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# URBAN IMAGERY COMBINING PHOTOGRAMMETRIC AND REMOTE SENSING TECHNIQUES: A NEW TRAINING COURSE AT ENSAIS STRASBOURG

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### ABSTRACT:

Several scientific communities concentrate their efforts using photogrammetric techniques in the field of modelling urban areas. On the other side – with the access to high resolution satellites – also remote sensing in urban areas is present since a few years. At the same time, the shift from analytical to digital photogrammetry is now effective. Therefore, remote sensing and photogrammetry become closer as never before and this tendency is also remarkable in the corresponding software.

Remote sensing is an invaluable tool in fields where spatial and spectral information is required. For topics like land use evaluation or change detection at regional scales, image processing techniques used for optical satellite imagery have proved their potential. Familiarised with the problem of modelling urban areas using photogrammetric techniques, our team extended its research topics by integrating knowledge resulting from satellite imagery processing.

For this purpose, investigations with photogrammetric software and remote sensing software are realised during practical works with students of the department of surveying at ENSAIS Strasbourg. After creating a digital terrain model resulting from the restitution of stereoscopic photographs, several orthophotos are created and mosaicked together. The step of geocoding and mosaicking images has been attempted in parallel using on the one side exclusively photogrammetric tools and on the other side solely remote sensing tools. Results were assessed in a quantitative way, based on local and global precision and in a qualitative way, visualising the mosaicked area through a three dimensional representation.

### RESUME:

Un grand nombre de scientifiques concentre ses efforts autour de la modélisation urbaine par photogrammétrie. Depuis le développement des appareils photo numériques et des capteurs à très haute résolution, la photogrammétrie et la télédétection se trouvent liés comme jamais auparavant. Ces domaines se rejoignent non seulement sur la base des capteurs employés mais également des outils utilisés en terme de correction géométrique, radiométrique, et de traitement d'images.

La télédétection a déjà fait ses preuves dans la cartographie thématique, dans la détection de changements, l'observation de la Terre à échelle régionale. Elle emploie des outils puissants davantage pour le traitement de l'information radiométrique que de l'information géométrique en raison de la faible résolution spatiale qui caractérisait les images satellitaires jusqu'ici.

Notre équipe de recherche, familiarisée avec le problème de la modélisation urbaine sur la base d'outils photogrammétriques aimerait élargir cette problématique en s'intéressant aux outils réservés aux traitements d'images satellitaires. Dans ce contexte, un projet a été proposé aux étudiants en dernière année de formation Ingénieur en Filière Topographie de l'ENSAIS.

L'objectif principal du projet consiste à mettre en évidence les apports et potentiels de logiciels de télédétection et de photogrammétrie à la réalisation, non seulement d'orthophotographies, mais aussi de modèles tridimensionnels urbains.

## 1. CONTEXT OF THE STUDY

ENSAIS is an Engineering College of the Polytechnicum of Strasbourg. Every year, about 250 engineers and architects are graduated in eight different fields of study. Academic and training programmes are divided into three phases.

The first phase of 2 years begins after the completion of the Baccalauréat and is dedicated to preparatory classes ("classes préparatoires scientifiques"). The second phase lasts 2.5 years (5 semesters of theoretical and technological courses including laboratory work).

At the department of surveying, during the first year, courses are offered in topometry, instruments and measurement techniques, cartography, computer science and computer aided design,...i.e. main principals of surveying.

During the second year, they look further into their knowledge in topography with learning adjustment methods, photogrammetry, geographical information systems, digital elevation model generation, etc. These courses are accompanied by practical work where teachers examine the progress of the work of each student individually.

Lastly, the third year, while continuing training in geodesy, photogrammetry, remote sensing, etc. gives more autonomy to the students. Indeed, each course is based on many team projects with well defined problems. Students have to organise their work and to distribute the tasks in order to be able to carry out all the stages leading to solve the problem. This work also aims at waking up the capacity of analysis of the students and to confront them with problems which do not happen during the theoretical and practical working sessions.

The project presented here is an application of various methods leading to the development of urban three-dimensional models based on the use of aerial, terrestrial or satellite images. It aims, on the one hand, to sensitise the students with the concept of correction and geometrical precision they meet in topography, in particular in photogrammetry and remote sensing; on the other hand, it aims to confront them with different methods and systems leading to orthorectified images.

The topic of this project corresponds to the research themes of the Photogrammetry & Geomatics Group of the Department of Surveying, involved since 1990 in different projects in the domain of architecture, archaeology and environment.

Thus, students can validate their knowledge in photogrammetry and remote sensing on the basis of a complete project carried out over one week. At the end, each team has to describe all processing steps, to compare various methods, as well as to analyse quantitatively and qualitatively its results in a short report.

