Annual Report 2004

Centre for Image Analysis

Centrum för bildanalys
Cover:
Illustrations from the four PhD theses presented at CBA during 2004. See Abstracts in Section 4.2.

Top-left:
Anders Hast – A new function for specular highlights makes it possible to change the size of the highlight linearly and it is easy to create arbitrary small sizes, which was not practically possible with the power function used in the Phong specular highlight model.

Top-right:
Xavier Tizon – Composite rendering of an abdominal MRA subvolume. The arterial centerlines are displayed as small spheres at each voxel location, colored with the curvature value at each voxel. Curvature measures how much the vessel locally deviates from a straight line.

Bottom-left:
Felix Wehrman – The picture shows the regular sampling of two-dimensional shapes and scenes. Subject to variation, such an object resides on a low-dimensional, nonlinear manifold in the hyperspace of measurements.

Bottom-right:
Mats Erikson – Aerial image and its segmentation into individual tree crowns.

Edited by:
Gunilla Borgefors, Ida-Maria Sintorn, Robin Strand, Lena Wadelius
Centre for Image Analysis
Uppsala, Sweden
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1 Introduction

1.1 General background

The Centre for Image Analysis (CBA), founded 1988, 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 in image analysis and visualization, both theoretic and applied.

We had four dissertations 2004, two at each university. The new doctors are Anders Hast and Felix Wehrmann at UU and Mats Erikson and Xavier Tizon at SLU. The four theses are illustrated on the cover of this report.

CBA personnel received two important rewards, showing that our work is appreciated by potential users. Julia Åhlén got the “Best industry-relevant paper Award” at the Swedish Symposium on Image Analysis 2004. Ida-Maria Sintorn, together two colleagues, got the Second prize in an innovation competition awarded by the European Regional Development Fund and three universities in Stockholm.

CBA was host for the annual Swedish Symposium on Image Analysis, SSBA2004, where most researchers in image analysis participate and present their work, this year about 100. The conference is the official meeting of the for Swedish Society Automatic Image Analysis (SSBA).

Even though its is a subject distinct from image analysis, CBA has, ever since its start, taken the responsibility for undergraduate education at UU in computer graphics and carried out some projects in graphics and visualization. This has been necessary, as three dimensional images can not be viewed directly (the retina being two dimensional). Since 2003 there is a Chair in Computer Graphics and Visualization placed at CBA (jointly between UU and University College of Gävle). This year, a lecturer in visualization was recruited, Ingela Nyström, so we now have research base at UU.

Image processing is in its essence interdisciplinary, its foundations being in mathematics, statistics, physics, and computer science, and its applications – in our case – ranging from shape analysis of protein molecules to detection of coral bleaching in tropical seas. This may seem like a too wide area of research, but, in fact, we do concentrate on two areas of basic research and on applications suitable for these. The first of these areas is volume (three-dimensional) images, e.g., tomographic images of the human body. In this area we work both quite theoretically, together with mathematicians and with applications, both analysis and visualization, together with physicians. We are the strongest group in Northern Europe on volume image processing. The second area is spectral/hyper spectral images, that is images with 3–200 layers, where each layer represents a specific spectral band. Such images are, e.g., used to detect water pollution.

Most of our application projects are carried out in close co-operation with researchers from other scientific areas, or with industry. We also co-operate internationally. For the extensive list of national and international co-operation partners, see Section 5.2. We there list the 19 international groups in twelve countries and 35 national groups with which we have had active co-operation in 2004.

How many we are at CBA is a question with several answers. If we count the number of persons “in house” (excluding Master thesis students and visiting scientists) for at least part of their time we were 25 at 2004-12-30. If we count the time spent at CBA we had the equivalent of about 19 full time persons at the end of the year. The employees are formally employed at either university. The whole of CBA is administrated through UU.

All personnel at CBA participates, more or less intensely, in undergraduate education, mainly through the large Dept. of Information Technology at UU but also through the Dept. of Mathematics. There is also an undergraduate course at SLU.

We are very active in international and national societies, e.g. Ingela Nyström is President of the Swedish Society for Automated Image Analysis (SSBA), Stefan Seipel served as Vice Chair of Swedish Society for Computer Graphics (SIGRAD), and Gunilla Borgefors became one of three Area Editors for the Scientific Journal Pattern Recognition Letters. Ewert Bengtsson continues to serve as advisor
to the Rector of UU on information technology and also as Chair of the Virtual Faculty of information technology, together with many other related appointments.

Since 1993/94 CBA assembles extensive annual reports, that describes in some detail what we have achieved during the year. These annual reports are intended for anyone interested in our work, not only financial sponsors, but for users of image analysis in society and industry, co-operation partners, and research colleagues. This is especially important for us, since we belong equally to two universities. *Note* that each Section in this report starts with a short summary printed in a larger font than the following detailed material.

Our annual reports have been available on the Internet since 1998. For this issue, see http://www.cb.uu.se/verksamhet/annual_report/AR04html/

### 1.2 Summary of research

According to the founding documents, the objective of the CBA is “to create the know-how needed for an operative and sensible use of digital image analysis in society, particularly in the fields of environment and medicine.” Traditionally, the research has been more or less organized in three groups, led by Prof. Ewert Bengtsson, Prof. Gunilla Borgefors, and Doc. Tommy Lindell. However, the borders between the groups have become more and more fuzzy, sometimes non-existent. This is a development we encourage, the goal being to create as much high quality research as possible not to maintain organizational structure. Also, and new configurations have appeared and old are disappearing. The group on aquatic remote sensing led by Lindell is decreasing since Lindell has retired and is only working part time. We have unfortunately not been able to find support for a new position to continue work in this field. Instead, a new group on graphics and visualization, which nicely complements our 3D image analysis work, has been added. Prof. Stefan Seipel, recruited in 2002, works 20% of his time at CBA. This year, new Associate Prof. (lecturer) in visualization, Doc. Ingela Nyström, was recruited. In addition, we recruited a new Assistant Prof., Carolina Wåhlby, who received her PhD at CBA in October 2003. The other seniors involved in research are Prof. Fredrik Bergholm, Assistant Prof. Stina Svensson, and Dr. Bo Nordin.

Other welcome additions to the group, adding a new international dimension to our work, are two new “sandwich” PhD students from Sri Lanka that will spend about half of each year at CBA and half at their home universities. We already have a similar arrangement with one student from Novi Sad, Serbia. We also recruited two “normal” PhD students.

From this year, we do not divide this summary according to “the groups”. The order of main activities below follow that in Section 5.1, which is arbitrary (even though similar projects are grouped).

For a number of years we have been working on wood fibre applications, both fibres in the wood and in paper. The ultimate goal is to understand how individual fibres build up paper and what effect different types of fibre networks have on paper properties. This year, a new PhD student, Maria Axelsson, was engaged to continue the investigations of the 3D structure of paper and board. Svensson and Sintorn has looked at the pore structure of board. Also, there have been no less than five Master Thesis on various aspects on paper, in co-operation with StoraEnso or STFI-Packforsk.

Forest inventory from air-borne sensors have been an active and productive research field in the group since its beginning in 1994. The aim is to make inventory from such data so detailed and correct that it can replace most field inventories. This year, Mats Erikson defended his thesis on tree crown and tree species classification in color infrared high resolution aerial images. On the stand level, classification is 95% correct, when distinguishing between the four most common species in Sweden: spruce, pine, birch, and aspen.

Pathology in plants can be detected early using hyperspectral data. We have used our expertise on extracting information from hyperspectral data for judging disease severity in wheat, in a co-operation
between PhD students Hamed Hamid Mohammed and Anders Larse at Dept. of Biometry and Engineering, SLU, Uppsala.

We believe image analysis can provide some of the key tools for understanding biology at all levels of resolution from the molecular via the intra- and inter-cellular, tissue organizational, and up to the organ and organism levels. We have projects at almost all those levels, seeking to develop the new tools and methods needed.

On the molecular level we have two projects. PhD student Ida-Maria Sintorn and Stina Svensson are working on segmentation in 3D based on both geometry and grey-level values, and applying the methods to Sidec Electron Tomography (SET) images of protein molecules. The goal is to find possible proteins in very noisy images. Patrick Karlsson and Carolina Wählby, in collaboration with Dept. of Genetics and Pathology, UU, studied how the small 3D “blobs” created by the imaging system from signals from a few molecules, i.e. far below optical resolution, can be resolved to give good quantitative data about the distributions of the different labeled molecules.

Sintorn has also, together with Dept. of Medicine, Karolinska Institute, been involved in the identification and classification of human cytomegalovirus capsids in noisy transmission electron microscopy images. This work won an innovation prize 2004.

On the cellular level, we have developed ways of segmenting and tracking the development of individual cells over time in time lapse photography sequences of cell cultures. This work has been carried out in collaboration with Dept. of Signals and Systems, Chalmers University of Technology and Dept. of Clinical Neuroscience, Göteborg University. The new PhD students Magnus Gedda and Sri Lankan Amalka Pinidiyaraarachchi has been doing most of this work together with Karlsson, Wählby and Bengtsson. Also, a Chinese visiting student “April” Tang Chunming contributed by developing a prototype tracking program.

Wählby and Sintorn has also worked on segmentation of various sub-cellular structures, in co-operation with Dept. of Oncology/Pathology, Karolinska Institute. Immunostaining and fluorescence microscopy is used, and the goal is to understand the 3D organization of normal and pathological cell nuclei.

On the organ level, PhD student Xavier Tizon has investigated the uses of grey-level connectivity and fuzzy set theory for use in, mainly, Magnetic Resonance Angiography (MRA) images. One application is arteries-veins separation, in co-operation with Dept. of Medicine and Care, Linköping University. The main activity this year was project where the task is analysis of the main artery tree in whole-body MRI. Minimal user interaction should be necessary for segmentation. After segmentation, measures for a total plaque burden were developed. The methods are aimed at massive scanning programmes for early detection of arteriosclerosis. This work is done in close co-operation with Dept. of Oncology, Radiology, and Clinical Immunology, UU Hospital. Tizon defended his thesis in Oct. 2004.

PhD student Pascha Razifar is also working on organ level images, studying the statistical properties of Positron Emission Tomography (PET) images. He is developing better ways of modeling the imaging process and of extracting relevant parameters. This work is done in close collaboration with Imanet AB, Uppsala.

Also on the organ level is the work we do using haptics. Haptics use the sense of touch, via a force feedback probe, in addition to stereo vision. Erik Vidholm and the other Sri Lankan student, Suthakar Somaskandan, are the PhD students doing this work. We are developing new ways for interacting with 3D images, mainly from magnetic resonance imaging (MRI). The first result was a method for improved interaction with the MRA images from Tizon’s work. The group has now moved on to study liver segmentation issues. As visualization is important for the haptic projects, Nyström is closely involved. This year, we also had a master thesis project, in which a good tool for object manipulation and visualization was developed.

During the last quarter of the year Bengtsson was on sabbatical at University of Queensland, Brisbane, Australia, that will last until March 2005. He chose this host for his sabbatical because they are one of the more active groups in one of his long standing areas of interest, the automated screening of cell
preparations for early detection of cervical cancer. The host researchers are also very much interested in analysis of magnetic resonance time sequence images of breasts for accurate cancer diagnosis, which ties in very well with the methods development for 3D and 4D image analysis CBA. Therefore, so most of the work during Bengtsson’s stay in Brisbane has been on the latter problem. This collaboration will likely continue after Bengtsson’s return to Uppsala.

In addition to the application oriented image analysis work described above, we also develop new, general, image analysis methods, especially for volume (and higher dimensional) images and hyperspectral data.

PhD student Felix Wehrmann has explored a number of different ways of expressing general shape, without relying on landmarks. He has come to the conclusion that a special kind of neural networks offers interesting new possibilities. Bergholm has worked together with Wehrmann, who presented his thesis in May 2004.

Four PhD students are jointly advised by Prof. Christer Kiselman, Dept. of Mathematics, UU and Borgefors. Two are placed at CBA, the others at Dept. of Mathematics. PhD student Ola Weistrand aims to develop global shape descriptions for volume objects, using linear combinations of spherical harmonics. First, the object boundary is mapped onto a sphere using harmonic functions. This leads to distortions, that make immediate application of spherical harmonics impossible. This year, the work has been concentrated on removing or alleviating these distortions.

Robin Strand is the other joint PhD student at CBA. He is funded by the Graduate School in Mathematics and Computing at UU. Strand develops image processing tool for volume images digitized in the bcc and fcc grids (where voxels are not cubes, but “rounder” polyhedra). He developed distance transforms, resolution pyramids, and skeletonization algorithms for these grids.

We are particularly interested in finding ways of registering images with many channels and to analyze such images. This is usually called imaging spectrometry. Fredrik Bergholm and PhD student Hamed Hamid Mohammed has developed a new concept for a color mosaic sensor which has led to a patent application. Hamid Muhammad has also developed new ways of normalizing and interpreting the hyperspectral information using independent component analysis and neural networks techniques.

Serbian PhD student Nataša Sladoje is working on fuzzy shape analysis in 2D and 3D. This means development of shape analysis directly in grey-level images or in fuzzy segmented images. Work has concentrated on precise area and volume measurements, shape moments, and analysis of shape signatures. This work is partly done in co-operation with Dept. of Radiology, University of Pennsylvania, Philadelphia, USA, and INPG, Grenoble, France.

Our long-time co-operation with Istituto di Cibernetica, “E. Caianiello”, CNR, Pozzuoli, Italy, continues. Involved from CBA are mainly Borgefors, Nyström and Svensson. We have long worked on digital distance transforms, decompositions, and skeletons (in 2D, 3D, 4D), and recently on using binary methods in 3D to accomplish various 2D grey-level image methods. We have also this year written a number book chapters on our pet subjects – distance transforms and skeletons – that will be published 2005 (or later).

Our graphics and visualization research is still not very extensive, but a number of projects are being pursued. In fact, even before we officially had positions for graphics and visualization we have been active in that field. A result of that is the thesis by Anders Hast from Gävle University College, who, together with Tony Barrera, has been studying how various image rendering algorithms can be implemented more efficiently. The work has resulted in several publications describing how shading and bump mapping algorithms can be significantly improved. Hast defended his thesis in April 2004.

Stefan Seipel is working mainly at University College of Gävle, but 20% of his time with us. One of his two main projects is efficient visualization of forest data. The visualization includes synthesizing detailed vegetation and animating it. Animation is essential for generating visual clues. The models are aimed for long-term forest planning and education. The other main project is to research new methods for visualizing data efficiently for a group of people who interact in the same physical environment. This
project is done in co-operation with the Swedish Defence College.

Somaskandan and Nyström are developing techniques for exploration of 3D medical images for visualization on standard PC hardware. Earlier, interactive techniques required very expensive computers, but today a PC with a standard graphics card, developed for the game market, could be used.

Aquatic remote sensing has been a strong and active research topic at CBA from its beginning, but is now, sadly, soon coming to an end. However, there are still a number of projects going on. Activities vary from mapping and monitoring of algae blooms and distribution of plumes in lakes to mapping and monitoring of tropical coasts and sea bottoms.

Lindell and Philipson have continued co-operation with the Italian groups from our earlier EU project in ROSALMA, monitoring of chlorophyll and macrophytes from satellites; and in NYMPHA, experimentation on a remote sensing integrated system for lake water monitoring. This project has also involved NIVA, Norway in field work and in applying MERIS data to the developed techniques from imaging spectrometry.

The co-operation with NIVA was extended to a new project on arctic and sub-arctic conditions, headed by Bergholm.

Lindell and Philipson, together with the Swedish Environmental Protection Agency, classified the habitats along the entire Swedish coast using Landsat-7 imagery.

An important aspect of our theoretical work is applying linear transformations methods, based on such as ICA (Independent Component Analysis) to hyperspectral images of Swedish lake waters. This research is mainly performed by PhD student Hamid Mohammed.

Lindell and Philipson have also continued the development of image analysis methods for imaging spectrometry. The long-term goal here is using satellite, together with airborne hyperspectral data, for different environmental applications. For some years, the work has focused on the detection of coral bleaching from remote sensing sources.

Finally, PhD student Julia Åhlén from University College Gävle has developed ways of correcting images taken with standard digital cameras under water for the loss of light with longer wavelengths with increasing depth. Her work can be important for many applications, such as marine biology and underwater archaeology. Her work won an award at the Swedish image analysis symposium this year, for being most relevant for industry.

Our image analysis platform IMP which has been used for many years in our research projects and in our courses is now approaching retirement and a new generation software, named PIXY, has been launched. There are, however, many things tied to the old system so the transition will likely take a number of years. Both systems have been designed and implemented by Bo Nordin.

CBA has also supervised as many as eleven Master Theses that were completed this year, seven of them with industrial co-operation partners. The theses treated: A general image analysis system; Finding cow teats for automatic milking; Analyzing fibre orientation in paper; Classification of usefulness of images of fluorescent molecules; Analyzing layering in stratified paper; Registration of 3D images of rats from computer tomography, magnetic resonance, and PET images; Segmenting the pulp layers in cross-section images of paper board; Automatic acquisition of cross-section images of paper in a scanning electron microscope; Real time surface rendering for our haptic environment; Visualization of the 3D fibre structure of paper; and Determining bark content in wood-chips for pulping.

1.3 How to contact CBA

CBA maintains home-pages on the World Wide Web (WWW) both in English and in Swedish. We have tried to make them easy to navigate by giving them a simple structure and layout. The main structure contains links to a brief presentation, staff, vacant positions (if any), and “activities,” which is probably the most interesting part. “Activities” contains information on courses, seminars – note that our Monday 15.15 seminar series is open to all interested persons – a popular introduction to image analysis, this
annual report (as .html and .pdf files), lists of all publications since CBA started 1988, and other material.

**CBA home-page:** http://www.cb.uu.se/

In addition to the CBA home page, all personnel have their own home pages, that are linked to the CBA “Staff” page. On these, you can usually find detailed course and project information and other interesting things.

CBA can be contacted in the following ways:

- **Address:** Lägerhyddsvägen 3
  SE-752 37 Uppsala
  Sweden
- **Telephone:** +46 18 471 3460
- **Fax:** +46 18 553447
- **E-mail:** cb@cb.uu.se
2 Organization

CBA is a joint entity belonging equally to Uppsala University (UU) and Swedish University for Agricultural Sciences (SLU), but administered through UU.

How many we are at CBA is a question with several answers. If we count the number of persons “in house” (excluding Master thesis students and visiting scientists) for at least part of their time we were 25 at 20041230. In addition we supervise one PhD student at University College of Gävle. If we count the time spent at CBA we had the equivalent of about 19 full time persons at the end of the year. For many years, about half the graduate students have belonged to each university, but at the moment there are more graduate students at UU. Most seniors belong to UU. The activity at CBA is similar to any department within a single university, but the administration becomes more complicated due to our close relation to two different universities.

Our total turnover for 2003 was 12.1 million SEK which is the same as last year. Total income was also 12.1 million, which was 1.6 million more than last year. However, some of that is earmarked for 2005. The research income about 42% come from outside sources (up from 39% last year) and the rest from the two universities, 33% from UU and 25% from SLU.

2.1 Constitution

The CBA was founded in 1988. In 1995 a re-organization of CBA took place to give it its present constitution. We are now a joint University entity (due to administrative rules, we can not be denoted “Department”) between UU and SLU. The employees are employed at either university, and the PhD students are admitted at either the faculty of Science and Technology (TN) at UU or at the faculty of Forest science (S) at SLU. CBA is associated with Dept. of Information Technology (IT) at UU regarding undergraduate education, as we are not directly responsible for undergraduate education at UU, even though we are organize and teach many courses, especially those in image analysis and computer graphics. The whole of CBA is administered through UU.

All personnel (from both universities) is employed directly at CBA, except Lecturers at UU. These are employed by IT, and teach there. Their research activities, however, are carried out at CBA to a degree (usually 25%-75%) which is regulated by individual contracts.

CBA is thus an independent entity within the TN faculty at UU and within the S faculty at SLU, respectively. It is directed by a Board appointed by the Vice Chancellor of UU, with representatives from the universities (three each) and the unions (two). The Board is appointed for three years. There has been a vacancy in the board for over a year, but SLU has suggested no replacement. At present the board members are:

- Ewert Bengtsson TN-faculty UU
- Christer Kiselman TN-faculty UU
- Mats Bergström Medical faculty UU
- Raili Raininko deputy UU
- Gunilla Borgefors S-faculty SLU
- vacant S-faculty SLU
- Lennart Norell Natural Resources and Agricultural Sciences faculty SLU
- Mats Nylinder deputy SLU
- Nils-Einar Eriksson TCO
- Tommy Lindell SACO

In between Board meetings CBA is headed by a Director, appointed by UU, who also serves as Chairman of the board. Prof. Gunilla Borgefors has served as Director with Dr. Olle Eriksson as deputy Director, both since 1996.

According to the founding documents, the objective of the CBA is “to create the know-how needed for an operative and sensible use of digital image analysis in society, particularly in the fields of environment and medicine.”
The research work is loosely organized in four groups: The image analysis group at UU which works mainly with medical applications and is headed by Prof. Ewert Bengtsson; the image analysis at SLU headed by Prof. Gunilla Borgefors, which works with various applications in forestry and industry, as well as in basic research, mostly digital geometry; and the group in aquatic remote sensing at UU, headed by Docent Tommy Lindell; and the scientific visualisation group at UU, headed by Prof. Stefan Seipel (20%) and Docent Ingela Nyström.

2.2 Finances

CBA is financed through the two universities and through research grants and contracts. Some of the personnel expenses are covered by undergraduate education at UU, mostly by the PhD students of both universities, who all teach 15% of their time. (The UU Lecturers’ teaching is not included in our finances.)

The summary in Table 1 describes our overall economy for the year 2004. Since part of our economy is handled at UU and part at SLU, this summary is based on joining the two accounts and clearing internal transactions between the universities. The numbers are rounded to the nearest 1000 SEK. The same numbers for income and costs are also given as pie charts in Figure 1. Which projects that are financed by whom can be ascertained in Section 5.1, where each project is listed.

Changes in income from last year is that Governmental grants have increased by 1.1 million SEK and funding from UU has increased by one postgraduate position (“forskarassistent”), 0.6 million. Non-governmental grant, contracts, ans SLU funding are roughly the same.

Total turnover has increased only 0.1 million from last year (much of the funds used during 2003 had arrived already 2002, thus the seeming discrepancy when looking when looking at the increase in income). The same is true this year – some of the 2004 income is intended for 2005. The major costs are for personnel (salaries). To have a balanced economy, we have continued the process to decrease the number of permanent employees. It should be noted that after 2004, we have no saved resources. In fact, we have an old deficit in our common economy that we are now trying to pay off, from project money, during the next five years.

