DIGITAL ORTHOPHOTOGRAPHY AND TERRAIN MODELING

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Abstract

There is a growing interest in utilizing raster format data in civil engineering applications. An essential question is how to use photographs as digital reference data in geographical information systems (GIS) or equivalent applications. This is possible using orthophotographical solutions. Software development has made it possible to use computerized methods in orthorectification process. This paper presents basic concepts of digital orthophotography, which include the properties of a conventional (aerial) photograph, rasterizing and orthorectification. Digital orthorectification utilizes digital terrain modeling techniques, which are discussed briefly. Some practical applications are also discussed.

1. DIGITAL ORTHOPHOTOGRAPHY

Aerial photographs cannot be interpreted directly as vertically viewed maps of landscape. Photos are made by a process referred to as central projection shooting in which all points are projected through one point called the perspective centre (Figure 1). Due to the central projection shooting, objects with different elevations are viewed in different scales. Tilting of the shooting aeroplane creates additional errors into the images. An orthophoto is an image that has been converted to a specified coordinate system and corrected to remove any distortion due to tilt and terrain relief.

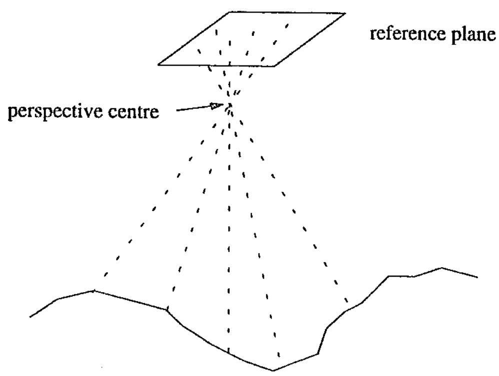

Figure 1. *The principle of central projection shooting.*

The conventional method of converting an aerial photo into an orthophoto is differential rectification via optical-mechanical devices. Development in softcopy photogrammetry allows digital orthorectification of images. Digital processing of ortho images has many advantages. The development in software and hardware technology has made ortho image generation fast and digital images can easily be transferred to GIS-systems.

Aerial photographs provide a wealth of information much of which is under utilized. Recently introduced low-priced software has made it possible to create ortho images with existing workstations. In this study GRASS-software is used to process ortho image with a normal Unix-workstation. The software was developed by USACERL (US Army Construction Engineering Research Laboratory) and is designed to be a modification and maintenance system of GIS-products. The part of orthorectifying software is in the test phase and only a-version is used.

2. CONVERTING AN AERIAL PHOTO TO A DIGITAL ORTHO-PHOTO

Aerial photographs are transferred to digital form by scanning at a specific resolution. Usually, a resolution between 15 and 42 μm is used to scan the photo. Higher resolution improves the quality of the ortho photo product, but file size and processing time of ortho images are increased. The selection of digitizing resolution depends on available scanners and desired output resolution.

The first step in determining the rectification parameters is the transformation from scanner coordinates to the original photo coordinate system. This is done by measuring the fiducial marks in the images that have known calibrated coordinates. Camera position and tilt angles are computed from collinear equations using a set of well-defined ground control points [4].

$$\begin{bmatrix} X - Xo \\ Y - Yo \\ Z - Zo \end{bmatrix} = \frac{1}{f} \times M \begin{bmatrix} x - xo \\ y - yo \\ 1 \end{bmatrix}$$

with:

X_0, Y_0, Z_0 = camera position
M = tilt angle matrix
f = focal length
x_0, y_0 = image perspective centre

The following scheme (Figure 2) illustrates the procedure.

