ACQUISITION OF URBAN BUILDING MODELS WITH THE USE OF DIGITAL PHOTOGRAMMETRY, IMAGE PROCESSING AND GIS

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Abstract

The applications in data capture for Geographic Information Systems are increasing with the technological development in stereo photogrammetry.
Evaluations of urban building models which can be used for radio network planning as well as for various types of imission tests are especially important at present.
The creation of urban building models at digital level is a process which includes the generation of **building polygons**, **orthophoto production**, the measurement of a **digital terrain model** and a **digital relief model.**
Up-to-date building models for the eleven largest German cities can be obtained from PHOENICS in the data depth and resolution as described.

Kurzfassung

Mit der technologischen Entwicklung in der Digitalen Stereophotogrammetrie wachsen die Anwendungen in der Datenbeschaffung für Geoinformationssysteme.
Einen besonderen Schwerpunkt bilden derzeit Auswertungen von städtischen Gebäudemodellen, die für Funkausbreitungsmodelle genauso eingesetzt werden wie für Immissionsuntersuchungen unterschiedlicher Art.
Bei der Ableitung eines städtischen Gebäudemodelles auf digitaler Ebene handelt es sich um ein Verfahren, das die Erzeugung von **Gebäudegrundrissen**, die **Orthophotoherstellung**, die Messung eines **Höhenmodelles der Erdoberfläche** und eine **Gebäudehöhenmessung** einschließt.
Für die elf größten Städte Deutschlands können aktuelle Gebäudemodelle in der beschriebenen Datentiefe und Auflösung bei der Firma PHOENICS bezogen werden.

Résumé

L'évolution technologique enregistrée par la Photogrammétrie Stéréoscopique Numérique engendre de nouvelles applications dans la collecte de données pour les systèmes de géoinformation.
L'accent repose tout spécialement à l'heure actuelle sur l'analyse et l'exploitation de maquettes de bâtiments urbains, dont l'utilisation convient au même titre pour les maquettes de diffusion radioélectrique que les analyses des rejets de nuisance en tout genre.
Il s'agit, lors de l'extrapolation d'un modèle de bâtiment urbain à l'échelon numérique, d'un procédé englobant la génération des **projections horizontales du bâtiment, la confection des orthophotos,** la mesure **d'une maquette en hauteur de la surface du globe** et **une mesure de la hauteur des bâtiments.**
Des maquettes de bâtiments ultra récentes caractérisées par des données ayant l'ampleur prescrite et la résolution indiquée sont disponibles à la société PHOENICS pour les onze plus grandes villes d'Allemagne.

1. DIGITAL DATA ACQUISITION

Today photogrammetric data acquisition can no longer be separated from image processing and GIS applications.
Digital photogrammetry is a constituent part of a data acquisition environment which unites several integrated software solutions on various hardware platforms. Systems are used which can communicate with one another directly and without complicated interfaces.

The aim is the formation of a **hybrid working environment**, offering equally high performance both at vector and raster level and making it possible to intelligently combine both data types.
The following hardware and software components are used for the various applications In the evaluation service of PHOENICS GmbH:

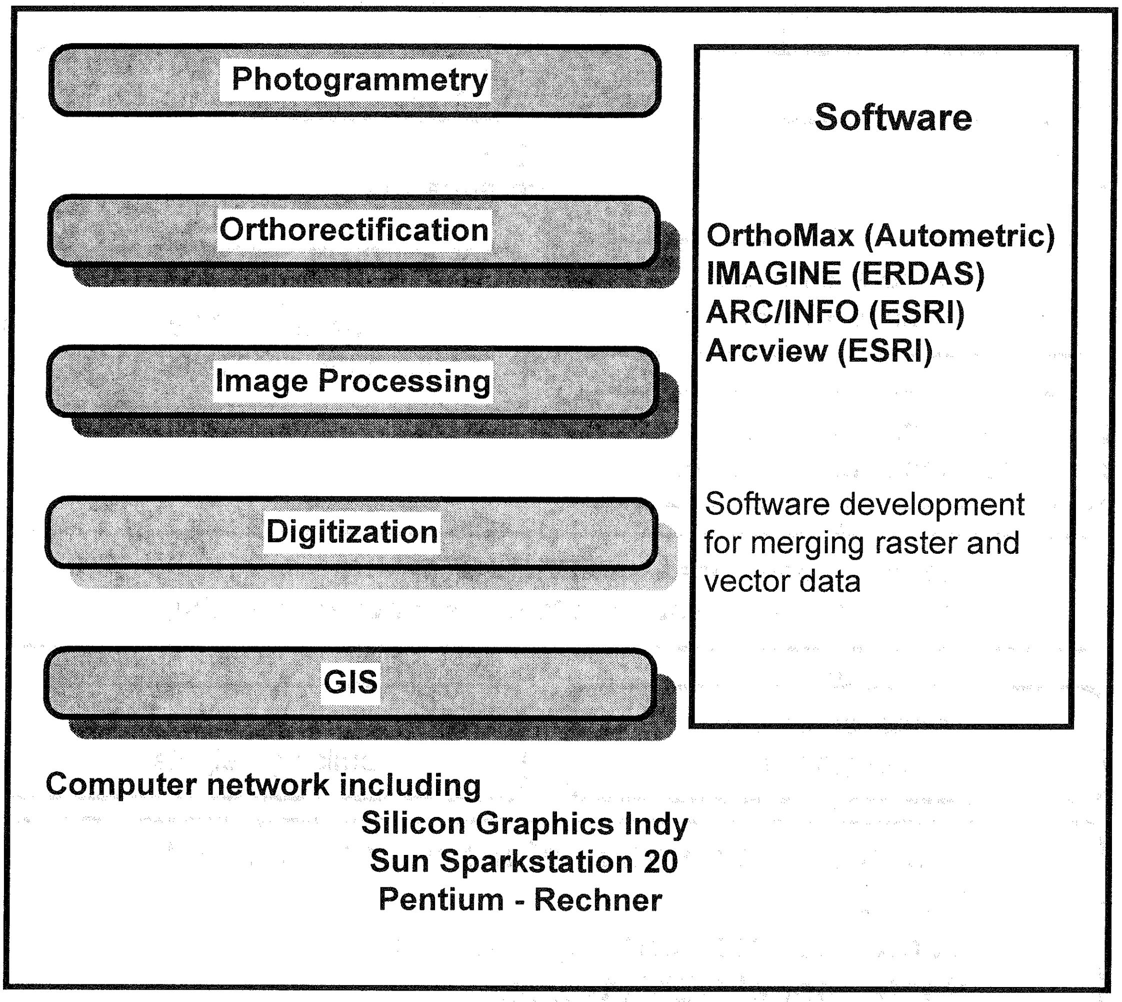

Fig. 1: Hardware and software environment for the processing of aerial photography.

Digital **stereo photogrammetry** has the advantage over analytical photogrammetry that nowadays many processing stages are handled automatically. At present, various companies are developing programs for **fully automated triangulation** of image blocks. The first operational solutions can be expected this year.
A central component of our relief acquisition is a highly developed process of **automatic image matching** for the measurement of three dimensional grids of any density.
Algorithms for the semi-automatic recognition of topographical objects such as roads, buildings and waterways offer an important step towards the **automation of line measurement**. Initially, there will only be isolated solutions for specific objects in this field. In the medium term, however, analytical photogrammetry will be replaced by semi-automatic systems.
Visualisation and control of three-dimensional data components are of central importance to the stereo workstation.
Generation of orthoimages is becoming increasingly important as the costs have decreased markedly by the digital rectification of aerial photographs into map projections. The use of digital orthophotos for updating existing spatial data is evidently spreading. **On screen digitizing** in an orthophoto on a powerful pentium PC under **Arcview** is an inexpensive updating method.
Image processing offers a wide range of possibilities. It is used for image preparation, the classification for the production of thematic maps and for the processing of three dimensional point data in a raster format. Only at this level it is possible and viable to process up to 1 million points per square kilometre to form a relief model.
A **Geographic Information System** for data storage and the analysis of the vector data obtained is indispensable in the field of digital data acquisition.

2. BUILDING MODEL ACQUISITION

A decisive difference between analytical and digital building registration is the separation of building borderline measurement and height detection .
The complete process can be sketched as shown in figure 2.