The total turnover is thus 12.1 million for 2004, compared to 12.1 million for 2003. The percentage of research financed from outside sources have increased from 39% to 42% but this is not enough. During past years it has for a number of years been about 50%. We are very actively trying to reach this figure again – but will not do so during 2005. In fact, it will in all probability decrease.

Table 1: CBA income and costs for 2004.

<table>
<thead>
<tr>
<th>Income</th>
<th>Costs</th>
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<tbody>
<tr>
<td>UU 3656</td>
<td>Personnel 7424</td>
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<tr>
<td>SLU 2745</td>
<td>Equipment 253</td>
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<td>SLU undergraduate education 35</td>
<td>Rent 1028</td>
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<tr>
<td>Governmental grants 1 2589</td>
<td>University overhead 1530</td>
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<tr>
<td>Non-governmental grants 2 421</td>
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<tr>
<td>Contracts 3 1694</td>
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<tr>
<td>Financial netto 24</td>
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</tr>
<tr>
<td><strong>Total income 12138</strong></td>
<td><strong>Total cost 12167</strong></td>
</tr>
</tbody>
</table>

1) The Swedish Research Council, Sw. National Space Board, SIDA, The European Social Fund
2) SSF, Research foundations
3) Swedish Environmental Protection Agency, internal invoices, compensations, etc.
4) Including travel and conferences
Figure 1: CBA income (top) and costs (below) for 2004.
2.3 Staff

Gunilla Borgefors, Professor, PhD, Director, SLU
Olle Eriksson, Lecturer, PhD, Deputy Director, (part time) UU

Maria Axelsson, Graduate Student, 0601–, SLU
Ewert Bengtsson, Professor, PhD, UU
Fredrik Bergholm, Professor, PhD, UU
Mats Eriksson, Graduate Student, SLU
Magnus Gedda, Graduate Student, 0601–, UU
Hamed Hamid Muhammed, Graduate Student, UU
Patrick Karlsson, Graduate Student, UU
Joakim Lindblad, PhD, 0101–0229 1101–1231, UU
Tommy Lindell, Docent, PhD, (part time) UU
Bo Nordin, Researcher/Lecturer, PhD, (part time) UU

Ingela Nyström, Docent, PhD, UU
Amalka Pinidiyaarachchi, (part time), 0830–, UU and University of Peradeniya, Sri Lanka
Pascha Razifar, Graduate Student, (part time) UU and Uppsala Imanet
Ida-Maria Sintorn, Graduate Student, SLU
Stefan Seipel, Professor, (part time 20%) UU and University College of Gävle
Nataša Sladoje Matic, (part time) SLU and University of Novi Sad, Serbia
Suthakar Somaskandan, (part time), 0830–, UU and University of Jaffna, Sri Lanka
Robin Strand, Graduate Student, UU

Stina Svensson, Researcher, PhD, SLU
Xavier Tizon, Graduate Student, –1015, SLU
Erik Vidholm, Graduate Student, UU
Felix Wehrmann, Graduate Student, –0615, UU
Ola Weistrand, Graduate Student, Dept. of Mathematics, UU
Carolina Wåhlby, Researcher, PhD, UU

Lena Wadelius, Administration

Master Thesis students:
Jonas Agmund, Henrik Boström, Erik Cedheim, Emma Gustafsson, Ingemar Holmqvist, Per Holting,
Mattias Klippinge, Tomas Lundström, Kristin Norell

In addition to the above Graduate Students,
E. Bengtsson is supervisor to
   Anders Hast, Dept. of Mathematics, Natural Sciences, and Computing,
      University College of Gävle –0429
   Julia Åhlén, Dept. of Mathematics, Natural Sciences, and Computing,
      University College of Gävle

G. Borgefors is assistant supervisor to
   Anders Larsolle, Dept. of Biometry and Engineering, SLU
   Erik Melin, Dept. of Mathematics, UU
   Hania Uscka-Wehlou, Dept. of Mathematics, UU

The letters after the name indicate the employer for each person: UU - Uppsala University, SLU - Swedish University of Agricultural Sciences. The e-mail address of the staff is Firstname.Lastname@cb.uu.se.
3 Undergraduate education

At SLU we are responsible for a course in basic image analysis. At UU, staff from CBA organizes and participates in many undergraduate courses, even though we are not officially the unit responsible for them. Of course we organize and teach the courses in image analysis and computer graphics, but we also teach other courses, such as programming and mathematics.

We offer a number of Master Thesis projects (examensarbeten) each year. Twelve were completed during 2004, which is a little above average.

3.1 SLU courses

1. Digital image analysis A, 5p
   Examiner: Gunilla Borgefors
   Lecturers: Gunilla Borgefors, Mats Erikson, Petra Philipson, Ida-Maria Sintorn, Robin Strand, Carolina Wählby
   Application Lecturers: Ewert Bengtsson, Mats Erikson, Anna Rydberg, and Matti Pariika, Dept. of Bioenergy, SLU
   Computer Exercises: Ida-Maria Sintorn, Petra Philipson
   Period: 0402–03
   Comment: A course in image analysis for undergraduate students at SLU. It’s open to all, but is integrated into the Forestry and Natural Resources Programmes.

2. Natural science research school: digital cell image analysis
   Examiners: Gunilla Borgefors, Ida-Maria Sintorn
   Period: 040801–07
   Comments: “Naturvetenskapliga Forskarskolan” is a research summerschool for 40 students studying the third year of the Natural Science program of the Swedish gymnasiun (high school). During the summerschool, the students listen to lectures by researchers within several different fields of the natural sciences. The afternoons and evenings are spent working on one-week laboratories supervised by PhD students. The summerschool is held at Alfred Nobels Björkborn, Karlskoga, Sweden. Sintorn was in charge of the organisation of the summerschool and also participated as supervisor.

3. Basic programming, 5p
   Examiner: Olle Eriksson
   Period: 0411–0501

3.2 UU courses

CBA does not organize undergraduate courses at UU. However, we teach in many such courses, mainly organized through the Dept. of Information Technology, UU but also at the Dept. of Mathematics, UU. Many of these courses are on subjects closely related to our research, i.e., Computerized image analysis and Computer graphics. We have also taught courses in mathematics, and in programming languages such as C++ and Java.

1. Software architecture with Java, 5p
   Olle Eriksson
   Period: 0401–03

2. Computer graphics II, 5p
   Fredrik Bergholm
   Period: 0401–03
   Comment: Course credits can be either 4 or 5.

3. Scientific computing I, 4p
   Hamed Hamid Muhammed
   Period: 0401–03
4. **Scientific programming, 4p**  
   Olle Eriksson  
   *Period*: 0401–04

5. **Computers and programming TDB1, 5p**  
   Erik Vidholm  
   *Period*: 0401–04

6. **Calculus of several variables, 6p**  
   Robin Strand  
   *Period*: 0401–05  
   *Comment*: 18 problem sessions.

7. **Object oriented programming with C++, 5p**  
   Bo Nordin  
   *Period*: 0403–06  
   *Comment*: Distance Course.

8. **Scientific programming II, 4p**  
   Olle Eriksson  
   *Period*: 0403–06

9. **Computer assisted image analysis, 5p**  
   Carolina Wahlby  
   *Period*: 0403–06  
   *Comment*: Ida-Maria Sintorn gave two lectures and Xavier Tizon gave one “guest lecture”.

10. **Computer graphics I, 5p**  
    Patrick Karlsson, Erik Vidholm, Anders Hast, Fredrik Bergholm  
    *Period*: 0403–06

11. **Internet programming, 5p**  
    Olle Eriksson, Bo Nordin  
    *Period*: 0406–08

12. **Introduction to mathematics, 2p**  
    Robin Strand  
    *Period*: 0408–09  
    *Comment*: Three problem sessions.

13. **Interactive graphical systems, 5p**  
    Stefan Seipel  
    *Period*: 0409–0410

14. **Introduction to computers, 1p**  
    Maria Axelsson  
    *Period*: 0409–10  
    *Comment*: 24 laborations with students from the NV program.

15. **Medical technology, 5p**  
    Ewert Bengtsson  
    *Period*: 0410  
    *Comment*: A double lecture about imaging and image processing in medicine.

16. **Scientific programming, 4p**  
    Olle Eriksson  
    *Period*: 0410–12

17. **Computers and programming TDB2, 5p**  
    Bo Nordin  
    *Period*: 0410–0501  
    *Comment*: Distance course.
3.3 Master theses projects

1. **Real-time rendering of accumulated snow**  
   **Student:** Per Ohlsson  
   **Supervisor:** Stefan Seipel, Lars W. Pettersson  
   **Examiner:** Stefan Seipel  
   **Publisher:** Uppsala Master Theses in computer science 267.  
   **Abstract:** This thesis presents a method of computing snow accumulation as a per pixel effect while rendering the scene. The method is similar to the shadow mapping method for shadow calculations. A depth buffer is used to find out how much snow a particular surface should receive. The amount of snow is then modified depending on the slope of the surface. To render the snow in a convincing way 3D noise is utilized for the lighting of the snow surface.

2. **Computer-based morphometric assessment of spiral ganglion neurite outgrowth in vitro using image processing**  
   **Student:** Tomas Lundström and Henrik Boström  
   **Supervisor:** Ingela Nyström  
   **Examiner:** Ingela Nyström  
   **Partner:** Dept. of Otolaryngology at UU Hospital  
   **Publisher:** CBA Master Thesis No. 64, 75p., 2004, UU School of Engineering, UPTEC IT04 001  
   **Abstract:** There is a pioneer research going on among medical researchers from all around the world; they want to make deaf people hear again in a natural way. To achieve this goal they want to make neuron-cells grow inside the human ear to reestablish the ability for deaf people to hear again.
   The research processes involves growing a huge amount of neurons in the laboratories and keeping track of the growth-rate and growth-behavior of these cells. There can be thousands of cells to keep track of every week. To perform these quantitative assessments of the growing cells the researchers started measuring the lengths of the neurite outgrowths, growing out from the seed of the cells.
   In this master thesis we have developed a digital image processing computer software for extracting and measuring neurite outgrowths in digital images.
   The processing of one such image involves four main digital image processing fields; these are thresholding, object classification, morphological operations and measuring by skeletonizing.

3. **Leprechaun, a program for image analysis**  
   **Student:** Erik Andersson  
   **Supervisor:** Carolina Wählby  
   **Examiner:** Ewert Bengtsson  
   **Publisher:** CBA Master Thesis No. 65, 35p., 2004,  
   **Abstract:** This Master Thesis is about creating a program to handle image analysis in general with watershed segmentation as its main focus. The program is written in Java and is available for many platforms, such as Windows and Solaris. Many of the standard image analysis operations are implemented and extending the program is quite easy; menus and dialogs are created from xml-files and new commands can be inserted into a running program. The supported image types are grayscale, color, 3d and multi-spectral.
4. **Multi-camera arrangement for automatic milking**  
   **Student:** Maria Pettersson and Johan Andrén Dinerf  
   **Supervisors:** Fredrik Bergholm, Ingela Nyström, Anders Hallström  
   **Examiner:** Fredrik Bergholm  
   **Partner:** DeLaval International AB, Dept. VMS (Voluntary Milking System), Tumba  
   **Publisher:** CBA Master Thesis No. 66, 94p., 2004,  
   **Abstract:** The teat detection and positioning system used today on the DeLaval automatic milking system, VMS, comes with a number of drawbacks, that could be solved if it was replaced with a stereo vision system, placed outside the milking robot. This would decrease the damages on the present camera/laser detection device, and possibly increase the speed of the robot. This thesis is a feasibility study to find out if such a system is possible. The stereo calculations show that a stereo vision system is very sensitive. If such a system should work with high enough accuracy, the system needs to continuously be recalibrated, using reference points in the VMS. Results show that average error in absolute measurements is usually within the accepted range. The demand is higher when attaching a teat cup. Therefore relative measurements between objects in the picture is of higher interest. For example between a teat and the teat cup. Errors in relative measurements depend on the size of the relative measurement and is 8 high. The image analysis does not detect the teats with high enough accuracy today, but shows that it is possible in an environment with appropriate illumination. All teats are seen using two stereo vision systems. Basics regarding both image analysis and robot milking are also presented. The main problem is divided into sub problems, which are investigated separately. To evaluate the methods, two extensive tests were performed. Final test 1 tests the actual stereo calculations while final test 2 tests the image analysis for teat detection. The final conclusion is that such a system is possible but is very sensitive. A final system needs to be more robust and exact. This project led to three Swedish patent applications.

5. **Development of the fiber orientation analyzer SPADES: a system using polarization-axis direction estimation**  
   **Student:** Simon Hensing  
   **Supervisor:** Marco Lucisano, STFI-Packforsk AB, Stockholm  
   **Examiner:** Gunilla Borgefors  
   **Partner:** STFI-Packforsk AB, Stockholm  
   **Publisher:** CBA Master Thesis No. 67, 31p., 2004,  
   **UU School of Engineering, UPTEC F04 022**  
   **Abstract:** The properties of a paper sheet is to a large extent dependent on the fiber orientation in the plane of the sheet. The purpose of this thesis is to create an on-line system for fiber orientation measuring based on the polarization effects of paper and to investigate whether his technique can be implemented in the on-line system SOFA. The equipment consists of a polarization analyzer and uses a CCD-camera as light detector. Results show that the polarization axis of paper at visible wavelengths correlates very well with the fiber orientation. The polarization effect is, however, quite limited and measurements require low noise levels. The conclusion is that the speed and accuracy of the system makes it a very competitive method for off-line fiber orientation analysis. However, the low noise levels required make it difficult to implement in SOFA and further development into an on-line system should be put on hold.

6. **Automatic classification of images detected in Gyrolab**  
   **Student:** Pontus Olson  
   **Supervisor:** Tobias Söderman, Gyros AB, Uppsala  
   **Examiner:** Ewert Bengtsson  
   **Partner:** Gyros AB, Uppsala  
   **Publisher:** CBA Master Thesis No. 68, 37p., 2004,  
   **UU School of Engineering, UPTEC F04 044**  
   **Abstract:** Gyros AB is a biotechnical company which manufactures a system for protein quantification. Protein concentration is calculated from images produced from fluorescent molecules. Automatic classification of these images is desirable on a scale from poor to good, which indicates the quality of the preceding process if the image is suitable for protein quantification. In this thesis project, a classification system has been designed. Firstly, a set of parameters for the images has been constructed. Secondly, a neural network is used as a classifier. Results show that it is possible to a reasonable level of accuracy distinguish poor images from good images.
7. **Image analysis as a tool for characterization of layering in stratified paper**

*Student:* Maria Sannes Lande  
*Supervisor:* Marco Lucisano, Ingela Nyström, Gunilla Borgefors  
*Examiner:* Gunilla Borgefors  
*Partner:* STFI-Packforsk AB, Stockholm  
*Publisher:* CBA Master Thesis No. 69, 66p., 2004, UU School of Engineering, UPTEC F04 057

**Abstract:** The driving force in the paper industry is the ambition to make a paper that is both lighter and stronger than conventional paper of today. This may come true if paper has a layered structure, where the fibers in different layers have different properties. Producing such a paper is difficult at low basis weight. The forming method (i.e. the creation of the basic structure of the final paper) that works best, stratified forming has the disadvantage of layer mixing by which the fibers of the inner layer reach the surface of the paper. The study of the evolution of structure properties in the thickness direction of multiplayer paper is important to the design and optimization of machinery and processes for the commercial application of stratified forming. The goal of this project has been to develop tools to evaluate the quality of multi-layer paper based on image analysis to get information about the mixing of the layers. Three main questions were posed: 1; How do the layers mix? 2; How well do the outer layers cover the inner core? 3; How do flocs (fibers entangled in each other) move in the thickness direction? Although these questions have not fully been answered, I have developed methods that bring us a step closer to answering these questions. To study the paper on the inside, the paper has been split in thin layers. The paper has been produced in such a way that the fibers going into the inner and outer layers have been dyed differently instead of using fibers with different properties. To find out how the layers mix, a method was developed and programmed that identifies the fibers coming from the inner or outer layers and calculates the percentages of the two differently dyed fibers in the splits. To avoid user errors the program has been made so that the calculations are done automatically. To find out how well the outer layers cover the inner layer I have developed a program that rebuilds the paper digitally in the computer. The method works well. By studying flocs in the thin layers of the paper it is possible to see how these are spread in the paper and this might help to understand how flocs influence paper properties. A method that identifies flocs has been developed and the possibility to make volume images of flocs has been investigated.

8. **Registration of tomographic animal volume images, from microPET, CT and MRT**

*Student:* Emma Gustafsson  
*Supervisor:* Mats Bergström, Uppsala Imanet AB  
*Examiner:* Ewert Bengtsson  
*Partner:* Uppsala Imanet AB  
*Publisher:* CBA Master Thesis No. 70, 26p., 2004, UU School of Engineering, UPTEC F04 063

**Abstract:** Medical imaging is of great importance in many fields, both in clinical work and in medical research. Different imaging systems give different information about the patient, why it is valuable to combine/register different images to one another. The co-registrations allow precise comparisons of organs, anatomical regions and pathological processes between modalities. Many methods and programs have been developed for registration of human images, mostly brains, while little work has been done on full body animal images. Registration of animal images are of interest since many medical experiments are performed on rats or monkeys. This report describes the construction of a program performing registrations on animal images from three different modalities; PET, CT and MRT. The basis of the work have been another program, created for registration of human brain images. Changes and additions have been made to meet the requirements from this new field of application. Both global and local registrations have been used. Three experiments have been done to test the final program. The test images were from rats and a Marmoset monkey. The experiments showed that a method developed for human brain images can be used for full body registrations of animal images with a satisfying result, especially if the images are from the same animal. When the images are from different individuals the results are a little poorer, but still fairly good.
9. Layer segmentation in cross-section images of board

Student: Ingemar Holmqvist
Supervisor: Gunilla Borgefors
Examiner: Gunilla Borgefors
Partner: Örjan Sävborg, StoraEnso Research, Falun
Publisher: CBA Master Thesis No. 71, 53p., 2004, UU School of Engineering, UPTEC F04 067

Abstract: Paper is one of the most common substances in the world having literally thousand of uses - from tissues to cardboard boxes. In the 3D Tracking of fibres in Paper-project (1997-2002, within the National VISIT programme) a small digital volume of three layer paper board, was meticulously created through the use of an electron microscope with the idea that image analysis could be used to further our knowledge about the inner structure of paper. This volume consists of 102 consecutive high resolution cross-section images showing the fibre structure of the paper. In this thesis, a layer segmentation algorithm based on simple image processing techniques such as filtering, edge detection and morphological operations is developed with the intent of separating the volume into its three different layers. We begin by filtering the images to remove the fibre structure and access the hidden inner layer structure. Edge detection algorithms are then used on the filtered images to extract possible layer borders. Depending on the a priori knowledge of the layer borders different techniques based both on morphological operations and interpolation are used to extract the best possible border candidates. Experiments conducted both on the whole volume set and separate reference images shows that developed methods are both powerful and accurate.

10. Automatic method for acquiring paper cross section images using a scanning electron microscope

Student: Åsa Odell
Supervisor: Örjan Sävborg, StoraEnso Research, Falun
Examiner: Gunilla Borgefors
Partner: StoraEnso Research, Falun
Publisher: CBA Master Thesis No. 72, 30p., 2004, UU School of Engineering, UPTEC F04 076

Abstract: Stora Enso Research center Falun performs research on paper. Small cross sections of paper, about two cm long, are sequentially viewed and photographed using a scanning electron microscope, SEM. The images from the SEM are stored on the hard drive of the microscope computer and are then analyzed. Each paper sample produces about 100 to 150 images. For each acquiring of an image, the operator of the microscope has to perform certain image settings and operations through clicks and scrolling with the computer mouse. A series of about 100 sample images demands large amounts of time when many operations must be performed per image. In fact it takes several hours to acquire all images from just one sample. In order to decrease the amount of work for Stora Enso staff, through lessening the need for staff to be present at the SEM during image acquisition and also to speed up the analyzing process to win time, thereby increasing cost efficiency, a method to automate the process of image acquiring has been created. To accomplish this task image analysis and computer communication were used as the main tools. Image analysis acts as a virtual eye to determine characteristic and/or critical points in a SEM image for decision making. Computer communication is used for commanding the SEM to perform certain actions. Combining these tools, a program acquiring images without human intervention was created and hidden behind a user friendly interface. The program was tested on many different kinds of paper. It could be concluded that the total time demanded for the acquisition of a series of images, was drastically reduced. A series of a total of 100 images of any sample type can now take a little less than 1 h to acquire, as opposed to the several hours before, from the moment when the first scanning of an image starts, and no staff needs to be present at the SEM during that time.
11. **Real-time surface rendering for interactive volume image segmentation in a haptic environment**  
   **Student:** Jonas Agmund  
   **Supervisor:** Erik Vidholm and Ewert Bengtsson  
   **Examiner:** Ewert Bengtsson  
   **Publisher:** CBA Master Thesis No. 73, 35p., 2004,  
   UU School of Engineering, UPTEC F04 071  
   **Abstract:** Volume image segmentation is a very important step when analyzing medical volume images. This Masters thesis describes the implementation of a fast surface rendering algorithm that allows interactive volume image segmentation in a haptic environment. The implementation uses a highly optimized marching cubes algorithm which is made efficient by dividing it into two major parts, surface extraction and triangle generation. The surface extraction is implemented by an efficient surface tracking algorithm that avoids searching empty space. The resulting surface information is used in conjunction with an intelligent caching strategy for fast triangle generation. The implementation of the surface renderer in the haptic environment makes it possible to achieve real-time frame rates while editing segmented objects guided by haptic feedback. Segmentation by thresholding has been implemented along with basic editing tools such as drawing, erasing, erosion and dilation. The surface renderer has shown to be efficient for arbitrary volume image sizes, and allows interactive segmentation and manipulation of moderately sized volumes.

