

Accuracy Checks in the Production of Orthophotos

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Abstract

Orthophotos have been used extensively in many applications today. In an attempt to map the earth's surface in a shortest possible time and provide information for monitoring and planning, Orthophotos have proved reliable as far as these are concerned. Orthophotos are one of the most important base layers of data for GIS systems. The use of Orthophotos in a GIS often implies seamless image data. The major advantage of Orthophotos is their ability to be produced in a short time to provide up-to-date information for urgent planning. They are also produced at a less expensive production price than line or vector maps.

The need therefore for quick and reliable data for many rising applications has led to the development in this technology and hence finding ways to make it better in terms of its appearance (radiometric enhancements) and geometric accuracy. This paper looks at the creation of an Orthophoto and enumerates the factors that ensure the geometric accuracy of the Orthophoto.

Users of Orthophotos must understand that to make measurements on an Orthophoto, one needs to know the quality of the underlying surface description since this affects the geometric accuracy of the Orthophoto. In this paper the geometric accuracy with which an orthophoto is produced is analysed. Accuracies during the orientation of the input image and scanning resolution of the scanned image and accuracy at DTMs stage are considered in this paper.

Keywords: Orthophoto, geometric accuracy, orientation and DTM.

1. Introduction

The advancement in technology and the need for quick and reliable maps in real time for planning and mapping purposes has led to finding a way to produce such data. Whereas maps have been very useful, it falls short of the fact that the real picture of the ground is not depicted.

Orthophotos are images that have all distortions due to camera obliquity and terrain relief removed.

Many application areas like resource inventory (forestry and agriculture), urban planning, land use mapping and road network updating have desired more than what the line maps can offer. These applications, which benefited from Orthophoto products, derived from these Orthophotos a pictorial view of the earth's surface and a completeness of topographic information. These reasons, coupled with the use of Orthophotos in combination with line maps and as a background layer in GIS techniques have made Orthophotos to be much favoured lately.

Unlike vector map products, which are basically an interpretation of what someone else thinks you want to know, a digital Orthophoto is flexible and allows map information to be shared more easily. For example, if a line map is made for a public works department and shows roads, sewer and water lines, it may not be useful for the parks department, which is interested in trees and flower beds. On the other hand, the digital Orthophoto contains everything that was on the original photograph.

One major advantage of Orthophotos are, that it can be produced in a short time and provides up-to-date information, which can be applied for urgent planning purposes whereas vector (line) maps will have to be produced in a longer time. Orthophotos are also less expensive to produce than line maps.

Because Orthophotos are images that have all distortions due to camera obliquity and terrain relief removed direct measurements on them can be made just like on line maps.

Due to this reason one has to take into consideration the factors that affect the accuracy of the production of Orthophotos. DTMs, orientation of the input image and scanning resolution of the scanned image are but a few areas to consider in its production.

One has to therefore consider the overall accuracy of these factors before measurements for particular applications are made. If accuracy of measurements is not an important factor like in finding out the approximate position of objects for urban planning, then there is no need to consider how very accurate the positions of the features are with respect to their true positions on the ground.

Some other applications require however that the features positions are accurate to centimetre level. In such cases a very precise data set like the DTM used and orientation must be very accurate.

Orthophotos are becoming more popular over the years, and many large-scale mapping projects have used this technology in place of or in addition to traditional vector (line) mapping. Orthophotos combine the image characteristics of a photograph with the geometric qualities of a map.

This paper therefore addresses the following:

- Production of an Orthophoto from aerial Photographs.

- Analysis of the factors that affects the accuracy of the Orthophoto : Accuracy of DTM, Orientation ,scanning resolution of images used , the right scale of the produced orthophoto and the limiting pixel size of the final orthophoto.

2. Materials and Methods

Materials and software used include : Aerial photos ,Socet Set application software, Microstation, Digital Photogrammetric Workstation, including the following components -two display monitors one for stereo viewing and the other for a general display and 3D Mouse (trackball) for the control of the floating mark and height control, ArcView 3.1 and Erdas Imagine.

