# THE SWEDISH NATIONAL REPORT FOR PHOTOGRAMMETRY AND REMOTE SENSING 2000 - 2004

Prepared for the Swedish Cartographic Society by
Dr. Dan Klang
National Land Survey, Gävle, Sweden
Dan.Klang@lm.se

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**ABSTRACT:**
The Swedish Society for Photogrammetry and Remote Sensing, the former Swedish member of ISPRS, merged in April 2003 with the Swedish Cartographic Society. A new section for Photogrammetry and Remote Sensing of the Swedish Cartographic Society, the new ISPRS member, was established at the same time. Introduction of laser scanning and digital cameras within the digital Photogrammetry increases the requirement of relevant education and research. Unfortunately, the status of Swedish economy has influenced the size of grants for research and development to universities and governmental organisations. Thanks to private consultants Sweden still holds a strong international position in research and development of Photogrammetry and Remote Sensing topics.

## 1. THE SWEDISH CARTOGRAPHIC SOCIETY

### 1.1 Organisation

The Swedish Cartographic Society was founded in 1908, and is most probably one of the oldest of its kind. The Society's goal is to increase the interest in cartography and other topics related to mapping and/or the use of maps in Sweden and to try to encourage a development in the area.
In April 2003 the Swedish Cartographic Society merged with the Swedish Society for Photogrammetry and Remote Sensing.
Before the merge the Society was organised in three separate sections, namely the sections for Historical maps, Geographical information systems (GIS) and Geodesy. After the merge two new sections were formed; the section for Cartography and the section for Photogrammetry and Remote sensing. Each section has a front-end responsibility for its respective disciplines and, amongst other activities, arranges seminars or study visits.
In the beginning the Society's activities was concentrated to Stockholm. During later years the Society's activities has been substantially reformed and expanded. There are now ten regional sub-organisations within the Society. These arrange meetings and study visit in their regions.

### 1.2 Events

One of the main activities of the Society is to organise an annual conference “Kartdagar” – Map days - combined with a trade show with participants from different companies in the GIS/GIT area. The conference program consists of seminars within the areas of Cartography, Historical Cartography, Geographic Information Systems (GIS), Photogrammetry, Visualisation, Geographic Information Technology (GIT), Remote Sensing and Geodesy. Beside of the conference and trade show there are also study visits and different forms of social arrangements. Last year some 1000 persons took part in the Map Days. Four times a year the Society publishes a cartographic journal, which recently got the new name “Mapping and Image Science”. During the latest years the number of members in the Society has increased. The members are interested in the areas of surveying, cartography, GIS, GIT, visualisation, and geodesy.

### 1.3 Publications

The Society produces every fourth year a national report at the congress of the international cartographic association - ICA.

Ekman M. 2002. Latitude, longitude, altitude and depth. 138 pages. (In Swedish)

Torlegård K, Ottoson L, Ternryd K-O. 2004. Swedish Photogrammetry and Remote Sensing during the 2000 century. 270 pages. (In Swedish)

### 1.4 Address

Swedish Cartographic Society
c/o Patrik Ottoson
ULI, S-801 82 Gävle, Sweden
Home page: www.kartografiska.com/index-eng.html

## 2. KTH - ROYAL INSTITUTE OF TECHNOLOGY, DEPARTMENT OF INFRASTRUCTURE - FORMER DEPARTMENT OF GEODESY AND PHOTOGRAMMETRY

### 2.1 Organisation

In 2001 the Department of Geodesy and Photogrammetry merged with other departments into the Department of Infrastructure, as a part of the reorganization of KTH. Geoinformatics and Photogrammetry forms a group within the department, Geodesy another group. This report refers to the Geoinformatics and Photogrammetry group, now consisting of 8 persons (In 2000 22 persons). Prof Dr Kennert Torlegård retired in 2002. As a replacement for the chair in photogrammetry a chair in geoinformatics is established.

### 2.2 Education

The department gives courses for MSc students in surveying, Environmental Engineering and Media Technology, in Measurement and Mapping, Analytical and Digital

Photogrammetry, Photography, Geoinformatics and Cartography, Remote Sensing Technology and Error Theory. A great number of MSc theses have been produced.

**2.2.1** Theses work

Three doctoral theses (Burman, Carballo and Ottoson) and two licentiate theses (Mahlander and Dunkars) were defended during the period.

**2.2.2** Photogrammetry and remote sensing facilities

Leica-Helava Socet Set photogrammetric workstation
Intergraph Image Station photogrammetric workstation
Leica DSR-11 analytical plotter
Zeiss Stecometer stereo comparator
Three-dimensional test field for camera calibration
Kodak/Nikon DCS 460 digital camera

### 2.3 Research

• INVISIP – Information visualization for site planning (Hans Hauska)
• Determination of image quality for very high resolution satellites (Anders Boberg)
• Integrated sensor technology for remote sensing and photogrammetry (Helén Burman)
• Integration of digital elevation and geophysical data for geodynamic studies (Maria Roslund)
• Autonomous photogrammetry using a ground-based inertially navigated digital camera (Kennert Torlegård, Milan Horemuz)
• Real-time determination of position and attitude for robotic tools (Milan Horemuz, Kennert Torlegård)
• Calibration of digital cameras for integration with laser scanner (Helén Burman)
• GPS software for integrated GPS/INS navigation of unmanned helicopter (Milan Horemuz, Kennert Torlegård)

### 2.4 International engagements

At the ISPRS 2000 congress in Amsterdam, KTH was represented by 3 persons (Torlegård, Burman and Boberg). Torlegård was outgoing first vice president of ISPRS, Boberg was Swedish representative at the General Assembly and outgoing member of the Financial Commission.
In 2000 Torlegård was outgoing Chairman of the OEEPE Science Committee.
In 2002 an international symposium Photogrammetry meets Geoinformatics was organized in Jönköping in honor of prof Torlegård, led by Anders Boberg.