12. **Visualization of the three dimensional fibre structure of paper**  
   **Student:** Erik Cedheim  
   **Supervisor:** Gunilla Borgefors  
   **Examiner:** Gunilla Borgefors  
   **Partner:** Örjan Sävborg, StoraEnso Research, Falun  
   **Publisher:** CBA Master Thesis No. 74, 56p., 2004,  
   UU Master Thesis in Computing Science  
   **Abstract:** This master thesis focuses on visualization of the three dimensional fibre structure of paper-board. The data was originally captured by StoraEnso using Scanning Electron Microscopy (SEM) and was later assembled by Mattias Aronsson into a 3D structure. The assembled volume has a low resolution in the z-direction making visualization as well as analysis a difficult task. Included in the task is the visualization of three different layers, originally segmented by Ingemar Holmkvist. The program is developed so that the user can interactively rotate and manipulate the volume in real-time. The program structure is focused on speed and memory efficiency rather than perfect image quality which makes the final product highly interactive with a good visualization of the fibre structure.
4 Graduate education

This year, there were four dissertations at CBA, two at UU and two at SLU. This is a little more than average. We gave three PhD courses, one for our own students, one Summer school for Image analysis students from all Sweden, and one for students in other areas that need basic knowledge about image analysis.

At the end of 2004, we were main supervisors for eleven and assistant supervisors for five PhD students; eight at UU (one supervised by Borgefors), and three at SLU. Of these eleven, eight are permanently working at CBA, four are here part-time, and four are employed elsewhere; three at the Dept. of Mathematics, UU, one at the Dept. of Biometry and Engineering, SLU, and one at the University College of Gävle. This mix of PhD students is a proof of our extensive cooperation with other research units.

4.1 Courses

During 2004 the following graduate courses were given:

1. Modern imaging systems, 5p
   **Examiner:** Ewert Bengtsson
   **Lecturers:** Ewert Bengtsson, Lars Bååth, Anders Liljeborg, Åsa Kassman Rudolphi, Ulf Skoglund, Hans Lundqvist, Mats Bergström, Tomas Jansson, Ove Steinvall, Lars Ulander, Petra Philipsson
   **Period:** 0401–04
   **Description:** A PhD course systematically covering the different ways in which images can be created with modern imaging devices.
   **Comment:** The course had 28 participants.

2. Deformable models in digital image analysis, 2p
   **Examiner:** Gunilla Borgefors
   **Lecturer:** Ghassan Hamarneh
   **Period:** 0408
   **Description:** This summercourse in deformable models and active shape models consisted of two days of lectures and excercies at CBA. In addition, a report from the excercises and the algorithms applied to own image material was compulsory. The wish for a summercourse in image analysis was expressed at the PhD day in connection to the annual symposium for the Swedish Society for Image Analysis (SSBA). Ola Weistrand and Ida-Maria Sintorn volonteered to orgianize such a course.
   **Comment:** 20 PhD students from all over Sweden attended the course. SSBA, SLU and UU sponsored the course.

3. Research methodology for image analysis, 2p
   **Examiners:** Gunilla Borgefors
   **Lecturers:** Gunilla Borgefors, Ewert Bengtsson, Ida-Maria Sintorn, and Caroline Myrberg, Beurling Library, UU
   **Period:** 0409–10
   **Description:** The course gives general and useful knowledge about how to become a good and published researcher in image analysis and/or various applications thereof (especially medicine, forest industry and remote sensing). Many questions of the type "How?" and "Where?" was answered.
   **Comment:** The course had 10 participants.

4. Application oriented image analysis, 5p
   **Examiner:** Gunilla Borgefors
   **Lecturers:** Gunilla Borgefors, Mats Erikson, Petra Philipsson, Ida-Maria Sintorn, Robin Strand, Stina Svensson
   **Computer exercises:** Maria Axelsson
   **Period:** 0410-12
   **Description:** The aim of this course is to give PhD students in other areas enough knowledge to use image
analysis in their research. It is application oriented in the sense that it does not go too deeply into fundamental mathematics, but concentrate on basic concepts and general methodology. The course book is "Gonzalez & Woods, Digital Image Processing, Addison & Wesley, 2002”.

Comment: The course had 20 participants.

4.2 Dissertations

1. Improved algorithms for fast shading and lighting
   **Anders Hast**
   Date: 20040429
   Publisher: Acta Universitatis Upsaliensis, ISBN 91-554-5916-1, Uppsala 2004
   Supervisor: Ewert Bengtsson
   Opponent: Jos Stam, Alias Wavefront, Toronto, Canada
   Committee:
   Ken Museth, Linköping University
   Stefan Seipel, Uppsala University
   Mark Ollila, Linköping University
   Abstract: Shading is a technique that is used in computer graphics to make faceted objects appear smooth and more realistic. In the research presented in this thesis we have investigated how shading can be generated as efficiently as possible without sacrificing quality.

   In the classical approach to high quality shading proposed by Phong, the illumination equation is computed per pixel using an interpolated normal. The normals at the vertices are bi-linearly interpolated over the polygon to obtain a normal per pixel. Correct shading requires normalization of these normals, which is computationally demanding involving a square root. In our research we have shown how this normalization can be eliminated through the use of spherical interpolation and the Chebyshev recurrence formula, reducing the calculation to a few single arithmetic operations per pixel.

   Still a substantial setup operation is needed for each scanline. We have studied how also this can be made more efficient, with some limited progress so far. An alternative approach is to do the most of the setup on polygon level and incrementally compute the setup needed per scanline. In particular, we have studied quadratic shading approaches, i.e. fitting second degree surfaces to the polygons. The most successful approach has been through what we have called X-shading, where the setup is calculated by using an efficient approximation for the mid-edge normals. This setup is about four times faster than previously known methods.

   In the process of studying shading methods we have also made some contributions to improving bump-mapping and simulation of different kinds of light sources.

   The developed methods will be of interest in future generations of computer graphics software and hardware systems, ranging from high end systems to generate realistic movies and 3D games, to handheld devices such as mobile phones with graphics displays.

2. On modelling nonlinear variation in discrete appearances of objects
   **Felix Wehrmann**
   Date: 20040519
   Publisher: Acta Universitatis Upsaliensis, 91-554-5951-X, Uppsala 2004
   Supervisor: Ewert Bengtsson
   Assistant supervisor: Fredrik Bergholm
   Opponent: Timothy Cootes, Imaging Science and Biomedical Engineering, University of Manchester, UK
   Committee:
   Antanas Verikas, Halmstad University
   Gunilla Borgefors, CBA, SLU
   Magnus Borga, Linköping University Hospital
   Abstract: Mathematical models of classes of objects can significantly contribute to the analysis of digital images. A major problem in modelling is to establish suitable descriptions that cover not only a single object but also the variation that is usually present within a class of objects.

   The objective of this thesis is to develop more general modelling strategies than commonly used today. In particular, the impact of the human factor in the model creation process should be minimised. It is presumed
that the human ability of abstraction imposes undesired constraints on the description. In comparison, common approaches are discussed from the viewpoint of generality.

The technique considered introduces appearance space as a common framework to represent both shapes and images. In appearance space, an object is represented by a single point in a high-dimensional vector space. Accordingly, objects subject to variation appear as nonlinear manifolds in appearance space. These manifolds are often characterised by only a few intrinsic dimensions. A model of a class of objects is therefore considered equal to the mathematical description of this manifold.

The presence of nonlinearity motivates the use of artificial auto-associative neural networks in the modelling process. The network extracts nonlinear modes of variation from a number of training examples. The procedure is evaluated on both synthetic and natural data of shapes and images and shows promising results as a general approach to object modelling.

3. Algorithms for the analysis of 3D magnetic resonance angiography images

Xavier Tizon

Date: 20041015
Supervisor: Gunilla Borgefors
Assistant supervisors: Örjan Smedby (1), Hans Frimmel (2)
(1) Dept. of Medicine and Care, Linköping University Hospital
(2) Dept. of Oncology, Radiology, and Clinical Immunology, UU Hospital
Opponent: Grégoire Malandain, INRIA, Sophia-Antipolis, France
Committee:
Lars-Erik Persson, Luleå University of Technology
Raiili Raininko, UU Hospital
Anders Heyden, Malmö University

Abstract: Atherosclerosis is a disease of the arterial wall, progressively impairing blood flow as it spreads throughout the body. The heart attacks and strokes that result of this condition cause more deaths than cancer in industrial countries. Angiography refers to the group of imaging techniques used through the diagnosis, treatment planning and follow-up of atherosclerosis. In recent years, Magnetic Resonance Angiography (MRA) has shown promising abilities to supplant conventional, invasive, X-ray-based angiography. In order to fully benefit from this modality, there is a need for more objective and reproducible methods.

This thesis shows, in two applications, how computerized image analysis can help define and implement these methods. First, by using segmentation to improve visualization of blood-pool contrast enhanced (CE)-MRA, with an additional application in coronary Computerized Tomographic Angiography. We show that, using a limited amount of user interaction and an algorithmic framework borrowed from graph theory and fuzzy logic theory, we can simplify the display of complex 3D structures like vessels. Second, by proposing a methodology to analyze the geometry of arteries in whole-body CE-MRA. The vessel centreline is extracted, and geometrical properties of this 3D curve are measured, to improve interpretation of the angiograms. It represents a more global approach than the conventional evaluation of atherosclerosis, as a first step towards screening for vascular diseases.

We have developed the methods presented in this thesis with clinical practice in mind. However, they have the potential to be useful to other applications of computerized image analysis.

4. Segmentation and classification of individual tree crowns

Mats Erikson

Date: 20041126
Supervisor: Gunilla Borgefors
Opponent: François A. Gougeon, Pacific Forestry Centre, Victoria, British Columbia, Canada
Committee:
Johan Fransson, SLU, Umeå
Sten Nyberg, Swedish Defence Research Agency, Linköping
Kennert Torlegård, Royal Institute of Technology, Stockholm

Abstract: By segmentation and classification of individual tree crowns in high spatial resolution aerial images, information about the forest can be automatically extracted. Segmentation is about finding the individual tree crowns and grouping each of them a unique label. Classification, on the other hand, is about
recognising the species of the tree. The information of each individual tree in the forest increases the knowledge about the forest which can be useful for managements, biodiversity assessment, etc.

Different algorithms for segmenting individual tree crowns are presented and also compared to each other in order to find their strengths and weaknesses. All segmentation algorithms developed in this thesis focus on preserving the shape of the tree crown. Regions, representing the segmented tree crowns, grow according to certain rules from seed points. One method starts from many regions for each tree crown and searches for the region that fits the tree crown best. The other methods start from a set of seed points, representing the locations of the tree crowns, to create the regions. The segmentation result varies from 73 to 95% correctly segmented visual tree crowns depending on the type of forest and the method. The former value is for a naturally generated mixed forest and the latter for a non-mixed forest.

The classification method presented uses shape information of the segments and colour information of the corresponding tree crown in order to decide the species. The classification method classifies 77% of the visual trees correctly in a naturally generated mixed forest, but on a forest stand level the classification is over 90%.
5 Research

CBA is conducting a whole range of projects ranging from basic image analysis research to direct application work, and increasingly in scientific visualization. By keeping close touch both with theoretical front line research and with real life application projects, we believe that we make the best contribution to our field. On the theoretic side, we are especially strong in volume and multispectral image analysis. In line with the stated goal for CBA, we give priority to applications in the fields of biomedicine and the environmental sciences, including the forest industry (we are part of the Faculty of Forest Science at SLU).

In this section, we list the 39 research projects that were active during 2004. Some are big projects that have been active for a long time, while others are small and short-lived. We started six new projects this year, and eight were finished.

This year, the list starts with forest and agricultural projects; followed by image medical applications (from proteins to organs); haptic medical applications; image analysis theory; computer graphics and visualization; and finish with aquatic remote sensing. For each project we list who at CBA is involved, where the funding comes from, when the project started (and finished), and who our co-operation partners outside CBA are.

As is obvious from the descriptions, most of the projects are carried out in close co-operation with researchers from other universities and from other research areas. In Section 5.2, we list the 19 international groups in twelve countries and 34 national groups with which we have had active co-operation in 2004.

5.1 Current research projects

1. **Image Analysis of the internal paper structure in 3D images of paper**
   - Maria Axelsson, Ida-Maria Sintorn, Stina Svensson, Gunilla Borgefors
   - **Funding:** SLU S-faculty
   - **Period:** 0406–
   - **Partners:** STFI-Packforsk, Stockholm, StoraEnso, Falun, Norwegian Pulp and Paper Research Institute (PFI), Trondheim, Norway
   - **Abstract:** The internal structure of paper is important to study since many paper properties correspond directly to the properties of single fibres and their interaction in the fibre network. How single fibres in paper bond and how this effects paper quality is not fully understood, since most structure analysis of paper has been done in cross sectional 2D images and paper is a complex 3D structure. Image analysis of 3D images of paper and development of measurements of network properties and individual fibre properties can be a great contribution to the development in this area.

   In this project, both segmentation algorithms for individual fibres and for the porous structure are investigated, see Figure 2 for individually segmented pores. The project objective is to achieve a fully segmented paper volume where any measurement of the internal structure is available, creating relations between microscopical and macroscopical properties of paper. These methods can also be used for other fibrous and porous materials.

   In the project a volume image of paper, created from a series of 2D scanning electron microscopy (SEM) images at StoraEnso in Falun, is available for the studies. Other volume images are also used and new methods for creating other sample volume images are investigated.

2. **Automated analysis of forest using high resolution CIR aerial images**
   - Mats Erikson, Gunilla Borgefors
   - **Funding:** SLU S-faculty
   - **Period:** 9508–0411
   - **Partners:** Tomas Brandtberg; Kenneth Olofsson, Dept. of Forest Resource Management and Geomatics, SLU, Umeå
   - **Abstract:** The main goal of the project is to develop methods for computerised analysis of high spatial resolution remotely sensed data, i.e., digitised aerial photographs and laser scanning data, and to use the results
Figure 2: A surface rendering of five segmented pores. The fibre network is shown behind the pores.

in forestry and environmental assessment instead of (or as a complement to) field visits by humans. A set of 50 research aerial images (digitised colour-IR film), with resolution approximately 10 cm and 3 cm (flight height 600 m, focal length 300 mm) to make the individual tree crowns clearly visible is used. Interesting forest stand parameters to measure in the images are: number and positions of trees, horizontal tree crown areas, tree heights, and tree species composition. Features related to the individual tree species are, e.g., colour, internal structure (texture), and boundary structure. Algorithms for very precise segmentation of individual tree crowns have been developed during the years. Also an algorithm for classification of the tree crowns into the tree species, birch, aspen, spruce, and pine has been developed. On the stand level, the classification results are 95% correct. One of the segmentation methods has also been used to segment tree crowns in tropical forest with promising results. A new thesis has come out from the project, see Section 4.2.

3. New techniques for information extraction from hyper spectral crop reflectance data

Hamed Hamid Muhammed

Funding: UU TN-faculty, Swedish National Space Board

Period: 0201–

Partners: Anders Larssolle, Dept. of Biometry and Engineering, SLU, Uppsala

Abstract: The impact of plant pathological stress on crop reflectance can be measured both in broad band vegetation indices and in narrow or local characteristics of the reflectance spectra. Our goal is to use the whole spectra in the objective examination of how different parts of the spectrum contribute in describing disease severity in wheat. A reference data set is first collected, consisting of hyper spectral crop reflectance data vectors and the corresponding disease severity field assessments. Two approaches were addressed to achieve this goal:

• A hyper spectral reflectance spectrum was considered as a mixed signal, i.e. the integration of the effects of all active objects in the investigated area. Independent component analysis (ICA) was used to blindly separate mixed statistically independent signals. Principal component analysis (PCA) was also used to extract interesting components. The ICA or PCA results had then to be interpreted efficiently. This was achieved by using a technique called Feature Vector Based Analysis (FVBA), which produces a number of “component-feature vector” pairs, which represent the spectral signatures and the corresponding weight coefficients of the different constituting source signals. High correlations were
found between these weight coefficients and the corresponding field assessments of disease severity in the crop. The effects of increased disease severity could be easily observed from the resulting disease-specific signatures.

- The hyper spectral vectors, from the reference data set, are first normalised into zero-mean and unit-variance vectors by performing various combinations of spectral- and band-wise normalisations. Then, after applying the same normalisation procedures to the new hyper spectral data that we wish to analyse, a nearest neighbour classifier is used to classify the new data against the reference data. Finally, the corresponding signatures, that describe the studied stress, are computed using a linear transformation model. High correlation is obtained between the classification results and the corresponding disease severity, confirming the usefulness and efficiency of this approach. The low computational load of this approach makes it suitable for real-time on-vehicle applications. A paper about this topic has been submitted for publication.

4. Identification and representations of proteins in volume images
Ida-Maria Sintorn, Magnus Gedda, Stina Svensson, Gunilla Borgefors
Funding: SLU S-faculty; UU TN-faculty
Period: 0401–
Partners: Susana Mata, Rey Juan Carlos University, Madrid, Spain; Sidec TM Technologies AB, Stockholm
Abstract: Sidec TM Electron Tomography (SET) is a 3D protein imaging method which produces volumes with a resolution of a few nm. This is good enough to give coarse structural information about the shape of proteins and how they interact with other proteins. The shape information available is, however, limited as the proteins only consist of a few thousand voxels, which is a small amount when it comes to 3D analysis. We develop several methods related to the analysis of 3D images of proteins, acquired using SET or reconstructed from atom positions available from the protein data bank. The SET volumes contain hundreds of objects of which true proteins are visually identified after grey-level thresholding of the volume and size discrimination of connected components. The visual inspection is very time consuming and varying background makes it difficult to find a suitable threshold. Proteins can also, after thresholding, consist of several disconnected parts or be connected to other objects. The consequence of this is that true proteins are easily discarded by the size discrimination step. During 2004 a method which combines a stable edge detection algorithm and contour based template matching was developed to identify objects in the volumes resembling the true protein. The method reduces the amount of visual inspection needed and adresses the problems of varying background and size discrimination. It shows very promising results but need to be evaluated on more SET volumes.

To facilitate the recognition and analysis of proteins in volume images, two representation schemes are being developed. One way of representing an object is to use decomposition into significant parts. Object recognition can then be seen as a hierarchical process. Each part can be analysed individually as well as how it is connected to other subparts to create the complete object. During 2003, a decomposition method, also developed at CBA and designed for binary images, was further developed to incorporate grey-level information and adapted to the application of protein decomposition. This method was presented at the International Symposium on Biomedical Imaging (ISBI) 2004.

Another way of representing an object is by a medial skeletal-like curve. A medial surface representation extracted directly from the grey-level image has earlier been developed at CBA. This representation differs from other surface skeletons by prioring grey-level to shape. A great advantage with this approach is that no segmentation of the object is needed prior to extracting the representation. Since the grey-level distribution within a protein is of great importance for function this medial representation was adapted to suit proteins in volume images during 2004 giving a curve connecting the locii of the different parts of the protein as a medial representation. The representation serves as a complement to the protein decomposition method. This protein medial grey-level based representation will be presented at the IbPRIA conference in June 2005. In Figure 3, the two representation schemes are shown on three antibody proteins imaged using SET.
5. **Segmentation and classification of human cytomegalovirus capsids**

Ida-Maria Sintorn, Gunilla Borgefors  
*Funding:* SLU S-faculty  
*Period:* 0111–  
*Partners:* Mohammed Homan, Cecilia Söderberg-Nauclèr, Dept. of Medicine, Karolinska Institute, Stockholm  
*Abstract:* Human Cytomegalo Virus (HCMV) is a rather unexplored virus belonging to the herpes virus family. The goal of this project is to segment, classify, and describe virus capsids at different maturation stages from transmission electron microscopy (TEM) images of infected cell nuclei. The virus capsids are to be classified to three different stages of the maturation pathway. The segmentation is done by template matching for one class at a time. The templates were produced from normalised radially averaged images of a number of typical particles of each class. A journal paper describing the method was published in Computer Methods and Programs in Biomedicine in 2004. During the year a means of measuring certain structural features of the capsids was also developed.

6. **Algorithms for segmentation of fluorescence labeled cells**

Carolina Wahlby, Joakim Lindblad, Ewert Bengtsson  
*Funding:* Amersham Biosciences, Uppsala, Cardiff, UK; UU TN-faculty; (This project was previously part of the Swedish Foundation for Strategic Research VISIT programme)  
*Period:* 9902–0401  
*Partners:* Lennart Björkesten, Amersham Biosciences, Uppsala; Stuart Swinburne, Simon Port, Alla Zaltsman, Gareth Bray, and Dietrich Ruehlmann, Amersham Biosciences, Cardiff, UK  
*Abstract:* The interaction with and effect of potential drugs on living cells can be observed by fluorescence microscopy. High throughput methods for analysis of cells can be used as a tool in the drug discovery process. The overall objective of this project was to develop image analysis methods for segmentation, feature extraction, and classification of cells and sub-cellular structures in fluorescence microscopy images. The cell nucleus has a well-defined shape and is relatively easy to detect. The cytoplasm is however more
complex. The first goal of this project was to develop a fully automatic method for cytoplasm segmentation. The present algorithm, inspired by literature and previous experience, consists of an image pre-processing step, a general segmentation and merging step followed by a quality measure and a splitting step. By training the algorithm on one image, it is made fully automatic for subsequent images created under similar conditions. A summary of the results was presented in Pattern Recognition and Image Analysis in 2004. Based on the experience from the segmentation of cytoplasms, a more problem specific project was initiated in cooperation with Amersham Biosciences in Cardiff, UK, in 2002. The aim of this project was to develop algorithms enabling fully automatic, real-time segmentation and analysis of fluorescence images of cells so as to quantitatively estimate the IGF-1 induced translocation of GFP-Rac1 to the cellular membrane for individual cells. Due to the ultimate goal of analyzing one image containing roughly 200 cells in less than two seconds, effort was taken not to use algorithms of high time complexity. The results were presented in Cytometry in January 2004.

7. **Segmentation and analysis of point-like fluorescent signals**
   Patrick Karlsson, Joakim Lindblad, Carolina Wåhlby, Ewert Bengtsson
   **Funding:** UU TN-faculty; (This project was previously part of the Swedish Foundation for Strategic Research VISIT programme)
   **Period:** 0305–
   **Partners:** Mats Nilsson, Department of Genetics and Pathology, Uppsala University
   **Abstract:** The interior of a cell is elaborately subdivided into many functionally distinct compartments, often organized into intricate systems. One way of studying such compartments is by the use of different fluorescent markers that bind specifically to the objects of interest. This type of staining followed by imaging through a microscope often results in point-source signals, or "blobs", together with a background of noise and autofluorescence. Analysis of spatial relationships requires pre-processing followed by separation and segmentation of the different blobs by combining intensity and shape information. Once the different blobs are detected, the goal is to detect non-random patterns in the blob distribution. True patterns were compared with synthetic model patterns created by hypothesis-based placement of blobs. Part of the work presented at an international conference (ISBI-04).

