TECHNICAL COMMISSION III:
Theory and Algorithms

Submitted by T. Schenk

1. State of Science and Technology of Commission Topics

Commission III activities span a wide range from data acquisition, surface reconstruction, object recognition to image understanding. The State of Science in these diverse topics can be judged from papers presented at the symposium and at several workshops. The following summary also includes emerging trends that may eventually become state-of-the-art in future.

There is an increasing trend of using several different sensors in data acquisition, including non-optical sensors. As a consequence, data and extracted information must be combined. Solutions to this fusion problem are offered on several levels, for example on the sensor level (sensor integration, geo-registering, data fusion), feature level, or symbolic level. Such a neat separation is desirable but often very difficult to achieve. More research on the fusion problem will hopefully clarify these issues. It is interesting to observe that direct platform orientation almost completely disappeared from the research agenda as it has reached operational maturity. For applications that do not require utmost accuracy direct orientation eliminates the need for aerial triangulation.

As has been noted in the symposium report, automatic generation of DEMs used to be the central topic in digital photogrammetry. Attention has shifted to surface reconstruction with an emphasis on more explicit surface descriptions, for example by delineating surface discontinuities and segmenting the surface into piecewise smooth patches. Moreover, deriving surfaces from laser altimetry, perhaps in combination with surface information extracted from multiple images, including shape from shading, has gained considerable interest. The complete reconstruction of large-scale, urban scenes is far from being solved, however.

The majority of research related to Commission III is in the area of object recognition and image understanding. Since these are hard problems, progress is incremental. Most work concentrates on recognizing buildings and roads. Arguably, the single most deficient building block in the object recognition paradigm is modeling real-world objects. Recent advances in modeling include scale-space theory, as well as multispectral data, although this is mostly restricted to color at the moment. Yet another promising approach is to employ learning methods for establishing models.

2. Accomplishments of Commission during 1998

The major accomplishment in 1998 was the successful organization of the symposium, held in Columbus, OH from July 7 to 10. The conference topic *Object recognition and scene classification from multispectal and multisensor pixels* attracted over 160 participants from 16 countries. The presentations are published in ISPRS Intern. Archives, vol. 32, part 3/1 and 3/2, available from RICS. Six papers, selected by a

review committee under the direction of WGIII.3 (Helmut Mayer) and WGIII.4 (Eberhard Gülch), will appear in a special PERS issue.

The test site of Ocean City, established 1997, has been extended. Thanks to efforts of NGS and JPL, a hyperspectral data set with 2 meter ground resolution has been added. Commission III WEB site contains updated information about the data set. Moreover, a paper by Csatho and Schenk, Intern. Archives, vol. 32, part 3/2, describes the test site and data sets.

Technical sessions for the Congress in Amsterdam have been designed as far as convenor, session title and brief description are concerned.

3. Working Group Activities during 1998

WG III/1 Integrated Sensor Calibration and Orientation

Chair Peggy Agouris
Co-chair Ismael Colomina
Secretary Anthony Stefanidis

Accomplishments of WG during this period

During this period we continued to communicate with our members and exchange ideas, opinions, and news, mainly through e-mail and our WG Web pages, incl. the questionnaire page. We also had the opportunity to interact with interested scientists during the ISPRS Commission III Symposium in Columbus, OH, where some of our members participated with papers and presentations. It is worth mentioning that in Columbus, members of our WG presented 16 papers, the second highest number of 1998 CommIII Symposium papers per WG. We need to report here that we noticed a declining research interest and shrinking volume of new research efforts in the traditional issues associated with calibrations and orientations of existing sensors and an increase of interest in the issues of multi-sensor and multi-source integration as well as on the orientation methods of newer, non-optical sensors. Currently, we are participating in the organization of a multi-WG Workshop to take place in Munich next September (1999). In addition, we are organizing our own Workshop on the issues which are related to our WG's terms of reference, which is to take place in Portland, Maine in June 1999. ISPRS WG VII/1 is also participating in this effort. Our WG is also supporting the organization of an NSF-sponsored Workshop on "Integrated Spatial Databases: Digital Images and GIS", to take place also in Portland this coming June and in conjuction with the WG III/1 Workshop. Our future plans, beyond the two Workshops that we are currently organizing for 1999, include the organization of a short, informal meeting in Barcelona by the end of 1999, hopefully in cooperation with IAG and OEEPE, on "Direct vs. indirect methods for sensor orientation".

