## TUTORIALS

Tutorial Coordinator: **Robert Ecker** (Austria)

### TU 1 - Integration and Orientation of Sensor Systems

9 July 1996, 08:45 - 17:00

**Authors:**
**I. Colomina**, Institut Cartografic de Catalunya, Spain.
**K. Novak**, TRANSMAP, Ohio, USA.
**H. Schade**, Leica, Heerbrugg, Switzerland.

**Reporter:**
**F. Rottensteiner**, Institute for Photogrammetry and Remote Sensing, Vienna University of Technology, Austria.

**Summary:**
The tutorial started with an introduction to the GPS system by H. Schade. Both space control and user segments were described and the types of observations which can be taken were discussed together with the mathematical models involved. H. Schade also talked about systematic errors which might occur and terminated with the introduction of the concept of differential GPS.

The second part of the tutorial comprised an introduction to inertial sensors and to methods for their calibration, which was given by I. Colomina. The principle of laser gyros was explained together with the mathematics and possible error sources involved. As inertial sensors show errors which grow with time, careful calibration of such sensors is very important.

After that, H. Schade came up with the problem of time synchronisation of hybrid sensors with GPS which has to be done with an accuracy better than 1ms. Time pulses from GPS or a GPS system capable of catching pulses from the other sensors can help to solve this problem. The importance of calibration of the spatial offset between different sensors in a laboratory was stressed.

The tutorial was continued with examples for GPS based aerial triangulation given by I. Colomina. GPS errors are modelled by shift parameters; the procedure is now well established at an almost industrial scale. Discussion showed that aerial triangulation without any ground control appears to be impossible although the amount of ground control can be reduced considerably by using GPS.

K. Novak started with an introduction to digital and analogue cameras which can be used for image acquisition. The development of these systems is a revolutionary one, but there are still problems with sensor stability and data storage which have to be solved. K. Novak also presented practical experiences made with a mobile mapping system which integrates GPS, inertial sensors, a time controlled video tape and digital stereo cameras. It is the purpose of such systems to overcome the bottleneck of data collection for GIS. The tutorial was closed with a demonstration of the photogrammetric software used in that mobile system.

### TU2 - Computer Vision in Photogrammetry and Remote Sensing

8 July 1996, 08:45 - 17:00

**Authors:**
**Werner Schneider**, Institute for Surveying and Remote Sensing, Vienna University of Agriculture, Forestry and Renewable Resources, Austria.
**Axel Pinz**, Institute for Computer Graphics, University of Technology Graz, Austria.

**Reporter:**
**M. Kerschner**, Institute for Photogrammetry and Remote Sensing, Vienna University of Technology, Austria.

**Summary:**
Computer Vision can be defined as the science dealing with the automatic extraction of information from images by a computer. The application of computer vision methods in photogrammetry and remote sensing can lead to the automation of various tasks.

The tutorial gave a survey of the state-of-the-art of computer vision. Several levels of representation were presented. An image describes a scene of the real world at one specific moment. Image segmentation techniques lead to 2-D image descriptions. These techniques include filtering operations or feature extraction. Object reconstruction methods generate 3-D scene descriptions. Besides reconstruction computer vision methods can be used for interpretation tasks.

Digital photogrammetric systems can make use of developments in computer vision. Some subtasks can be solved automatically, e.g. obtaining the interior orientation or the relative orientation of aerial stereo images as well as the DEM generation. The task of automatic classification of remote sensing data can also be improved by applying computer vision methods.

The tutorial concluded with demonstrations of software (Match-T, KB Vision) and presentation of some applications (3-D city reconstruction, roof reconstruction).

**TU 3 - Technologies for Handling Very Large Volumes of Spatial Data**
9 July 1996, 08:45 - 17:00

**Author:**
**E. Otoo**, Center for Distributed and Parallel Computing, Carleton University Ottawa, Canada.

**Reporter:**
**R. Ecker**, Institute for Photogrammetry and Remote Sensing, Vienna University of Technology, Austria.

**Summary:**
Spatial information systems and geographic information systems, generally deal with storage access and manipulation of large databases of different data types and from heterogeneous repositories. These repositories contain data that are in one or more of the following formats: vector, raster data of still or video images, structured text, unstructured text and a knowledge base. These databases are typically distributed over multiple sites. To access and manipulate them as an integrated information resource requires the support of not only distributed access but the use of high performance parallel computation as well. The tutorial addressed the issues involved in handling and disseminating large volumes of spatial data.