### 2.5 Other engagements

In 2001 prof Kennert Torlegård and Anders Boberg were elected honorary members of the Swedish Society for Photogrammetry and Remote Sensing.
The department has been engaged in planning of measurements on the warship Vasa, using geodetic methods as well as laser scanning, to a limited extent also photogrammetry (Boberg, Horemuz).

### 2.6 Events

In 2001 OEEPE organized a workshop at KTH on Airborne Laser Scanning and Interferometric SAR for Detailed Digital Elevation Models, led by prof Torlegård.

### 2.7 Address

Geoinformatics and Photogrammetry, Dept. of Infrastructure
Drottning Kristinas väg 30
SE-100 44 Stockholm, Sweden
Home page: www.geomatics.kth.se/index_eng.html

### 2.8 Key publications

Boberg A. 2001. Fracture Mapping at Exposed Rock Faces by Close Range Digital Photogrammetry and Geodetic Total Station. (With Q. Feng and O. Stephansson). Rock Mechanics in the National Interest. Elsworth et al, eds, Swets & Zeitlinger Lisse. 38th U.S. Rock Mechanics Symposium, Washington DC, July 7-10, 2001.

Boberg A. (ed) 2002. Proceedings, Symposium "Photogrammetry meets Geoinformatics". Bildteknik/Image Science 2002:1. 238p.

Burman H. 2000. Calibration and Orientation of Airborne Image and Laser Scanner Data Using GPS and INS. Doctoral dissertation. KTH Dept of Geodesy and Photogrammetry, Stockholm. TRITA-GEOFOTO 2001:11. 111p.

Carballo G. 2000. Statistically-based Multiresolution Network Flow Phase Unwrapping for SAR Interferometry. Doctoral dissertation. KTH Dept of Geodesy and Photogrammetry, Stockholm. TRITA-GEOFOTO 2000:1. 186p.

Dunkars M. 2001. Automatic Generation of a View to a Geographical Database. Licentiate thesis. KTH Dept of Geodesy and Photogrammetry, Stockholm. TRITA-GEOFOTO 2001:18.

Ottoson P. 2001. Geographic Indexing and Data Management for 3D-Visualisation. Doctoral dissertation. KTH Dept of Geodesy and Photogrammetry, Stockholm. TRITA-GEOFOTO 2001:17.

Torlegård K. (ed) 2001. Proceedings of OEEPE workshop on Airborne Laser Scanning and Interferometric SAR for Detailed Digital Elevation Models. KTH Dept of Geodesy and Photogrammetry, Stockholm. TRITA-GEOFOTO 2001:17.

## 3. UNIVERSITY OF GÄVLE, PHOTOGRAMMETRY AND REMOTE SENSING AT THE GEOMATICS PROGRAMME

### 3.1 Organisation

The Geomatics Programme at the University of Gävle covers an integration of topics like geodesy, photogrammetry, remote sensing, cartography and geographical information technology.
The undergraduate programme at the university is a three-year programme and leads to a Bachelor of Science in Geomatics Engineering. This programme is also open for English spoken exchange students, being at the same level at their home University, wanting to spend a part of their studies abroad. In Gävle we offer a full academic year in English. The postgraduate programme is a two-year programme and requires the undergraduate, or an equivalent, programme for admission. The programme is primary meant to widen the vocational abilities of the enrolled students and a completion leads to a Degree of Master of Geomatics. This programme is fully open for English spoken exchange students who fulfils the admission

requirements and want to obtain a masters degree at the university

### 3.2 Education

**3.2.1** Photogrammetry and remote sensing courses
In the photogrammetry and remote sensing discipline following undergraduate courses are currently given and similar courses have been given during the period 2000-2004:

**3.2.2** Photogrammetry and image processing, levelA-basic. (in Swedish)
The course is an introduction to photogrammetry whit focus on photogrammetric mapping from aerial images. Throughout the course a project work is realised, including orientation of a stereo pair and stereo plotting in both an analytical instrument and a digital photogrammetric workstation. Basics in image processing processes, related to digital photogrammetry, are also covered.

**3.2.3** Photogrammetry analytical/digital, levelB-intermediate. (in English if requested)
The course includes analytical fundamentals in photogrammetry and standard processes in modern digital photogrammetry; e.g. aerial triangulation, generation of elevation models and production of ortho photos.

**3.2.4** Remote sensing level C-advance. (in English, if requested)
Different types of satellites, sensors, etc., are treated. However, the main emphasis is put on image interpretation and analysis. The course also consists of a project work where a satellite image is classified with respect to land use.

**3.2.5** Industrial and special measurements level C (advance). (in English, if requested)
Terrestrial photogrammetry is treated in the course with the purpose of detecting e.g. displacements caused by, for instance, stress. Also detection of 3D medium- to high-speed movements by photogrammetric methods are treated.

**3.2.6** Thesis work
Throughout the period both Swedish and international exchange students have been using the terrestrial laser scanning equipment in their thesis work. Laser scanning for elevation modelling have been compared with traditional surveying techniques, measurement and modelling of different types of environments have been tested, including image based texture mapping, and accuracy performance tests have been accomplished. Besides thesis work using terrestrial laser scanning, other students finalised their thesis work at the National Land Survey of Sweden comparing data acquisition from film based digital imagery with data acquisition from digital imagery directly captured with a Leica ADS40 camera.

