CHAPTER 14

Orthophotography

14.1 GENERAL

Today, many uses for geospatial mapping products require current planimetric feature data. Analysis and design from geospatial data sets generally require a known positional accuracy of features. The collection and updating of planimetric features in a data set can be costly. Many end users are also not accustomed to viewing and analyzing vector-based mapping data sets. They prefer to view planimetric features as a photo image. As an example, the Arch National Monument in St. Louis, MO would simply be drawn as a long, narrow strip vector shape parallel to the Mississippi River on a vector map. An orthophoto map would show the arch as an easily identifiable unique image feature.

The cost to collect and update planimetric features can be significant. Costs can sometimes be minimized by the production of a photo-based digital map set that is spatially accurate throughout. Many GIS data sets make use of photo-based image data for these purposes.

The Internet offers orthophotograph tutorials which may aid managers interested in the basic study of the subject. Those interested can refer to the following web sites:

- One which comments on principles, project design, issues, utility, accuracy, and economics can be found at http://www.gisqatar.org.qa/conf97/links/h1.html.
- The other — dealing with aerial photography, scales, relief displacement, digital orthophoto generation, accuracy, and image quality — can be found at http://pasture.ecn.purdue.edu/~aggrass/esri95/to150/p124.html.

14.2 ORTHOPHOTOS

Orthophotographs are photographic images constructed from vertical or near-vertical aerial photographs. The processes used to generate orthophotos remove the effects of terrain relief displacement and tilt of the aircraft. When properly generated, these digital images have a predictable constant positional accuracy throughout the entire image (see Figure 14.1).

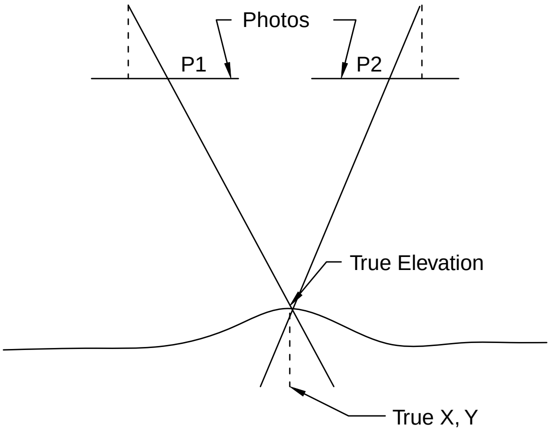

Figure 14.1 The effects of relief and how it is corrected for orthophotos.

A digital orthophoto image is a raw digital aerial photo image rectified to a suitable DEM of the same area. Software merges the digital image with the DEM and aligns the image orthogonally.

Currently, scanning technology and software allow end users to generate products that may appear as orthorectified images at very little cost. However, the techniques used to generate many of these products will not produce a positionally accurate digital image. The employment of such products may be justified for some projects, but should never be confused with or considered as a digital orthophoto. Nondigital orthophoto products are generally considered to be digital image enlargements or semi-rectified digital images.

14.3 DIGITAL ORTHOPHOTO IMAGE PRODUCTION

Figure 14.2 illustrates a flow diagram of orthophoto production.

14.3.1 General

Many end users of digital orthophotos today have very robust hardware and sophisticated software to view and manipulate orthophoto images. They require the ability to view selected image features and perform analysis such as relative distance, area, or even change analysis. In order to meet these demands, proper design of an orthophoto is imperative. Design should consider the following factors:

1. Expected uses of the orthophotos and smallest features to be viewed and studied
2. Accuracy requirements (relative and feature)
3. Anticipated equipment with which the orthophotos will be viewed
4. The equipment, data, and processes used to generate the orthophotos

The end user and project manager should consider and be prepared to relay the information in Items 1, 2, and 3 to the photogrammetry technician. The photogrammetry