In particular the following topics were covered:
- State-of-the-art technology for maintenance, accessing and computing with large volumes of spatial data
- Data parallelism in high performance parallel computers
- Multidatabase access and interoperability in heterogeneous data repositories
- Data compression and interchange between systems

**TU 4 - 3D Image Metrology Systems and Applications**
9 July 1996, 08:45 - 17:00

**Authors:**
**E. Baltsavias**, Institute of Geodesy and Photogrammetry, ETH-Hönggerberg, Switzerland.
**H. Beyer**, IMETRIC, Switzerland.

**Reporter:**
**S. Robson**, Department of Civil Engineering, City University London, United Kingdom.

**Summary:**
Having set the scene with an introduction describing the order and scope of their tutorial, the authors embarked upon a step by step description and analysis of techniques and technologies employed in 3D metrology systems.

Beyer began with an overview of image acquisition with solid state sensors. He paid particular attention to the structure, geometry and current restrictions in the manufacture of CCD sensors. Summarising the sensor advances which could be expected in the next few years, he finished by detailing some of the digital cameras currently available.

After a short break Baltsavias described the fundamentals behind a few commonly used image processing and target location methods. The image processing techniques included: image pyramids, image restoration and enhancement; and feature extraction.

Beyer continued the tutorial with a discussion of metric accuracy performance. He began by emphasising the importance of checking the performance and reliability of each individual system component. Matching the quality of the derived data to the end users requirements was then discussed. It was interesting that clients accuracy comparisons between different commercial systems were problematic due to difficulties in obtaining control measurements of suitable quality. Beyer stressed the need to develop standard procedures for 3D image metrology systems, since the current standards derived for co-ordinate measuring machines were often inappropriate. This section of the presentation was illustrated by a range of industrial applications undertaken by IMETRIC.

Baltsavias continued with an overview of image matching techniques following the theme of matching strategy. A wealth of information was provided concerning critical processing steps and methods of circumventing potential algorithmic problems.

A demonstration of one of IMETRICs still video camera systems then followed. Despite the fact that the targeted object chosen was simple in design, the demonstration provided a good example of the rapidity and ease with which high quality measurements could be obtained.

The final presentation in the tutorial was by Baltsavias. He began by discussing the use of colour, noting how its careful use could be of importance in object discrimination. He then continued describing a variety of allied optical technologies and measurement techniques. These included laser point triangulation, coded light, and phase shift methods. Finally some applications of 3D image metrology undertaken at ETH-Zürich were outlined.

**TU 5 - Advanced DTM Technology**
9 July 1996, 08:45 - 17:00

**Authors:**
**L. Molnar, R. Ecker, D. Heitzinger, F. Hochstöger, N. Pfeifer, A. Sindhuber, J. Wintner, B. Wöhrer**, Institute for Photogrammetry and Remote Sensing, Vienna University of Technology, Austria.

**Reporter:**
**M. Koehl**, Department of Surveying, ENSAIS Strasbourg, France.

**Summary:**
The morning session contained four major blocks of presentations which were presented simultaneously in English and German.

The first and introducing presentation was given by L. Molnar who discussed developments and aspects of software, operating systems and programming environments. For efficiency reasons in software development the Institute of Photogrammetry and Remote Sensing (IPF) of the Vienna University of Technology will propose a solution available on all desktops and workstations using an application framework "XX" and the DTM system SCOP in a new technological generation.

The second part presented a new approach for modelling 3D-surfaces. D. Heitzinger and N. Pfeifer gave theoretical and experimental information on managing "full 3D" objects in a DTM using triangulation algorithms and Bezier triangles.

The main topic of the third part was management of country-wide digital elevation data. After analysing elevation data and looking at potential users F. Hochstöger demonstrated the utility of such a system by means of the functionality (managing topology in terms of relationality) of the new SCOP module SCOP.TDM for topographic data management.