WG III/2 Algorithms for Surface Reconstruction

Chair Amnon Krupnik
Co-chair Charles Toth
Secretary Maxim Fradkin

Accomplishments and State of Science of WG Topics

The main activity of the Working Group during 1998 was the preparation and participation in Commission III symposium, held in Columbus last July. A total of 12 papers related directly to the subjects covered by the working group were presented in two technical sessions.

From the WG sessions at the symposium, as well as from papers in other sessions and related papers published in other meetings and journals, one may draw the following observations:

Automatic surface reconstruction and DEM generation are already considered as an existing technology, for which commercial software is widely used.

Despite the determination in (1), there is still an extensive research for finding new and improved matching and interpolation techniques. These include, e.g., discontinuity detection, least-squares matching in different domains (gradient image, frequency) and multi-image shape from shading.

Integration between surface reconstruction and object reconstruction/extraction has been investigated by many research groups. In particular, buildings are considered. Further research in this area is expected to open an avenue for automatic surface reconstruction in urban areas. Cooperation with WG III/3 and III/4 will intensify this research direction.

Several studies have shown the use of laser altimetry for direct surface reconstruction. Further research is still required in order to test the applicability of this technology, but there is no doubt it can be helpful in occasions where "traditional" surface reconstruction methods fail.

Using high resolution satellite imagery for surface reconstruction is expected to be efficient and accurate. Nevertheless, no actual results could be shown due to the delay in launching these systems.

The working group takes part in the organization of the ISPRS conference on "Automatic Extraction of GIS Objects from Digital Imagery," which will be held in Munich on September 1999. Regarding item (3) in the observations discussed above, surface reconstruction plays a major role in extracting such objects.

WG III/3 Feature Extraction and Grouping

Chair Helmut Mayer
Co-chair Ram Nevatia
Secretary Albert Baumgartner

State of Science and Technology

The importance of differential geometry and scale-space theory for feature extraction became clear only recently. The former enables one to define the features rather formally while the latter allows for handling the dependence of features on scale.

Sub-pixel analysis, alleviating the mixed pixel problem, seems to be a way to overcome problems in multi-spectral image classification.

Fusion of satellite imagery with different resolutions can improve the classification outcome but results in a need for additional modeling in image and also object space.

As the approaches reach their limits, their evaluation becomes more and more important. Recently, it was shown analytically and experimentally that a high sub-pixel accuracy can be reached for edge or line extraction combining Gaussian smoothing with differential geometry.

Grouping is essential because feature extraction alone cannot be expected to result directly into parts of objects. Particularly, two trends can be noticed: First, grouping uses more and more attributes such as the strength of the gradient or color values of the features themselves as well as of adjacent features. The other tendency is that grouping is done in three-dimensional object space using photogrammetric camera models.

Optimization techniques like snakes, which were used mainly in a semi-automatic manner until now, show a high potential for the verification of automatically extracted hypotheses for objects.

Simulated annealing and similar techniques make it feasible to optimize/learn parameters for image processing with the advantage of being able to overcome local minima.

Accomplishments of the WG in 1998

Meetings: WG Sessions during Symposium of Commission III, Columbus, Ohio, USA, July 6-10, 1998.

WG News

Plans for Meetings

September 6-10 99: Conference in Munich, Germany in cooperation with WG II/6, II/8, III/1, III/2, and III/4, Helmut Mayer and the former WG Chair Heinrich Ebner are in the Conference Chair.

Spring 2000: Workshop in Los Angeles, USA

PERS Special Issue

Together with Eberhard Gülch from WG III/4 a special issue of the Journal Photogrammetric Engineering & Remote Sensing (PERS) is being prepared. It will contain 6 papers which are the outcome of a review process of 14 pre-selected papers. Those have been the most exciting papers presented at the sessions of WG III/3 and III/4 during the symposium of Commission III in Columbus, OH, USA, July 6-10, 1998.