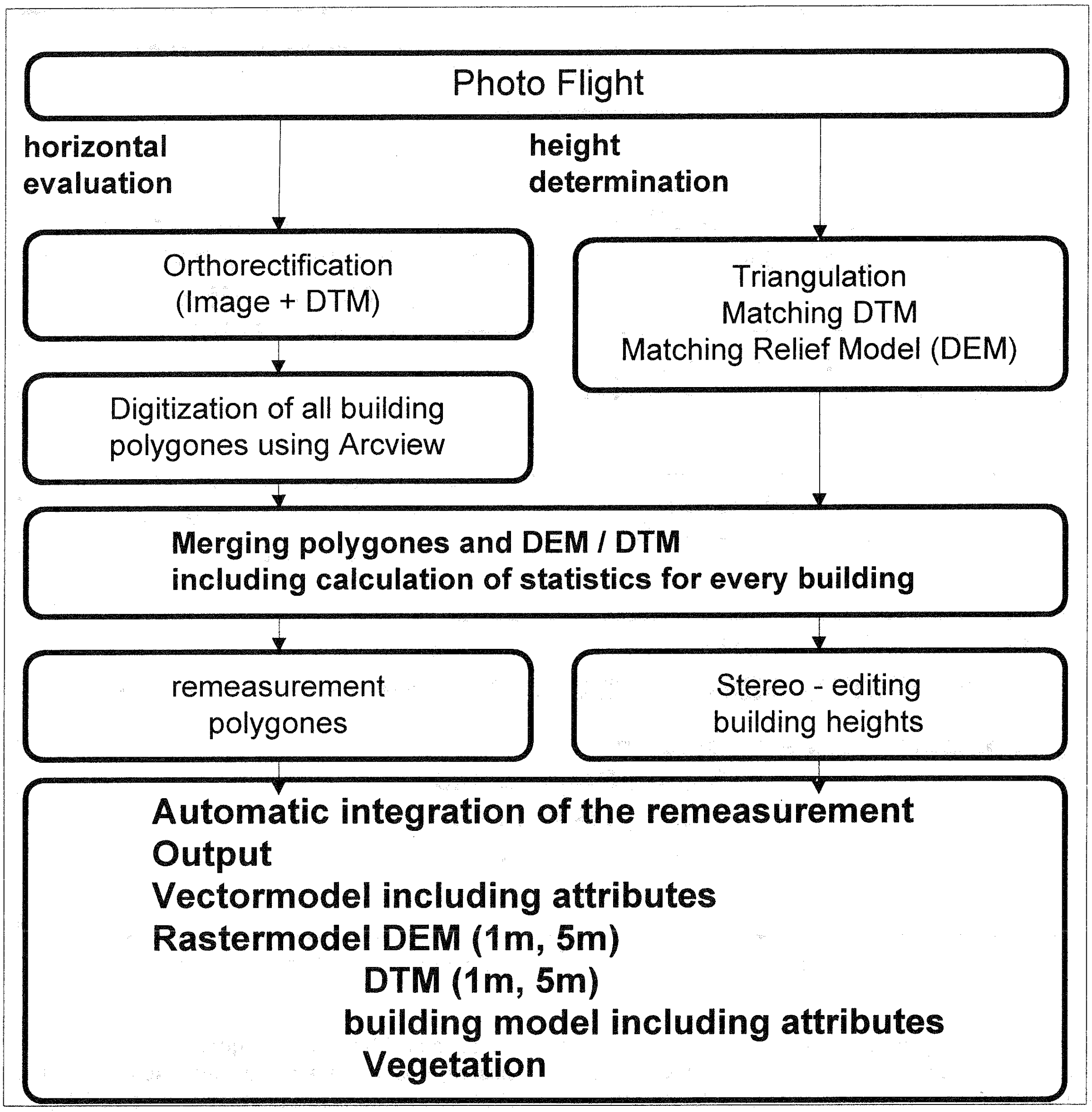

Fig 2: Sequence of building model acquisition

2.1. Aerial photography

The prerequisite for successful evaluation is aerial photography which fulfils the following criteria:

- Care should be taken in preparing the flight path so that systematic positional and relief errors are avoided by flying perimeter strips vertical to the area of interest.
- A **focal length of 30 cm** should be used in urban areas in order not to have to take account of more areas of potential blind spots in the stereo model than necessary and in order to minimize radial distortion at the edges of the ortho photos.
- **Aerial photography in spring or autumn**, i.e. outside the vegetation periods, simplifies the automatic height finding of buildings and the earth's surface.