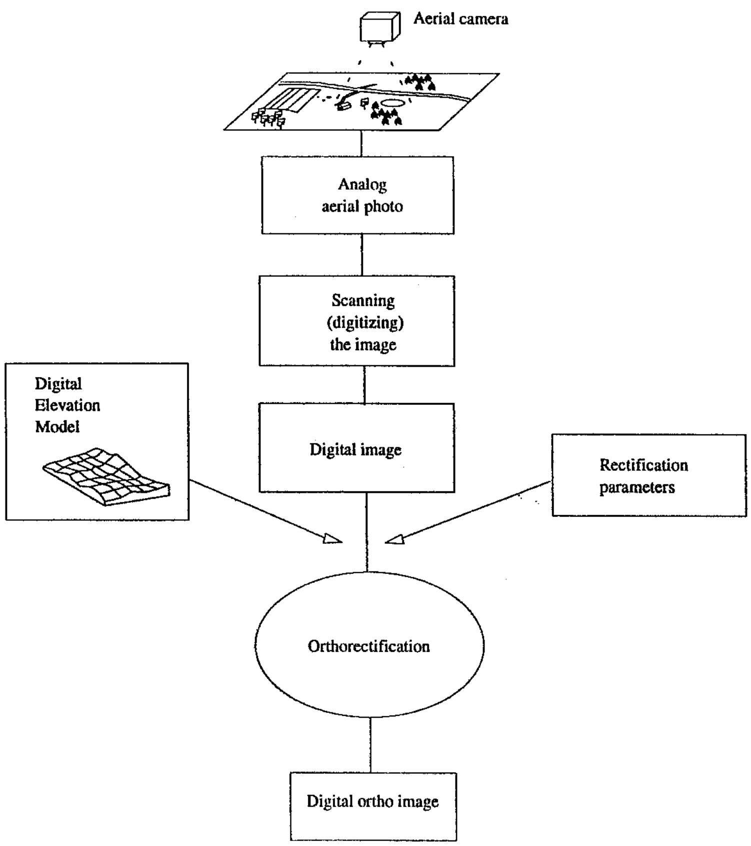

Figure 2. *Orthorectification of a digital image.*

A digital elevation model (often referred to as DEM) is used to correct the terrain relief of images. The quality of ortho images is greatly dependent on the accuracy of DEM. Traditional means to gather the height information are analytical photogrammetry and ground surveying. Also contour information is usable if accuracy permits. Elevation measurements can also be made with an integrated digital video plotter system.

DEM defines the computational terrain elevations in any planimetric position of the surface. The elevations between the points are computed using either linear methods or higher degree models. Triangular irregular network (TIN) is the most accurate, when the source data is randomly sampled (see Figure 3). This model has to be rasterized when used in orthorectification process.

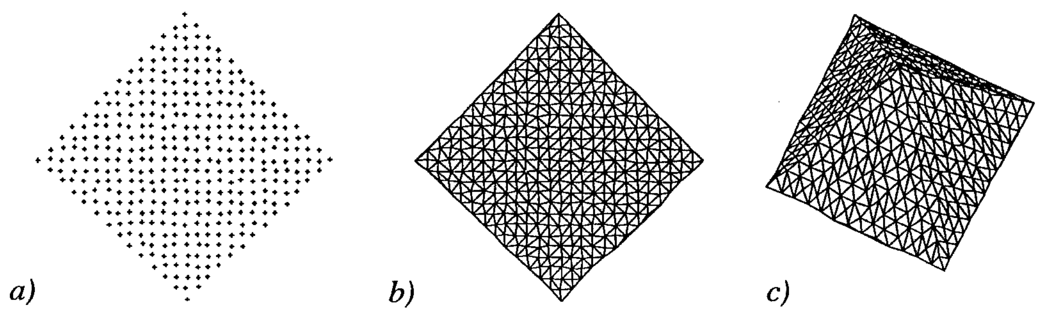

***Figure 3:** A set of random data points modelled with the triangular irregular network (TIN) method. Random data points **a)**, triangulated surface **b)** and a perspective view of the model **c)**.*

Using gridwise DEM solutions it is possible to get appropriate rasterized source data directly. However, a gridded model has some drawbacks. These include accuracy problems with larger grid intervals, difficulties in handling faults, rivers, breaklines and other discontinuities in the surface (see Figure 4). Triangular surface modelling can handle these problems and it requires less computing capacity. This is an important aspect as the number of points increases [5]. The grid approach is a recommendable choice when the original point data is captured as a regular grid [3]. Interlacing the raster DEM data with vector data (such as breaklines) is one possibility to improve accuracy of the height model [2].