WG III/4 Image Understanding/Object Recognition

Chair Wolfgang Eckstein
Co-chair Eberhard Gulch
Secretary Carsten Steger

State of Science and Technology

Fusion of multiple data sources is applied in research, but so far mostly limited to two sources, e.g., multiple images and map (GIS) data, digital surface models (DSM) and map (GIS) data, or DSM and image data. No general trend can be observed, nor a comparative evaluation of the suitability of either combination on various tasks.

Existing cartographic information is regarded useful for object recognition and reconstruction tasks, despite the unsolved problems of handling generalization or outdated information. Little research concerns the automation of change detection and almost none the following updating process.

Building extraction from images and/or laser scan data attracts numerous researchers, as well as road/road-network extraction from aerial and satellite imagery. Multiple views are a pre-requisite for many algorithms, with color information being of increasing interest. Several commercial systems offer laser scan data of high quality, suitable for detection and coarse reconstruction of buildings, including detection of vegetation. However, the automatic extraction of building ground plans and heights in urban areas are still unsolved.

In building and road reconstruction more complex models are used, e.g., buildings are reconstructed by parts, or road detection algorithms are able to handle crossings or partially occluded areas. The problems of correctness, accuracy, and optimal choice of level of detail of the models are still unsolved.

Newest developments concern the learning of models to reduce the search space. They have attracted several researchers. First attempts have been published in 1998.

Almost all object recognition systems developed so far contain a problem-specific control structure. Therefore, the adaptation of these systems to, even slightly, changed conditions or new applications remains very difficult.

There is a definite trend to real incorporation of interaction, due to the so far limited success rates of so called "fully automatic" methods, this holds for object recognition in images and digital surface models. Both types of interaction, post-editing of automatically derived results or accompanying the extraction process, are applied. However there are no comparative studies on the advantages of either method.

Some new investigations concern the quality and efficiency of image understanding algorithms and results on building and road extraction have been presented. There is also an increasing interest in the performance characteristics of algorithms from the computer vision community, which is documented by various workshops and ECVNet benchmarking and performance evaluation activities.

Accomplishments of the WG in 1998

Meetings

Participation in the ISPRS Commission III Symposium on "Object Recognition and Scene Classification from Multispectral and Multisensor Pixels", Columbus, Ohio, USA, July 6-10, 1998. Three of the 15 technical sessions (approx. 20% of the papers) at the symposium were devoted to WGIII/4.

Tutorial on "Image Understanding" given by Wolfgang Eckstein and Carsten Steger at the ISPRS Commission III Symposium.

Other Activities

Preparation of a special issue of PE&RS with selected papers from the ISPRS Commission III Symposium; guest editor: Eberhard Guelch (in cooperation with Helmut Mayer, WGIII/3)

Preparation of the Joint ISPRS Commission II/III Conference in Munich, 1999 (cf. below)

Communication

Continued update of the WWW site for the working group, http://wwwradig.informatik.tu-muenchen.de/ISPRS/wgIII.4.html

Mailing of 2 WG newsletters, predominantly by email.

Plans for Meetings in 1999

Conference on "Automatic Extraction of GIS Objects from Digital Imagery" in cooperation with ISPRS WGs II/6, II/8, III/1, III/2, and III/3, Munich, Germany, September 6-10, 1999.

WG III/5 Remote Sensing and Vision Theories for Automatic Scene Interpretation

Chair Beata Csatho
Co-chair DeLiang Wang
Secretary Erzsebet Merenyi

State of Science and Technology

The integration of multisensor/multispectral information for object recognition (OR) has become one of the most important research topics. Different sensory data, DEMs, maps (GIS) are merged, fused and combined. The results are mostly experimental and existing pattern recognition and OR techniques are combined to achieve a particular goal, for example for extracting buildings from laser scanner data and visual imagery. The development of a conceptual framework for the application of the different techniques from remote sensing, photogrammetry and computer vision in a synergistic fashion is still a challenge for future research.

So far the application of multispectral information has mostly been limited to low spatial resolution multispectral images in visible and NIR. Techniques for detecting materials in subpixel quantities has successfully been adapted from remote sensing for

urban applications. The inclusion of hyperspectral data as well as middle infrared and thermal IR images (3-14 micron) into the object recognition has not been explored yet. Recent data acquisition campaigns (e.g. low flight altitude AVIRIS, HYDICE) provide plenty of high spatial resolution hyperspectral scenes for experiments.