8. **Time-lapse microscopy and cell migration modeling**
   Carolina Wåhlby, Amalka Pinidyaarachchi, Magnus Gedda, Patrick Karlsson, Ewert Bengtsson
   **Funding:** Swedish Research Council; UU TN-faculty; (This project was previously part of the Swedish Foundation for Strategic Research VISIT programme)
   **Period:** 0306–
   **Partners:** Karin Althoff, Johan Degerman, Tomas Gustavsson, Jonas Faijerson, Torsten Olsson and Peter Eriksson, Chalmers University of Technology, Göteborg, Dept. of Clinical Neuroscience, Göteborg University
   **Abstract:** Stem cells are cells that have the capacity to both renew themselves and generate progeny of more than one type. The field of stem cell research has rapidly evolved as a promising area in medicine, and one way of verifying the characteristics of stem cells is by time-lapse microscopy of cells in culture. Our partners at Chalmers have developed a time-lapse microscopy system equipped with a computer controllable motorized stage for automated compensation of stage motion displacement and auto focus. The system is suitable for in-vitro stem cell studies and allows for multiple cell culture image sequence acquisition, tracking and migration analysis. The goal of this project is to develop automated segmentation and tracking methods for comparative studies concerning rate of cell splits, cell motion analysis as a function of progeny type. Stable and robust tracking methods require a combination of segmentation and feature extraction combined with multiple hypothesis testing for tracking. Segmentation results based on variance filtering and seeded watershed segmentation are shown in Figure 4. A guest student Tang Chunming, from Harbin University, China, is also taking part in this project.

9. **Segmentation of 2D and 3D images of tissue**
   Carolina Wåhlby, Ida-Maria Sintorn, Ewert Bengtsson, Gunilla Borgefors
   **Funding:** UU TN-faculty; SLU S-faculty; (This project was previously part of the Swedish Foundation for Strategic Research VISIT programme)
   **Period:** 0209–
   **Partners:** Fredrik Erlandsson, Dept. of Oncology/Patology, Karolinska Institute, Stockholm
   **Abstract:** Shape and distribution of various sub-cellular structures and components can be observed by im-
Figure 4: Segmentation of neural stem cells growing on a glass surface. Original image (left), approximate object locations found by variance filtering (middle), and final segmentation result by seeded watershed segmentation (right).

Munostaining and in situ hybridization of fluorescent markers followed by fluorescence microscopy. The 3D images are acquired by making non-invasive serial optical sections of the object. Studies of the distribution of signaling factors involved in the cell cycle control indicate that minor changes in the signaling systems are the first signs of cancer transformation and tumor formation. Understanding the 3D organization of normal and transformed cell nuclei is therefore of great interest as a new approach to understanding the pathways of cancer. All image cytometry requires robust segmentation techniques. Clustered objects, background variation, as well as internal intensity variations complicate the segmentation of cells in tissue. An algorithm for segmentation of images of cell nuclei in tissue that combines intensity, shape, and gradient information has been developed and tested on 2D as well as 3D data. The results were published in Journal of Microscopy in July 2004.

10. **Arteries-veins separation in magnetic resonance angiography images**  
Xavier Tizon  
**Funding:** SLU S-faculty; (This project was previously part of the Swedish Foundation for Strategic Research VISIT programme)  
**Period:** 0301–0410  
**Partners:** Örjan Smedby, Anders Persson, Adam Löfving, Dept. of Medicine and Care, Linköping University Hospital  
**Abstract:** This project is aimed at selecting a subset of volumetric data, and presenting it in such a way as to make diagnosis easier. In magnetic resonance angiography (MRA), it is of great interest to be able to separate arteries from veins. This problem is not trivial, because the vessels can be close and parallel throughout the image, especially in the neck region. Our algorithm extends the concept of binary connectedness to grey-level connectedness, using fuzzy sets. As start sets, we used small sets of voxels marked by the user. Good user interaction possibilities, portability and reusability are important concerns in this project. That is why we provided an implementation as a "plug in" for the public domain package ImageJ. Clinical validation is in progress at Linköping University Hospital.

11. **Plaque Burden Index estimation on whole-body magnetic resonance angiography images**  
Xavier Tizon, Gunilla Borgefors  
**Funding:** SLU S-faculty; (This project was previously part of the Swedish Foundation for Strategic Research VISIT programme)  
**Period:** 0209–0410  
**Partners:** Håkan Ahlström, Hans Friimmel, Tomas Hansen, Lars Johansson, Joel Kullberg, Dept. of Oncology, Radiology, and Clinical Immunology, UU Hospital; Qingfen Lin, previously at Computer Vision Laboratory, Dept. of Electrical Engineering, Linköping University  
**Abstract:** As part of a large clinical trial, launched in order to study multiple factors causing arteriosclerosis, a large number of volunteers are participating in a whole-body MR angiography study at UU Hospital. Our goal is to develop Image Analysis tools to derive global measures of arteriosclerosis, from the characteristics of a limited portion of the arterial tree. The volume image analysis is split in four sub-tasks: (a) Registration of sub-volumes. The acquisition technique produces four MRA volumes that correspond
to the head and upper torso, the abdomen, the upper legs, and the lower legs. The acquisition procedure is optimized for patient comfort, producing a whole-body data set in only a few minutes. As a consequence, images show considerable geometric distortion near the borders of the volume. We use a tubular phantom, consisting of plastic tubes filled with water and contrast media, to produce an image using the standard MRA protocol. This image is rectified, as the geometry of the object is known, to estimate the original distortion of MRA data. This work has also resulted in a Master Thesis Master thesis at the MR Department of UU Hospital.

(b) Segmentation and identification of the arterial structure. Once the full volume has been registered and reconstructed, the arteries are segmented from the rest of the visible structures. Using limited user interaction and a modified Fast Marching algorithm, we are able to identify a predetermined subset of the arterial tree, removing veins and arteries with low diagnostic interest. The proposed method computes a cost map, from which it is possible to find the best (i.e. lowest cost) path between any point in the image and a given starting point. A graph is built, representing a simplified version of the arterial tree, that can be used for comparison between patients, and for localization of detected features along the arteries.

(c) Geometric measures to give an estimate of plaque burden. The geometry of the tubular structure of the arterial tree has to be studied. Candidate measures indicating the plaque burden that have been developed are: irregularities in the diameter along the central line of the vessel; curvature of the vessels; torsion of the vessels. Differential geometrical methods are used, together with scale-space theory, to study the degree to which structures resemble tubes. The potential measures must of course be clinically evaluated. Testing. A clinical study will help to choose which ones are the best for the physician to use.

12. Simultaneous visualization of 3D anatomical and multidimensional physiological information- with application to positron emission tomography

Pasha Razifar, Ewert Bengtsson

Period: 0110-

Funding: Amersham Foundation, UU TN-Faculty

Partners: Mats Bergström, Harald Schneider, UU and Uppsala Imanet

Abstract: Positron emission tomography (PET) is a powerful imaging technique with the potential of obtaining functional or biochemical information by measuring distribution and kinetics of radiolabelled molecules in a biological system, both in vitro and in vivo. PET images can be used directly or after kinetic modeling to extract quantitative values of a desired physiological, biochemical or pharmacological entity. PET images are generally rather noisy, meaning that the individual images are not optimal for the analysis and visualization of anatomy and pathology. Therefore it is essential to understand how noise affects the derived quantitative values. A pre-requisite for this understanding is that the properties of noise such as variance (magnitude) and texture (correlation) are known.

In earliest phase of the project, a technique for studying the pattern of noise distributions and correlation in both synthetically and experimentally generated PET images, using autocorrelation function (ACF) was developed. The results were illustrated as one-dimensional (1D) profiles and even visualized as two-dimensional (2D) ACF images, revealing information about the noise properties which was then further explored. Experimental PET data were acquired in 2D and 3D acquisition mode and reconstructed by both analytical filtered back-projection (FBP) and iterative ordered subsets expectation maximization (OSEM) methods. Also, the results from these studies were compared with results from covariance matrix. Furthermore ACF has been applied on other medical imaging modalities such as Single Photon Emission Computed Tomography (SPECT), Computed Tomography (CT) and PET-CT for investigation of noise properties in these imaging tools.

Average images have been used to reduce the noise in PET images, but these average images tend to dampen the differences between regions of different kinetics. Parametric images, aiming at extracting areas with specific kinetic properties can enhance the discrimination between regions and normal contra pathology, but such methods typically enhance noise or at least do not optimize signal-to-noise ratio. It is clear that in several types of PET studies, the existing methods for generating diagnostic images, using either summations or parametric images, are not optimal. Therefore, Principal component analysis (PCA) and Independent Component Analysis (ICA) have been studied on dynamic PET images to study if it is possible to generate images, which emphasized regions with differences in behavior.

Different types of normalization algorithms have been suggested and studied for better optimization of
signal-to-noise ratio in PET images before applying PCA and ICA. These studies have even been followed by studies concerning application of these two multivariate methods on normalized PET images, utilizing time-activity data obtained by using a reference region. The methods are adopted for certain PET applications, notably for the diagnosis of Alzheimer's disease with a new amyloid binding PET tracer. The methods are probed and fine tuned both on synthetic and clinical PET images with the purpose to optimize the signal to noise ratio in these images.

13. Improved interactive medical image analysis through new haptic display methods
Erik Vidholm, Ewert Bengtsson, Ingela Nyström, Stefan Seipel
Funding: Swedish Research Council
Period: 0301–
Partners: Lennart Thurfjell, GE Healthcare, Uppsala/London, UK; Gunnar Jansson, Dept. of Psychology, UU; Hans Frimmel, Dept. of Oncology, Radiology, and Clinical Immunology, UU
Abstract: Modern medical imaging techniques provide 3D images of increasing complexity. Better ways of exploring these images for diagnostic and treatment planning purposes are needed. Combined stereoscopic and haptic display of the images form a powerful platform for such image analysis.
In order to work with specific patient cases it is necessary to be able to work directly with the medical image volume and to generate the relevant 3D structures directly as they are needed for the visualization. Most work so far on haptic display has used predefined object surface models. In this project we are creating the tools necessary for effective interactive exploration of complex medical image volumes for diagnostic or treatment planning purposes through combined use of haptic and 3D stereoscopic display techniques. The project is based on an evaluation of previous approaches from literature and our own previous experiences. The developed methods are tested on real medical application data.
During 2004, we have developed a fast surface renderer for interactive modeling and manipulation of image data with haptic feedback. We have also developed a haptic interaction method based on gradient diffusion for enhanced navigation. See Projects 14 and 15.

14. Fast surface rendering for interactive medical image segmentation with haptic feedback
Erik Vidholm, Jonas Agmund, Ewert Bengtsson
Funding: Swedish Research Council
Period: 0401–
Abstract: In this project, we have developed a haptic-enabled application for interactive editing in medical image segmentation. We use a fast surface rendering algorithm based on marching cubes (MC) to display different segmented objects, and we apply a proxy-based volume haptics algorithm to be able to touch and edit these objects at interactive rates. As an application example, we show how the system can be used to initialize a fast marching segmentation algorithm for extracting the liver in magnetic resonance (MR) images and then edit the result if it is incorrect, see Figure 5.
The project results are documented in the MSc thesis by Agmund, see Section 3.3, and in a conference publication that was presented at SIGRAD’04, Gävle, Sweden.

15. **Haptic interaction methods for semi-automatic segmentation of medical volume images**

Erik Vidholm, Xavier Tizon, Ingela Nyström, Ewert Bengtsson  
*Period:* 0301–  
*Funding:* Swedish Research Council; SLU S-faculty; (This project was previously part of the Swedish Foundation for Strategic Research VISIT programme)  
*Abstract:* The manual step in semi-automatic segmentation of medical volume images typically involves initialization procedures such as placement of seed-points or positioning of surface models inside the object to be segmented. The initialization is then used as input to an automatic algorithm. We investigate how such initialization tasks can be facilitated by using haptic feedback.  
By using volume haptics we aim to make the initialization process easier and more efficient. In April 2004, we presented a haptic-enhanced seeding method for magnetic resonance angiography (MRA) images in order to separate arteries and veins at the IEEE International Symposium on Biomedical Imaging (ISBI’04). The haptic interaction was based on the volume gradient and made it possible to trace vessels by sliding against the inner vessel wall.  
During 2004, we also started a project for interactive segmentation of MR images of the liver as a step in surgery planning. To be able to work with larger objects such as the liver we base the haptic interaction on gradient vector flow (GVF) that propagates edge information from strong boundaries into the center of objects. This approach allows a user to feel object boundaries while still being centered inside the object. The method is not limited to elongated structures such as vessels. Initial results are documented in a paper that will be presented at the conference WorldHaptics in March 2005, Pisa, Italy.

16. **Modelling of natural objects**

Felix Wehrmann, Ewert Bengtsson  
*Funding:* UU TN-faculty  
*Period:* 9912–0405  
*Abstract:* This project started under the scope of the general idea of model-based segmentation. A large number of images, especially from the medical sector, lack a proper description of the objects the image analyst is interested in. Often, this leads to poor results of automated segmentation procedures, if any. Incorporating information about the character of an object, like shape information or colour appearance, is one possible completion of a description. However, many models that are used for description lack the property to compensate for the variation nature supplies us with. As an example, we could ask ourselves, which features make us easily recognise and localise a brain in a medical 3D-image, a task which has automated solutions only in specific cases.  
With the intention to compensate for natural variation, we applied a number of common concepts to the problem. In particular, orthogonal transforms, such as PCA and ICA, have been inspected in an attempt to derive the characteristic correlations between similar shapes. Moreover, the applicability of Markov random fields as a local stochastic modeling concept was analysed.  
It turned out that a general model should not be dependent on landmarks as required for the previous transformations. It has been realised that the avoidance of landmarks place shape data on a ground comparable to images. Since variations in landmark-less shape data appear as non-linear manifolds, as well as the appearance change of colour in images, a neural network was designed to acquire the particularities of the data. After training on examples, the network provides a non-linear representation of object appearance by means of its modes of variation. Neural networks have been found a promising representation for the explored kind of variation in the data. They were applied to a variety of data and their learning abilities have been studied further. This project lead to a PhD for Wehrmann, see Section 4.2.

17. **New techniques for information extraction by using new neuro-fuzzy systems**

Hamed Hamid Muhammed  
*Funding:* UU TN-faculty, Swedish National Space Board  
*Period:* 0201–  
*Abstract:* New neuro-fuzzy systems (Weighted Neural Networks, WNN) which can characterize the distribution of a given data set were developed in this work. The basic idea is based on the famous Hebb’s postulate which states that the connection between two winning neurons gets stronger. The WNN algorithm produces a net of nodes connected by edges. Additional weights, which are proportional to the local densi-
ties in input space, are associated with the resulting nodes and edges to store useful information about the
topological relations in the given input data set. A fuzziness factor, proportional to the connectedness of the
net, is introduced in the system. The resulting net reflects and preserves the topology of the input data set,
and can be considered as a fuzzy representation of the data set. Two main types of WNNs were developed:
incremental self-organising and fixed (grid-partitioned) depending on the underlying ANN algorithm.

- Weighted Fixed Neural Networks (WFNN): A number of zero-weighted nodes are uniformly dis-
tributed in input space where the given data set is found. Then, weights are assigned to these
nodes, where a relatively higher node-weight corresponds to a relatively denser region of the data
set. Weighted connections are established between neighbouring nodes, where the weights are also
proportional to the local density of input data. The work has resulted in a journal paper presenting the
WFNN algorithm.

- Weighted Incremental Neural Networks (WINN): The model is built by successive addition, adapta-
tion, and sometimes deletion of elements (i.e., nodes and edges), according to suitable strategies, until
a stopping criterion is met. Here also, a weighted connected net, which preserves the topology of the
input data set, is produced. The algorithm begins with only two nodes connected by an edge, then
new nodes and edges are generated and the old ones are updated (and sometimes deleted) while the
learning process proceeds until a certain stopping criterion is met. The work has resulted in a jour-
WINN with WFNN.

18. **Global shape description in 2D and 3D by polynomial expansion**

Ola Weistrand, Gunilla Borgefors

*Funding:* Swedish Research Council; UU TN-faculty

*Period:* 9701–

*Partners:* Christer Kiselman, Dept. of Mathematics, UU; Örjan Smedby, Dept. of Medicine and Care,
Linköping University Hospital

*Abstract:* Shape description derived from volume images is usually local, e.g., finite elements, surface
facets, and spline functions. This can be a severe limitation on usefulness, as comparison between different
shapes becomes very difficult. In 2D, Fourier descriptors is a successful and often used global descriptor
with adaptable accuracy. This concept cannot be immediately generalised to 3D because it relies heavily
on the existence of an ordering of the boundary pixels. The aim of this project is to overcome this problem
and develop methods for global shape description in 3D. At the moment we study a limited class of objects,
those that are homotopic to the sphere. By using harmonic functions we map the object’s surface onto
the sphere and correct distortions resulting from this mapping by non-linear optimization methods. Shape
invariants can then be calculated using spherical harmonic functions.

19. **Digital distance transforms in 2D, 3D, and 4D images**

Gunilla Borgefors, Ida-Maria Sintorn, Stina Svensson

*Funding:* SLU S-faculty

*Period:* 9309–

*Abstract:* In a distance transform (DT), each picture element in an object is labeled with the distance to the
closest element in the background. Thus the shape of the object is “structured” in a useful way. Only local
operations are used, even if the results are global distances. DTs are very useful tools in many types of
image analysis, from simple noise removal to advanced shape recognition. We have investigated DTs since
the early 1980’s.

In medical and industrial volume images, the picture elements are often rectangular boxes rather than cubes,
because the images are created as a stack of “slices”, either physically or by computation. It would be time
and memory saving to work directly in such grids, rather than first interpolating the image to a cubic grid.
However, DT based methods (among others) are not directly applicable to non-cubic grids. Therefore, we
have investigated DTs in box grids, where voxels have two equal sides and the third is longer. A voxel in
such a grid has five different types of neighbours, for which optimal weights were calculated as a function
of the voxel elongation. The optimisation in 3D gives rise to four types of regular DTs of which one, the
simplest, was further investigated. An article with the results was published in Pattern Recognition Letters
20. **Image processing and analysis of 3D images in the bcc and fcc grids**
Robin Strand, Gunilla Borgefors

*Funding:* Graduate School in Mathematics and Computing (FMB)

*Period:* 0308–

*Partners:* Christer Kiselman, Dept. of Mathematics, UU

*Abstract:* Volume images are usually captured in one of two ways: either the object is sliced (mechanically or optically) and the slices put together into a volume or the image is computed from raw data, such as X-ray or magnetic tomography. In both cases, voxels are usually box-shaped, as the within slice resolution is higher than the between slice distance. Before applying image analysis algorithms, the images are usually interpolated into the cubic grid. However, the cubic grid might not be the best choice. In two dimensions, it has been demonstrated in many ways that the hexagonal grid is theoretically better than the square grid. The body-centered cubic (bcc) grid and the face-centered cubic (fcc) grid are the generalizations to 3D of the hexagonal grid. In the bcc grid the voxels consist of truncated octahedra, in the fcc grid the voxels consist of rhombic dodecahedra. The voxels in these grids are better approximations to Euclidean balls than the cube, a fact that is justified by looking at the voxels neighbours. A voxel in the fcc grid has as many as twelve first neighbours and thus constitutes the densest periodic packing of the grids. A voxel in the bcc grid has 14 face neighbours, of which eight are first neighbours.

The main goal of the project is to develop image analysis and processing methods for volume images digitized in the fcc and bcc grids, especially distance transform based and morphological methods for shape description and analysis. Weighted distance transforms, see also Project 19, in the fcc and bcc grids have been investigated and the results have been submitted. A skeletonization algorithm based on iterative, topology preserving, thinning of distance transformed objects in the fcc and bcc grids has been developed. The results were presented at the ICPR conference.

21. **Fuzzy shape analysis in 2D and 3D**
Nataša Sladoje (Matić), Ingela Nyström, Joakim Lindblad, Gunilla Borgefors

*Funding:* SLU S-faculty, UU TN-faculty

*Period:* 0109–

*Partners:* Punam K. Saha, MIPG, Dept. of Radiology, University of Pennsylvania, Philadelphia, USA; Jocelyn Chanussot, Signal and Image Laboratory (LIS), INPG, Grenoble, France

*Abstract:* Fuzzy segmentation methods, that have been developed in order to reduce the negative effects of the unavoidable loss of data in the digitisation process, initialise the interest for new shape analysis methods, handling grey-level images. We assume that in the segmentation process most picture elements easily can be classified either as object or background, but for elements in the vicinity of the boundary of the digitised object it is hard to make such a discrimination. One way to treat such an element is to determine the extent of its membership to the object as the fraction of its area that belongs to the original object. We have performed studies on perimeter and area of 2D, and surface area and volume of 3D fuzzy subsets, where the focus has been on objects with fuzzy borders. We have implemented a method where we propose perimeter and area estimators, as well as surface area and volume estimators, adjusted to the discrete case. We have concluded that our method highly improves both accuracy and precision of the results obtained from crisp (hard) segmentation, especially in the case of low resolution images, i.e., small objects.

During 2004, our defuzzification method based on feature invariance has been further developed. The idea is to use, not only membership and/or gradient information, which is a common approach, but also shape information, in order to generate a crisp representation of a fuzzy shape. Having precise area and perimeter estimates, we incorporated them, together with the centre of gravity of a shape, into a defuzzification method. We have developed and tested a number of optimization algorithms for finding the crisp object which most resembles the observed fuzzy object. Having a computationally demanding task, we try to provide a balance between speed and quality/precision of the procedures. Our method can be useful whenever it is important to preserve reliable measures of the original object, along the object analysis procedure. An example of a defuzzification of a region close to a bone implant, by using the suggested method, is shown in Figure 6.