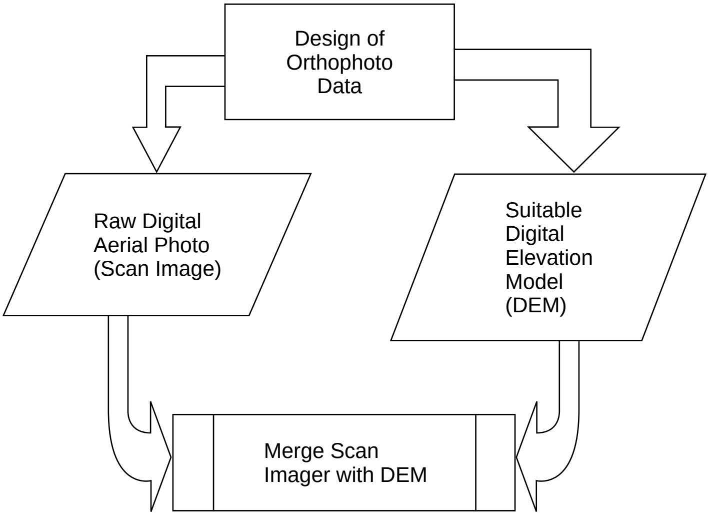

Figure 14.2 Flow diagram of orthophoto production.

technician should then design the orthophoto data collection and production around the equipment and processes necessary to meet these requirements (Item 4).

14.3.2 Design Parameters

Design parameters for an orthophoto are generally tied to the expected final accuracy. Suitable imagery and ground control are the basic elemental data that determines the final orthophoto reliability which involves both the accuracy of distances and areas within the orthophoto as well as the relative accuracy of features with respect to their true location on the earth. Distance and area accuracy are based on the pixel size. Relative feature precision is based on the accuracy of the DEM used in the rectification process. The relative accuracy cannot be more precise than the reliability of the DEM.

14.3.2.1 Imagery and Ground Control

Proper selection of imagery scale and ground control as stated above are critical to the reliability of the final orthophoto. Imagery either can be from existing sources (aerial photography or satellite/airborne imagery) or can be obtained specifically for the project. The key is the suitability of the imagery to meet the intended uses of the orthophotos. Some items to consider are as follows:

- Scale of the imagery
- Type of imagery required (i.e., black and white, natural color, and color infrared)
- Clarity of the imagery (i.e., cloud cover, vegetation cover, seasonal requirements)
- Timeliness of the imagery
- What is the format of the imagery and how effectively can it be introduced into the orthophoto generation process

Table 14.1 Digital Orthophoto Enlargement Factor from Photo Negative Scale

ASPRS Class	Enlargement
1	4–7 times
2	6–8 times
3	7–10 times

A frequently accepted accuracy standard for photogrammetric mapping and orthophotos is the ASPRS standards that have been discussed in detail in Chapter 8. Imagery design for orthophotos can therefore be tied to the ASPRS Class 1, 2, and 3 horizontal accuracy requirements and an expected ground pixel size (resolution). Generally, the pixel size is based on the scale of the photonegative. For example, if the smallest feature that the end user must be able to see in an orthophoto is a typical sewer manhole (approximately 2 ft in diameter), then the imagery must be of a horizontal scale capable of viewing the feature and the pixel resolution should be approximately 2 ft.

Photogrammetric equipment today allows for suitable orthophotos to be generated from photography at photo negative scales that are smaller than the intended final orthophoto scale. Table 14.1 lists recommended digital orthophoto enlargement factors for photo negative scale.

To illustrate, a final 1:2400 (1 in. = 200 ft) scale orthophoto that requires ASPRS Class 1 horizontal accuracy may be obtained from an aerial photo scale of 1:7200. A 1 in. = 200 ft photograph will be able to adequately produce a 1-ft pixel resolution image. This capability allows for time and cost savings in the production process.

14.3.2.2 Image Scanning

Imagery for digital orthophotos may be converted to a digital image with a specific pixel resolution. Obviously, existing digital imagery that is suitable for an orthophoto image does not require this process. A suitable digital image from original processed analog film may be created with the aid of a high-resolution metric scanner such as that illustrated in Chapter 7, Figure 7.5.

These scanners are capable of scanning processed aerial film at very high resolutions (7 μm) if required. High-resolution scanners also have the capability of scanning black and white, natural color, and color infrared film. The end user must be mindful of the fact that color digital images require three times the data storage space. This fact can affect performance and utility of the final products and should be taken into consideration during the design of an orthophoto project. Each pixel consists of a radiometric value plus an XY coordinate set. Radiometric gray scale of a single picture element may fall between reflectance values 0–255. Zero is no reflectance (black), and 255 is full reflectance (white).