To begin with, a preparation stage was gone through where all the available data of the project area is collected and assessed. Information about the scanned image is first collected, example the scanning resolution and the scale of the photograph. The camera calibration is collected and checked. This includes information about the fiducial coordinates, distortion parameters and the focal length of the camera. Control point information is also got, along with sketches and descriptions of these points. Using the above information, the image was imported and subsequent orientations done (inner, relative and absolute). After this an automatic DTM of the area is created and Interactive terrain editing tools used to edit the DTM. A check of the accuracy of the DTM was done using a coarser resolution DTM, control points and some point features digitised in Microstation.

2.1 Preparation and Expected Accuracy

This includes the project creation, the importation and characteristics of the input image, the ground control point data and the expected accuracy.

2.1.1 Creation of Project with specifications

The following specifications of the image was defined: Datum - WGS_84 , Units-Meters Vertical reference – Ellipsoid, Minimum ground Elevation -204.000m, Maximum Ground elevation: 290.000m

The input images used were two photographs from a strip with 60% overlap to form a stereo pair . The scale of the photographs is 1:13 000. From the scale and the principal distance from the camera calibration file, the flying height was calculated as follows

$$1/\text{scale} = f(\text{focal length}) / \text{flying height (H)},$$

$$\text{Scale} = 1/\text{scale number} = c(\text{principal distance})/H(\text{flying height above ground}).$$

$$H = C * \text{scalenumber}$$

$$H = 154.006\text{mm} * 13000$$

$$H = 2002078\text{millimeters}$$

$$H = 2002.078\text{meters} \approx 2000\text{m}$$

2.1.2 Calculation of resolution of photographs

The images were scanned with 30 μm pixel size.

Resolution is therefore 33.3 pixels/mm.

The photo scale is 1:13000

$$\text{Ground step is therefore} = 13000 * 0.000030$$

$$\text{Ground step} = 0.39\text{m/pixel}$$



Figure 1. left photograph



Right photograph

2.1.3 Camera Data

The camera information was checked and its content typed in the project for use later on for orientation. The fiducial coordinates, fiducial IDs, distortion parameters and focal length were specified.

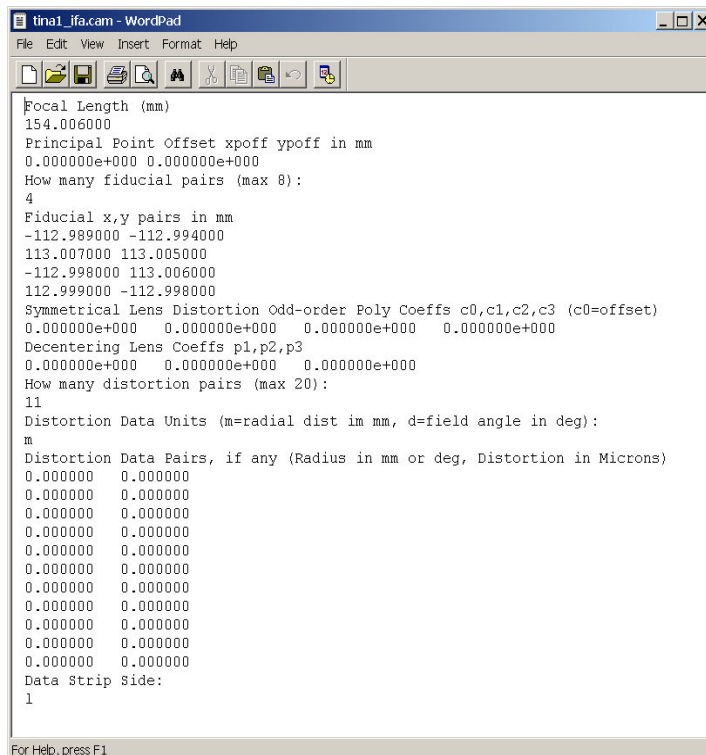


Figure 2. Camera file data

2.1.4 Ground Control Data

There were nine ground control points in total for the model. The description of the location for these points were collected and identified on the digital images.