Following the main goal of extending various shape descriptors to the fuzzy case, we analysed different ways of computing the signature of a fuzzy shape, based on the distance from the shape centroid. The encouraging results advocate use of fuzzy shapes to improve precision of the descriptor, especially at low resolutions. These results will be published in the journal *Pattern Recognition Letters* in early 2005.
22. **Discrete 3D tools applied to 2D grey-level images**

Ingela Nyström, Gunilla Borgefors

*Funding:* UU TN-faculty, SLU S-faculty

*Period:* 0209–

*Partners:* Gabriella Sanniti di Baja, Istituto di Cibernetica, CNR, Pozzuoli, Italy

*Abstract:* 2D grey-level images are interpreted as 3D binary images, where the grey-level plays the role of the third coordinate. In this way, algorithms devised for 3D binary images can be used to analyse 2D grey-level images without prior segmentation into hard object and background. One algorithm computes an approximation of the convex hull of the 2D grey-level object, by building a covering polyhedron closely fitting the corresponding object in a 3D binary image. The obtained result is convex both from a geometrical and a grey-level point of view. Another algorithm skeletonizes a 2D grey-level object by skeletonizing the top surface of the object in the corresponding 3D binary image. The obtained 3D curve skeleton is pruned, before being projected back to a 2D grey-level image. This is suitably post-processed, since the projection may cause spurious loops and thickening. This algorithm can find applications in optical character recognition (OCR) and document analysis or in other situations where shape analysis by skeletons is desired. For an example, see Figure 7.
23. **Decomposition of 3D objects**  
Stina Svensson  
*Funding:* SLU S-faculty; CNR Italy  
*Period:* 9801–  
*Partners:* Carlo Arcelli and Gabriella Sanniti di Baja, Istituto di Cibernetica, CNR, Pozzuoli, Italy  
*Abstract:* When analysing the shape of an object it is not only of interest to study the object itself but also its complement. This can give us information on, for example, the structure of tunnels possibly existing in the object. We start the analysis by identifying the convex deficiency of the object, i.e., the difference between the convex hull of the object and the object. The convex deficiency can then be decomposed into regions corresponding to cavities or tunnels in the object. The structure of the tunnels can be further analysed with respect to branching, thickness, and length. An article describing this analysis in detail is published in Image and Vision Computing in February 2005.

24. **Shape analysis in four dimensional images**  
Stina Svensson  
*Funding:* SLU S-faculty  
*Period:* 0210–  
*Partners:* Pieter Jonker, Pattern Recognition Section, Faculty of Applied Physics, Delft University of Technology, Delft, The Netherlands  
*Abstract:* In medical applications, devices giving three dimensional (3D) images are in use since the sixties for imaging anatomical or functional aspects of the human body. It is also possible to use images with more than three dimensions. Four dimensional (4D) images can be used to represent a 3D object traversing in space-time, e.g., a beating heart or a moving robot. We have started to analyse the shape of the objects in such images. As 4D images contain huge amounts of data, we first need to find a suitable representation with a reduced amount of data, still containing enough information to actually perform shape analysis. Skeletons is such a representation (see Projects 22, 4), were dimension is reduced one or several steps. We have started the work on developing topologically correct 4D skeletonization methods.

25. **Open boundary conditions: shallow water waves**  
Fredrik Bergholm  
*Funding:* UU TN-faculty  
*Period:* 0207–  
*Partners:* Kristoffer Döös, Dept. of Meteorology, Stockholm University, Stockholm  
*Abstract:* This is a topic in numerical analysis: Open boundary conditions for shallow water waves. Early reports on the theme from 2000 (MISU, Stockholm) describe simulation experiments using some known techniques, but current research (2003–) focuses on intermittent open boundaries — a new idea — presented at a seminar in Sept. 2003, for researchers from TDB and CBA. The goal is to reduce artificial reflections of waves at the open boundary. A preliminary research report on the topic, with 2D experiments, has been written and will be finalized early 2005.

26. **New approach to multi- and hyperspectral imaging**  
Hamed Hamid Muhammad, Fredrik Bergholm  
*Funding:* UU TN-faculty, Swedish National Space Board  
*Period:* 0306-  
*Abstract:* Despite an impressive evolution of multi- and hyper spectral sensors, there are still very few or crude ways of obtaining an instantaneous multi- or hyper spectral 2D-image of the environment. In particular, in many applications it may be quite useful to have a portable multi spectral camera where instantaneous images are captured in uncontrolled conditions. What would be more convenient than using the digital camera you like, and upgrade it to a multi spectral sensor by adding a color mosaic to the optics? The idea of using color mosaics attached to the CCD is standard, and can of course yield many more spectral bands sacrificing resolution somewhat. However, this approach has several disadvantages. In a digital camera, the manufacturer has already put in a color mosaic, and it is very difficult and expensive to change these color filters. Making color mosaics on the chip requires microscopic filter mosaics, and if the filter mosaic coincides with the glass sealing the CCD chip, the operation must be done in a (camera manufacturer) laboratory. This is slightly inconvenient for people involved in remote sensing, photogrammetry or image analysis, who rather would like to use a non-invasive technique, where technical details on how the CCD chips is built-up should stay secondary concern. How would one avoid “invading the chip” and mounting
something permanent or semi-permanent in front of the chip? In this pilot study we have investigated the possibility of placing the filter mosaic (say a plane parallel plate) in some favourable position in the path of light through the lens system. This technique really produces an image that is able to reveal the differences between near-by colors, or between different materials that appear to have similar colors in the RGB-domain; i.e., a sort of a multi spectral image, with a higher spectral resolution than an ordinary RGB-image, is obtained by using this color mosaic. During the year, a patent application on the color mosaic technique has been filed. The patent is financed by UUAB. The robustness of the calculation from image data to multi- or hyper-spectral data (pixel-wise spectra) is analyzed in a report to be submitted 2005 for journal publication. Cooperation with SLU has been established, for tests with field spectra.

27. Efficient algorithms for computer graphics
Anders Hast, Ewert Bengtsson
Funding: Dept. of Mathematics, Natural Sciences, and Computing, University College of Gävle; The Knowledge Foundation
Period: 9911–0404
Partner: Tony Barrera, Barrera Kristiansen AB, Uppsala
Abstract: Computer graphics is increasingly being used to create realistic images of 3D objects. Typical applications are in entertainment (animated films, games), commerce (showing 3D images of products on the web which can be manipulated and rotated), industrial design, and medicine. For the images to look realistic high quality shading and surface texture and topology rendering is necessary. Many fundamental algorithms in this field were developed already in the early seventies. The algorithms that produce the best results are computationally quite demanding (e.g., Phong shading) while other produce less satisfactory results (e.g., Gouraud shading). In order to make full 3D animation on standard computers feasible high efficiency is necessary. We are in this project re-examining those algorithms and are finding new mathematical ways of simplifying the expressions and increasing the implementation speeds without sacrificing image quality, see Figure 8. The project is carried out in close collaboration with Tony Barrera at Barrera Kristiansen AB. Several publications was accepted this year and several papers where presented on conferences as follows: One short paper was presented at the WSCG’04 conference in Plzen Czech Rep. And one full paper was published in IEEE Transactions on Visualization and Computer Graphics. Two papers was published at the national conference SIGRAD, which was held in Gävle this year. One of them was a work in progress paper and it was written together with prof. Stefan Seipel and Daniel Wesslen, and this collaboration with the group in Gävle will continue besides the ongoing collaboration with prof. E. Bengtsson and T. Barrera.

Figure 8: An original Warn spotlight model (left), a new fast soft edge model (middle), and a proposed hard edge model (right)

28. Efficient forest data visualization
Stefan Seipel
Funding: County Council in Gävleborg, EU Goal2, North
Period: 0308–
Partners: Daniel Wesslén, University College of Gävle
Abstract: The objective of this project is to develop and assess efficient methods for visualization of information related to forest industry. The goal is to find rendering techniques that are effective in terms of runtime as well as developing graphical representations that can be processed efficiently from a human-cognitive point of view. At the current stage of the project we are investigating techniques for realistic rendering of
detail-rich Scandinavian forests. In contrast to previous research in complex plant systems we develop algorithms for procedural modeling, which, based on a parametric description, automatically synthesize typical structures of Scandinavian vegetation. For realistic experience of virtually rendered eco-systems, the model is animated at the host side at given animation frames. Thereafter, updated models must be transferred to the graphics subsystem to be rendered. Current graphics hardware is by all means capable of storing and rendering very high detail plant models. However animation of is hampered due to the limited memory bandwidth between host system and graphics subsystem. Our current research utilizes advanced vertex and pixel shader programming capabilities to perform the entire pipeline of model generation, animation and rendering on the graphics subsystem. Interactive visualizations of realistic Scandinavian forests is an important tool to perform long-term forest planning and in education.

29. **Interactive exploration of medical images for visualization on standard PC hardware**

Suthakar Somaskandan, Ingela Nyström, Ewert Bengtsson

**Funding:** Sida  
**Period:** 0409–

**Abstract:** Several of the modern imaging systems provide 3D volume information, e.g., CT, MRT, SPECT, and ultrasound. This is very useful since the human body is 3D. Display devices are, however, 2D. Therefore, the 3D image volumes need to be projected onto the 2D computer screens in some way. So far mainly slice by slice projections have been used. There is, however, potential for using much more sophisticated display methods.

It is particularly useful to device methods where the user interactively can explore the 3D information in the images to reach, e.g., a diagnostic conclusion. Earlier, allowing dynamic interaction with medical image volumes of realistic, clinically useful resolution required very expensive display stations driven by high-performance computers. Today, a PC equipped with a high end standard graphics card can be used quite effectively for that purpose. Such cards typically cost less than 1,000 Euro since they are mass produced for the game markets. But they also offer very interesting potential for use together with appropriate software algorithms for medical visualization. Still much research work is needed to find out the most effective way of using such display facilities for exploring medical image volumes. The research task will be to develop and evaluate such display methods.

30. **Co-located information visualization**

Stefan Seipel, Lars W. Pettersson

**Funding:** Swedish Defense College, Stockholm  
**Period:** 0401–0412

**Partners:** Swedish Defense College, Stockholm

**Abstract:** Advanced graphical visualizations of complex data become increasingly important in decision-making processes where many different stakeholders are involved. Often, these collaborative decision processes can be found in situations where information is gathered and represented in a geographical context. Advanced visualizations which provide 3D visual information to several simultaneous observers call for new display techniques and visualization methods. The objective of this project is to research new methods for visualizing data efficiently for a group of people who interact in the same physical environment. Our research builds upon a novel graphical display system which provides up to eight independent visual channels in the same physical place. With this technology available, new rendering and visualization techniques become feasible that support several people in sharing 3D graphical content. In this project our current research focus is on the design of visualization techniques and consequently on quantitative studies of the humans capacity to utilize 3D graphical content.

31. **Colour correction of underwater multi- or hyper spectral data.**

Julia Åhlen, Tommy Lindell, Ewert Bengtsson

**Funding:** The Knowledge Foundation  
**Period:** 0102–

**Abstract:** Color restauration of underwater images can be important for many applications, such as marine biology and underwater archaeology. The absorption of light as we descend under water cause production of color corrupted images, see Figure 9 (left). Objects are blue or green colored since shorter wavelengths are absorbed last in the water. The aim of the project is to examine the effects introduced by the optical
properties of the water column and present a method for removing these negative effects from images. As a first step for this project we estimate a diffuse attenuation coefficient for three wavelengths. The estimation is possible as we are using known reflectance values of a reference gray target that is present on all tested images. To calculate new intensity values we are using Beers Law, where the depth parameter is derived from images that are taken at different depths approximately 50 cm from each other. The suggested method provides a quite effortless and economical way for color reconstruction in degraded underwater images. Another parameter that needs to be taken into account is the image enhancement functions built into the camera. We use a spectrometer and known reflectance standard to obtain the data needed to approximate the joint effect of these functions and the transmittance factor for water mass. This model is used to pre-process the underwater images taken by digital cameras so that the red, green and blue channels show correct values before the images are subjected to correction for the effects of the water column through application of Beer’s Law., see Figure 9 (right).

Figure 9: An underwater color corrupted image (left), and color corrected (right).

32. **Remote sensing for change detection and monitoring of Case II and lake waters**  
   Petra Philipson, Tommy Lindell  
   **Funding:** Foundation for Strategic Environmental Research (MISTRA), RESE programme  
   **Period:** 9701–  
   **Partners:** Niklas Strömbeck and Don Pierson, Dept. of Evolutionary Biology, Limnology, UU  
   **Abstract:** The ability to map and monitor water quality parameters in Case II and lake waters is of great environmental interest. Remote sensing is an important constituent for monitoring and an invaluable complement to field observations. Earlier work has been concentrated on finding relations between the water quality variables (Chl, SPIM and CDOM) and remote sensing images from a spectrographic sensor (CASI). However, it is unlikely that the resulting algorithms from these kind of empirical relationships will be sufficiently general to be used in a variety of contexts. During this project, a simple bio-optical model was developed and used together with historical water quality measurements from Lake Mälaren, Sweden, to construct algorithms for retrieval of water quality parameters from remote sensing data. These image independent algorithms have been applied to the atmospherically corrected CASI data from Lake Mälaren and Lake Erken and the resulting concentration maps have been validated using ground truth measurements. The results from the validation of the CASI algorithms were satisfying, and the modelled concentrations and absorption coefficients corresponded well to the ground truth measurements, which is very encouraging for the future work. This project was finished with the RESE project ending in December 2003, but got further funding from Swedish National Space Board and has continued within the Department of Limnology by Petra Philipson, now working for Swedepower.

33. **New techniques for information extraction from remotely sensed hyper spectral images of Swedish inland waters**  
   Hamed Hamid Muhammed, Tommy Lindell, Ewert Bengtsson  
   **Funding:** UU TN-faculty, Swedish National Space Board  
   **Period:** 0001–  
   **Abstract:** A substance can be characterised and recognised by its spectral signature. The benefit of hyper spectral imagery is that a sufficient number of narrow spectral bands is available to be able to accurately
determine the spectral response at each pixel in the image. A pixel (or a point spectrum) in a hyper spectral image can be considered as a mixture of the reflectance spectra of several substances that can be found in the corresponding imaged region. Independent Component Analysis (ICA) and Principal Component Analysis (PCA) have been used to transform the hyper spectral image data as a first step to get a new set of data that is more suited for further processing than the original data. The next step is to interpret and use the ICA or PCA results efficiently. This can be achieved by using a new technique called Feature-Vector Based Analysis (FVBA) which has been developed earlier in this project.

The outputs of the transformation step (which are a number of basis vectors and projections of the original data on these vectors) are considered as so called Component-Feature-Vector pairs in the subsequent FVBA step. The FVBA task itself is application dependent. But, the common idea of FVBA is to look at the (simpler) Feature Vectors to understand the corresponding (more complicated) Components. FVBA can be used for four main types of applications. In the first two, either well-defined Feature Vectors or well-defined Components are available. The other two types of applications are feature extraction and classification.

When studying hyper spectral images of Swedish inland waters, the obtained Feature Vectors and the corresponding Components represent the spectral signatures and the corresponding weight-coefficients images (e.g. the relative concentration maps) of the different constituting substances. The work has resulted in two publications at reviewed conferences, one described FVBA itself, and another one about using FVBA for analysing hyper spectral images. We are now planning to try to apply the methods developed for the hyper spectral crop reflectance data (consisting of 164 spectral bands) in the previously described project, to the much-lower-spectral-resolution hyper spectral images (consisting of 14 spectral bands) of Swedish inland waters.

34. **Field measurements, Abisko, Lake Torneträsk**
Tommy Lindell, Fredrik Bergholm  
*Funding:* UU TN-faculty, Dept. of Infrastructure, KTH, Stockholm  
*Period:* 0406–  
*Partners:* Kai Sörensen, Norwegian Institute for Water Research (NIVA); Terry Callaghan, Abisko Scientific Research Station (ANS)  
*Abstract:* From June 20 to July 2, 2004, spectrometer measurements were performed by Fredrik Bergholm, in birch forest around Abisko Naturvetenskapliga Station (ANS), and spectral mesurements were performed by Tommy Lindell and Kai Sörensen, in Lake Torneträsk. These field measurements will be part of data base, for the Scandinavian NorSEN project, with start in 2005. The project deals with validation of satellite images, and build-up of ground-based spectral sensors around ANS.

35. **HYSENS — Hyper spectral remote sensing using a new version of ROSIS**
Tommy Lindell, Petra Philipson  
*Funding:* European Space Agency, Deutsche Zentrum für Luft und Raumfahrt  
*Period:* 0001–0406  
*Partners:* Don Pierson, Dept. of Evolutionary Biology, Limnology, UU; Eugenio Zilioli, CNR, Milan, Italy; Province Environment Protection Agency of Trent (APPA), Province Ecological Agency of Verone (ECOV) and Regional Environment Protection Agency, Verone, Italy  
*Abstract:* ROSIS for Algal Mapping in Lacustrine Environment (ROSALMA). ROSALMA was essentially oriented to a double task:

- to correlate basic water quality parameters like chlorophyll, suspended sediment concentrations and Secchi disc to the hyper spectral data by using a semi-analytical approach already proved in other geographic conditions and with other hyper spectral devices;
- to determine the best optical spectral windows for mapping the macrophyte growth, in order to design a possible operational tool to be used for environmental emergencies of this kind, especially in mapping its spatial distribution.

Lindell & Philipson have participated in the work on Lake Garda, Italy earlier and in the evaluations. The focus of the last part of this project was devoted to applications of the MERIS sensor to water quality monitoring together with Kai Sörensen, NIVA, Oslo, and using the experiences gained from the CASI and ROSIS sensors. The Final Report was delivered in June 2004.
36. **Digital video and colour camera in remote sensing of water**
   Tommy Lindell  
   **Period:** 0001–  
   **Partners:** CNR, Milan, Italy  
   **Abstract:** Test of the usefulness of air-borne digital camera and video for mapping water variables. Lindell has been constructing a holder for the digital video/camera for small aircrafts. Data have been collected from Lakes Erken and Mälaren, and from coral bottoms in Biscayne National Park. Recently, tests of the usefulness of those images have been performed for the classification of the Swedish coastline.

37. **Classification of habitats along the Swedish coast using Landsat images**
   Petra Philipson, Tommy Lindell  
   **Funding:** Swedish Environmental Protection Agency  
   **Period:** 0304–0402  
   **Partners:** Cecilia Lindblad and Christina Rappe, Swedish Environmental Protection Agency  
   **Abstract:** The Natura 2000-code is a network of ecosystems and environments for species that the EC-countries have agreed to protect. To be able to chose appropriate areas for protection and for other planning purposes, information about existing habitats and land use is important. For the above stated reasons, as a request from the Swedish Environmental Protection Agency, the entire coastal zone of Sweden has been mapped. Landsat-7 ETM+ images from the Image 2000 database have been used, which resulted in a resolution of 25 meters in the final digital classification. These satellite images are geometrically corrected to RT 90 and can therefore be compared all national Swedish maps. Five classes exist in the classified result: Rock, Stone, Sand, High vegetation and Low vegetation. The result, including report and the digital classification result was distributed to the Swedish Environmental Protection Agency and to all Swedish counties in February 2004.

38. **Detecting coral reef bleaching from optical satellites (CORBOS)**
   Petra Philipson, Tommy Lindell  
   **Funding:** Foundation for Strategic Environmental Research (MISTRA), RESE programme  
   **Period:** 0001–  
   **Abstract:** Recent dramatic bleaching events on coral reefs have enhanced the need for global environmental monitoring. Remote sensing is an important constituent for monitoring of reefs, and an invaluable complement to field observations. We have been investigating the possibilities and limitations of present high resolution satellites for mapping and monitoring coral reefs, with focus on detection of coral bleaching. The work included investigation of the sensor limitations, the optical properties of the bottom features and understanding of the influence of the atmosphere and water column on the collected remote sensing data. The sensors with the best spatial and radiometric resolution available today, e.g. IKONOS, can be useful for mapping and monitoring of reefs, but they are too costly for global surveys. However, our coral bleaching studies indicate that massive bleaching could be detected even from satellites with lower resolution, like Landsat, SPOT and IRS. They could also be useful for coarser, from a spatial and thematic point of view, global mapping and updating purposes. A field study was performed around Bakers Rendezvous, in Belize in 2002. The project was reported in Ambio in December 2003, but it is continually worked on using local support.

39. **The development of a general image analysis software platform**
   Bo Nordin, Ewert Bengtsson  
   **Funding:** UU TN-faculty  
   **Period:** 8807–  
   **Abstract:** In recognition of the need in image analysis research to have a good platform for interactive work with digital images, we several years ago started a project with the aim of developing such a platform. The project originally involved some 10 man years of work, which would have been impossible to finance by regular research money. But through a cooperation with a group of companies we co-ordinated our interests of obtaining a good software platform for research with their interest in development of a new software product. Unfortunately, the companies never actively turned the resulting system, which was given the name IMP, into a product. At CBA, however, the IMP system has been used as a software basis for most of the teaching and research in image analysis for the last decade. Some years ago, we started a major revision of the system as a “background task” for Nordin. The main goal was to re-program the core system in C++ to make it easier to maintain and extend. In 2002, we decided
to write a completely new program platform, pixy, based on the new C++ core and with all image analysis functions written in C++ in order to take advantage of the C++-specific language constructs (classes, inheritance, polymorphism, templates, etc.) to enhance the programmer’s API and make the code more reusable. In pixy, it is easy to add plug-in modules with new functionality and new classes: several such modules have been implemented: MUSE (multivariate segmentation) and filter editors for editing filters in the spatial domain as well as in the Fourier domain. Pixy was released internally at CBA during 2003 and will be released externally during 2005.

5.2 Cooperation partners

CBA has extensive cooperation with other research groups, locally as well as nationally and internationally. We have, and are constantly building, the highest possible expertise in image processing within CBA, and cooperate with a number of other research groups in these respects. For applications, our research philosophy is that good application work in image analysis requires good competence both in image analysis technology and in the specific application field. Therefore, we have cooperation with researchers in our different application fields. Finally, we are also trying to bring our results from the research environment into real world use. In order to achieve this, we are cooperating with several companies, local and central government agencies, and hospitals.

The names of our cooperation partners can be found in various places in this report, but to give an overview, we list below the partners with whom we had direct project cooperation during 2004.