**3.2.7** Photogrammetry and remote sensing facilities
In 2001 investments were made in four digital photogrammetric Delta DPS system from GeoSystem in Ukraine. Later 2001 the university invested in the latest technology in terrestrial laser scanning, a Cyrax 2500 system from Leica Geosystems. The university also holds an analytical Zeiss P33 stereo-instrument, still in use, and for the remote sensing course the University uses the Erdas Imagine software from Leica Geosystems. For image interpretation ten mirror stereoscopes are available as well as a wide range of aerial photographs for different types of analysis. In 2002 the analogue Wild A7 stereo-instrument was dismantled and 2003 our Balplex equipment and our Wild A8 instrument was taken apart. The Wild A8, equipped with encoders for digital read-out, was in use until 2001, the Wild A7 and the Balplex, on the other hand, had not been in use for many years.
The Centre for Built Environment at the university possess one FLIR THV 1000 longvawe infrared camera (8-14μm) to be mounted on a cart, a mast on a car, helicopter or fixed-winged aircraft. The centre also has one FLIR THV 570 (8-12μm) infrared camera which could be used as stationary unit, handhold or car mounted. The infrared systems described are mainly used within different R&D projects for building, technical infrastructure and environmental applications.

### 3.3 Research

Research and development has lately focused on the newly invested terrestrial laser scanning equipment. Staff from the university have attended international events like; the 5th International Conference on Optical 3-D Measurement Techniques in Vienna, Austria 2001, the CIPA International Workshop on Scanning for Cultural Heritage Recording and the ISPRS Symposium Close-Range Imaging, Long-Range Vision both in Corfu, Greece 2002, and the 4th International Conference on 3-D Digital Imaging and Modeling in Banff, Canada 2003. At the CIPA Workshop in Corfu, the PhD student from the university, Mikael Johansson, presented his paper – "Exploration into the Behaviour of Three Different High-Resolution Ground-Based Laser Scanners in the Built Environment".
During the period 2000 – 2004 the main R&D activities at Centre for Built Environment have been devoted to development of passive gas imaging methods for methane, LPG and biogas detection, which represent the Swedish part of an EU-project named "Visualisation of Gas for Utilities and the Environment" (VOUGE ENK6-CT2000-00054). The Swedish budget runs to a total about 6 milj SEK, and is financed EC and by the Swedish Government through the research council STEM. Swedish partners in the VOGUE-project are University of Gävle, Swedish Gas Centre (SGC), Southgas (Sydgas AB) Malmö Firebrigade, and The Solid Waste Company of Southwest Scania (SYSAV). Other EU-project partners are ADVANTICA (former British Gas), Italgas, Glasgow University, Siemens AG Germany, AOS Technology Ltd (AOS) UK, Electrabel Ebel) Belgium.
In another ongoing project infrared technology has been used to detect temperature anomalies in a greenhouse heated by gas driven IR-radiators. The title of the main project is "Gas based infrared radiant heating in greenhouses. Aspects of energy use and plant development". Project partners are the Energy Institute LTH Lund, Swedish Agriculture University Alnarp, University of Gävle, Swedish Gas Centre (SGC), Kjell Ingvars Greenhouse Company AB, Sotuthgas Malmoe, etc. The project is financed by among others the Swedish Government through the research council STEM.

### 3.4 Events

In October 2002, a two-day seminar about terrestrial laser scanning was realised at the university, with more than 100 attendees and all major developers of terrestrial laser scanning present as exhibitors.

### 3.5 Address

University of Gävle

S-801 76 Gävle, Sweden
Home page: www.hig.se

### 3.6 Publications

Johansson, M. ”Exploration into the Behaviour of Three Different High-Resolution Ground-Based Laser Scanners in the Built Environment”, Proceedings of the CIPA WG 6 International Workshop on Scanning for Cultural Heritage Recording, September, 1-2, 2002, Corfu, Greece.

Ljungberg, S-Å, Jönsson, Owe. Infrared Thermograpy-A tool to map temperature anomalies of plants in greenhouse heated by gas fired infrared heaters. Thermosens XXIV, SPIE Vol 4710, Bellingham, Washington, 2002.

Ljungberg, S-Å, Jönsson, Owe. Passive gas imaging-preliminary results from gas leak simulations – a field study performed during real world conditions. Thermosense XXIV, SPIE Vol 4710, Bellingham, Washington, 2002.

Näslund, M, Schussler, H, Ljungberg, S-Å, Jönsson, O. ”Gas based infrared radiant heating in greenhouses. Aspect of energy use and plant development”, World Gas Centre Symposium, 29 Maj 2003, Tokyo.

## 4. LULEÅ UNIVERSITY OF TECHNOLOGY

### 4.1 Organisation

Luleå University of Technology was established in 1997, when the former university college in Luleå attained the status of university of technology. The university conducts research within the Faculty of Engineering and the Faculty of Arts and Sciences. The university also provide education in the spheres of engineering, the social sciences, the humanities, teaching, the health sciences, music, media education, and drama. It has about 11300 students enrolled and a staff of 1400. In addition to the main campus in Luleå, the university have campuses in Piteå, Kiruna, Boden and Skellefteå. The university has currently 14 departments, one of them being the department of environmental engineering.
The department of environmental engineering is one of the larger departments of the university. It has a staff of 90-100 employees and is divided into 8 divisions, representing different scientific fields such as waste science and technology, renewable energy, geographic information technology, applied ore studies, applied geophysics, applied geology, traffic engineering and sanitary engineering. The department is responsible for several educational programs, such as the MSc program in environmental engineering and the BSc program in environmental and quality management.
The division of geographic information technology was established in 1993. It has a staff of around 10 employees, mainly teachers and PhD students. The division is responsible for providing GIS-related courses within the university and to conduct research in GI science.

### 4.2 Developments in teaching and education

During the last 4 years, the conditions for higher education in Sweden have changed considerably. The income for giving courses is nowadays based on the number of students attending the course and the number of students completing the courses. In addition, the students now have the possibility to design their own study plan, which means that they can freely select any course given at the university. As a consequence, each department and division has to pay an increasing amount of attention on student satisfaction, within this new more competitive environment.

