GIS Vision
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Create Accurate Orthophotos with Softcopy Photogrammetry

Continued ...

The 4 Coordinate Systems

The photogrammetric solution incorporates the camera/sensor, the film or digital imagery, and the ground into a series of mathematical equations. These polynomial functions solve for the x,y,z coordinates of the exposure station (the aircraft when the camera is triggered essentially) and the rotation angles of the camera (aircraft pitch, roll and yaw) around the line perpendicular to the image plane. The pixel coordinate system, image coordinate system, image space coordinate system, and the ground coordinate system are the four ways to mathematically define the photogrammetric solution mentioned earlier. The raw image file, comprised of digital data organized in columns and rows, often with a numbering system starting in the upper left corner, is the basis of the pixel coordinate system. The image coordinate system defines the image plane in the camera or sensor and is used to locate the principal point and fiducials of the camera if they exist. Measurements are in microns or millimeters. The image space coordinate system incorporates the focal length of the camera into the image coordinate system by adding a z dimension. Finally, the ground coordinate system are the X,Y, and Z map units of the projection you are using. Z can be in mean sea level elevations or in ellipsoid heights, depending on the vertical reference system.

Interior Orientation

In softcopy photogrammetry, measurement of the fiducial marks on a standard metric camera frame is accomplished by a semi-automated process of picking the center of the cross hairs and assigning pixel coordinates to these fiducials, which have known physical locations inside of the camera. Converting the image pixel coordinate system to the image space coordinate system is done mathematically by combining information about the following:

- focal length,
- the principal point (the intersection of the fiducials by rays drawn with a grease pencil in the old days),
- the location of the fiducials,
- lens distortion parameters.

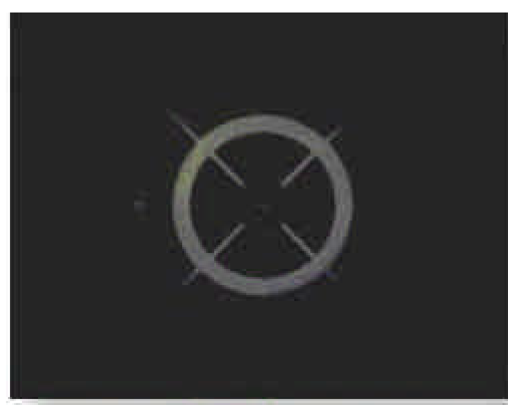

Figure 2.
Metric camera fiducial. The dot in the center has precisely known image pixel coordinates.

The 6 Unknowns

The exterior orientation of an image or aerial photograph can be described with 6 parameters that describe the location of the camera at the time of exposure and the rotation of the sensor around the perspective sensor. The perspective center of the image plane is calculated in the ground coordinate system (UTM. Geographic, etc.) and the rotations are defined as 3 angles. There are several ways to calculate these 6 unknowns:

- Collection of ground control points to mathematically calculate the location and angles.
- Airborne GPS can calculate the perspective center very accurately.
- Inertial measurement units(IMU) can calculate the angles of rotation around the perspective center.
- Any combination of these methods can be used to calculate the 6 unknown exposure station parameters.

When preparing RFP's for photogrammetry projects, it is advantageous to select a vendor that has an aircraft equipped with airborne GPS and an IMU, however, most companies charge a premium for these services. Theoretically it is possible to eliminate the use of ground control points when the exterior orientations of the images are known. This may be advantageous where collecting ground control is difficult, dangerous, or impossible. If only the perspective center coordinates are known, then ground control may only be necessary at the corners of the image block or at the ends of the flightlines. Collecting ground control points may be the most costly aspect of photogrammetry projects, so minimizing their use, up to a point, is advantageous.

The Camera Calibration

Figure 3.
Camera serial number, manufacturer and focal length in mm (153.28mm) from a metric frame.

All metric aerial cameras should have a current (within the last two years) camera calibration report provided by the aerial photography company. If the company cannot or will not provide this information, find another vendor. Many aerial photo archives (USDA, SCS, USGS NHAP and NAPP http://mac.usgs.gov/mac/tsb/osl/calreports.html) can provide camera calibration reports for their historical imagery. The USGS here in the United States is responsible for providing camera calibration through its aerial camera laboratory. In Europe, camera manufacturers provide this service. Recent debate about this topic can be found at www.asprs.org/asprs/news/archive/final_report.html. The essential information that you will need from the camera calibration report is the following:

- focal length in mm
- location of the principal point in either mm or microns
- the location of the fiducials in mm or microns
- the radial lens distortion coefficients

Most software packages have camera templates for the standard aerial metric cameras that can be modified with this information. It is important to note that minor differences exist from camera to camera, so be sure to verify the serial number of the camera you are using (usually superimposed on the film emulsion) against the camera calibration report.

Aerial Metric Frame Cameras vs Digital

Recently, several companies have developed digital metric cameras that have camera calibrations, but use CCD arrays instead of film. The advantages of these systems are rapid turn-around times and lower costs because there is no film to be processed or scanned. For very high resolution imagery (2" to 6" pixels) it may still be necessary to use traditional film systems. Digital sensors can operate in lower light conditions because the gain on the CCD array can be adjusted to capture images in cloudy or reduced lighting conditions. Additionally, some of these cameras can capture reflectance in the infrared range of the spectrum making them useful for vegetation studies. These cameras may or may not have fiducials depending on the type of camera used, therefore it is important to verify that your software will work with these images.