International

School of ITEE, University of Queensland, Australia

Inst. of Information and Communication, Harbin Engineering University, Harbin, China

Hunan Normal University, China

Laboratoire LIRIS, Université Lumière Lyon 2, Lyon, France

Signal and Image Laboratory (LIS), INPG, Grenoble, France

University of Hannover, Germany

Istituto di Cibermetica, National Research Council, Milan, Italy

Istituto di Cibermetica, National Research Council, Pozzuoli (Napoli), Italy

Province Environment Protection Agency of Trent (APPA), Italy

Province Ecological Agency of Verone (ECOV), Italy

Regional Environment Protection Agency, Verone, Italy

Inst. of Media and Information Technology, Chiba University, Japan

Faculty of Applied Physics, Delft University of Technology, Delft, The Netherlands

Norwegian Institute for Water Research, Norway

Norwegian Pulp and Paper Research Institute (PFI), Trondheim, Norway

Faculty of Engineering, University of Novi Sad, Serbia

Dept. of Computer Science, Statistics and Telematics, Rey Juan Carlos University, Madrid, Spain

Amersham Biosciences, Cardiff, UK

Dept. of Radiology, University of Pennsylvania, Philadelphia, PA, USA
National
Abisko Scientific Research Station, Abisko
Amersham Biosciences, Uppsala
Barrera Kristiansen AB, Uppsala
BioAgri, Uppsala
DeLaval International AB, Tumba
GE Health care, Uppsala/London
Gyros AB, Uppsala
Imanet AB, Uppsala
Sidec Technologies AB, Stockholm
StoraEnso Research, Falun
Swedish Defense College, Stockholm
Swedish Pulp and Paper Research Institute (STFI), Stockholm
Swedish Environmental Protection Agency, Stockholm
Dept. of Genetics and Pathology, The Rudbeck Laboratory, UU
Dept. of Information Technology, UU
Dept. of Limnology, Evolutionary Biology Centre, UU
Dept. of Mathematics, UU
Dept. of Oncology, Radiology, and Clinical Immunology, UU Hospital
Dept. of Otolaryngology, UU Hospital
Dept. of Psychology, UU
Uppsala Learning Lab, UU
Dept. of Biometry and Engineering, SLU, Uppsala
Dept. of Forest Resource Management and Geomatics, SLU, Umeå
Dept. of Mathematics, Natural Sciences, and Computing, University College of Gävle
Dept. of Clinical Neuroscience, Göteborg University, Göteborg
Dept. of Signals and Systems, Chalmers University of Technology, Göteborg
Dept. of Electrical Engineering, Linköpings University, Linköping
Dept. of Medicine and Care, Linköping University Hospital, Linköping
Dept. of Medicine, Karolinska Institute, Stockholm
Dept. of Oncology-Pathology (CCK), Karolinska Institute/Hospital, Stockholm
NADA, Royal Institute of Technology, Stockholm
Dept. of Computer Science, Royal Institute of Technology, Stockholm
Dept. of Meteorology, Stockholm University, Stockholm
Dept. of Technology, Örebro University, Örebro
6 Publications

It is true in science (as in other instances) that "The job isn’t finished until the paperwork is done". We therefore consider the publication of our results very important and try to find the best places to do it. This means international scientific journals and fully refereed international conference proceedings are preferred for works both on theory and on different applications. To be able to meet other scientists in our area we sometimes publish in non-reviewed conferences, but those results are usually eventually also published elsewhere. We do aim to also produce some popular articles, but are less successful in this respect. We do, however, give a number of such seminars each year.

This list covers all publications with a publication date in 2004. We have edited two conference proceedings for meetings we organised. We have published nine journal articles and 18 articles in refereed international conference proceedings. In addition we published ten papers in non-refereed or abstract refereed conference proceedings and six CBA reports. These numbers are a little less than 2003, but that was an unusually productive year. The figures for 2004 are still above the average. Unusually, we also have a patent application this year.

6.1 Patent application

System and method for multispectral and hyperspectral imaging

Inventors: Hamid Muhammed, H.; Bergholm, F.

Abstract: The invention is a system for acquiring instantaneous multi- or hyper-spectral 2D-images, exploiting multiple color mosaic filters, where at least one color mosaic filter is positioned externally to the image sensor, in converged light in the optical path, for instance positioned in a lens accessory part of the imaging system. Such color mosaics may be produced cost efficiently by available color printing techniques, and need not be narrow band. Given the registered \( N \) color band images, the system comprises a method, a calculation unit, where spectral information is transformed into approximate spectra.

6.2 Edited conference proceedings

1. Swedish Symposium on Image Analysis (SSBA 2004)
   Editors: Bengtsson, E.; Eriksson, M.
   Publisher: Swedish Society for Automated Image Analysis, CBA Report No. 31.
   ISSN: 1100–6641, 202 pages, 2004

2. SIGRAD 2004: Special theme - Environmental visualization
   Editor: Seipel, S.

6.3 Journal articles

1. Faster shading by equal angle interpolation of vectors
   Authors: Barrera, T. (1); Hast, A.; Bengtsson, E.
   (1) Barrera Kristiansen AB, Uppsala
   Abstract: We show how spherical linear interpolation can be used to produce shading with a quality at least similar to Phong shading at a computational effort in the inner loop that is close to that of the Gouraud method. We show how to use the Chebyshev’s recurrence relation in order to compute the shading very efficiently. Furthermore, it can also be used to interpolate vectors in such a way that normalization is not
necessary, which will make the interpolation very fast. The somewhat larger setup effort required by this approach can be handled through table look up techniques.

2. **Robust cell image segmentation methods**  
   **Authors:** Bengtsson, E.; Wåhlby, C.; Lindblad, J.  
   **Abstract:** Biomedical cell image analysis is one of the main application fields of computerized image analysis. This paper outlines the field and the different analysis steps related to it. Relative advantages of different approaches to the crucial step of image segmentation are discussed. Cell image segmentation can be seen as a modeling problem where different approaches are more or less explicitly based on cell models. For example, thresholding methods can be seen as being based on a model stating that cells have an intensity that is different from the surroundings. More robust segmentation can be obtained if a combination of features, such as intensity, edge gradients, and cellular shape, is used. The seeded watershed transform is proposed as the most useful tool for incorporating such features into the cell model. These concepts are illustrated by three real-world problems.

3. **Species classification of individually segmented tree crowns in high-resolution aerial images using radiometric and morphological image measures**  
   **Author:** Eriksson, M.  
   **Journal:** Remote sensing of environment 91:469–477, 2004  
   **Abstract:** This paper presents a method to automatically classify segmented tree crowns from high spatial resolution colour infrared aerial images as one of the four most common tree species in Sweden. The species are Norway spruce (Picea abies Karst.), Scots pine (Pinus sylvestris L.), birch (Betula pubescens Ehrh.), and aspen (Populus tremula L.). The proposed method uses four different image measures, one measure for each species. The measures are based on colour information as well as the shape of the segmented tree crowns. A segment is examined by the measures one by one and if one measure becomes true, the segment is interpreted as that species. The analysis continues with the next segment. The method is evaluated on two sets of images. The first set consists of 14 images of naturally regenerated forest with pixel size corresponding to 3 cm. These images contain approximately 50 visible tree crowns each; a total of 791 crown segments are used. The overall classification result for these images is 77%. If only the distinction between conifers and deciduous is made, the result is 91%. The second set consists of two images with a pixel size of 10 cm. Here, the overall classification result is 71%.

4. **Unsupervised fuzzy clustering using weighted incremental neural networks**  
   **Author:** Hamid Muhammed, H.  
   **Journal:** International Journal of Neural Systems (IJNS) 14(6):1–18, 2004  
   **Abstract:** A new more efficient variant of a recently developed algorithm for unsupervised fuzzy clustering is introduced. A Weighted Incremental Neural Network (WINN) is introduced and used for this purpose. The new approach is called FC-WINN (Fuzzy Clustering using WINN). The WINN algorithm produces a net of nodes connected by edges, which reflects and preserves the topology of the input data set. Additional weights, which are proportional to the local densities in input space, are associated with the resulting nodes and edges to store useful information about the topological relations in the given input data set. A fuzziness factor, proportional to the connectedness of the net, is introduced in the system. A watershed-like procedure is used to cluster the resulting net. The number of the resulting clusters is determined by this procedure. Only two parameters must be chosen by the user for the FC-WINN algorithm to determine the resolution and the connectedness of the net. Other parameters that must be specified are those which are necessary for the used incremental neural network, which is a modified version of the Growing Neural Gas algorithm (GNG). The FC-WINN algorithm is computationally efficient when compared to other approaches for clustering large high-dimensional data sets.

5. **Image analysis for automatic segmentation of cytoplasms and classification of Rac1 activation**  
   **Authors:** Lindblad, J.; Wåhlby, C.; Bengtsson, E.; Zaltsman, A. (1)  
   (1) Amersham Biosciences, Cardiff, UK  
   **Journal:** Cytometry 57A(1):22–33, 2004  
   **Abstract:** Background: Rac1 is a GTP-binding molecule involved in a wide range of cellular processes. Using digital image analysis, agonist-induced translocation of green fluorescent protein (GFP) Rac1 to the cellular membrane can be estimated quantitatively for individual cells.
Methods: A fully automatic image analysis method for cell segmentation, feature extraction, and classification of cells according to their activation, i.e., GFP-Rac1 translocation and ruffle formation at stimuli, is described. Based on training data produced by visual annotation of four image series, a statistical classifier was created.

Results: The results of the automatic classification were compared with results from visual inspection of the same time sequences. The automatic classification differed from the visual classification at about the same level as visual classifications performed by two different skilled professionals differed from each other. Classification of a second image set, consisting of seven image series with different concentrations of agonist, showed that the classifier could detect an increased proportion of activated cells at increased agonist concentration.

Conclusions: Intracellular activities, such as ruffle formation, can be quantified by fully automatic image analysis, with an accuracy comparable to that achieved by visual inspection. This analysis can be done at a speed of hundreds of cells per second and without the subjectivity introduced by manual judgments.

6. **Weighted distance transforms for volume images digitized in elongated voxel grids**
   **Authors:** Sintorn, I.; Borgefors, G.
   **Journal:** Pattern Recognition Letters 25:571–580, 2004
   **Abstract:** Weighted distance transforms in volume (3D) images using a voxel grid with equal resolution along two axes and lower, one, along the third are investigated. The weights (neighbour distances) in a local neighbourhood of size $3 \times 3 \times 3$ are optimized by minimizing the maximum error in a cubic image.

7. **A refined circular template matching method for classification of human cytomegalovirus capsids in TEM images**
   **Authors:** Sintorn, I.; Homman-Loudiyi, M. (1); Söderberg-Nauclér, C.(1); Borgefors, G.
   (1) Dept. of Medicine, Karolinska Institutet, Stockholm
   **Journal:** Computer Methods and Programs in Biomedicine 76:95–102, 2004
   **Abstract:** An automatic image analysis method for describing, segmenting, and classifying Human Cytomegalovirus capsids in transmission electron micrograph (TEM) images of host cell nuclei has been developed. Three stages of the capsid assembly process in the host cell nucleus have been investigated. Each class is described by a radial density profile, which is the average grey-level at each radial distance from the centre. A template, constructed from the profile, is used to find possible capsid locations by correlation based matching. The matching results are further refined by size and distortion analysis of each possible capsid, resulting in a final segmentation and classification.

8. **Froth delineation based on image classification**
   **Authors:** Wang, W. (1,2); Bergholm, F.; Yanga, B. (1)
   (1) Hunan Normal University, China
   (2) Royal Institute of Technology, Stockholm
   **Abstract:** This paper describes a set of image segmentation algorithms for mineral froth images, based on gray-value valley detection and a kind of image classification. The size, shape, texture and color of froth bubbles are very important pieces of information for production optimization in mineral processing. In order to determine these parameters, bubbles in a froth image first have to be delineated. Froth images display a large variation of image patterns and quality, thus it is difficult to use only a single algorithm for segmenting all images. To achieve successful segmentation the images are first classified into image classes. Then sets of segmentation algorithms are used, based on the different image classes. The segmentation algorithms and classification algorithms have been tested in a laboratory and in industrial on-line systems for froth images, the test results show that they are robust for froth images. The processing speed for the segmentation algorithm is much faster than for a standard morphological segmentation algorithm. The processing accuracy is comparable to manual drawn result. This test shows that the algorithms work satisfactorily.

9. **Combining intensity, edge and shape information for 2D and 3D segmentation of cell nuclei in tissue sections**
   **Authors:** Wåhlby, C.; Sintorn, I.; Erlandsson, F. (1); Borgefors, G.; Bengtsson, E.
   (1) Dept. of Oncology-Pathology, Karolinska Institutet, Stockholm
   **Journal:** Journal of Microscopy 215:67–76, 2004
   **Abstract:** We present a region-based segmentation method in which seeds representing both object and background pixels are created by combining morphological filtering of both the original image and the
gradient magnitude of the image. The seeds are then used as starting points for watershed segmentation of the gradient magnitude image. The fully automatic seeding is done in a generous fashion, so that at least one seed will be set in each foreground object. If more than one seed is placed in a single object, the watershed segmentation will lead to an initial over-segmentation, i.e. a boundary is created where there is no strong edge. Thus, the result of the initial segmentation is further refined by merging based on the gradient magnitude along the boundary separating neighbouring objects. This step also makes it easy to remove objects with poor contrast. As a final step, clusters of nuclei are separated, based on the shape of the cluster. The number of input parameters to the full segmentation procedure is only five. These parameters can be set manually using a test image and thereafter be used on a large number of images created under similar imaging conditions. This automated system was verified by comparison with manual counts from the same image fields. About 90% correct segmentation was achieved for two- as well as three-dimensional images.

6.4 Refereed conference proceedings

1. Incremental spherical linear interpolation
   Authors: Barrera, T.(1); Hast, A.; Bengtsson, E.
   (1) Barrera Kristiansen AB, Uppsala
   Editor: Seipel, S.
   Publisher: Linköping University Electronic Press
   Abstract: Animation is often done by setting up a sequence of key orientations, represented by quaternions. The in between orientations are obtained by spherical linear interpolation (SLERP) of the quaternions, which then can be used to rotate the objects. However, SLERP involves the computation of trigonometric functions, which are computationally expensive. Since it is often required that the angle between each quaternion should be the same, we propose that incremental SLERP is used instead. In this paper we demonstrate five different methods for incremental SLERP, whereof one is new, and their pros and cons are discussed.

2. Fast intensity distribution functions for soft and hard edged spotlights
   Authors: Hast, A.; Barrera, T.(1); Bengtsson, E.
   (1) Barrera Kristiansen AB, Uppsala
   Abstract: The purpose of this paper is twofold: to propose two fast distribution functions for spotlights and to use terminology used in stage lighting to model these luminaries. In OpenGL and other API’s the original Warn model is used where the light distribution is computed using a power function. In professional modeling tools, a linear or a cubic function is often used. We propose the use of two different quadratic functions instead that will make the computation involved faster than using the power function or a cubic function. Moreover it will be more flexible than using a linear function. These functions can be used to model both hard and soft edged spotlights

3. Improved diffuse anisotropic shading
   Authors: Hast, A.; Wesslén, D. (1); Seipel, S.
   (1) Dept. of Mathematics, Natural Sciences, and Computing, University College of Gävle
   Editor: Seipel, S.
   Publisher: Linköping university electronic press
   Abstract: Cloth, hair, brushed metal, and other surfaces with small, regular surface features exhibit anisotropic reflectance properties for which common isotropic shading methods are not suited. Shading of such materials is often implemented by computing the normal giving the maximum light contribution instead of solving the integral that is the sum of all reflected light. In this paper we show that this integral can be simplified if the direction to the viewer and fibre geometry is not taken into account. Still, this will give a more accurate result than the very rough simplification of using the maximum contribution. This computation is simple for diffuse light. However, the specular light still needs some more elaboration to work.

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4. Development of a virtual laboratory system for science education and the study of collaborative action

Authors: Jensen, N. (1); Seipel, S.; von Voigt, G. (1); Raasch, S. (1); Olbrich, S. (1); Nejdl W. (1)

(1) University of Hannover, Germany

Conference: World Conference on Educational Multimedia, Hypermedia & Telecommunications (AACE ED Media Conference) 2004

Abstract: The paper specifies the development of a toolkit to run synthetic science laboratories. The aim was to facilitate collaborative experimenting for problem-based learning in a virtual lab. The goal was to demonstrate virtual experimenting by use of interactive 3D visualization and simulation. Technology was developed over six years and in part designed in explicit accordance to didactic models. For tests, we built a virtual lab that comprised media tools and complex computer simulations, and we evaluated it with promising results. Students used data from meteorology and experimented together. Generally, they enjoyed using the system and collaborated in a motivated way. We identified which tools they preferred. The paper indicates ways to improve the design of virtual labs by use of our toolkit.

5. Segmentation and separation of point like fluorescent markers in digital images

Authors: Karlsson, P.; Lindblad, J.


Publisher: Mira Digital Publishing

Abstract: We present a method for accurate segmentation of point like signals from fluorescent markers, in digital microscopic images with subcellular resolution. The method is able to segment and separate clustered signals, which facilitates accurate dot counting. The method performance is evaluated using synthetic images, that are modeled after real digital microscopy images of cells. The results show that the method is able to detect point like fluorescent signals as accurately as a manual operator.

6. Real-time rendering of accumulated snow

Authors: Ohlsson, P.; Seipel, S.


Editor: Seipel, S.

Publisher: Linköping University Electronic Press

Abstract: This paper presents a method of computing snow accumulation as a per pixel effect while rendering the scene. The method is similar to the shadow mapping method for shadow calculations. A depth buffer is used to find out how much snow a particular surface should receive. The amount of snow is then modified depending on the slope of the surface. To render the snow in a convincing way 3D noise is utilized for the lighting of the snow surface.

7. 2D grey-level skeleton computation: A discrete 3D approach

Authors: Sanniti di Baja, G. (1); Nyström, I.

(1) Istituto di Cibernetica, National Research Council of Italy (CNR) Napoli, Italy


Editors: Kittler, J.; Petrou, M.; Nixon, M.

Publisher: IEEE Computer Society

Abstract: A discrete 3D binary approach to compute the skeleton in 2D grey-level images is presented. The 2D grey-level input image is converted to a 3D binary image and the top surface of the foreground is identified. This discrete surface then undergoes skeletonization. The obtained 3D curve skeleton is pruned, before being projected back to a 2D grey-level image. This is suitably post-processed, since the projection may cause spurious loops and thickening. This algorithm can find applications in optical character recognition and document analysis or in other situations where shape analysis by skeletons is desired. An important property of the suggested method is that no hard segmentation into foreground and background is needed prior to the skeletonization.

8. Using grey-level and shape information for decomposing proteins in 3D images

Authors: Sintorn, I.; Mata, S. (1)

(1) Dept. of Computer Science, Statistics and Telematics, Rey Juan Carlos University, Móstoles-Madrid, Spain


Publisher: Mira Digital Publishing

Abstract: An image analysis method for decomposing 3D objects using a combination of grey-level and
shape is presented. The method consists of two major parts: seeding based on grey-level information and growth from the seeds based on shape information. The growth is performed in two steps in order to prevent seeds located in peripheral or protruding parts of the object from growing into other parts. The method was developed to decompose 3D reconstructions of proteins into their structural subunits. The proteins are imaged with SET (Sidec Electron Tomography) at a resolution of approximately 2nm, and delineated from the background by thresholding prior to application of our decomposition method. Decomposition can be a useful tool in the second step of the segmentation process to help distinguish between true protein molecules and other objects. It can also be useful for analyzing and visualizing interactions between proteins.

9. Defuzzification of discrete objects by optimizing area and perimeter similarity
   Authors: Sladoje, N.; Lindblad, J.; Nyström, I.
   Editors: Kittler, J.; Petrou, M.; Nixon, M.
   Publisher: IEEE Computer Society
   Abstract: We present a defuzzification method which produces a crisp digital object starting from a fuzzy digital one, while keeping selected properties of them as similar as possible. Our main focus is on defuzzification based on the invariance of perimeter and area measures while taking into account with the membership values. We perform a similarity optimization procedure using on a region growing approach to obtain a crisp object with the desired properties.

10. Surface skeletons in grids with non-cubic voxels
    Author: Strand, R.
    Editors: Kittler, J.; Petrou, M.; Nixon, M.
    Publisher: IEEE Computer Society
    Abstract: An algorithm for computing surface skeletons on the face-centered cubic (fcc) grid and the body-centered cubic (bcc) grid is presented. The fcc grid and the bcc grid are three-dimensional grids where the voxels are rhombic dodecahedra and truncated octahedra, respectively. The DT is used to generate the set of centres of maximal balls (CMBs) which will be “anchor points” when constructing the skeleton. Simple points are used in order to make the skeleton topologically correct and CMBs to produce a fully reversible skeleton. Using only simple points and the CMBs generates a skeleton with a lot of branches. By using a set of additional conditions for removal and preservation of gridpoints, most of these branches are merged into surfaces. For comparison, the algorithm is also implemented for the cubic grid.

11. Fast surface rendering for interactive medical image segmentation with haptic feedback
    Authors: Vidholm, E.; Agmund, J.
    Editor: Seipel, S.
    Publisher: Linköping University Electronic Press
    Abstract: In this work, we present a haptic-enabled application for interactive editing in medical image segmentation. We use a fast surface rendering algorithm to display the different segmented objects, and we apply a proxy-based volume haptics algorithm to be able to touch and edit these objects at interactive rates. As an application example, we show how the system can be used to initialize a fast marching segmentation algorithm for extracting the liver in magnetic resonance (MR) images and then edit the result if it is incorrect.

12. Haptic guided seeding of MRA images for semi-automatic segmentation
    Authors: Vidholm, E.; Tizon, X.; Nyström, I.; Bengtsson, E.
    Publisher: Mira digital Publishing
    Abstract: We investigate how stereo graphics and haptics can be combined to facilitate the seeding procedure in semi-automatic segmentation of magnetic resonance angiography (MRA) images. Real-time volume rendering using maximum intensity projections (MIPs) has been implemented together with a haptic rendering method that provides force feedback based on local gradients and intensity values. This combination allows a user to trace vessels in the image, and to place seed-points directly in the 3D data set. Seed-regions are propagated from the seed-points according to an algorithm that favors bright voxels. An experienced user have tested the interface on whole-body MRA images with promising results.

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13. **GPU-assisted Surface Reconstruction and Motion Analysis from Range Scanner Data**  
**Authors:** Wesslén, D. (1); Seipel, S.  
(1) Dept. of Mathematics, Natural Sciences, and Computing, University College of Gävle  
**Conference:** SIGRAD 2004: Special theme - Environmental visualization, Linköping electronic conference proceedings, vol 13, pp. 51-52  
**Editor:** Seipel, S.  
**Publisher:** Linköping University Electronic Press  
**Abstract:** We present a method for rapid GPU-assisted surface reconstruction from range scanner data producing meshes suitable for visualization and analysis of very slow-moving objects from multiple scans of the same area.  
**Comment:** Short paper.

