of the camera lens, e.g., focal length (f) = 15 cms, altitude (H) = 1,500 m; 8.5.2 The effect of tilt and height displacement The scale of an aerial photo changes from point to point due to tilt of the camera lens (i.e. aircraft attitude) and changes in height of the terrain unless the terrain is absolutely flat (Figure 8.7). The top of a high mountain, therefore, will be at a larger scale than a valley because it is nearer the camera lens when photographed (unless the photo has been rectified). Figure 8.8 a shows a rectangle of roads in absolutely flat country photographed with a perfectly vertical camera. There is no distortion so they appear on the photo as they would in a line map. Figure 8.8 b shows the distorted appearance of the roads on a tilted photo; Figure 8.8 c shows the appearance of the information after rectification, i.e. the roads are restored to their proper shape but the print itself is no longer square. When hilly country is photographed there is no means of completely removing the effects of tilt and the differences of terrain height in one photo. Differential rectification, however, minimizes these effects. 8.6 Plotting Techniques The following simple techniques may be used for plotting detail from aerial photographs onto line maps without the use of sophisticated equipment (refer to Section 7): i) Transfer-by-eye sketching: If the line map shows considerable detail it may be possible to add further information by visual referencing with a satisfactory degree of accuracy; ii) Direct transfer after reduction or enlargement of the photograph to the line map scale: The photograph is projected at the appropriate scale onto the line map to be revised; photo detail is then drawn on the map. To minimize distortion, the enlargement/reduction factors should be calculated only for small areas at a time. Instruments such as the Kail projector and Map O'Graph may be used for this task (refer to Section 7.6.6); iii) Transfer by grids, triangles, etc.(Figure 8.9): These are methods derived from the basic principle that a straight line on the ground will appear as a straight line on the photograph if the terrain is relatively flat. Height distortion, however, will introduce small errors in vertical photographs and excessive errors in obliques. All methods require that at least four points be identified on both the photograph and the existing line map (refer to Section 7.6.6); Figure 8.7 Variations in scale in relation to aircraft attitude. (After C.H. Strandberg, 1967) Figure 8.8 An undistorted aerial photograph (a); distorted (b); and rectified (c). (After P.J. Oxtoby and A. Brown, 1976) Figure 8.9 Grid for transference of detail form an aerial photographs to a map: (a) polar grid; (b) polygonal grids. (After G.C. Dickinsin, 1969) a) Polar grid (Figure 8.9 a): Identical grid constructions are drawn on the line map and the photograph: - the four points used may be A, B, C and D; - AD and BC are extended to meet at E; - AB and CD are extended to meet at F; - Through G, the intersection of AC and BD are drawn EGH and FGJ. Detail can now be copied from any triangle on the photograph onto the corresponding triangle on the map; b) Polygonal grid (Figures 8.9 b): When more than four common points can be identified on the photo and line map, extended points as in the polar grid need not be drawn. The points are simply plotted on both line map and photograph and the area within the resultant polygon subdivided by joining each point to all the others. 8.7 Interpretation Using normal vision "on the ground" an object can be distinguished by a combination of the three processes of observation: i) size and shape; ii) colour; iii) features with which it is associated. The same processes are used by photo interpreters but with different conditions and emphasis within each group: i) Size: may be the deciding factor when distinguishing between objects alike in shape. Measuring may be necessary; ii) Shape: the general form (which includes the three-dimensional stereoscopic view) may be the single most reliable evidence for identification; iii) Tone: variation in tone results from differences in the reflective qualities of objects, e.g., light, dark, etc.; iv) Texture: when changes in tone are too small to be discernable, texture may assist identification, e.g., stippled, granular, rough, smooth, etc.; v) Shadow: provides a ground view of the object, hence an important clue. Lengths of shadows can be used to determine heights of objects if the surrounding terrain can be assumed to be flat; vi) Pattern: the arrangement on the landscape of physical and cultural features is often distinctive and may be useful for recognition and evaluation; vii) Site: the location on the landscape can contribute to identification, e.g., particular vegetation may appear in specific locations only; viii) Associated features: features commonly found adjacent to the object under investigation. These have a characteristic appearance and so immeasurably assist photo interpretation, e.g., rocks and soil, water, vegetation (woods, grasslands, crops), roads, railways, towns and historic sites. 8.7.1 General rules for photographic interpretation In general photographs should be interpreted from the whole to the part, i.e. broad distinctions defined first. Interpretation should be approached systematically: i) A literature review is a necessary part of any study and as much information as possible should be obtained from these sources; ii) The photograph should be orientated. This may be possible with the aid of shadows. Many air photographs are taken near mid-day for optimum light conditions resulting in the shadows pointing between north-east and north-west in the northern temperate latitudes; iii) A pattern or shape should be selected on the photograph which will be easily identified on the line map, e.g., coastline. An apparent match should be confirmed by supporting evidence; iv) Photographic "keys" or file photos of significant features are extremely useful as aids to current investigation and as "memory joggers" in complex situations. 