In 1998, the GIT division was giving 10 different GI-related courses, with an average of 22 students per course. Since then, the education has moved away from cartography and surveying courses to courses related to software engineering, system development and web services. One course has been removed (photogrammetry) and 7 more courses has been added. The total number of courses is now 16, with an average of 43 students per course. The total number of students has been tripled, which is an indication of the interest and attention current students pay modern geographic information technology. Today, the following courses are given

- Geographic information technology, basic course
- Remote sensing
- Spatial analysis
- Cartographic Visualization
- Geodesy, calculation techniques
- Geographic real-time systems
- Basic programming
- Basic course in database systems
- System construction on the technology front
- System development in geographic information technology
- Introduction to VB.NET and Windows based application development
- Introduction to Web Services .NET
- Web mapping
- Geographic database technology
- Implementation of geographical information systems
- Metadata and XML

Another major change during the last four years is the introduction of net-based learning. Today, all courses above are given on the Internet, the lectures as well as the exercises. To facilitate this, investments have been made in a central Citrix server. Using this concept, the students only need a PC with a web browser and a fair internet connection, to have access to all lectures and exercises including software and data. Most of the courses are also given in English.

### 4.3 Research

The research at the division of geographic information technology is mainly performed by PhD students. During the period 1999-2002, the research activities have increased by 71% (in person months), with an average of 54 person months per year as an average. During the period, three PhD students has been awarded a licentiate degree with the following thesis’s

Magnus Åström - Implementing artificial neural networks in microsimulation.
Johan Esko - Synthetic microdata.
Christian Lundberg - Geographic information in internet related technologies.

The current research activities are based on the use of Web services. Standardized Web services as defined by the Open GIS Consortium (OGC) are implemented in the baseline of research facilities. Then, as a part of the research, additional

web services are built on top, facilitating the use of the baseline services.
The current research program of the division is focusing on themes such as

- Data quality and data usability
- Environmental modelling
- Real-time and mobile systems
- Metadata and SDI's

During the period, around 25 MSc theses and 30 BSc theses have been completed.

### 4.4 Address

Luleå University of Technology
SE-971 87 Luleå, Sweden
Home page: www.luth.se

## 5. THE REMOTE SENSING LABORATORY, DEPARTMENT OF FOREST RESOURCE MANAGEMENT AND GEOMATICS, SWEDISH UNIVERSITY OF AGRICULTURE SCIENCE, UMEÅ

### 5.1 Organisation

The Remote Sensing Laboratory currently has a staff of about 20 persons. The fields of activity are teaching in GIS and remote sensing, research in forestry remote sensing, but also operational environmental monitoring.

### 5.2 Research

One research field has been the use of spatial statistics for combining forestry field plot information and image data into spatially continuous raster databases. A PhD thesis has been finalized (Wallerman 2003), where the performance of different statistical methods has been compared.
Another very active research field has been laser scanning of forest resources. Both stand level and single tree level methods for estimating forest parameters have been developed. At stand level, forest stem volume can be estimated with an accuracy of about 10 – 15 % RMSE, which is better than other remote sensing methods. At single tree level, tree height and canopy diameter can be measured with an accuracy of about 0,6 m for about 70 % of the trees in a forest stand (Persson et al., 2002). This research was done in co-operation with the Swedish Defense Research Institute, FOI. A PhD thesis about laser scanning of forest resources was finalized (Holmgren, 2003). In connection to that event, the first European scientific workshop about laser scanning of forest resources was also held (Hyyppä et al, 2003). Research is also ongoing in the field of single tree detection in optical imagery, using template matching techniques.
The radar remote sensing research has under the period been concentrated on VHF SAR, using the Swedish CARABAS-II sensor. The research has been carried out in co-operation with FOI, Chalmers University of Technology, and the company Dianthus. Robust results on stem volume estimation for mature boreal coniferous forests have been demonstrated at a number of test sites, without any signs of saturation of the radar signal for high stem volumes. Furthermore, a pilot study has been carried out with the objective to assess this capability in an operational scenario. A fully integrated production line has been developed for this purpose, i.e. to derive forest variables in the end-user data format from the VHF SAR data acquisitions (Fransson et al. 2002).

### 5.3 Development

It is now possible to receive GPS positions from animals via cell phone technology. Using co-ordinates from moose with GPS collars, and raster maps of forest variables derived from satellite images, the habitat selection of moose have been studied (Dettki et al, 2002).
In the field of operational environmental monitoring, the group has finalized a number of forestry related products which are based on the combined use of a nation wide coverage of Landsat TM data, digital map masks, and about 50 000 GPS positioned, 10 m radius, national forest inventory plots. All products have in common that the images and field plots also are processed together in a pre-processing chain, where slope effects, within-scene haze differences, and the effects of geometric errors, have been reduced. The products developed to date are: a nationwide forest classification, used in the national version of the CORINE database; continuous estimates of forest variables (mainly volume per species) for 25 m pixels (Reese et al., 2003); and routines for improving the results from the sample plot based national forest inventory using post-stratification. The products have been financed by a number of national authorities.
Finally, staff from the remote sensing laboratory is also participating in the interpretation of air photos for a systematic sample of 600, 5 * 5 km areas in Sweden. The purpose of the project, called National Inventory of Landscapes in Sweden, is to establish a foundation for monitoring of landscape development. The interpretation is done in digital photogrammetric workstations.

### 5.4 Address

The Department of Forest Resource Management and Geomatics, SLU.
SE-901 83 Umeå, Sweden
Home page: www.resgeom.slu.se/eng/avdelningar/Fjarranalys/

### 5.5 Key publications

Fransson, J.E.S., Frölind, P.-O., Gustavsson, A., Smith, G., Ulander, L.M.H., and Walter, F. 2002. Introducing VHF SAR data in forestry applications. In Proceedings of ISPRS 2002 Conference, 29th International Symposium on Remote Sensing of Environment, Buenos Aires, Argentina, 8-12 April, 2002, 6 pages (CD-ROM).