In the last presentation R. Ecker gave an overview of DTM applications such as visualisation, DTM algebra, digital orthophotos, image classification, volume computation, visibility maps, sky plots, monoplotting, etc.

In the afternoon session the participants were asked to choose two of four practical exercises about the theoretical morning presentations.

**TU 6 - Digital Photogrammetry in Small Scale Imagery**
9 July 1996, 08:45 - 17:00

**Authors:**
**D. Fritsch, N. Haala, M. Hahn, M. Sester**, Institute of Photogrammetry, Stuttgart University, Germany.

**Reporter:**
**F. Amhar**, Institute for Photogrammetry and Remote Sensing, Vienna University of Technology, Austria.

**Summary:**
The tutorial consisted of 8 lessons given by 4 experts of the Institute of Photogrammetry. First D. Fritsch explained camera models and sensor systems with special focus on the German MOMS02. Fundamental formulas describing the imaging process as well as hardware characteristics of the imaging systems were given. Next M. Sester presented fundamentals of digital image processing, segmentation and classification. Different types of filter techniques, geometric transformations and classification algorithms were discussed. M. Hahn continued talking about matching techniques such as: classical correlation, intensity based matching, feature based matching and relational matching. The morning session was closed with applications of matching techniques for photogrammetric tasks.

In the afternoon N. Haala discussed digital orthophoto techniques. D. Fritsch showed the potential of digital photogrammetry for the automation of orientation tasks (interior orientation, relative orientation, exterior orientation) and point transfer . M. Hahn discussed the acquisition of digital terrain models based on image matching techniques. The presentations were closed by N. Haalas lecture on extraction of cartographic features. Examples for road and building extraction were given.

**TU 7 - Digital Orthophotos applied for Topographic Mapping**
8 July 1996 01:30 - 17:00

**Authors:**
**M. Franzen, G. Kohlhofer**, Federal Office of Metrology and Surveying, Vienna, Austria.

**Reporter:**
**C. Malle**, R+A. Rost, Vienna, Austria.

**Summary:**
The half-day tutorial given at the Federal Office of Metrology and Surveying consisted of three parts.

In the introduction G. Kohlhofer gave an historical review on the generation of orthophotos for documentation purposes and map revision. Today orthophoto maps of Austria in scale 1:5000 and 1:10000 based on aerial images in scale 1:30000 are available. Control points for orientation purposes of these images were derived from stereo-models of other flights. A digital elevation model covering all Austria already exists from former mapping projects with a point density of about 30 meters in mountainous areas and 100 meters in flat areas. For the interpolation of a regular grid with a point density of 25m to 20m the DEM software SCOP is used.

Next a demonstration of the Zeiss-Intergraph Photoscanner PS1 was given by G. Kohlhofer. The radiometric resolution of the PS-1 is 8-bit (11-bit internal) and the possible pixelsizes range from 7.5 to 120 microns. A discussion emerged about advantages and drawbacks of scanning positives or negatives.

In the third part processing of orthophotos by ERDAS-IMAGINE Orthomax and Intergraph Image Station were presented. After scanning the aerial images with a resolution of 30 microns on the PS1, project definition, interior and exterior orientation has to be done to get the required image orientation parameters. For the orthophoto rectification also access to a DEM is required. A discussion about different resampling methods such as bilinear or cubic convolution

emerged. Eventually image enhancement and mosaicing techniques were demonstrated.

**TU 8 - Image Quality**
8 July 1996, 01:30 - 17:00

**Authors:**
**H. Ziemann**, Dep. of Surveying, College Anhalt, Dessau, Germany.
**A. Boberg**, Dept. of Geodesy and Photogrammetry, Royal Institute of Technology, Stockholm, Sweden.

**Reporter:**
**P. Grussenmeyer**, Department of Surveying, ENSAIS Strasbourg, France.

**Summary:**
The use of digital images in photogrammetry and remote sensing has increased the need to convert photographic images into digital data and thereby the need to understand the micro-image characteristics of photographic images, the digitisation process and digital images.

