Airborne Platforms and Sensors

Development of aerial photography
The airborne platforms
The types of aerial photographs
Cameras, films, and filters
Photogrammetry
Acquisition of aerial photographs

Current remote sensing systems
- Classified by technology
  - Active remote sensing
  - Passive remote sensing
- Classified by platforms
  - Airborne systems
  - Spaceborne systems
- Classified by sensors
  - Photographic remote sensing
  - Digital remote sensing

Types of platforms and sensors

<table>
<thead>
<tr>
<th>Platforms</th>
<th>Airborne</th>
<th>Spaceborne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Digital</td>
<td>Airborne radar</td>
<td>Satellite radar</td>
</tr>
<tr>
<td>Photographic</td>
<td>Aerial photography</td>
<td>space mission photography</td>
</tr>
<tr>
<td>Passive Digital</td>
<td>Airborne scanner</td>
<td>Satellite imagery</td>
</tr>
</tbody>
</table>
Development of aerial photography

- The photographic camera is the oldest and the most frequently used remote sensing instrument.
- 1909: Wright and a Pathé news cameraperson took motion pictures of Centotelli, Italy.

1860 picture of Boston Harbour

This 1860 picture of Boston Harbour is thought to be the first aerial photograph taken in the US. The exposure was made from a balloon at an altitude of about 365m above the ground.

Old air-borne platforms

Above: Stalwart pigeon photographers prepare to work. The tiny pigeon cameras were designed in 1903 and weighed about 70g. Right: Peering down a camera viewfinder from the open cockpit of a Curtiss Jenny, a flyer practices the early techniques of aerial photography. (Courtesy Strain and Engle, 1992)

Airphoto – Hong Kong 1945
Airborne platforms

- High-altitude platforms: high-altitude balloons, U-2 reconnaissance aircraft, etc.
- Mid-altitude platforms: normal aircraft
- Low-altitude platforms: light aircraft, remotely piloted aircraft (RPA)

- Perspective views
- Mission-based data acquisition

Remote sensing aircraft

- Mid-altitude remote sensing aircraft.

High-altitude airborne platforms

- Left: high-altitude balloon that can reach the top edge of the atmosphere; Above: U-2 military spy aircraft that flies near 30,000 meters.

Low-altitude platforms

- Left: a remotely piloted aircraft (RPA) flying at a very slow speed and low altitude of 30 meters.
- Right: a light two-seater aircraft that is capable of flying at a slow speed and low altitude of 100 meters.
Types of aerial photographs

Depending upon the orientation of the camera’s optical axis with respect to the earth’s surface, airphotos are classified as:

- Vertical airphotos
- Oblique airphotos
  - High-oblique
  - Low-oblique

Orientation of an aerial camera

Orientation of an aerial camera for vertical, low-oblique, and high-oblique photography. Also shown is the shape and relative size of the ground area associated with each type of photograph.

Vertical airphoto

Vertical airphoto of Maipo wetland of Hong Kong and adjacent Shenzhen urban built-up area (1997)

High-oblique airphoto

High-oblique airphoto (horizon included) of Yuen Long and rural area of Hong Kong, by Lands Department of HKSAR (1999).
Low-oblique airphoto

Low-oblique airphoto (horizon not shown) of Aberdeen, Hong Kong (1999).

The framing camera

- Camera body
  - lens - focal plane and focal length
  - shutter - control exposure speed
  - diaphragm - control apertures
- Film exposure
  - film exposure - the quantity of light that is allowed to reach the film
  - F/number = f / d (progressed by √2, ~1.4)
  - Lens speed: light-gathering power of a lens = the F/number of the full aperture.

Camera lens

A classical Carl Zeiss camera lens with 180mm focal length, note marks of diaphragm and focus range.

Multispectral camera

A nine-lens multispectral camera.
Angular field of view (AFOV)

\[
\theta_l = 2 \arctan \left( \frac{L}{2f} \right) \quad \theta_w = 2 \arctan \left( \frac{W}{2f} \right) \quad \theta_h = 2 \arctan \left( \frac{\sqrt{L^2 + W^2}}{2f} \right)
\]

Classification of Lens Angles

<table>
<thead>
<tr>
<th>Range of Angles</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 60°</td>
<td>Narrow angle</td>
</tr>
<tr>
<td>60 - 75°</td>
<td>Normal angle</td>
</tr>
<tr>
<td>75 - 100°</td>
<td>Wide angle</td>
</tr>
<tr>
<td>&gt; 100°</td>
<td>Super-wide angle</td>
</tr>
</tbody>
</table>

Ground distance

\[
D_l = 2 \left( H \tan \frac{\theta_l}{2} \right) \\
D_w = 2 \left( H \tan \frac{\theta_w}{2} \right)
\]

Films and filters

- Black and white films
  - panchromatic or infrared
- Colour films
  - natural colour and colour infrared
A mapping camera

Aerial survey cameras

Aerial survey cameras and other equipment mounted inside an airplane.