The project lasts 28 hours and is composed of three different approaches using three different systems :

- ERMAPPER (Earth Resource Mapping Inc.) firstly a satellite image processing software,

- ORTHOPRO (Z/I Imaging) an orthophoto production system,

- PHOTOMODELER (Eos Systems Inc.) for 3D models and measurements from photographs.



Figure 1: Uncorrected aerial photograph (1/8000) covering a part of Strasbourg town (June 1998)

## 2. AVAILABLE DATA AND STUDY AREA

Data available for this project are mainly aerial photographs:

- 6 aerial photographs taken in 1998 at 1/8 000 scale and chosen in a database of the city of Strasbourg (image pixel size: 30  $\mu\text{m}$ ; ground pixel size approx. 24 cm). One of them is presented in figure 1.
- a stereopair of aerial images at 1/30 000 acquired in 1990 by IGN (National Geographical Institute) and covering the town of Strasbourg (image pixel size: 30  $\mu\text{m}$ ; ground pixel size approx. 90 cm)
- camera calibration details corresponding to each data file (focal length = 211.03 mm for 1/8000 photographs and focal length = 151.79 for 1/30000 photographs)
- ground control points resulting from various sources:
  - GPS measurements
  - topographic surveys
  - cadastral database
  - aerotriangulation
- digital images of specific buildings (for architectural photogrammetry purposes)
- topographical maps from the French mapping agency (IGN) with scale 1/25000

Additional data (to be completed until the end of 2002):

- IKONOS scene (1m pixel size in panchromatic mode) or QuickBird2 (0.61m pixel size in panchromatic mode)
- DAIS image (78 spectral bands at variable spatial resolution from 3 to 20 m depending on the flight altitude) to be acquired in July 2002

### 3. FLOW CHART OF THREE APPROACHES

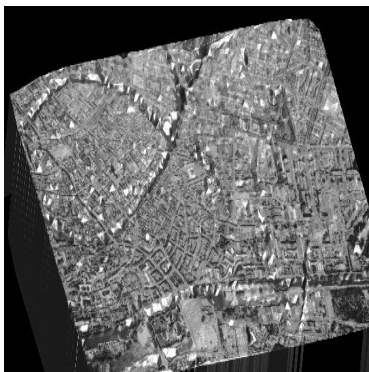
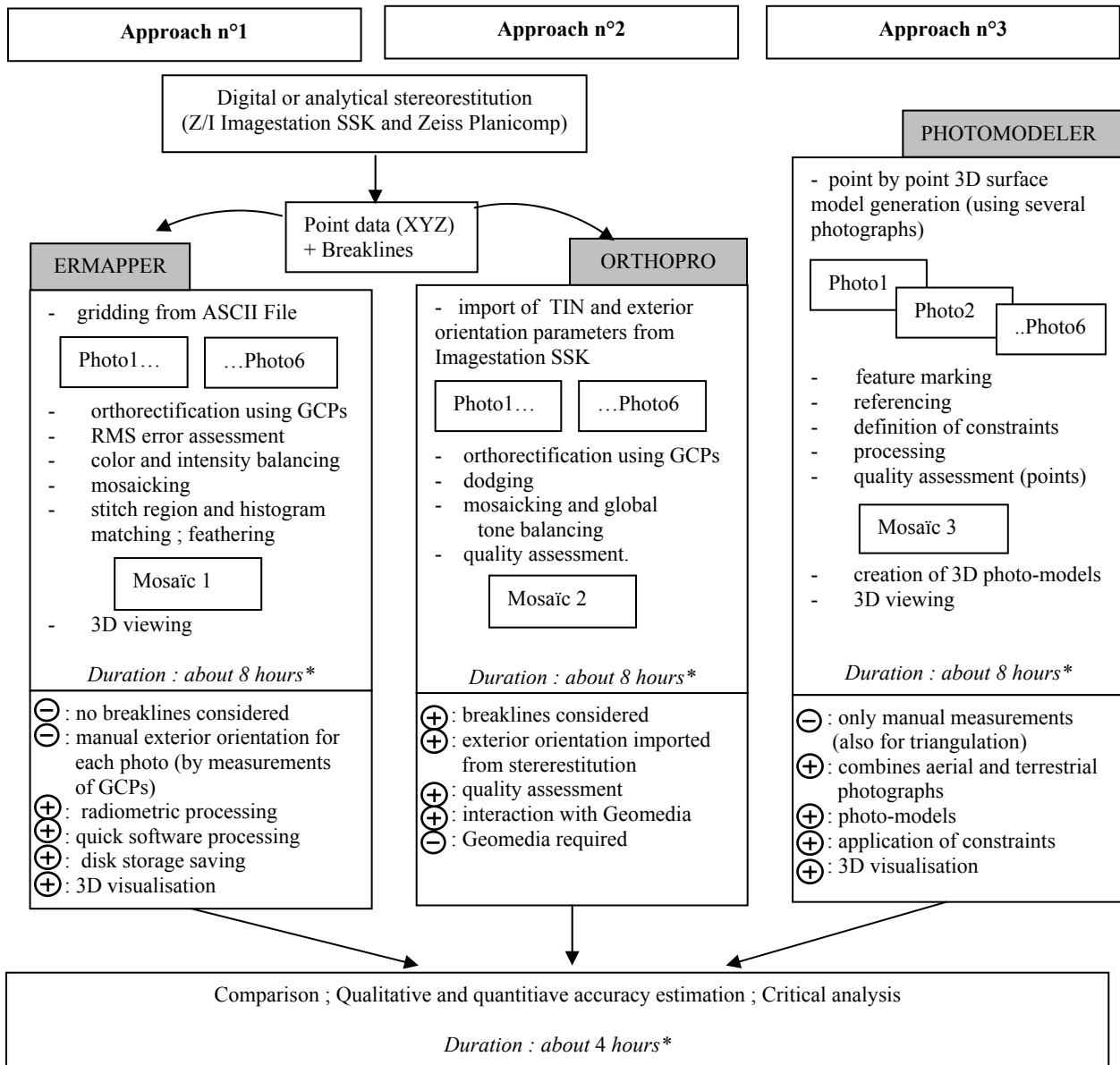