More effort is needed for modeling the different object and sensor combinations for supporting the interpretation of the extracted features, such as edges in different spectral bands (from visible to microwave domain) or land cover types. The available library spectra are mostly for different soil and rock types and vegetation. Systematic study and archival of spectra of man-made materials is necessary.

Laser scanner/profiler data are extensively used independently or in a combination with visible imageries for surface reconstruction and feature extraction. Only a few attempts has been made to study the relationship between the surface elevation and reflectivity in the footprint and the measured range.

The application of the scale-space theory for jointly describing the spectral and spatial behavior of a scene is still unsolved.

Software tools capable of effective analysis of multispectral, multisensor data sets including sensor models, classification tools, computer vision tools etc. are not available yet. The development of such operational systems is not expected in the near future.

Accomplishments of the WG in 1998

Meetings

Organization of Intercommission workshops (C III and C VII) on "GIS, Airborne Remote Sensing and Geospatial Clearinghouse", February 19-20, 1998, in Budapest, Hungary.

Participation at the Commission III Symposium on "Object Recognition and Scene Classification from Multispectral and Multisensor Pixels on July 6-10, Columbus, OH. 2 sessions with 12 papers were devoted to the WG topics.

Other WG activities

Continuous update of WG web page and mailing of two circular letters

Continuing the effort to establish standard data sets for testing and evaluating advanced image interpretation algorithms. A preliminary set of requirements for standard data sets has been circulated. A small group of experts is currently working on establishing the requirements of ground truth and sampling as well as data formats and documentation. A repository ftp site to will be maintained by the Pan American Center for Earth and Environmental Studies at the University of Texas at El Paso.

Preparation for the joint ISPRS/EARSeL workshop on "Fusion of Sensor Data, Knowledge Sources and Algorithms for Extraction and Classification of Topographic Objects"

Participation of WG in forthcoming events

Joint ISPRS/EARSeL workshop on "Fusion of Sensor Data, Knowledge Sources and Algorithms for Extraction and Classification of Topographic Objects", which will be held on June 3-4, 1999 in Valladolid, Spain (organized by ISPRS WGs III/5 and VII/4, IC WG IV/III.2, EARSeL SIG Data Fusion)

Workshop on "Integrating Classification and Object Recognition Approaches" organized by WG III/4, III/5, and IC IV/III.1 in November 1999

WG III/6 Theory and Algorithms for SAR

Chair Laurent Polidori
Co-chair Soren Madsen

State of Science and Technology and Accomplishments

WG III.6 has organized a workshop (January 1998) and a dedicated session in Commission III Symposium (July 1998).

The workshop on review of theory and algorithms for SAR was held in Cannes (France) on 28-30 January 1998. It was an informal workshop (i.e. with no call for papers and no proceedings) in which some 15 international radar experts exchanged their views on the advances and limitations of radar image processing algorithms. For each of the following processing issues, some one presented the state-of-the-art and the different approaches were identified and discussed :

Overview of SAR interferometry : theory and processing steps

Review of phase unwrapping methods

Spatial resampling issues in SAR interferometry

Review of 3D mapping methods and their evaluation

Advances in stereo radargrammetry

SAR image quality impact on interferometric performance

Interferometric coherence for quality assessment and thematic mapping

Canopy height estimation from interferometric SAR

SAR maps : geometric modelling and geocoding

SAR maps : mosaicking issues

Non-conventional SAR algorithms (e.g. ScanSAR) : overview of techniques and interferometric applications

Model inversion issues in SAR image processing

Speckle filtering

No proceedings have been issued, but it was decided that a "commented bibliography" would be undertaken within the work group. Some preliminary contributions have been collected.

The session dedicated to SAR in the Commission III mid-term symposium was not very successful, probably because it was organized on the same week as the IGARSS'98 symposium (which the main annual event for the radar community). However, this session gave the opportunity to present radar techniques and applications to the image processing community which in general deals with optical imagery. Radar techniques and their merging with optical techniques should gain importance within Commission III activities.

Since several ISPRS working groups are dedicated to radar imagery in different commissions, it has been recommended that a joint workshop on radar should be organized in 1999. The date, place and scope are being discussed.