Table 1. Coordinates of ground control points

Point no	<u>x</u>	<u>y</u>	<u>z</u>
30301	3517.41	1921.06	228.80
30501	5028.66	1898.41	204.11
40301	3581.96	3142.40	285.34
40501	5027.19	3214.01	250.18
20301	3674.94	1050.05	206.36
20501	4906.05	1030.01	279.69
30401	4228.47	2082.75	207.74
40401	4213.01	3182.53	277.56
20401	4182.09	1053.45	240.94

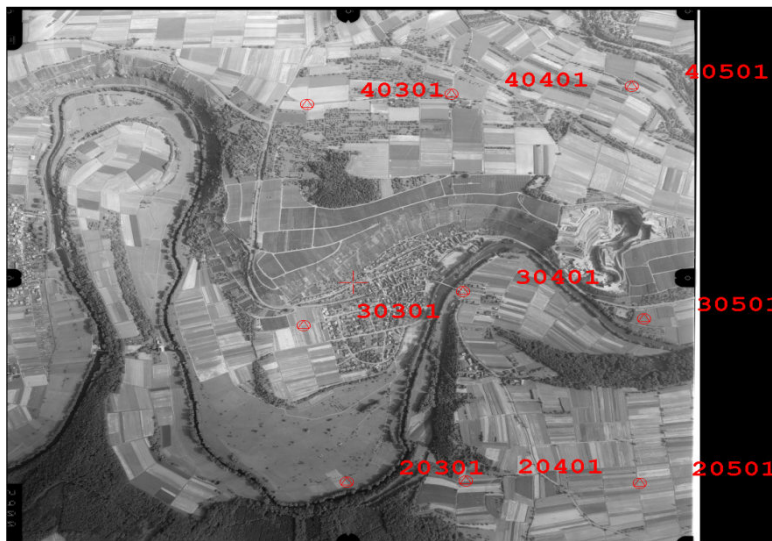


Figure 3. Ground control points locations on photograph

2.2 Orientations

This process uses the imported camera calibration file which indicates the principal point x and y offsets, entering in the fiducial coordinates and the distortion parameters, imported images, and control files. Minifications or overviews are done at this stage which is essential for zooming and for automatic measurements.

2.2.1 Inner Orientation

Interior or inner orientation is the reconstruction of the bundle of rays, which formed the image at the time of exposure and defines the position of the projection center with respect to the image. This is done by transforming the coordinates of the fiducial marks measured in the image to the camera coordinate system.

A 6-parameter affine transformation, which consists of two shifts, two scales and two rotations (that is one each for the x-axis and for the y-axis) was used.

2.2.2 Exterior Orientation

This includes relative and absolute orientation. It involves the orientation of the images with respect to each other (Relative orientation) and the orientation of the model formed with respect to the terrain and finally a bundle adjustment.

Relative orientation is done to allow reconstruction of a geometric model of the terrain. This is done by making corresponding rays intersect (without y_ parallax). Homologous points were measured on the two photos. These are well recognized and well distributed points locatable on both photographs. The points were chosen such that they were widely spread in the overlap area of both photographs. 9 tie/homologous points in all were chosen and their positions are displayed as shown below.

Absolute orientation scales, rotates, translates and levels the stereo model to a ground reference coordinate system.

This ensures that the model is reconstructed to fit the terrain. After inner and relative orientation, the two photographs are oriented correctly with respect to each other and a good representation of the terrain is achieved. However, the coordinates are not terrain coordinates but model coordinates. To convert the model coordinate to terrain coordinates, a 3D similarity transformation was done. The requirement in this case is ground control points and in this paper, 9 full ground control points were used for the stereo model. The coordinates of the ground controls are displayed in Table 1. The specifications for the absolute orientations includes the Ground Point files, the forward overlap, aircraft altitude and mean ground elevation.