Fig.2: Mosaic draped over DTM

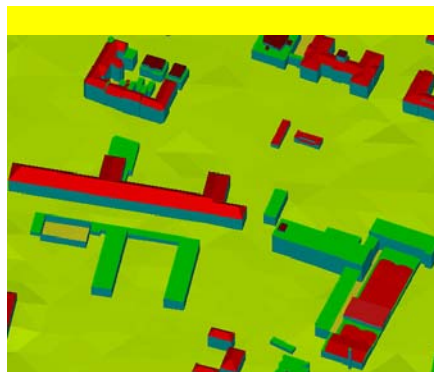


Fig. 3: 3D model of ENSAIS



Fig. 4: Photo-model (Alsatian house)

\*The number of photographs used will depend on the progress of the work and on the a priori knowledge of the packages.

#### 4. DESCRIPTION OF EACH APPROACH

The group consisting of about 30 students is divided into 15 teams of 2 people realising each one of the 3 approaches presented above and defined below.

In order to save time, the long stages (ex.: stereorestitution for acquiring XYZ points) are mainly completed by the assistants.

An orthorectified aerial image (figure 5) is a scale correct representation of the terrain surface in digital form. To prepare for orthorectification, several data are required : interior and exterior orientation parameters and a digital elevation model (DEM). With these parameters and using equations of collinearity, orthorectification corrects local and global distortions by adjusting the image for camera characteristics, platform positions and terrain details.

##### 4.1 Approach n°1: Orthorectification using ERMAPPER software

ERMAPPER software is used at ENSAIS for remote sensing data processing. Orthorectification methods are the most accurate geocoding methods provided by ERMAPPER because they include terrain and camera information in their calculations. Since exterior orientation parameters are unknown in our project, we use orthorectification using GCPs in order to solve exterior orientation parameters.

For this first approach we need:

- camera calibration information (focal length of the camera, calibrated positions of fiducial reference points, optical distortions due to irregularities in camera's lens) for interior orientation
- DEM file (produced by a previous gridding process)
- GCPs referenced by their East, North, Altitude coordinates

DEM creation: The DEM is built by gridding process since well regularly spaced points should be available after stereorestitution. Triangulation interpolation program has been used for grid creation. Triangulation provided by ERMAPPER constructs a Triangulated Irregular Network (TIN) and "regularises" the grid by using a linear approximation for each triangle to calculate values at grid points. Triangulation works best when the input points are evenly distributed over the grid area.

Orthorectification: After digitising fiducial points for interior orientation, GCPs measurements are made in the selected photograph and are used to perform exterior orientation. This step must be repeated for each photograph.

Mosaic: When two or more images are adjacent and in the same coordinates system (same datum and map projection), they can be mosaicked together into a large image. ERMAPPER enables that each image can have a different number of bands, different data formats and a different cell size.

Radiometric processing: once each aerial photograph is geocoded, its colour and intensity must be balanced. Colour balancing corrects the tendency for the edges to be more blue than the centre of the image because they are further from the aircraft. Intensity balancing corrects for changes in intensity in the aerial photograph from the centre to the edges caused by the thickness of the lenses in the aerial camera.