Both quality and economy must be factored into the selection of the pixel size. As discussed earlier in this chapter, proper flight altitude and scan rate must be designed for the orthophoto design horizontal scale. Reducing pixel size greatly increases database magnitude, which affects storage capacity and processing time.

Table 14.2 Recommended Approximate Pixel Sizes for Selected Digital Orthophotograph Map Plot Scales

Final Map Plot Scale	Approximate Ground Pixel Resolution Required to Meet ASPRS Accuracy Standards
1:500	0.0625 m
1 in. = 50ft	0.25 ft
1:1000	0.125 m
1 in. = 100 ft	0.5 ft
1:1500	0.250 m
1:2000	0.375 m
1 in. = 200 ft	1.0 ft
1:2500	0.5 m
1 in. = 400 ft	2.0 ft
1 in. = 500 ft	2.5 ft
1 in. = 1000 ft	5.0 ft

Table 14.3 Digital Orthophoto File Size Based on a Neat Double (7.2 × 6.3 in.) Model for Black and White Uncompressed Images

Scan sample rate	7.5 µm	15 µm	22.5 µm	30 µm
	3386 dpi	1693 dpi	1128 dpi	846 dpi
File size	496 Mb	124 Mb	55 Mb	31 Mb

A single aerial photograph may require as much as 100 megabytes of memory, depending on the pixel resolution. Contrarily, smaller pixels may assure greater accuracy.

After the data are scanned, histograms can be developed with which to adjust radiometric contrast in the formation of a more pleasing overall image tone. Table 14.2 can be of assistance in determining the ground pixel resolution of a standard digital image, and Table 14.3 affirms the expected file size for a black and white digital orthophoto when scanned at various scan sample rates.

14.3.2.3 Ground Control

Ground control is required to rectify (georeference) the imagery to its true geographical position on the earth's surface. Simple rectification (rubber sheeting) is not suitable. Generally, a process known as differential rectification is used. Differential rectification is a phased procedure which uses several XYZ ground control points to georeference an aerial photograph to the earth, thereby creating a truly orthogonal image which can provide accurate measurements throughout its bounds. The exact location and number of ground points required are based upon the scale and accuracy of the final orthophoto as well as the negative scale and number of photo images required to cover the entire project area. Selecting the ground control points is generally not a task for the project manager and should be decided by the photogrammetric technician designing the project based upon his/her experience and equipment.

14.3.2.4 Digital Elevation Model

A suitable DEM must be obtained to provide a vertical datum for an orthophoto. Some projects may allow inclusion of a DEM for the project area that was developed from other imagery. This may be the case when the ground in the project area has not changed significantly between the time the imagery was collected for the DEM and the new orthophoto imagery collection date. However, most large-scale orthophoto projects require a DEM to be developed from the new imagery. This will insure and improve the accuracy of the image rectification.

A DEM for orthophoto rectification does not have to be as dense or as detailed as a terrain model for contour generation. Most projects will only require a coarse grid of points along with breaklines to define areas of abrupt change (i.e., edges of roads, streams, etc.). This task is achieved using the same processes described in Chapter 12, "Photogrammetric Map Compilation." Stereopairs (digital or analog), incorporated into an analytical stereoplotter system or softcopy workstation and rectified to the earth, allow the photogrammetric technician to compile a coarse grid of points and breaklines throughout the project area. The density and spacing of the DEM points and breaklines are dependent largely upon the accuracy requirements, the horizontal scale of the final orthophoto, and the character of the land.

The web site http://www.woolpert.com/news/articles/ar072500.html provides an insight to combining LIDAR and photogrammetric mapping. A practice application of a project LIDAR and a digital camera for collecting DEM data and creating orthophotos can be found at http:/www.esti.com/library/userconf/proc00/professional/papers/PAP726/p726.htm.