Dettki, H., Löfstrand, R., and Edenius, L. 2003. Modeling habitat suitability for moose in costal northern Sweden. Empirical vs. Process-oriented Approaches. Ambio 32:549-556.

Holmgren, J. 2003. Estimation of forest variables using airborne laser scanning. Acta Universitatis Agriculturae Suecia, Silvestria 278.

Hyyppä, J., Næsset, E., Olsson, H., Granqvist Pahlén, T., and Reese, H. Proceedings of the Scandlaser Scientific workshop on airborne laser scanning of forests. Working paper 112. Department of forest resource management and geomatics, Swedish university of agricultural sciences.

Persson, Å, Holmgren, J., Söderman, U. Detectiong and measuring individual trees using an airborne laser scanner. PERS 68:925-932.

Reese, H., Nilsson, M., Granqvist Pahlén, T., Hagner, O., Joyce, S., Tingelöf, U., Egberth, M., and Olsson, H. 2002. Countrywide estimates of forest variables using satellite data and field data from the national forest inventory. Ambio 32:542-548.

Wallerman, J. 2003. Remote Sensing Aided Spatial Prediction of Forest Stem Volume. Acta Universitatis Agriculturae Suecia, Silvestria 271.

## 6. CENTRE FOR IMAGE ANALYSIS - UU, SLU

### 6.1 Organisation

The Centre for Image Analysis (CBA) is a joint university entity between Uppsala University (UU) and the Swedish University for Agricultural Sciences (SLU). The main activities at CBA are graduate education and research. Image analysis is in its essence interdisciplinary, its foundations being in mathematics, statistics, physics, and computer science, and its applications – with respect to CBA – are ranging from shape analysis of HIV viruses to detection of coral bleaching in tropical seas.

### 6.2 Research

Forest inventory from air-borne sensors have been an active and productive research field in the *SLU Forest group* since its beginning in 1994. The aim is to make inventory from such data so detailed and correct that it can replace field inventories, except for small investigations to collect ground truth. Earlier work has been dedicated to development and evaluation of methods for extracting stand-wise forest parameters from CARABAS VHF SAR images. Lately, accurate segmentation methods for tree crowns, and species identification based on this segmentation, has been developed. The main goal is to be able to differentiate between spruce and pine. Even though they have the same spectral signatures, they do have, on the average, different shapes and internal structure.
There has been several projects at CBA that investigates the possibility to use satellite data for agricultural analyses. During 2000 and 2001 the aim of these projects, within the *SLU agricultural group,* were to develop general methods for automatic field segmentation in satellite images, which is important for mapping and for improving classification. Multispectral edge detection was combined with regions extraction and shape analysis.
The research of the UU Aquatic Remote Sensing group is focused on different environmental applications of digital remote sensing. The present activities vary from mapping and monitoring of algae blooms and distribution of plumes to mapping and monitoring of tropical coasts and sea bottoms. One important area of research is our continued development of image analysis methods for imaging spectrometry. Much effort has been put into the procedures for pre-processing of remote sensing data and the development of bio-optical modelling for more operational monitoring of water quality from space. The long-term goal here is using satellite, together with airborne hyperspectral data, for algae bloom detection, eutrophication, and pollution in Nordic waters. One aspect of the latter we have worked on is detection of industrial plumes in lakes and seas. The aquatic group at CBA also work on the detection of coral bleaching from remote sensing sources. The work includes sensors like IRS-LISS-III, SPOT, and IKONOS. A new project in the group is focused on acquisition and colour correction of underwater multi- or hyperspectral data (e.g., colour photos). This can be important for many applications, such as marine biology and underwater archaeology.
CBA also work theoretically on developing techniques for analysis of hyperspectral image data. An important aspect is developing linear transformations method, based on such transforms as the familiar PCA (Principal Component Analysis) and the more recent ICA (Independent Component Analysis.) New techniques for information extraction using neuro-fuzzy systems, i.e., so-called Weighted Neural Networks (WNN) are also being developed.

### 6.3 Address

Centre for image analysis
Lägerhyddsvägen 3
SE-752 37 Uppsala, Sweden
Home page: www.cb.uu.se/index_eng.html

### 6.4 Key publications

Fransson, J.E.S.; Walter, F.; Ulander, L.M.H.; Estimation of forest parameters using CARABAS-II VHF SAR data . IEEE Trans. on Geoscience and Remote Sensing. - 2000 (38): 2, pp. 720-727.

Rydberg, A., Multispectral Image Analysis for Extraction of Remotely Sensed Features in Agricultural Fields . 2001. Acta Universitatis Agriculturae Sueciae. Agraria 296.

Östlund C; Flink P; Strömbeck N; Pierson D; Lindell T, Mapping of the water quality of Lake Erken, Sweden, from Imaging Spectrometry and Landsat Thematic Mapper. Science of the total environment. - 2001 (268):1-3 , s. 139-154.

Ammenberg Petra, Flink Peter, Pierson Don, Lindell Tommy and Strömbeck Niklas, Bio-optical Modelling Combined with Remote Sensing to Assess Water Quality. International Journal of Remote Sensing. - 2002 (23) 8 , s. 1621-1638.

Brandtberg, Tomas, Individual Tree-based Species Classification in High Spatial Resolution Aerial Images of Forests using Fuzzy Sets. Fuzzy Sets and Systems. - 2002 (132):3 , s. 371-387.

Erikson, Mats, Segmentation of individual tree crowns in colour aerial photographs using region growing supported by fuzzy rules. Canadian Journal of Forest Research. - 2003 (33):8, s. 1557-1563.