8.7.2 Stereoscopes and stereoscopic vision Aerial photographs convey only a weak impression of relief unless a stereoscope is used to produce a three-dimensional image. The three-dimensional impression which is obtained in normal vision is due to the fact that with two eyes set about 6 cms apart, each eye is able to present to the brain a slightly different perspective of the object that is being observed. From the differences in perspective between these two images, the brain is able to assess depth and build up a three-dimensional picture. This is the basic principle involved in the use of two adjacent aerial photographs with considerable overlap (a stereo pair) and a stereoscope to produce a three-dimensional image. There are a number of types of stereoscopes, including: i) Pocket stereoscope (Figure 8.10); ii) Mirror stereoscope (Figure 8.11): This type uses pairs of parallel mirrors to "spread" the line of sight, thus increasing the three-dimensional area under view at one time. Detachable binoculars give greater magnification; Figure 8.10 Pocket stereoscope. (After G.C. Dickinson, 1969) Figure 8.11 Mirror stereoscope. (After G.C. Dickinson, 1969) iii) Twin stereoscope: This modified mirror stereoscope enables two interpreters to view the same photograph simultaneously, a considerable advantage. 8.8 Orthophotographs The perspective image of a photograph can be changed to an orthogonal projection with the aid of an orthophotoscope which removes scale distortion caused by height variation. All points are thus in their correct relative locations, scale is constant and angles are true. The most common method of producing an orthophotograph is as follows: the projection of a three-dimensional stereoscopic image produced by a stereoscopic plotter is exposed to photographic film through a very small opening moved across the stereoscopic model. As the tiny aperture moves along a narrow strip, the film remains stationary in its horizontal position but is moved in the vertical dimension to keep the aperture "in contact with the surface" of the three-dimensional image. After the aperture has moved across the model once, it is moved sideways a distance equal to the width of the opening, and the operation is repeated. More recent instruments electronically scan photographs and after correction by a computer, display the image on a video terminal. Because of the great amount of detail on photographs, orthophotographs can be more useful than a topographic line map for compilation in the field. 8.9 Mosaics Photographs can be assembled into mosaics, which can then be overprinted with selected thematic information to produce photo maps. Since a photo is a perspective view (projection), objects may not appear in their true horizontal position; this tendency is accentuated the further the object is from the photographic centre. Therefore, only the central parts of photographs usually are used in mosaics to reduce the amount of error due to relief displacement. The central areas are carefully trimmed along line features so that joints between components of the mosaic can be easily camouflaged upon assembly. Orthophotos can also be assembled to form a mosaic, which can be overprinted with thematic information to produce an orthophoto map. The orthophoto map has the advantage of accurate scale, in contrast with photo maps prepared from mosaics of conventional photographs, which suffer from displacement, hence scale discrepancies. Mosaics are of three types, according to the extent of geometric control: i) Uncontrolled: the sections of photographs are laid in place by matching the images; ii) Semi-controlled: mosaics constructed with limited ground control are semi-controlled mosaics. With the aid of a rectifying projector, line features such as rivers are "stretched" or "shortened" for best fit to an existing map; iii) Controlled: prior to photography, precise horizontal locations are marked on the ground and plotted on an existing accurate base map (thereby providing control). The photographs are then positioned so that the photo images of the control points coincide with the plotted control points on the base map. Ratioed and rectified prints are used to correct for perspective displacement of features. 8.10 Types of Aerial Photographic Film There are numerous types of aerial photographic film available. The following is a partial list of films and some of their uses and advantages: i) Colour transparency film, used for depth penetration, location of subsurface features, etc.: - less expensive than colour negative film which requires the production of paper prints; - good resolution (detail); - excellent visual presentation aid; ii) Colour negative film, used for land typing, etc. The colour prints produced from this film are: - easy to use in stereoscope; - excellent text illustration; iii) Colour infrared film, used for shoreline classification, vegetation analysis etc.: - excellent for comparison with normal colour films; iv) Colour video film, used for depth penetration, etc.: - quick turnaround and relatively cheap; - suitable for monitoring dynamic parameters; v) Black and white film, used for land typing, etc. The black and white prints made from this film are: - less expensive than colour prints; - useful for general coastal studies; - easy to reproduce; - make excellent base maps.