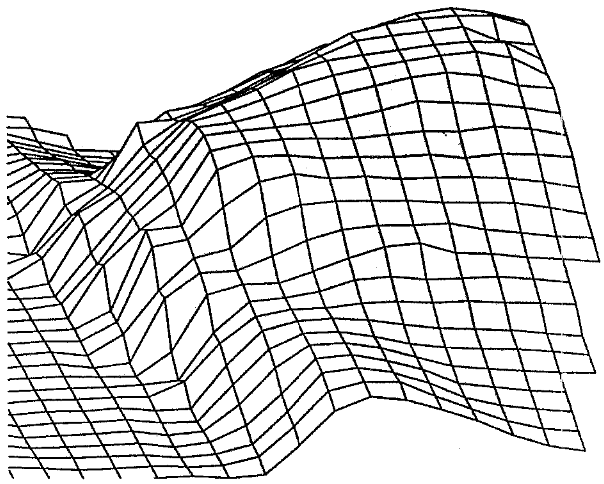

Figure 4: *A gridwise digital elevation model. Linear terrain features are rounded.*

3. PRESENT DAY AND FUTURE USAGE

Digital imagery provides the opportunity of working in an all digital environment. Digital imagery is also easily reusable for various purposes, because it is intelligent and has associated data values. Improving the image analysis makes it possible to extract geometric and attribute information for a growing variety of objects. This will lead towards object oriented solutions, where representation, methods and data will all be object dependent [1].

Automatization of DEM generation and orthorectification process will reduce labour time and cost. This will raise the popularity of softcopy photogrammetric tools. Present applications include, for example, water resource management, civil engineering projects, building site management, cartography and city planning. Future utilizers could be industries that develop facility management utilities, such as city authorities, real estate, banking and insurance companies.

Digital ortho images can easily be utilized in map production in all scales. Cartographic GIS applications such as digital maps using spaceborne and airborne remote sensing techniques will show the way to larger scale municipal engineering GIS. The quality of road design and city planning will be improved with the help of digital orthophoto technology. Large scale applications require more frequent data updating. This may be simpler and faster – and therefore cheaper – to accomplish using digital orthophotos.

***Figure 5:** Map updating: digital ortgo image fith superimposed older vector data from existing database. Orthophoto made with GRASS software (which includes overlay facilities), roof corners from a database of Tampere City.*

***Figure 6:** Rasterized DEM from Pyynikki ridge, Tampere. Produced with GRASS.*

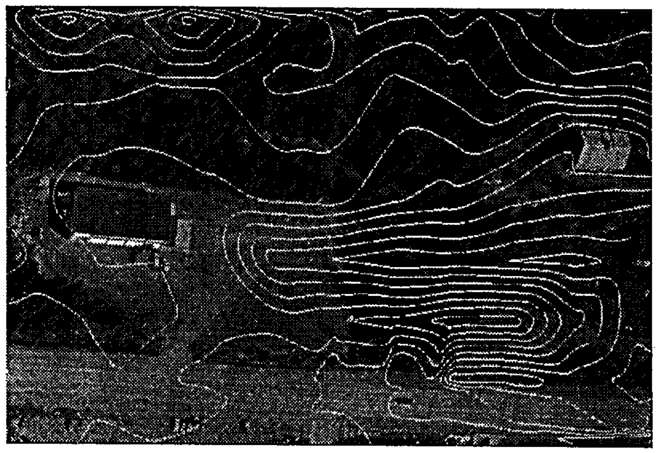

***Figure 7:** Design: vector data with a background ortho image to clarify the situation. Contours are brought to GRASS from a distinct DTM program.*

4. REFERENCES

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