When the photograph mosaic still shows remaining differences between the radiometry of individual images, it is possible to pick a « stitch » line (along roads for example). Through histogram matching, one photography can be chosen as a radiometric reference for the other photographs composing the mosaic. Furthermore, a « feathering » tool, like low-pass filter, enables transition between individual photographs.

3D view: At last, it is possible to visualise the resulting mosaic draped over the DEM as a 3D representation (figure 2).

Remark: ERMAPPER's revolutionary algorithm method processes imagery without intermediate image files and without requiring temporary disk storage for each stage of the process. This makes it easy to carry out the processing steps needed to create large aerial photograph mosaics quickly and easily.



Fig. 5: Orthophoto of Strasbourg 1/8000 - ENSAIS area (June 1998)

##### 4.2 Approach n°2: Orthorectification using ORTHOPRO software

Z/I Imaging's ImageStation ORTHOPRO software is a complete ortho production system including ortho-project planning, rectification, tone-balancing, mosaicking and quality assessment. ImageStation ORTHOPRO is integrated into GeoMedia (Intergraph) environment.

For this second approach we need:

- interior and exterior orientation parameters
- elevation data (TIN)
- GCPs referenced by their East, North, Altitude coordinates

Mains steps leading to mosaics are:

- project planning
- rectification
- dodging
- mosaicking and global tone balancing
- quality assessment

Rectification: ORTHOPRO rectifies multiple photos simultaneously and allows schedule jobs for later submission. Like ERMAPPER, one can define clipping areas to eliminate the black border containing fiducial points.

Dodging: this process is applied on orthophotos in order to correct for common photographic problems such as vignetting and other uneven exposure problems. It can be compared to the colour and intensity balancing step made by ERMAPPER.



Mosaicking and global tone balancing: performs tone matching and balancing of the radiometry of all images. It also mosaics images together along user-defined seam lines. Feather seam lines based on user-defined parameters.

Quality assessment: this routine calculates the absolute error and RMS error for one or more products and places control points automatically in the GeoMedia display.

In this software, digital elevation models can be imported as TIN or raw row/column formats for example. In the case of multiple overlapping elevation files of different types, it is not necessary to join them into one digital terrain model mosaic.

#### **4.3 Approach n°3: Orthorectification using PHOTO-MODELER software**

PHOTOMODELER is a software used to generate 3D models and 3D measurements from photographs. It's first aim consists in generating elevation drawings of existing structures or installations, as well as 3D models for professionals in architecture, archaeology, engineering measurements, close range photogrammetry (figure 4), i.e. based on terrestrial photographs. Considering orthophotos as particular 3D models, we decided to use PHOTOMODELER with aerial photographs for this training course.

For this third approach we need:

- camera calibration information
- GCPs referenced by their East, North, Altitude coordinates

The main steps leading to orthophotos are:

- import photographs of the study area
- define the camera (calibration)
- mark and reference photographs
- process information
- generate the surface model
- view and export the 3D model

Import photographs: first step consists in importing overlapping photographs from different angles of the study area.

Mark and reference photographs: one have to mark on the photographs the features (points, lines, surfaces) wanted in the final 3D model and to digitise points on different photographs representing the same location in the scene. These measurements can be completed by geometric constraints like distances, verticality constraints, perpendicularity constraints, etc.

Process information: processes camera and referencing data. Thus, the surface model is created and the texturing is applied.

View and export the 3D model: displays the resulting 3D model and also coordinates or distance and area measurements.

In this case, the DEM is created like a common 3D model, that means selecting points on different photographs representing the same location in the scene.

### **5. CONCLUSION AND OUTLOOK**

Three approaches are considered in the presented training course. Each approach leads to the generation of orthophotos and mosaics. Moreover, the whole study allows the extraction of advantages and constraints inherent to each system.

It becomes clear that photogrammetric algorithms are more elaborated for improving geometric corrections and creating orthophotos since they consider local ground breaklines. On the other hand, for mosaicking images together, feathering join lines and enhancing images, remote sensing processing techniques are more developed. To take advantage of reliable geometric and radiometric corrections, one has to combine specialities of both domains, i.e. photogrammetric and remote sensing techniques simultaneously.

Students should not only compare and criticise the packages, but also consider the reliability and the perspectives of each system. Indeed, the direct link to a GIS (provided by ORTHOPRO) or the capacity to combine aerial and terrestrial photographs (PHOTOMODELER) or to process several spectral layers (ERMAPPER) should be taken into account.

Soon, this project will be extended to a larger database integrating further images, like very high resolution satellite data (IKONOS data or Quickbird data) as well as hyper-spectral data (DAIS sensor) resulting from a campaign organised in July 2002. Thus, after being familiarised with geometrical problems, students will devote more time to radiometric problems. Therefore, this training course will be supplemented by an analysis of the systems on the basis of spectral data.

### **6. REFERENCES**

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