By H. Ziemann the following topics were presented:
- Image Quality - A review
- Introduction to image quality parameters
- Interrelation of image quality parameters

Various parameters defining image quality have been discussed, e.g. resolving power, point spread function, line and edge spread function, Fourier analysis, modulation transfer function (MTF), SyQuest frequency, effective and instantaneous field of view, pixelsize...
All parameters can be traced to the point spread function; hence, all are related to some extent. The comparison of advantages and disadvantages clearly shows that resolving power should be used with extreme caution, if at all.

A. Boberg discussed:
Image perception aspects of aerial image quality: the purpose was to understand the human image perception not only for development of image interpretation methods and image quality, but also for development of methods for computer vision and digital image matching.
Subjective image quality assessment: different parameters that influence subjectively experienced image quality were shown (example of the National Land Survey of Sweden)
Photographic aspects of image quality: the photographic process and the final image quality has been discussed as well as MTF analysis.

Discussion with the participants emerged about: usage of MTF; image scanning process and evaluation of images in digital photogrammetry; television technology.

**TU 9 - Projective Geometry for Image Analysis**
8 July 1996, 01:30 - 17:00

**Author:**
**R. Mohr**, Gravir-Inria, Grenoble, France.

**Reporter:**
**M. Kosmatin-Fras**, Institute for Geodesy and Photogrammetry, Ljubljana, Slovenia.

From the very beginning, development of photogrammetry was closely connected with projective geometry. Although some of its basics seemed to be forgotten later, significant progress has recently been made by applying tools from classical projective and algebraic geometry to fundamental problems in computer vision.

The tutorial basically focused on:
- Basic considerations of projective geometry and its computational aspects
- Invariance in projective geometry: the cross ratio and its applications
- Euclidean, affine and projective geometries
- Uncalibrated stereovision: the epipolar geometry and its estimation, projective 3D reconstruction, selfcalibration and Kruppas equations.

The main conclusions are that projective geometry:
- is a link between intuitive geometry and the powerful linear algebra.
- is the basic tool for handling uncalibrated cameras up to self calibration.
- together with powerful mathematical tools allows to solve recent hard problems like the Sturm problem.
- provides closed form solutions useful for initialising non-linear methods
- allows problem decomposition in subproblems

Further research in this field is concentrated on:
Geometry of multiple images, efficient self calibration, geometric reasoning with constraints, introduction of more general features (conics, general curves,...) and applications.

**TU 10 - Conceptual Aspects of GIS Technology**
8 July 1996, 08:45 - 17:00

**Authors:**
**M. Molenaar**, Department for Geo-Information Processing and Remote Sensing, Wageningen Agricultural University, Netherlands.
**R. Bill**, Department for Landeskultur und Umweltschutz, University of Rostock, Germany.
**D. Fritsch**, Institute for Photogrammetry, Stuttgart, Germany.

**Reporter:**
**E. Baltsavias**, Institute of Geodesy and Photogrammetry, ETH-Hönggerberg, Switzerland.

**Summary:**
The tutorial covered several aspects of spatial data modelling under the object oriented paradigm and was a refresher after the first tutorial on GIS in Wuhan, China in 1990. The emphasis was on 2D object models, their integration with DTMs and their database implementation.

The first part was conceptual and general, and covered aspects like data flow in GIS, tasks of IS and GIS with emphasis on data integration and integration of processing stages, definition of terms, different data modelling levels and types of querying. Different types of raster modelling and of querying of raster data were also covered. This first part emphasised the idea of topology being viewed as part of the geometry.

The second part treated geometric and thematic partitioning, hierarchical object modelling (incl. classification, aggregation and association hierarchies), object generalisation and the relationship between thematic and spatial resolution.

The third and fourth parts covered:
- Integration of spatial object models and DTMs
- 2.5D and 3D models
- Database implementation of spatial object models
- GIS design
- Aspects of querying, spatial analysis and visualisation

Discussions with the participants emerged about:
- How to model complex objects (ellipses, parabolas)
- Constraint specification in conceptual models
- Application of multiresolution techniques (e.g. wavelets) in GIS
- The possible future use of primary data, tables and operations to perform aggregation.

*Robert Ecker, Austria, the organiser of the tutorials, and docents: Michael Franzen, Austria; Dieter Fritsch, Germany; David Heitzinger, Austria; Martien Molenaar, The Netherlands and Kurt Novak, USA*