The further details assume standard aerial photography with the following parameters:

Flight Parameters	
Picture material	colour
focal length	30 cm
scale number	12,500
Ground cover	2,875 m
Flight altitude	3,750 m
overlap	approx 65%
sidelap	approx 30%
Base length	1000 m
Gap between flight paths	2000 m

Tab. 1: Flight Parameters

The base length as well as the gap between flight paths are designed to comply with sheet DGK5 (German base map 1:5,000). In this way an orthophoto covers a complete map sheet. This arrangement is not necessary; it does, however, simplify processing.

2.2. Aerotriangulation

Aerotriangulation takes place in analytical equipment with subsequent bundle block adjustment using the BLUH program system (bundle block adjustment of the University of Hanover). Horizontal and vertical control points are taken from the DGK5 for this scale. With this, all the following data can be acquired in the Gauß Krüger coordinate system.

2.3. Scanning of the aerial photographs

Scanning of the aerial photographs is carried out on a photogrammetric scanner in a resolution of 1000 dpi (approx 25 µm). This equates in our example to a pixel size on the ground of approximately 32 cm. In order to produce colour photos every second aerial photograph is scanned in three channels.

3. CORRELATION OF DTM AND RELIEF MODEL

A 1 m point grid is automatically produced with a computation speed of 200 points per second through model stereo matching. The **terrain model** (DTM) is produced by a specially developed finishing process on a raster base, whereby interference such as bushes or buildings are interpolated.
In order to acquire the **relief model** (DEM) we return to the original model.
It should be remembered that sharp edges are not recorded. The absence of sharp edges leads to smooth transitions where the earth's surface is characterised by hard edges. Despite this, the landscape structure can be modelled in great detail due to the high point density.
Data storage and processing of the large grid models is done using **ERDAS IMAGINE**. Again, this level allows morphological parameters (e.g. exposition, landscape gradients) to be derived via suitable processing methods, despite very high volumes of data.

3.1. Orthophoto generation

The **computation of orthophotos** takes place using a generalised form of DTM in OrthoMAX. The tilt of the building remains but the visible vertical masonry is represented faithfully.
The ground resolution of an orthophoto pixel is about 30 - 35 cm for the above- named image scale of 1:12,500.

3.2. Mosaicing

Mosaicing the individual orthophotos produces a complete picture. radiometric equalisation around the edges avoids hard transitions between the individual aerial photographs. The mosaics can be output in various pixel resolutions.

4. GIS OPERATIONS

Digitalization of all buildings is carried out in the orthoimage. At the same time reference is made back to the true height data (DEM) during digitalization so that measurement in the stereo model is not necessary.

4.1. Merging and Editing

Automated combination of the matched heights with the building polygons cannot be carried out using standard software. The programmes used for this purpose are a joint development of **IPI** (Institute for Photogrammetry and Engineering surveys of the University of Hanover) and **PHOENICS GmbH**.

The following processes run automatically:

- Allocation of all measured building heights to the relevant building polygons,
- Calculation of a statistic relevant to each building and calculation of spot heights,
- Establishment of buildings whose relief must be remeasured manually,
- Attributing raster and vector data sets with the heights above sea level for each building,
- Calculation of the absolute building height through calculation of differences of the building grid and the DTM.

Any conspicuous buildings (statistics) are marked additionally in the stereo model in order for subsequent measurement to be carried out if required, and to allocate the new height to the data set.
One of the results is the building model in figure 3.
The **acquisition of trees** corresponds to an analysis which results from the intersection of the DTM with the DEM taking all buildings into consideration. Vegetation with a height of > 3 m high can be acquired with a probability of > 95%.

4.2. Accuracy / Data control

The evaluation of the images is performed with the above-named photo scale with a horizontal accuracy of **dx = dy < 1,5m.** The height accuracy is **dz < 1,0m.**
Verification of relief data is done by reference measurements with analytical equipment.

4.3. Data output

The vector output of the buildings is in ARC/INFO export format. These are closed and attributed polygons.
Data output in DXF format or in ASCII is also possible as output in various other standard formats.
The raster files of buildings and DTM can stored with 16 bit depth and 1m or 5m grid width as IMAGINE, GRID, TIFF, SUN-Raster or other formats.