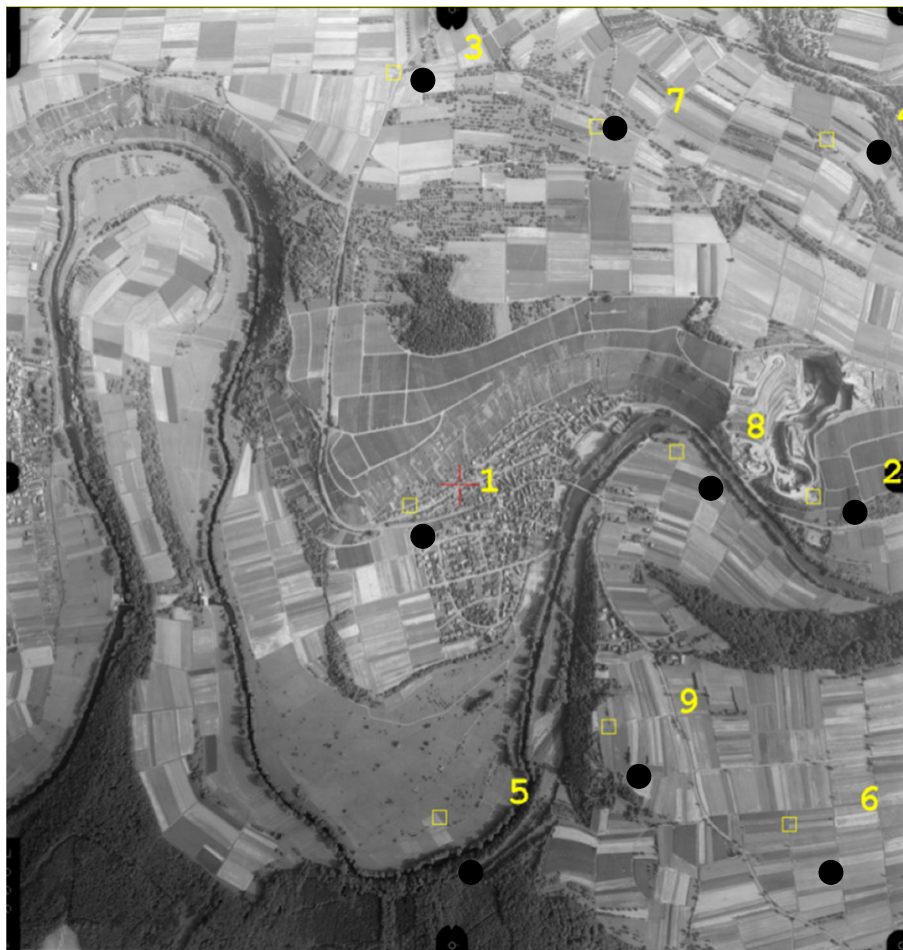


Figure 1. Locations of Tie Points on Photograph

2.3 DTM Generation

DTM (digital terrain model) is a digital representation of terrain relief, describing the geometry of the ground surface. It consists of a set of coordinates and an interpolation algorithm to give a continuous coordinate designation to every point on the ground surface. The coordinates are obtained by sampling the surfaces and measuring points X, Y and Z coordinates. The interpolation algorithm is used to define an uninterrupted surface using the set of coordinates. The generation of DTM was based on stereo matching technology for stereo viewing both the left and right photographs. The main steps are the automatic generation of the DTM and editing of the DTM. The DTM format used was, TIN with no smoothing and a high precision of the DTM was chosen, which takes time to process but gives the most accurate DTM. The DTM boundaries were chosen as the image boundaries. The spacing for the DTM was selected as 5m. The DTM extraction was done in 8 passes, the first pass done with the 128:1 reduced image and the last with 1:1 images. The TIN DTM format was chosen because it allows for the inclusion of break lines and prevents loss of quality of the DTM which in this case is important because of the rough terrain the project area. A small spacing 5m between the reference points was chosen to give a very high precision DTM and hence a good interpretation of the terrain. A TIN DTM does not have a fixed spacing and reference points are not arranged evenly. The creation of a TIN DTM in Socet Set is done in two phases: A Grid DTM is created based on the selected (or specified) spacing and the Grid points are eliminated and triangles formed according to the specified "precision and smoothing".