Hamid Muhammed, H.; Larsolle, A., Feature Vector Based Analysis of Hyperspectral Crop Reflectance Data for Discrimination and Quantification of Fungal Disease Severity in Wheat. Biosystems Engineering. - 2003 (86) : 2 , s. 125-134.

Philipson, Petra, Environmental applications of aquatic remote sensing. 2003. Acta Universitatis Upsaliensis 812.

Åhlén Julia, Sundgren David, Bottom Reflectance Influence on a Color Correction Algorithm for Underwater Images. 13th Scandinavian Conference, SCIA 2003 Göteborg, Sweden, June 29-July 2, 2003. - Springer Verlag Berlin Heidelberg New York, 2003 (1) : 1 - S. 922-926 - (Lecture Notes in Computer Science)

## 7. THE NATIONAL LAND SURVEY OF SWEDEN

### 7.1 Organisation

The National Land Survey of Sweden, originating from 1628, is a Government agency under the Ministry of the Environment. The mission is to give support for creating an efficient and sustainable use of Sweden's real property, land and water. The organisation has three main activities, which also form the organisational structure: Cadastral services, Land and Geographic Information Services, and Metria (working on a competitive, commercial basis). Support for these activities is provided by corporate functions. Swedesurvey is the overseas agency of the National Land Survey of Sweden. The headquarter is situated in Gävle with a total staff amount of 2,000.

### 7.2 Land and Geographic Information Services

This activity, which is carried out at the central office, comprises responsibility for gathering, administering and making available basic land-related data, geoinformation and information on Sweden's 3.2 million real properties. It includes basic geographical databanks, the series of official maps (printed and on CD), information from geodetic and aerial photo archives, the land data bank system, central registers of buildings, apartments and address as well as the credit market (mortgage) system. The responsibility for all kinds of basic information services lies on the division archives, registers, maps, databases but the division has no production resources.
The division works out the technical specifications needed and purchases the production from Metria (the commercial department) or from other providers. The division also holds the competence for development concerning geodesy, photogrammetry, cartography and geographic information systems.
Lantmäteriet are continuously covering Sweden with aerial images. Images are acquired from an altitude of 4600 meters with colour, near-infrared and black/white sensitive film. The ambition - a complete digital photogrammetric production - has formed the development and production activities for several years.
The scanning of positive film has been minimised of economical and environmental reasons. Next alternative, scanning directly from negative film rolls requires tonal adjustment, earlier manually performed. Lantmäteriet uses in-house developed softwares for tonal adjustment as well as image quality control.
In next phase digital images will be acquired by a digital camera, Digital Mapping Camera, produced and marketed by Z/I Imaging. Test flights from different altitudes will be performed and evaluated during the summer of 2004. A consequence of digital registrations, without any hard-copies, is the increased requirement of storage capacity. An investigation of these demands is also included in the evaluation of the complete digital production chain.
Sweden is covered by a digital elevation model, grid size 50 meter, accuracy rms > 2 m. The DEM, produced to meet earlier ortho photo requirements, need to be updated. Laser scanning from an altitude of 2000 meter, and covering an area of 625 $km^2$, will be processed and evaluated during 2004. The major topic to solve is the integration of vector data in the filtering and classification processes, which also leads to harmonised data sets. Requirements of production time, costs and accuracy will probably form areas with different quality demands and acquisition techniques.

### 7.3 Metria

Metria carries out its services on contract and operates on the national and international markets. Metria has a total staff of 400 of which more then 100 are working with EO- and GIS-related tasks.
Metria is a distributor of satellite imagery from all the commercially available sensors; i.e. EROS, IKONOS, SPOT, Landsat, IRS, Radarsat and ERS. During 2003 Metria concluded the Swedish CORINE Land Cover mapping including a national product with 1-5 hectares minimum mapping unit. Metria is a partner in four GMES Service Element, GSE, which was started in 2003. These are GSE Forest Monitoring, which focus on the Kyoto reporting and national forest legislations, GSE SAGE that focus on information requirements for the water framework directive, GSE RISK-EOS which include services for risk management such as flooding or forest fires and RESPOND focusing on information services for humanitarian aid.
Late in 2003 a project within the ESA EOMD program also was concluded. It focused on medium-scale mapping services for watershed monitoring by using ENVISAT MERIS satellite data.
Metria has been a partner within the Global Land Cover 2000 project, which was concluded during 2003, in which Metria was responsible for the land cover classification of the Baltic Sea drainage basin.
Metria has during 2003 carried out nine development projects together with Swedish users within the Swedish National Space Board's program for remote sensing applications, within areas such as environment, forestry and security. Metria has also carried out several mapping projects using remote sensing on contract from Swedish users such as the Swedish Environmental Protection Agency, the Swedish Board of Agriculture and the Swedish Nuclear Power Inspectorate.
Metria has been the programme manager for the large Remote Sensing for the Environment (RESE) programme, which was concluded during 2003 after six years. About 60 researchers from the major Swedish remote sensing institutions have been involved in the program. The RESE program has focused on the development of remote sensing methodology for environmental purposes, ranging from the marine environment to the mountainous areas.

### 7.4 Address

Lantmäteriet
SE-801 82 Gävle Sweden
Home page: www.lantmateriet.se

## 8. SWEDISH NATIONAL ROAD ADMINISTRATION - SNRA

### 8.1 Organisation

The SNRA is the national authority assigned the overall sectoral responsibility for the entire road transport system. The SNRA is also responsible for drawing up and applying road transport regulations. In addition, the SNRA is responsible for the planning, construction, operation and maintenance of the state roads.

### 8.2 Research

Since 2001 a major part of SNRA´s photogrammetric research, development and production is managed by consultants.
Investigations and tests of mobile mapping systems for road inventories have been made in corporation with commercial organisations, Visimind AB and WSP. Objects, close to the roads, where measured semi-automatically in stereo images, acquired from a moving vehicle. The technique was quality checked and used for i.e. road sign inventory.
Digpro, a GIS consultant company, investigated and evaluated digital image and measured data formats suitable for deliverance to SNRA. Laser scanning from helicopter, also a Digpro project, for road planning, mapping and investigations is another example of co-operation with an external company.