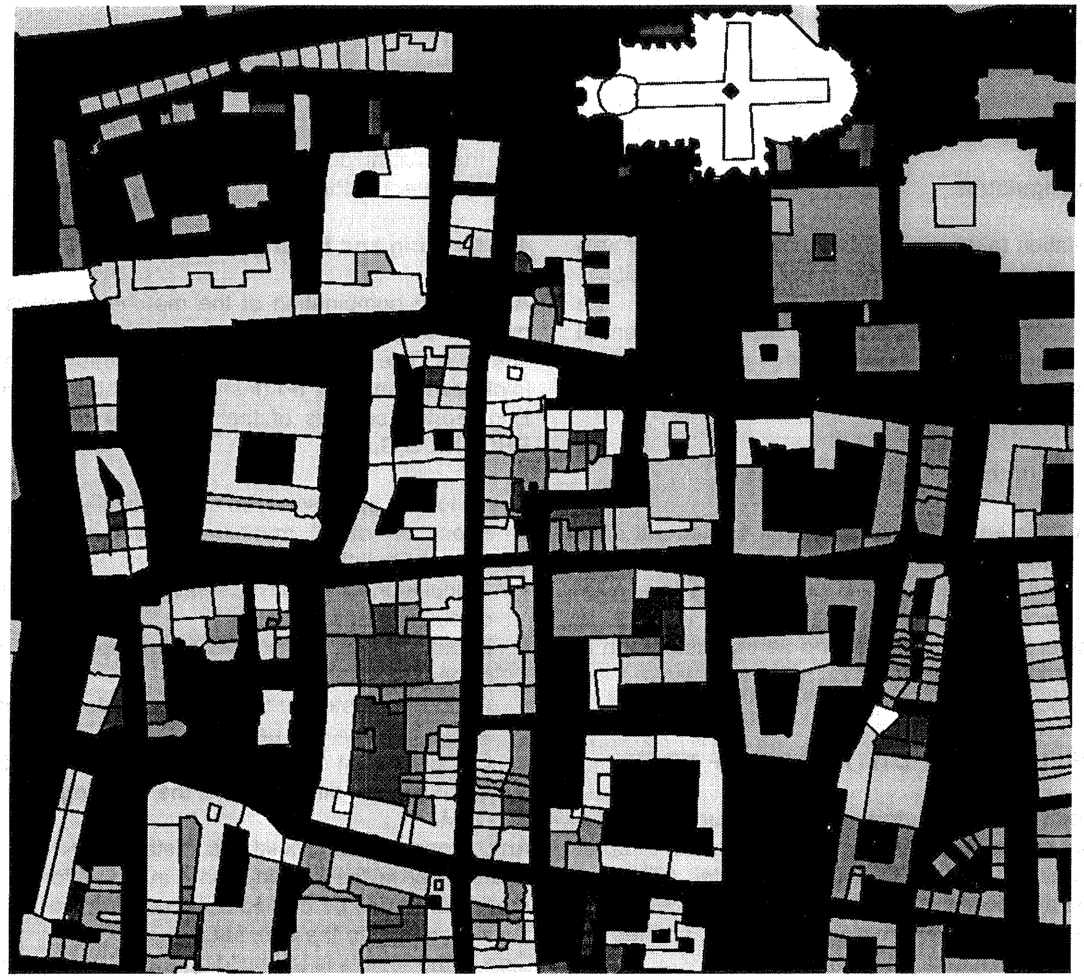

Fig. 3 Grey scale representation of a urban building model.
Presentation of the building height as per grey scale value.
A high building appears brighter than lower buildings (or part thereof).

5. SUMMARY

The acquisition of building models can be carried out using digital photogrammetry with high quality and more economically than with conventional methods.
At present, digital building models are being increasingly used by operators of mobile telephone communications as a data basis for the calculation of radio planning models and by public authorities for modelling emissions of various types.
As the costs of digital building models (photogrammetric products) have fallen significantly through the use of digital photogrammetry, it will in future be possible to integrate this data in GIS applications in other fields.

It is, for example, conceivable that Geographic Information Systems with a considerable depth of information can be built up at local authority level in which building data, orthoimages, relief models and vegetation can be linked with further information such as road data, waters, local boundaries or post code districts for planning and analytical purposes.