2.3.1 DTM Editing

An interactive Terrain edit tool was used to interactively review and edit the DTM. This allowed the DTM to be displayed in many forms like, editable contours, dots and mesh for editing. The DTM was displayed in mesh form for editing. Editing out of points falling on buildings and trees was done and breaklines were digitised to enable the presentation of other features like ridges, road edges, mountains, etc.

Mass points were added to areas where more points than created were needed. Points falling on buildings and trees were either moved to a nearby ground surface or deleted. The Z elevations were adjusted for points not lying on the ground making sure the points edited had the measuring mark properly landed on the ground.

2.4 Orthophoto Generation

To generate Orthophoto imagery, a DTM file, an image file and a boundary is selected. An interpolation method is also selected for the resampling of the pixels into the Orthophoto.

Additional options include eliminating buildings, embedding grid lines within the Orthophoto, minifications and a choice of an interpolation method. A ground sample distance of 0.5 was chosen which is equivalent to 100 μm specified. This value should not be smaller than the ground sample distance of the input images, which is 0.4m. This is because a ground sample smaller than the Input ground sample distance is not going change the resolution of the image anyway. The output boundary was selected using the DTM boundary. The Orthophoto will by default use the exact shape and size of the DTM specified. This yields a rectangular Orthophoto that is oriented along lines of north south and east west in the project's coordinate system.

The output format chosen is a Geotiff because this is georeferenced and can be used by other GIS and CAD softwares .

3. Results and Discussion

3.1 General Accuracy Factors

Generally the following accuracy factors are expected for analogue and analytical plotters.

Analogue plotter: RSME < 10 – 15 μm

Analytical plotter: RSME < 3 - 5 μm

For Absolute orientation:

Planimetry: $\sigma_p < 20 \mu\text{m}$ at photo scale

Height: $\sigma_p < 0.02\%$ of flying height

3.2 Expected accuracy of Orthophoto

This is determined mainly by the accuracy of the DTM

Error in height is the same as error in the DTM

3.3 Specifications of the input data and expected accuracy of the Orthophoto.

Input image scale = 1: 13 000

Flying height = 2000 meters above ground.

Height error is specified as 5% to 10% of the flying height

$\sigma_z = \text{DTM error}$

$\sigma_z = (0.2 * 2000)/1000 = 0.401 \text{ m}$

Expected accuracy in height is 0.4m

Maximum error = 3 * σ_z

= 1.2m = DTM error

3.4 Expected Planimetric Error

For objects located farthest from the center of the photograph the error caused by a DTM error will be maximum and can be calculated as follows:

Error in planimetry = (object radial distance/ principal distance)* σ_z

Object radial effect distance = $(92^2 + 92^2)^{0.5} \approx 130\text{mm}$

Maximum error in planimetry = maximum radial distance/ principal distance *(DTM error)

= $130/154.01 * 1.2$

= 1.01m

3.5 Planimetric accuracy for digitised features

If digitisation of images are to be done, further to the creation of the orthophoto , this needs to considered. For scales less than 1:20000, 90% of well-defined points fall within 0.5mm of their true position.

σ = standard deviation

90% = 1.645 σ_z

Therefore 1.645 $\sigma_z = 0.5\text{mm}$

$\sigma_z = 0.5/1.645$

$\sigma_z = 0.30395$

If no systematic errors are present then RMS = σ_z

3.6 Expected scale for Orthophoto

$M_p = C_1 * M_m^{C_2}$

M_p = photo scale

M_m = map scale

$C_1 = 200$

$C_2 = 0.5$

$$M_m^{0.5} = \frac{13000}{200}$$

$$M_m^{0.5} = 65$$

$$M_m = 65^2$$

$$M_m = 4225$$

Scale of Orthophotomap to be produced should therefore not be larger than 1:4225.