14. **The virtual forest**  
**Authors:** Wesslén, D. (1); Seipel, S.  
(1) Dept. of Mathematics, Natural Sciences, and Computing, University College of Gävle  
**Conference:** SIGRAD 2004: Special theme - Environmental visualization, Linköping electronic conference proceedings, vol 13, pp. 61  
**Editor:** Seipel, S.  
**Publisher:** Linköping University Electronic Press  
**Comment:** Poster

15. **Collaborative 3D visualizations of geo-spatial information for command and control**  
**Authors:** Winkler Pettersson, L. (1); Seipel, S.  
(1) Dept. of Information Technology, UU  
**Conference:** SIGRAD 2004: Special theme - Environmental visualization, Linköping electronic conference proceedings, vol 13, pp. 41–47  
**Editor:** Seipel, S.  
**Publisher:** Linköping University Electronic press  
**Abstract:** We present a prototype command and control system that is based on view-dependent co-located visualizations of geographically related data. It runs on a 3D display environment, in which several users can interact with view consistent visualizations of information. The display system projects four independent stereoscopic image pairs at full resolution upon a custom designed optical screen. It uses head tracking for up to four individual observers to generate distortion free imagery that is rendered on a PC based rendering cluster. We describe the technical platform and system configuration and introduce our unified software architecture that allows integrating multiple rendering processes with head tracking for multiple viewers. We then present results of our current visualization application in the field of military command and control. The command and control system renders view consistent geographical information in a stereoscopic 3D view whereby command and control symbols are presented in a viewpoint adapted way. We summarize our experiences with this new environment and discuss technical soundness and performance.

16. **In situ tomographic display for interactive data visualization**  
**Authors:** Winkler Pettersson, L. (1); Wesslén, D. (2); Seipel, S.  
(1) Dept. of Information Technology, UU  
(2) Dept. of Mathematics, Natural Sciences, and Computing, University College of Gävle  
**Conference:** Third Nordic conference on Human-computer interaction, Proc., pp. 93–96  
**Publisher:** ACM Press, New York  
**Abstract:** With tomographic in situ visualization we present a novel approach to interactive data visualization and exploration. This visualization concept is useful for presentation of spatially co-located information that is normally not visible to the human’s eye. The tomographic in situ display allows for interactive cutting through data in space by using a spatially tracked and calibrated display. In this paper we describe the technical apparatus of our prototype and describe an application for the tomographic in situ visualization in the field of indoor climate studies.

17. **Modeling image processing tasks as flexible workflows for improved quality of service**  
**Authors:** Zdravkovic, J.(1); Åhlén, J.  
(1) Dept. of Computer Science, Royal Institute of Technology, Stockholm  
**Conference:** IADIS International Conference on Applied Computing, Proc., pp. 363–370  
**Abstract:** Processing of nontrivial images is a difficult task performed throughout a set of ordered steps.
Besides the basic functionality that a process must satisfy, quality of service goals are to be met. Images should be processed within a certain time and a certain quality should be attained. To manage image-processing tasks in the optimal way, the process goals must be defined explicitly and their fulfillment has to be controlled. Modeling image-processing tasks with workflows would enable control of the fulfillment of goals. In addition, by introducing flexible semantics in the workflow, the process could be executed along optimal execution alternatives. In this paper, we propose an approach to model the class of image processing tasks with workflows that would, based on the extended semantics, allow for flexibility in the process execution toward optimal goals fulfillment.

18. **Supercovers of non-square and non-cubic grids**  
**Authors:** Linh, T. K. (1); Imiya, A (1); Strand, R.; Borgefors, G.  
(1) Chiba University, Japan  
**Conference:** 10th International Workshop on Combinatorial Image Analysis, Proc., pp. 88-97  
**Editors:** Klette, R.; Žunic, J.  
**Publisher:** Springer-Verlag, Lecture Notes in Computer Science Vol. 3322  
**Abstract:** We define algebraic discrete geometry of hexagonal- and rhombic-dodecahedral- grids on a plane in a space, respectively. Since, a hexagon and a rhombic-dodecahedron are elements for tilling on a plane and in a space, respectively, a hexagon and a rhombic-dodecahedron are suitable as elements of discrete objects on a plane and in a space, respectively. For the description of linear objects in a discrete space, algebraic discrete geometry provides a unified treatment employing double Diophantus equations. In this paper, we introduce supercover for the hexagonal- and rhombic-dodecahedral- grid-systems on a plane and in a space, respectively.

### 6.5 Non-refereed conferences and workshops

1. **Tessellations in mathematics, architecture and art**  
**Author:** Borgefors, G.  
**Conference:** Matematikbiennalen 2004, CD Proc., 4p. in Swedish

2. **Computer-based morphometric assessment of spiral ganglion neurite outgrowth in vitro**  
**Authors:** Boström H.; Lundström T.  
**Conference:** Swedish Symposium on Image Analysis (SSBA 2004), Proc., pp. 170-173  
**Editors:** Bengtsson E.; Eriksson M.  
**Publisher:** Swedish Society for Automated Image Analysis, CBA Report No. 31

3. **Modeling stem cell migration by Hidden Markov Model**  
**Authors:** Degerman, J. (1); Althoff, K. (1); Thorlin, T. (2); Wåhlby, C. Karlsson, P.; Bengtsson, E.; Gustavsson, T. (1)  
(1) Dept. of Signals and Systems, Chalmers University of Technology, Göteborg, Sweden  
(2) Inst. of Clinical Neuroscience, Göteborg University, Göteborg, Sweden  
**Conference:** Swedish Symposium on Image Analysis (SSBA 2004), Proc., pp. 122-125  
**Editors:** Bengtsson E.; Eriksson M.  
**Publisher:** Swedish Society for Automated Image Analysis, CBA Report No. 31

4. **Characterizing and estimating fungal disease severity in wheat**  
**Author:** Hamid Muhammed, H.  
**Conference:** Swedish Symposium on Image Analysis (SSBA 2004), Proc., pp. 194-198  
**Editors:** Bengtsson E.; Eriksson M.  
**Publisher:** Swedish Society for Automated Image Analysis, CBA Report No. 31
5. **Segmentation of point-like fluorescent markers**  
   **Authors:** Karlsson, P.; Lindblad, J.; Wåhlby, C.  
   **Conference:** Swedish Symposium on Image Analysis (SSBA 2004), Proc., pp. 146-149  
   **Editors:** Bengtsson E.; Eriksson M.  
   **Publisher:** Swedish Society for Automated Image Analysis, CBA Report No. 31

6. **Compensation for geometrical hardware- induced distortion in contrast enhanced whole-body magnetic resonance angiography**  
   **Authors:** Kullberg, J.(1); Frimmel, H.(1); Tizon, X.; Johansson, L.(1); Ahlström, H.(1)  
   (1) Dept. of Oncology, Radiology and Clinical Immunology, UU  
   **Conference:** European Society for Magnetic Resonance in Medicine and Biology (ESMRMB 2004)  
   **Comment:** Abstract review.

7. **National classification of Swedish shoreline types, from Landsat-7 data**  
   **Authors:** Lindell, T.; Philipson, P.  
   **Conference:** 12th Australian Remote Sensing and Photogrammetry Conference, CD Proc., 10 p.

8. **Object decomposition based on grey-level and shape information**  
   **Author:** Sintorn, I.  
   **Conference:** Swedish Symposium on Image Analysis (SSBA 2004), Proc., pp. 25–28  
   **Editors:** Bengtsson E.; Eriksson M.  
   **Publisher:** Swedish Society for Automated Image Analysis, CBA Report No. 31

9. **Weighted distances on the fcc and bcc grids**  
   **Authors:** Strand, R.; Borgefors, G.  
   **Conference:** Swedish Symposium on Image Analysis (SSBA 2004), Proc., pp. 17–20  
   **Editors:** Bengtsson E.; Eriksson M.  
   **Publisher:** Swedish Society for Automated Image Analysis, CBA Report No. 31

10. **Time-lapse microscopy and image analysis for tracking stem cell migration**  
    **Authors:** Wåhlby, C.; Karlsson, P.; Thorlin, T. (1) Althoff, K. (2); Degerman, J. (2); Bengtsson, E.; Gustavsson, T. (2)  
    (1) Dept. of Clinical Neuroscience, Göteborg University, Göteborg  
    (2) Dept. of Signals and Systems, Chalmers University of Technology, Göteborg  
    **Conference:** Swedish Symposium on Image Analysis (SSBA 2004), Proc., pp. 118–121  
    **Editors:** Bengtsson E.; Eriksson M.  
    **Publisher:** Swedish Society for Automated Image Analysis, CBA Report No. 31

11. **Improvement of a color correction algorithm for underwater images through compensating for digital camera behaviour**  
    **Author:** Åhlén, J.  
    **Conference:** Swedish Symposium on Image Analysis (SSBA 2004), Proc., pp. 142–145  
    **Editors:** Bengtsson E.; Eriksson M.  
    **Publisher:** Swedish Society for Automated Image Analysis, CBA Report No. 31  
    **Comment:** Awarded best industry relevant paper

12. **On colour reconstruction of underwater images taken in shallow waters**  
    **Authors:** Åhlén, J.; Bengtsson, E.  
    **Conference:** Ocean Optics Conference XVII, 2004  
    **Comment:** Poster presentation. The conference used extended abstract review.
13. **Preprocessing of images for underwater color correction**  
   **Author:** Åhlén, J.  
   **Conference:** Knowledge Foundation Conference  
   **Editors:** Bubenko, J.; Fisher-Hübner, S.; Lindskog, S.; Nilsson, A.  
   **Publisher:** Karlstad University Studies, Proc., pp. 251-257  
   **Comment:** This conference used full paper reviewing to provide feedback to authors, but all papers were accepted.

### 6.6 Other publications

See also Section 4.2 where the Doctoral theses presented during 2004 are listed and Section 3.3 for Master theses finished during 2004.

1. **CBA Annual Report 2003**  
   **Editors:** Borgefors, G.; Nyström, I; Sintorn, I.; Strand, S; Wadelius, L  
   **Publisher:** Centre for Image Analysis, 79 pages

2. **Summary of results from the VISIT, VISual Information Technology program**  
   **Editors:** Bengtsson, E.; Karlsson, P.  
   **Publisher:** Centre for Image Analysis, Report Series No. 32, ISSN 1100-6641, 176 pages  
   **Comment:** The VISIT (VISual Information Technology) program was funded by the Foundation for Strategic Research with the goal of strengthening Sweden’s position in image analysis and computer vision. It was active 1997-2002, involved seven Swedish Universities, was administered by CBA and used 48 million SEK. This report contains summaries of 17 Theses generated by VISIT.

3. **National classification of Swedish shoreline types**  
   **Editor:** Philipson, P.; Lindell, T.  
   **Publisher:** CBA Internal Report No. 28, 26 pages

4. **A short overview of the scale-space theory**  
   **Editor:** Erikson, M.  
   **Publisher:** CBA Internal Report No. 29, 22 pages

5. **Collection of the reports from the summercourse on deformable models**  
   **Editor:** Sintorn, I.  
   **Publisher:** CBA Internal Report No. 30

6. **Short descriptions of international journals on image analysis and its applications**  
   **Editor:** Borgefors, G.  
   **Publisher:** CBA Internal Report No. 31, 55 pages  
   **Comment:** From PhD course 3.
7 Activities

Apart from the activities reported in previous Sections, we also spend much time and effort on outside contacts. These contacts are aimed at colleagues in academia, at industries based on image analysis or need of it, and at society in general. We participate in conferences; give and organize seminars; receive visitors and make visits, both for long and short stays; and participate in many different committees, both international and national. In the following Sections we have listed these activities for the year 2004. We have left out all meetings within ongoing research projects and all lectures we have given or attended as part of the regular educational activities. Still, the lists are quite extensive.

This year CBA personnel received two important rewards: Julia Åhlén got the “Best industry-relevant paper Award” at the Swedish Symposium on Image Analysis 2004. The paper is selected from all presented at the Symposium by a committee from the industry. Ida-Maria Sintorn, together two colleagues from Karolinska Institut and Royal Institute of Technology, got second prize in an innovation competition awarded by the European Regional Development Fund and three universities in Stockholm.

This year, CBA was host for the annual Swedish Symposium on Image Analysis, where most researchers in image analysis participate and present their work, this year about 100. The conference is the official meeting of the for Swedish Society Automatic Image Analysis (SSBA). A conference proceedings (202 p.) was published. It was the fourth time we organised this meeting, the previous being 1986, 1992, and 1998.

Docent Ingela Nyström has served as President of the Swedish Society for Automatic Image Analysis and one of its representatives in the International association of Pattern Recognition. Prof. Stefan Seipel has served as Vice Chair of Swedish Society for Computer Graphics (SIGRAD). Prof. Ewert Bengtsson continues to serve as advisor to the Rector of UU on information technology and also as Chair of the Virtual Faculty of information technology, together with many other related appointments. Prof. Gunilla Borgefors became one of three Area Editors for the Journal “Pattern Recognition Letters” and Bengtsson became Senior member of IEEE.

To give some figures: We held 11 seminars outside CBA, most in the Uppsala area. We had four invited seminars at CBA, one from China, one from Australia, and two from Sweden. In addition we held 38 seminars in our “Monday seminar series”, of which 14 were Master Thesis presentations. We gave three oral and five poster presentations at international fully reviewed conferences – this is much less than usual, but many of our most interesting conferences are biannual on odd years; and nine other conference presentations. We had two long term visitors from abroad, from Spain and China. Ewert Bengtsson has spent a five month sabbatical at University of Queensland, Brisbane, Australia. We have also received a large number of national and international visitors at many different occasions and have often visited others ourselves.

Finally, we have listed 27 international and 44 national “committees” of the most varying types in which we have served.

7.1 Awards

1. **Julia Åhlén**

   *Award: Best industry-relevant paper award, Swedish Symposium on Image Analysis 2004, Uppsala, for her paper “Improvement of a color correction algorithm for underwater images through compensating for digital camera behaviour”, see Project 31 in Section 5.1.*
Date: 040312  
Comment: Sponsored by GasOptics Sweden AB, Nucletron Scandinavia AB, and TEKNO OPTIK AB.

2. **Gunilla Borgefors**  
   *Award:* IAPR Certificate of appreciation for “Outstanding service to the International Association for Pattern Recognition”.  
   *Date:* 040825  
   *Comment:* Borgefors served as Chair of the Constitution & Bylaws committee 2000-2004.

3. **Ida-Maria Sintorn**  
   *Award:* Second prize in an innovation competition awarded by Karolinska Institutet, The Royal Institute of Technology and Stockholm University and the European Regional Development Fund for their research on virus segmentation and classification, see Section 5  
   *Date:* 041015  
   *Comment:* Coauthors: Mohammed Homman, PhD student, Karolinska Institute and Martin Ryner, Royal Institute of Technology.

7.2 Organised conferences and workshops

1. **SSBA PhD Student day 2004**  
   *Organisers:* Robin Strand, Ola Weistrand  
   *Address:* CBA  
   *Date:* 040310  
   *Attendees:* 27 participants  
   *Topic:* In connection with the annual SSBA symposium, a PhD student day was organized.  
   *Comment:* PhD students in image analysis from different Swedish research groups participated in discussions about their situation.

2. **SSBA Symposium on image analysis 2004**  
   *Organisers:* Ingela Nyström, Ewert Bengtsson, Olle Eriksson  
   *Address:* Ångstrom laboratory, Uppsala  
   *Date:* 040311–12  
   *Attendees:* About 100 participants  
   *Topic:* The annual symposium of the Swedish Society for Automated Image Analysis (SSAB’2004)  
   *Comment:* The annual SSBA symposium is an overview of on-going image analysis research in Sweden. This was the fourth time it was arranged in Uppsala.

3. **ICT - a tool for poverty reduction?**  
   *Organisers:* IT faculty and Collegium for Development Studies at Uppsala University  
   *Address:* Uppsala  
   *Date:* 040927–28  
   *Attendees:* Around 100 international participants.  
   *Comment:* Bengtsson was one of two co-chairs of the conference.

7.3 Seminars held outside CBA

1. **Gunilla Borgefors**  
   *Date:* 040115  
   *Address:* SLU, Uppsala  
   *Title:* Presentation of CBA and the SLU undergraduate course in image analysis  
   *Comment:* Presentation for undergraduate students at SLU. Part of the SESAM project. Seminar repeated three times.

2. **Mats Eriksson**  
   *Date:* 040213  
   *Address:* SLU, Uppsala  
   *Title:* Image analysis – forest and environment
3. Gunilla Borgefors  
   Date: 040602  
   Address: MIC, UU  
   Title: On tessellations  
   Comment: The occasion was the Spring meeting 2004 of the Mathematical Society in Uppsala.

4. Gunilla Borgefors  
   Date: 040920  
   Address: SLU, Uppsala  
   Title: Presentation of CBA  
   Comment: Presentation for the Board of the Faculty of Forest Sciences.

5. Ida-Maria Sintorn, Stina Svensson  
   Date: 040920  
   Address: Sidec Technologies AB, Stockholm  
   Title: Recognition and description of molecular structures  
   Comment: The seminar was given to update the people at Sidec about our methods and ideas regarding their volume imagery.

6. Ewert Bengtsson  
   Date: 041004  
   Address: UU Administration  
   Title: Presentation of IT strategy issues to Uppsala University Management Group  
   Comment: Ewert Bengtsson, the vice chancellor and the other members of the university management group attended the meeting.

7. Carolina Wåhlby  
   Date: 041021  
   Address: Faculty of Veterinary Medicine and Animal Science, SLU, Uppsala  
   Title: Applied digital image cytometry  
   Comment: The presentation was held as a part of a course for graduate students at the faculty of veterinary medicine and animal science organized by Anna Lundén.

8. Gunilla Borgefors  
   Date: 041027  
   Address: MIC, UU  
   Title: How to compute global distances from local operations in digital space  
   Comment: Part of a special undergraduate course in mathematics organised by Christer Kiselman.

9. Ida-Maria Sintorn  
   Date: 041117  
   Address: Dept. of Biosciences, Karolinska Institute, Huddinge  
   Title: Shape representation in digital images: applications in 2D and 3D microscopy  
   Comment: Presentation of some methods with applications in electron microscopy imaging.

10. Carolina Wåhlby  
    Date: 041123  
    Address: Evolution Biology Centre, UU  
    Title: Digital image analysis with applications in microscopy  
    Comment: The seminar was hosted by Stefan Gunnarsson, and given as a part of a PhD course in methods for microscopy.

11. Ewert Bengtsson  
    Date: 041214  
    Address: ITEE Department, University of Queensland, Brisbane, Australia  
    Title: Haptic interaction and visualisation of 3D medical images  
    Comment: Presentation of CBA research results on haptics as part of the official seminar series at the department hosting Bengtsson’s sabbatical.
7.4 Seminars at CBA with invited guest lecturers

1. **Tony Barrera**  
   **Date:** 040503  
   **Title:** X-shading  
   **Address:** Barrera Kristiansen AB, Uppsala

2. **Tang Chunming**  
   **Date:** 040614  
   **Title:** Some methods and results in stemcell tracking  
   **Address:** Institute of Information and Communication, Harbin Engineering University, China

3. **Andrew P. Bradley**  
   **Date:** 040901  
   **Title:** A practical introduction to JPEG 2000  
   **Address:** University of Queensland, Brisbane, Australia

4. **Holland Cheng**  
   **Date:** 041101  
   **Title:** Essences of nanostructural polyvalence and protein network in virus infection  
   **Address:** Dept. of Biosciences, Karolinska Institute, Huddinge

7.5 Seminars at CBA

Seminars by seniors, Ph.D. students and Master thesis students at CBA. Some of these seminars were held in Swedish.

1. **Lina Martinsson**  
   **Date:** 040112  
   **Title:** The Nest: Managing a complex relational dataset  
   **Comment:** Master thesis presentation.

2. **Robin Strand**  
   **Date:** 040119  
   **Title:** The face-centered cubic grid and the body-centered cubic grid

3. **Ola Weistrand**  
   **Date:** 040126  
   **Title:** Harmonic functions, graphs and clusters

4. **Ingemar Holmkvist**  
   **Date:** 040127  
   **Title:** Layer segmentation in cross-section images of board  
   **Comment:** Master thesis presentation.

5. **Erik Vidholm**  
   **Date:** 040202  
   **Title:** Haptic volume rendering

6. **Pasha Razifar**  
   **Date:** 040209  
   **Title:** Introduction of some pre-clinical PET methodologies

7. **Julia Åhlén**  
   **Date:** 040216  
   **Title:** Camera specification issues for underwater imaging

8. **Nataša Sladoje**  
   **Date:** 040223  
   **Title:** Fuzzy shape analysis

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9. Mats Erikson  
   Date: 040301  
   Title: A preprocessing method for better segmentation

10. Xavier Tizon  
    Date: 040308  
    Title: Queue-based algorithms in Image Analysis

11. Magnus Gedda  
    Date: 040322  
    Title: Classification of proteins in electron tomography reconstructions  
    Comment: Master thesis presentation.

12. Simon Hensing  
    Date: 040329  
    Title: Development of the fibre orientation analyser SPADES: a system using polarization-axis direction estimation  
    Comment: Master thesis presentation.

13. Maria Petterson, Johan Andren Dinerf  
    Date: 040330  
    Title: Multi-camera arrangement for teat detection in robotic milking  
    Comment: Master thesis presentation.

14. Anders Hast  
    Date: 040405  
    Title: Spherical linear interpolation of Quaternions

15. Felix Wehrmann  
    Date: 040419  
    Title: On modelling nonlinear variation in discrete appearances of objects

16. Hamed Hamid Muhammed  
    Date: 040426  
    Title: Unique descriptive signatures

17. Erik Melin  
    Date: 040510  
    Title: Continuous digitization in Khalimsky spaces

18. Pontus Olson  
    Date: 040517  
    Title: Automatic classification of images detected in Gyrolab(TM)  
    Comment: Master thesis presentation.

19. Ida-Maria Sintorn  
    Date: 040524  
    Title: Hierarchical template based segmentation of proteins in TEM-volumes

20. Robert Hadeffjell  
    Date: 040525  
    Title: Improvement of stereo matching algorithm  
    Comment: Master thesis presentation.

21. Maria Sannes Lande  
    Date: 040601  
    Title: Image analysis as a tool to characterize layering in stratified paper  
    Comment: Master thesis presentation.