### 8.3 Production

Former SNRA photogrammetric equipment is used for educational purposes at KTH and at a regional level of SNRA. Quality control of external, consultant, produced information is also performed at the regional offices equipped with photogrammetric competence.

### 8.4 Address

Swedish National Road Administration
SE-781 87 Borlänge, Sweden
Home page: www.vv.se

## 9. SWEDISH METEOROLOGICAL AND HYDROLOGICAL INSTITUTE - SMHI

### 9.1 Organisation

SMHI, the Swedish Meteorological and Hydrological Institute, operates under the auspices of the Swedish Ministry of the Environment and uses its meteorological, hydrological and oceanographic expertise to promote efficiency, safety and a better environment in various areas of society.

### 9.2 Research

At the Research Department at SMHI methods and models are developed for utilising remote sensing information. The results are used within our core fields of meteorology, climatology, hydrology and oceanography. The main activities are founded on radar and satellite based platforms, but SMHI also uses other remote sensing systems. It could be ceiliometers, lightning location systems and instruments for observing the amount of stratospheric ozone.
Information from radar and satellite instruments are used in preparing forecasts but is also presented as animations or as pictures of the present weather for media and the public. In later years the remote sensing information, in particular from satellite based instruments (e.g. TOVS, MODIS) but also from radar have been included in the forecast models. The result has been notably improved forecasts. SMHI is active within the European co-operation EUMETSAT together with other institutes to utilise information from both polar and geostationary meteorological satellites. Our speciality is cloud analysis. Typical output products are cloud types, cloud top temperature and probability for precipitation. These products have to be available as soon and as frequent as possible to be used for near real time forecasting. We have been very successful and now the system will be developed further to be used for climatological applications.
In oceanography remote sensing data has been used for studies of ice cover extension, sea surface temperature and episodes of algae bloom, which is important for shipping, climate and water quality. In hydrology the interest has been focused on snow cover but the ultimate goal would be snow and ground water content.
Also radar data can be used in near real time. A co-operation between the Nordic countries (NORDRAD) gives a good spatial coverage. Present improvements have the goal to reduce the influence from error sources such as eliminate echoes that is not connected to precipitation. The large challenge is to quantify precipitation, which would be an important complement to the relatively sparse gauge network. By using Doppler technique wind profiles and 3-dim wind fields can be obtained. This information is assimilated in the meteorological forecast models.
At SMHI there is a model system for mesoscale analysis, Mesan. Within this system all available information on the atmosphere is assimilated and synthesised hour by hour. The goal is to have as good description of the atmosphere as possible for every hour for a number of variables, e.g. precipitation, clouds and temperature. Mesan covers a large part of northern Europe. Remote sensing data is a large and important component in this system.
The activities where remote sensing data is used is done by participation in national and international projects, e.g. Swedish National Space Board, in a number of EUMETSAT Satellite Application Facilities (SAF), NORDRAD2, COST-projects, EC funded projects.

### 9.3 Address

SMHI
SE-601 76 Norrköping, Sweden
Home page: www.smhi.se

### 9.4 Key publications

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Lindquist, K. K. 2003. Studies of the temporal and spatial variability of an ice cover, the sea surface temperature, and the colour of coral using satellite-based remote sensing techniques. Thesis for the degree of Licentiate in Philosophy presented at Göteborg University 2003. A86 2003, ISSN 1400-3813. 74 pp.

Michelson, D.B., 2003: Quality Control of Weather Radar Data for Quantitative Application. PhD thesis. Telford Institute of Environmental Systems, University of Salford, Salford, Greater Manchester, UK, 281 pp.

## 10. THE SWEDISH FOREST ADMINISTRATION

### 10.1 Organisation

The Swedish Forest Administration consists of The National Board of Forestry and The Regional Forestry Boards. The administration is among the largest users of remotely sensed data in Europe. Aerial photos has been used extensively for many, many years. Since 2003 is also digital ortho-photos among the standardised data sets that's being used in the whole administration all over the country.

### 10.2 Research

The organisation has already today an operational use of Earth Observation-data. We are using it on a recurrent basis since 1996. National coverage of either SPOT XS or Landsat TM data has been collected every year since 1999 and is now an essential part of the reforestation monitoring process.
A link between our GIS system and a remote sensing application called ENFORMA has been established in which the best part of both system can be fully exploited. Through the link are all the regeneration fellings detected in the whole country on a yearly basis. A total of about 40,000 – 50,000 cuttings are detected and mapped this way. All analysis activities are based on local knowledge and actual performance which means that more than 100 people are engaged in only the first step of this process.
Change detection is made on a pixel to pixel basis with image pairs from different years and the result is a single band 8-bit image. The resulting image is further refined through thresholding and minimum area filtering into a resulting clear-cut image. The clear-cut image is vectorised and imported to our GIS system were each and every found cutting is verified against other reference data as well as local knowledge.
The evolution potential is very strong. EO data has successfully proved to be a very powerful tool in the area of change detection. We have only seen the start of the use of it and are expecting to have several operational processes that deal with mainly monitoring tasks, just within a few years from now.
The organisation has adopted an image supply policy that not only deals with the basic supply of images but also the overall remote sensing competence for the main part of all employees and decision makers within the organisation. During 2004 will a comprehensive program start that will focus on improved competence and the use of EO data in conjunction with the organisations main goals.