14.3.2.5 Data Merge and Radiometric Correction

The final phase of the orthophoto process is the merger of the digital image and the DEM along with corrections in pixel intensity throughout the image. Software, used to merge the digital raster image with the DEM, makes adjustments in the horizontal location of pixels based upon their proximity to DEM points. This process removes the errors due to displacement and produces an image that is orthogonally accurate. The final step adjusts the intensity of selected groups of pixels in the orthophoto to ensure that seams between mosaicked images are minimized and/or to bring out features of interest or minimize aberrations. Figure 14.3 illustrates a technician creating an orthophoto image electronically.

14.3.2.6 Tiling and Formatting

The conclusive orthophoto image is finally broken into smaller areas that are more convenient to handle by the end user. This process is generally known as tiling or sheeting. Formatting may also be an important task in preparing an orthophoto for submittal to the end user. The final software format and any compression formats should be considered in the design of the orthophoto. Many large orthophoto projects quite often require data to be submitted in the original resolution (i.e., 1-ft pixel resolution) and also resampled and submitted with a 3-ft pixel resolution for quick

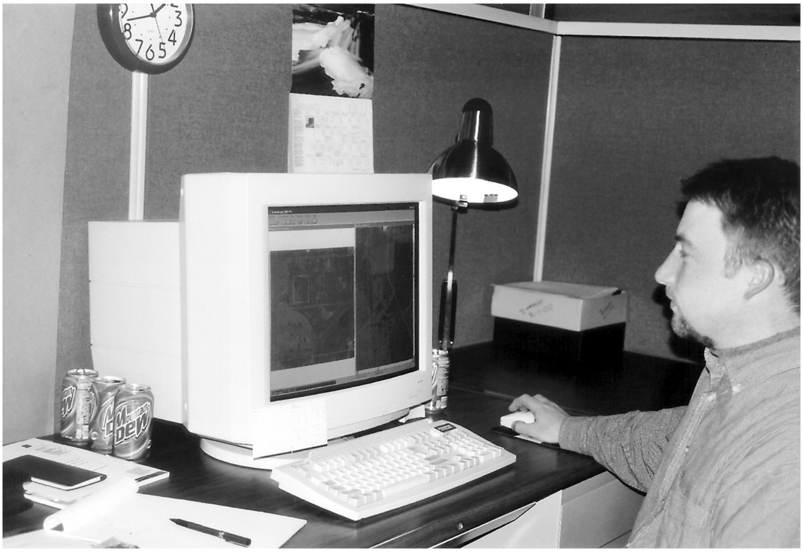

Figure 14.3 A photogrammetric technician creating an orthophoto image electronically. (Photo courtesy of authors at Walker and Associates, Fenton, MO.)

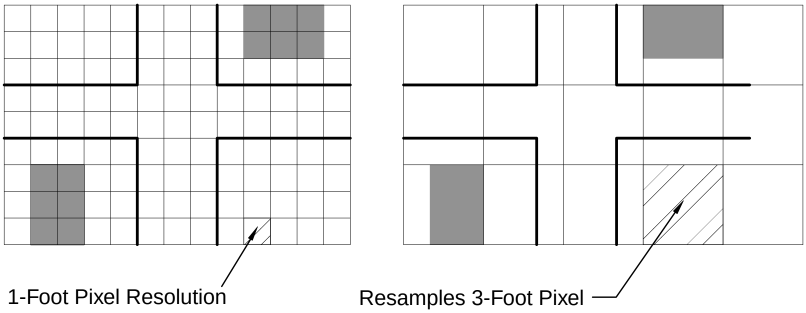

Figure 14.4 An example of an area at 1-ft pixel resolution resampled to 3 ft.

viewing and locating specific areas of concern. Refer to Figure 14.4 for an example of this situation.

14.4 ORTHOPHOTO COST

The cost of orthophoto generation varies widely and is largely dependent upon the scale and accuracy requirements and the availability of source data. Obviously, projects that require the development of new photography and DEM data will be the most labor intensive and costly. However, in many cases suitable orthophotos can be generated from existing imagery and DEM data. The project manager simply needs to ensure that the data will meet the project accuracy and feature needs.

USGS and USACE are two federal agencies that generate both large- and small-scale orthophotos of various parts of the earth. In addition, many federal, state, and local governments collect aerial photography and DEM data that may be used to generate orthophotos. The project manager should investigate these types of sources before investing in new data development when time allows.