In this case 1:5000 was used

3.7 Limiting Pixel Size of final Orthophoto

$$P_{\text{scan}} = (\text{input scale} / \text{Orthophoto scale}) * P_{\text{ortho}}$$

$$P_{\text{ortho}} = (30 \mu\text{m} * 13000) / 5000$$

$$P_{\text{ortho}} = 78 \mu\text{m} \approx 80 \mu\text{m}$$

100 μm is also acceptable in normal cases, thus this was used.

3.8 Accuracy of DTM

The most widely applied method to assess the accuracy of a DTM is to compare elevation computed from the DTM with check values at randomly distributed points and calculate the RMSE. Check points determined from the field surveying (as in control points) or accurately digitized points can be used to assess the accuracy of a DTM. A statistical analysis is then done to assess the accuracy of the DTM.

3.8.1 Accuracy of DTM created

Two DTMs were created, a coarser DTM (10m spacing) and the actual DTM (5m spacing) and the two compared to give a RMSE to measure the accuracy of the DTM.

Secondly some points were digitized in 3D in Microstation (using PRO600 from the Socet set menu) by creating a DGN file. These points were also checked against the DTM to give the accuracy of the DTM. The DTM was also checked against the control points given. The following are results:

DTM checked against control points

Point ID Z Diff

30301 -0.6122

30501 -0.7097

40301 0.1494

40501 -0.2602

20301 -0.0412

30401 0.0702

40401 -0.0635

20401 -0.1272

Average Z diff = 0.1620, RMS = 0.6551, STD = 0.6512

NOTE: Z diff = ground points - DTM

DTM checked against coarse DTM (10m Spacing)

After 36 outlier removal

No of points = 304139, RMS = 0.5284, std = 0.5279, bias = 0.0226

bias = (Z from Master) - (Z interpolated from Slave)

Z master is the actual DTM with 5m spacing and Z slave is coarse DTM with 10m Spacing between points.

Comparison of Check Point File To DTM File (from Microstation)

Number of Points = 165

Average Z diff = -0.0727, RMS = 1.4898, STD = 1.4926

Z diff = digitised 3D points - DTM

3.8.2 Assessment of methods used for checks of DTM

The above RMS gives an indication of the accuracy of the DTM generated.

As has already been ascertained in section 3.3, the Maximum DTM error is 1.2m

The first two checks for the DTM, which is with a coarse DTM and with the control points fell within the accuracy requirement. For the check with the Coarse DTM, the accuracy was an RMS of 0.53 while that of the check against control points was an RMS of 0.66.

For checking of DTM accuracy using 3D digitized points from Micro station, the accuracy was an RMS of 1.4898. This differs from the accepted accuracy by 0.29.

The method of checking a DTM against a coarser resolution DTM does not give an independent accuracy check on the DTM. This method only gives a rough idea about the fact that a coarser DTM produces a less accurate presentation of a terrain.

For a DTM checked against control points, the assessment is really a fair one but the points used here are only nine and these points are at good places where there is no difficulty in the extraction of the Z-values from the software.

The most accurate assessment in this paper is the check using digitized points from Micro station. This result gives a more independent approach to checking for accuracy of the DTM.

4. Conclusion and Recommendation

Orthophotography has been around for years, and many large-scale mapping projects have used this technology in place of or in addition to traditional vector (line) mapping. A digital Orthophoto is a fully corrected image, which means you can use it as a map.

Because direct measurements are made on Orthophotos, the factors that affect its accuracy should be considered in its production. At every stage, the accuracy with which products are made is discussed in this paper. A more detailed analysis of DTM accuracy was done due to the importance of height data in many applications. With this analysis therefore a user of an orthophoto is informed about the accuracy with which he is making measurements, especially with reference to geometric precision and height.

Some recommendations for further research in this area includes, the determination of the overall accuracy with which a feature on an Orthophoto could be measured and coming up with a kind of criteria for making measurements on an Orthophoto. Thus, calculating not at each stage but the total accuracy of an Orthophoto.

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