## 11. THE LOCAL AUTHORITIES

### 11.1 Organisation

The 290 local authorities in Sweden have a well-developed self-governance and are by constitution, autonomic. They are, by law, responsible for such things as social services, schools, health and environmental protection; refuse collection and waste disposal, rescue services, water and sewerage, order and security, spatial planning and building. To perform their tasks, geographical data and maps are used in several ways. There is a considerable need for different maps in a variety of activities and operations. The role of the local authorities in providing basic large-scale geographic data becomes more important as its usage increases in a lot of old and new applications, where GIS offers good support. There is also municipal co-operation within regions as well as between the municipalities and the state, in order to provide society with quality controlled geographic data. Most local authorities produce and update geographical databases or maps within their organisation.

### 11.2 Production

In approximately 10 municipalities the photogrammetric production is performed inside the organisation. Wide ranges of geographical information for different purposes at different scales are produced in digital photogrammetric workstations. Experiences show that production and revision of large-scale maps, digital elevation models, 3D-city models and visualisation are handled more cost and time efficient.
Environmental and vegetation studies in Norrtälje are handled in Erdas. In Umeå, Stockholm, Malmö, Linköping, Norrköping, Jönköping, Järfälla and Falun the Finnish ESPA system is used for different types of 3D mapping.

### 11.3 Education

Unfortunately employees without photogrammetric education or practical experiences are introduced to 3D mapping. Training, including some education is usually supplied by the photogrammetric software company. Consequences are seen in quality discrepancies including geometrical errors as well as object classification.

### 11.4 Address

Swedish Association of Local Authorities
SE-118 82 Stockholm, SWEDEN
Home page: www.svekom.se

## 12. PRIVATE PHOTOGRAMMETRY CONSULTANTS

The status of Swedish economy has influenced the size of grants for research and development to universities and governmental organisations. Consequently, a major part of the research and development of photogrammetry and remote sensing is performed by commercial consultant companies in Sweden. Below, a sample of organisations and their research projects are briefly described.

### 12.1 Digpro AB

**12.1.1** Organisation
Digpro is an IT consulting company with long experience of consulting and application development in the geographic IT field. Digpro has always used front-end technology and is today one of the leading providers of products and services in this field in Sweden.

**12.1.2** Research and products
Digpro is actively taking part in the development of Laser scanning and use of this front-end technique. The method is marketed together with Topeye AB, who sells and operates the airborne laser scanning system. Digpro offers services like filtering and classification of laser data, production of digital

terrain models (DTM), digital ortho photos, 3D city models, Virtual Reality Modeling Language (VRML) Models, mapping in 2D and 3D and visualisation.

**12.1.3** Home page: www.digpro.se

### 12.2 Visimind

**12.2.1** Organisation

Visimind AB is a Swedish company which was launched in 1997. The company is a continuation of a Ph.D. project carried out at Stockholm's, Royal Institute of Technology (KTH). The research focused on Mobile Mapping Technology (MMS), automatic image processing and digital photogrammetry. The company is based in Stockholm, Sweden, but is active all over the country. In 2002 Visimind expanded to Poland, introducing it's daughter company, Visimind Ltd..Visimind produces and supplies 2D and 3D images, image sequences, positioning data, GIS and ASP solutions for all types of objects and applications. Visimind also produces and maintains geographic databases for a number major Swedish power companies, such as Vattenfall and the Swedish National Road Administration (Vägverket), amongst others.

**12.2.2** Research and products

- Laser scanning of the warship "Vasa" including a 3D photo-realistic modelling.
- Mapping and inspection of power lines based on Mobile Mapping Technology.
- Traffic and Safety planning based on information acquired with Mobile Mapping Technology.
- Development of INS/Camera system for indoor survey and 3D visualisation.
- Development and testing of mono-vision system for data acquisition of ortho-corrected video sequences in co-orporation with TopEye AB

**12.2.3** Home page: www.visimind.se

### 12.3 Spacemetric

**12.3.1** Organisation

Spacemetric is a systems company working with solutions in the area of geographical information. Combining geographical information with enterprise information we provide solutions that support operational business processes. Our solutions encompass all types of geographical information, map and survey information in both raster and vector format, as well as airborne and satellite imagery.

**12.3.2** Research and products

- SIP/Ortho is an integrated satellite ortho image production suite developed and distributed by Spacemetric. It provides a scalable production capability using rigorous photogrammetric methods to give high-accuracy image products at low cost. SIP/Ortho is designed for use by ground stations, mapping organisations and image data value-adders that prioritise a professional quality of image production. SIP/Ortho supports the following Sensor Models.
- The Web Map server can be used in a range of scenarios and might typically provide a value-added interface to an image catalogue. It extracts imagery on the basis of user searches and passes back the matching imagery. The searches are submitted by the GIS application through the WMS interface and the imagery from the catalogue is transformed into the specific co-ordinate system and map projection defined in the search. If multiple images are located these can be combined into a mosaic. Both image rectification and mosaicing are on-demand processes performed in near-real time.

**12.3.3** Home page: www.spacemetric.se

### 12.4 Metimur

**12.4.1** Organisation

Metimur AB was launched 1984 in Gothenburg as a consultant company. Metimurs business idea is numerical documentation, to position, size, form and properties, of objects and landscape.

**12.4.2** Research and products

- Mobile measurements of objects with ATOS, Advanced Topometric Sensor. The scanning is carried out at the customer office or at Metimur in a room special designed for the measurements. High densities of 3D-measurements cover the complete object. Each scanning session generates approximate 20 points/mm$^2$, with point accuracy, rms < 0.02 mm.
- 3D Close-Range Photogrammetry is used for modelling of statues, aeroplanes, boats and cars. Archaeological reconstructions and studies of crashed cars are also performed using photogrammetric and laser measurements.
- Geographical Information in 3D is produced in analytical and digital photogrammetric stereo instruments. Metimur produces ortho photos from aerial images and digital elevation models, DEMs. The DEM information is mainly laser data registered from helicopter or aeroplane.

**12.4.3** Home page: www.metimur.se

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