Black-and-white film

Generalised diagram of a black-and-white film

Spectral-sensitivity curves for panchromatic, extended-red panchromatic, and infrared films

Panchromatic aerial photograph

A panchromatic aerial photograph of Tweed region, North NSW, Australia
A black-and-white infrared photo

Source: Ross Alford (www.pibweb.com/ross)

Normal colour and colour infrared films

Normal colour film. A haze filter is placed over the camera lens to stop ultraviolet radiation from reaching the blue-sensitive layer.

Colour infrared film. A yellow filter must be used to stop ultraviolet and blue radiation from reaching the three emulsion layers.

Colour formation with a colour-reversal film

A. Original scene reflectance

B. Film after camera exposure

Blue-sensitive layer

Yellow-sensitive layer

Red-sensitive layer

Green-sensitive layer

C. Film after processing

White layer

Magenta layer

Blue layer

Cyan layer

D. Resulting colours

Normal colour aerial photograph

A high-resolution (20cm) normal colour aerial photograph of a residential area in Berlin.

(Courtesy GeoContent GmbH; www.geocontent.de)
False-colour formation with a colour infrared-reversal film

A. Original scene reflectance
- Blue
- Green
- Red
- Infrared

B. Film after camera exposure
- Activated

C. Film after processing
- Cyan dye layer
- Yellow dye layer
- Magenta dye layer

D. Resulting colours
- Black
- Blue
- Green
- Red

Colour infrared aerial photograph

A high-resolution (20cm) colour infrared aerial photograph of a residential area in Berlin.
(Courtesy GeoContent GmbH: www.geocontent.de)

Using aerial photographs

- Marginal information of an aerial photograph:
  - Obvious: name of the place, date of photograph, flight height, photo index, and producer
  - Not-so-obvious: focal length of the camera lens, time of the photograph, position of the principal point of the photo

Marginal information

- Focal length of the camera lens
- Clock to show time of the photograph
- Notch to find principal point
- Name of the place, date of photograph, flight height, photo index, and producer
Example of paired photographs that produce a 3-dimensional image when viewed through a stereoscope.

3-dimensional photography (cont.)

3-dimensional photograph that was produced from a photograph pair that is coloured as cyan for the left photo and red for the right photo. The 3-dimensional vision can be viewed using a coloured spectacles with cyan on the left and red on the right.

Flight mission for stereo coverage

Aerial camera stations are spaced to provide for about a 60% forward overlap of aerial photographs along each flight line and a 20-30% sidelap for adjacent lines.
Stereoscopes

Desktop (left) and pocket (top) stereoscopes for stereo view of aerial photographs.

Photogrammetry

- Photogrammetry: the technique of obtaining reliable measurements of objects from their photographic images.
- Determination of scale ($RF$: representative fraction)
  - from focal length and altitude
  - from photo-map distance
  - from photo-ground distance

$$RF = \frac{f}{H}$$

$$RF = \frac{PD}{(MD)(MS)}$$

$$RF = \frac{PD}{GD}$$

Geometry of a vertical airphoto

$$f = \frac{DE}{AB}$$

$$\angle ACB = \angle DCE$$

Understanding distortion

- Perspective view
  - Systematic distortion controlled by the field of view that is determined by
    - focal length of the camera lens
    - size of the film media (e.g., 9 x 9 inches)
  - Random distortion specified as crab and tilt of aerial photographs
Factors to be considered

Using stereoscopic parallax
- \( d = \) object length from base to top
- \( r = \) radial distance from nadir to top
- \( H = \) flying height
- \( P = \) absolute stereoscopic parallax at the base
- \( dP = \) differential parallax
- \( \alpha = \) sun’s elevation angle
- \( s = \) shadow length

Computing heights

\[ h = \frac{d}{r} \]

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

\[ h = s \tan \alpha \]
Computing heights using shadow length

\[ \text{Height} = \text{shadow} \times \tan \alpha \]

Acquisition of aerial photographs

- Flight altitudes and focal lengths
- Seasonal consideration
- Time-of-day considerations
- Availability of existing photography
  - In Hong Kong, the territory has been covered at least once a year since late 1980’s.
  - Since 1993, the coverage has been made in natural colour photographs.
  - The airphotos can be purchased from the land department.

Seasonal consideration

Summer (leaf on) and winter (leaf off) airphotos for the same ground area in western Pennsylvania.

Hotspot

Hotspot problem often occurs with high sun angle for vertical photos, so that summer mid-day flight mission should be avoided.
Effects of 8 different illumination angles

70°  60°  50°  40°
30°  20°  10°  0°