22. Patrick Karlsson  
    Date: 040607  
    Title: Basic computer graphics theory explained
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<tr>
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<th>Name</th>
<th>Date</th>
<th>Title</th>
<th>Comment</th>
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<tr>
<td>23</td>
<td>Tarek Kasim</td>
<td>040621</td>
<td>Implementation proposal, analysis and investigation of possible methods for reading license plates using Optical Character Recognition (OCR)</td>
<td>Master thesis presentation.</td>
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<td>25</td>
<td>Emma Gustafsson</td>
<td>040913</td>
<td>Registration of tomographic animal volume images, from microPET, CT and MRT</td>
<td>Master thesis presentation.</td>
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<tr>
<td>26</td>
<td>Erik Vidholm</td>
<td>040920</td>
<td>A short introduction to VTK</td>
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<tr>
<td>27</td>
<td>Pasha Razifar</td>
<td>040927</td>
<td>Applying multivariate analysis on dynamic and noisy PET data</td>
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<tr>
<td>28</td>
<td>Mathias Klippinge</td>
<td>040930</td>
<td>Investigating an image analysis approach for characterisation and differentiation of fungal spores</td>
<td>Master thesis presentation.</td>
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<tr>
<td>30</td>
<td>Julia Åhlén</td>
<td>041011</td>
<td>On colour reconstruction of underwater images taken in shallow waters</td>
<td></td>
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<tr>
<td>31</td>
<td>Xavier Tizon</td>
<td>041013</td>
<td>Algorithms for the analysis of 3D magnetic resonance angiography images</td>
<td></td>
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<td>32</td>
<td>Erik Cedheim</td>
<td>041025</td>
<td>3D-reconstruction of paper volume</td>
<td>Master thesis presentation.</td>
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<tr>
<td>33</td>
<td>Hamed Hamid Muhammed</td>
<td>041115</td>
<td>Cognitive vision systems</td>
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<td>34</td>
<td>Erik Melin</td>
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<td>Manifolds</td>
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<tr>
<td>35</td>
<td>Mats Erikson</td>
<td>041123</td>
<td>Segmentation and classification of individual tree crowns in high spatial resolution aerial images</td>
<td></td>
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<tr>
<td>36</td>
<td>Fredrik Bergholm</td>
<td>041129</td>
<td>Robustness - calculation of spectra</td>
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7.6 Conference participation

7.6.1 Oral presentations - refereed conferences

1. **Conference:** International conference on Applied Computing (IADIS)  
   **Julia Åhlén**  
   **Date:** 040323–26  
   **Address:** Lisbon, Portugal  
   **Title:** Modeling image processing tasks as flexible workflows for improved quality of service

2. **Conference:** 17th International Conference on Pattern Recognition (ICPR 2004)  
   **Robin Strand**  
   **Date:** 040823–26  
   **Address:** Cambridge, UK  
   **Title:** Surface skeletons in grids with non-cubic voxels

3. **Conference:** SIGRAD 2004  
   **Erik Vidholm**  
   **Date:** 041124–25  
   **Address:** University College of Gävle  
   **Title:** Fast surface rendering for interactive medical image segmentation with haptic feedback

7.6.2 Poster presentations - refereed conferences

1. **Conference:** IEEE International Symposium on Biomedical Imaging 2004  
   **Ida-Maria Sintorn**  
   **Date:** 040415–18  
   **Address:** Arlington, VA, USA  
   **Title:** Using grey-level and shape information for decomposing proteins in 3D images

2. **Conference:** IEEE International Symposium on Biomedical Imaging 2004  
   **Erik Vidholm**  
   **Date:** 040415–18  
   **Address:** Arlington, VA, USA  
   **Title:** Haptic guided seeding of MRA images for semi-automatic segmentation

3. **Conference:** IEEE International Symposium on Biomedical Imaging 2004  
   **Patrick Karlsson**  
   **Date:** 040415–18  
   **Address:** Arlington, VA, USA  
   **Title:** Segmentation and separation of point like fluorescent markers in digital images

4. **Conference:** 17th International Conference on Pattern Recognition 2004 (ICPR 2004)  
   **Ingela Nyström, Natasa Sladoje**  
   **Date:** 040823–26  
   **Address:** Cambridge, UK  
   **Title:** Defuzzification of discrete objects by optimizing area and perimeter similarity, 2D grey-level skeleton computation: A discrete 3D approach  
   **Comment:** Nyström was session chair.
5. **Conference:** 12th Australasian Remote Sensing and Photogrammetry Conference  
   **Tommy Lindell**  
   **Date:** 041018–22  
   **Address:** Perth, Australia  
   **Title:** National classification of Swedish shoreline types, from Landsat-7 data

### 7.6.3 Oral presentations

1. **Conference:** Matematikbiennalen  
   **Gunilla Borgefors**  
   **Date:** 040122–24  
   **Address:** Mässan, Malmö  
   **Title:** Tessellations in mathematics, architecture, and art  
   **Comment:** Matematikbiennalen is a conference for Swedish teachers in mathematics. The presentation was held both 20040123 and 20040124 (in Swedish).

2. **Conference:** Swedish Society for Automated Image Analysis Symposium (SSAB’04)  
   **Robin Strand**  
   **Date:** 040311–12  
   **Address:** Uppsala  
   **Title:** Weighted distances on the fcc and bcc grids

3. **Conference:** Swedish Society for Automated Image Analysis Symposium (SSAB’04)  
   **Erik Vidholm**  
   **Date:** 040311–12  
   **Address:** Uppsala  
   **Title:** Facilitating semi-automatic segmentation of MRA volumes using haptics

4. **Conference:** Swedish Society for Automated Image Analysis Symposium (SSAB’04)  
   **Ida-Maria Sintorn**  
   **Date:** 040311–12  
   **Address:** Uppsala  
   **Title:** Object decomposition based on grey-level and shape information

5. **Conference:** Swedish Society for Automated Image Analysis Symposium (SSAB’04)  
   **Patrick Karlsson**  
   **Date:** 040311–12  
   **Address:** Uppsala  
   **Title:** Segmentation of point like signals from fluorescent markers

6. **Conference:** Swedish Society for Automated Image Analysis Symposium (SSAB’04)  
   **Carolina Wahlby**  
   **Date:** 040311–12  
   **Address:** Uppsala  
   **Title:** Time-lapse microscopy and image analysis for tracking stem cell migration

7. **Conference:** The Knowledge foundation Conference for the promotion of research in IT  
   **Julia Åhlén**  
   **Date:** 040505–07  
   **Address:** Karlstad University  
   **Title:** Preprocessing of Images for Underwater Color Correction
7.6.4 Poster presentations

1. **Conference:** Ocean Optics Conference XVII  
   **Julia Åhlén**  
   **Date:** 041025–29  
   **Address:** Fremantle, Australia  
   **Title:** On colour reconstruction of underwater images taken in shallow waters

2. **Conference:** Open house: Graduate School in Mathematics and Computing  
   **Robin Strand**  
   **Date:** 041115–16  
   **Address:** UU  
   **Title:** Distance transforms for three-dimensional grids with non-cubic voxels

7.6.5 Attendee

1. **Conference:** IT in the third world  
   **Ewert Bengtsson**  
   **Date:** 040113  
   **Address:** Computer Science Department, KISTA  
   **Comment:** This workshop discussed the plans for the formation of a Swedish center for IT cooperation with third world countries.

2. **Conference:** Dept. of Scientific Computing UU workshop - TDB04  
   **Gunilla Borgefors, Fredrik Bergholm**  
   **Date:** 040208–09  
   **Address:** Söderfors  
   **Comment:** Borgefors participated one of the two days.

3. **Conference:** SUN-ERC  
   **Ewert Bengtsson**  
   **Date:** 040229–0303  
   **Address:** Madrid, Spain  
   **Comment:** Discussing IT strategic issues in higher education.

4. **Conference:** Molecular Tools  
   **Carolina Wahlby**  
   **Date:** 040303–04  
   **Address:** MIC, Polacksbacken, Uppsala

5. **Conference:** Swedish Society for Automated Image Analysis Symposium (SSBA’04)  
   **Ewert Bengtsson, Gunilla Borgefors, Mats Erikson, Olle Eriksson, Hamed Hamid Muhammed, Tommy Lindell, Ingela Nyström, Pasha Razifar, Nataša Sladoje, Stina Svensson, Xavier Tizon, Felix Wehrmann**  
   **Date:** 030306–07  
   **Address:** Uppsala

6. **Conference:** IEEE conference on Biomedical Imaging  
   **Ewert Bengtsson**  
   **Date:** 040415–18  
   **Address:** Arlington, Maryland, USA

7. **Conference:** The Knowledge foundation Conference for the promotion of research in IT  
   **Ewert Bengtsson**  
   **Date:** 040505–07  
   **Address:** Karlstad University  
   **Comments:** This annual conference is arranged by the KK foundation for the PhD students they finance in the “Promote IT program”. Bengtsson served as Session Chair.
8. **Conference**: 17th International Conference on Pattern Recognition (ICPR 2004)  
   **Ewert Bengtsson, Gunilla Borgefors**  
   **Date**: 040822–26  
   **Address**: Cambridge, UK  
   **Comment**: Borgefors served as session chair.

9. **Conference**: Ocean Optics Conference XVII  
   **Tommy Lindell, Ewert Bengtsson**  
   **Date**: 041025–29  
   **Address**: Perth, Australia

10. **Conference**: Sticky floors – invisible obstacles in the academic world  
    **Carolina Wåhlby**  
    **Date**: 041111  
    **Address**: Evolutionary Biology Centre, Uppsala  
    **Comment**: Conference on career possibilities within the university. The conference was held in Swedish.

11. **Conference**: Open house: Graduate School in Mathematics and Computing  
    **Gunilla Borgefors**  
    **Date**: 041115  
    **Address**: UU

    **Ewert Bengtsson**  
    **Date**: 041121–23  
    **Address**: Akaroa, New Zealand  
    **Comment**: The national (reviewed) image analysis conference in New Zealand.

13. **Conference**: SIGRAD 2004  
    **Stefan Seipel, Jonas Agmund**  
    **Date**: 041124–25  
    **Address**: University of Gävle

14. **Conference**: International Workshop on Combinatorial Image Analysis (IWCLA 2004)  
    **Ewert Bengtsson**  
    **Date**: 041201–03  
    **Address**: Auckland, New Zealand  
    **Comment**: An international conference on combinatorial image analysis

### 7.7 Visiting scientists (staying at least 2 weeks)

1. **Susana Mata**  
   **Host**: Ida-Maria Sintorn  
   **Address**: Rey Juan Carlos University, Dept. of Computer Science, Statistics and Telematics  
   **Madrid, Spain**  
   **Date**: 040808–0909  
   **Topic**: Shape analysis of Proteins in TEM Volume Images.  
   **Comment**: Continuation of collaboration, started 2003.

2. **Tang Chunming (April)**  
   **Host**: Ewert Bengtsson  
   **Address**: Inst. of Information and Communication, Harbia Engineering University, China  
   **Date**: 030901-040830  
   **Topic**: Stem cell tracking.
7.8 Visits to other research groups (for at least 2 weeks)

1. Ewert Bengtsson  
   **Host:** Andrew Bradley  
   **Address:** University of Queensland  
   **Date:** 041009–050304  
   **Topic:** Sabbatical.

7.9 Short visits to other research groups and meetings outside CBA  
**Note:** Meetings occasioned by permanent appointments are listed in section 7.11

1. Carolina Wåhlby  
   **Hosts:** Åsa Henriksson, Björn Mellgård  
   **Address:** Discovery Medicine CVGI, AstraZeneca R&D Mölndal  
   **Date:** 040120  
   **Topic:** Presentation of PhD thesis “Algorithms for applied digital image cytometry”.

2. Gunilla Borgefors  
   **Hosts:** The board of FMB: The Graduate School in Mathematics and Computing  
   **Address:** MIC, UU  
   **Date:** 040126  
   **Comment:** Made a brief presentation of CBA and the FMB research at CBA.

3. Xavier Tizon  
   **Host:** Michel Paindavoine  
   **Address:** ESIREM, Dijon, France  
   **Date:** 040322  
   **Topic:** Presentation of work on whole-body angiography.

4. Tommy Lindell  
   **Host:** Kai Sörensen  
   **Address:** NIVA, Oslo, Norge  
   **Date:** 040401–04  
   **Comment:** Reviewing all available MERIS data over Scandinavia.

5. Ewert Bengtsson  
   **Host:** The board of the Wallenberg Global Learning Network, WGLN  
   **Address:** Stanford University, Palo Alto, California, USA  
   **Date:** 040420  
   **Comment:** Discussions about the future of this project which provides important funding for the Learning Lab activities.

6. Ewert Bengtsson  
   **Host:** Lois Brooks  
   **Address:** Stanford University, Palo Alto, California, USA  
   **Date:** 040421  
   **Comment:** Discussions about the possible participation from Uppsala in the SAKAI software development for web courseware.

7. Ewert Bengtsson  
   **Host:** SUNET Future Group Uppsala Meeting  
   **Address:** Ångstrom Laboratory, Uppsala  
   **Date:** 040426  
   **Comment:** Bengtsson was hosting the Uppsala meeting of the SUNET Future Group. He also gave a 15 minute presentation about UU IT policy.
8. **Ewert Bengtsson**  
*Host:* The Dutch university network SurfNet  
*Address:* SurfNet, Utrecht, Holland  
*Date:* 040525  
*Comment:* Meeting between the Dutch university network SurfNet and the SUNET Future Group.

9. **Ewert Bengtsson**  
*Address:* Uppsala County Administration  
*Date:* 040528  
*Comment:* Discussing some ideas about how to make the great competence in IT in Uppsala more visible. Peter Dahlström, Christoffer Nilsson, and Göran Lundström also participated in the meeting.

10. **Ewert Bengtsson**  
*Host:* Examination seminar for Lina Martinsson  
*Address:* The School of Architecture, KTH  
*Date:* 040607  
*Comment:* The Master thesis work of Martinsson at CBA was presented and evaluated. Bengtsson was asked to provide a written evaluation.

11. **Tommy Lindell**  
*Host:* Abisko Scientific Research Station  
*Address:* Abisko Scientific Research Station  
*Date:* 040628–0702  
*Topic:* Fieldwork for NorSEN.  
*Comment:* Fieldwork for NorSEN (Nordkalotten Satellite Evaluation co-operation Network) on Torne Träsk on optical properties of the lake.

12. **Gunilla Borgefors, Ingeborg Nyström**  
*Host:* Governing Board meeting of the International Association of Pattern Recognition (IAPR)  
*Address:* Cambridge, UK  
*Date:* 040824  
*Comment:* Nyström was Swedish representative and Borgefors attended as Chair of the Constitution & Bylaws Committee and as Proxy for Kalle Åström.

13. **Gunilla Borgefors**  
*Host:* Editorial meeting of Pattern Recognition Letters  
*Address:* Cambridge, UK  
*Date:* 040825  
*Comment:* All attending editors of this journal met for a working lunch at the ICPR2004 conference.

14. **Mats Eriksson, Kristin Norell**  
*Hosts:* Hans Holm, KG Paulsson, Ulf Höglind  
*Address:* Skoghall Mill, Skoghall  
*Date:* 040907  
*Topic:* Meeting with Skoghall on chip quality control using image analysis.

15. **Ida-Maria Sintorn, Maria Axelsson, Stina Svensson**  
*Host:* Stefan Gunnarsson  
*Address:* Evolutionary Biology Centre, UU  
*Date:* 040917, 041109  
*Topic:* Confocal microscopy of paper.  
*Comment:* Volume images of paper samples were collected through fluorescence microscopy to test whether it is possible to get deep enough into the sample with confocal techniques.

16. **Ida-Maria Sintorn, Stina Svensson, Magnus Gedda**  
*Host:* Sidec Technologies AB  
*Address:* Stockholm  
*Date:* 040920  
*Comment:* Discussion about continuation of collaboration between CBA and Sidec.
17. **Maria Axelsson, Gunilla Borgefors, Stina Svensson**  
*Host:* Catherine Östlund  
*Address:* STFI-Packforsk, Stockholm  
*Date:* 040923  
*Topic:* Future co-operation.  
*Comment:* Other people at STFI-Packforsk were also present, e.g., Marco Lucisano.

18. **Ewert Bengtsson**  
*Host:* IT department  
*Address:* MIC  
*Date:* 041007  
*Comment:* Discussion about research cooperation between IT and biomedicine at UU. About 15 professors in IT and Medicine participated.

19. **Ingela Nyström**  
*Host:* Nataša Sladoje  
*Address:* Faculty of Engineering, University of Novi Sad, Serbia and Montenegro  
*Date:* 041012–22  
*Topic:* Continued project on fuzzy shape analysis.

20. **Magnus Gedda, Ida-Maria Sintorn, Stina Svensson**  
*Host:* Sidec Technologies AB  
*Address:* Sidec Technologies AB, Stockholm  
*Date:* 041020  
*Topic:* Discussion about collaboration regarding analysis of proteins in volume images.

21. **Gunilla Borgefors**  
*Host:* Royal Veterinary and Agricultural University  
*Address:* Copenhagen, Denmark  
*Date:* 041021  
*Comment:* Planning meeting for a Norfa-funded Nordic summer course in MR image analysis. People from University Bergen, Norway, University Hospital in Aarhus and Royal Veterinary and Agricultural University Copenhagen, Denmark, participated.

22. **Carolina Wahlby**  
*Hosts:* Urban Wallin, Bo Sandhagen, Olav Mäpea and Albert Alm  
*Address:* Div. of Ophthalmology, Department of Neuroscience, Uppsala Academic Hospital  
*Date:* 041108  
*Topic:* Discussions on image analysis in fundus biomicroscopy.  
*Comment:* The MSc project work by Axel Hjälm (who was also present at the visit) was discussed.

23. **Ida-Maria Sintorn**  
*Host:* Holland Cheng  
*Address:* Dept. of Biosciences, Karolinska Institute, Huddinge  
*Date:* 041117  
*Topic:* Presentation of how image analysis methods can be useful for analyzing electron micrographs.

24. **Gunilla Borgefors, Kristin Norell**  
*Host:* Mats Nylander  
*Address:* Dept. of Forest Products and Markets, SLU Uppsala  
*Date:* 041222  
*Topic:* Wood chip quality.  
*Comment:* K.G. Persson and others were also present.
7.10 Other visitors

1. **Bengt Olsen**
   
   *Host:* Ewert Bengtsson  
   *Date:* 040122  
   *Comment:* Discussion about the project to record the history of Swedish IT development. Bengt Olsen is one of the persons driving this project, he was looking for support from UU.

2. **Heads of S-faculty, SLU**
   
   *Host:* Gunilla Borgefors  
   *Address:* SLU, Umeå  
   *Date:* 040210  
   *Number of visitors:* 3  
   *Topic:* Presentation of CBA to the new faculty leaders.  
   *Comment:* In addition to general talk, Borgefors’ PhD students and Vidholm presented their research.

3. **Karin Althoff, Johan Degerman, Tomas Gustavsson**
   
   *Host:* Carolina Wahlby, Patrick Karlsson, Ewert Bengtsson, April Tang Chunming  
   *Address:* Department of Signals and Systems, Chalmers University of Technology, Göteborg, Sweden  
   *Date:* 040310  
   *Topic:* Discussions on segmentation and tracking of stem cells.

4. **Ulla Conti**
   
   *Hosts:* Gunilla Borgefors, Ingela Nyström  
   *Address:* Akademikonferens, Uppsala  
   *Date:* 040317  

5. **K.-G. Paulsen (1), Mats Nylinder (2)**
   
   *Host:* Gunilla Borgefors  
   *Address:* (1) Höglind Marketing HB, Örebro; (2) Dept. of Forest Producers and Markets, SLU, Uppsala  
   *Date:* 040402  
   *Topic:* Possible Master Thesis on chip quality control.  
   *Comment:* This eventually led to a Master Thesis by Kristin Norell.

6. **Mats Nilsson**
   
   *Hosts:* Carolina Wahlby, Patrick Karlsson  
   *Address:* Department of Genetics and Pathology, Rudbeck Laboratory, Uppsala University  
   *Date:* 040506  
   *Comment:* Mats Nilsson came for several visits during 2004.

7. **Mats Nilsson (1), Ton A.K. Raap and George M.C. Janssen (2)**
   
   *Hosts:* Carolina Wahlby, Patrick Karlsson  
   *Address:* (1) Department of Genetics and Pathology, Molecular Medicine, Rudbeck Laboratory, Uppsala (2) Department of Molecular Cell Biology, Leiden University Medical Center, Leiden, The Netherlands  
   *Date:* 040601–02  
   *Topic:* Discussions on detection, segmentation and analysis of staining patterns of mitochondrial DNA in cells.

8. **Hans Hauska**
   
   *Host:* Gunilla Borgefors, Ewert Bengtsson  
   *Address:* Dept. of Geodesy & Photogrammetry, Royal Institute of Technology, Stockholm  
   *Date:* 040623  
   *Topic:* Discussion about possible cooperation CBA and KTH Photogrammetry.
9. **Tommy Forsell, Mark Dixon, Johan M Beskow, Daniel Evestedt, Lennart Thurfjäll**  
   *Hosts:* Erik Vidholm, Ewert Bengtsson  
   *Address:* SenseGraphics AB, Sollentuna  
   *Date:* 040623  
   *Topic:* Discussion about possible cooperation in Haptics between CBA and the new company Sense graphics AB.

10. **Anders Edin**  
    *Hosts:* Ida-Maria Sintorn, Magnus Gedda  
    *Address:* Sidec Technologies AB, Stockholm  
    *Date:* 040705  
    *Topic:* Continuation of collaboration regarding analysis of protein molecules in volume images.

11. **Örjan Sävborg**  
    *Host:* Gunilla Borgefors  
    *Address:* StoraEnso Research, Falun  
    *Date:* 040908  
    *Topic:* Master Thesis presentation of Åsa Odell and talk about future co-operation.

12. **Carina Johansson**  
    *Host:* Gunilla Borgefors  
    *Address:* Dept. of Technology, Örebro University  
    *Date:* 040909  
    *Topic:* Possible joint application, which was later done.

13. **Mohammed Homman**  
    *Host:* Ida-Maria Sintorn  
    *Address:* Department of Medicine, Karolinska Institute  
    *Date:* 040910  
    *Topic:* Continuation of collaboration regarding segmentation of virus capsid in electron microscopy images.

14. **Jens Levenfors**  
    *Host:* Bo Nordin  
    *Address:* BioAgri, Uppsala  
    *Date:* 040913, 041125  
    *Topic:* Image analysis for the detection of fungal infections of golf greens.

15. **Herdis Reynisdottir, Lars Roepsdorff**  
    *Host:* Gunilla Borgefors  
    *Address:* Dept. of Equine Studies, SLU, Uppsala  
    *Date:* 040916  
    *Topic:* Discussing the possibilities of judging the quality of Icelandic horses from photos  
    *Comment:* Reynisdottir will possibly become a PhD student at SLU with Roepsdorff as advisor and Borgefors as assistant advisor.

16. **Karin Althoff, Johan Degerman**  
    *Hosts:* Carolina Wählby, Ewert Bengtsson, Patrick Karlsson, Magnus Gedda and Amalka Pinidiyaarachchi  
    *Address:* Dept. of Signals and Systems, Chalmers University of Technology, Göteborg  
    *Date:* 040916  
    *Topic:* Discussions about the stem cell project.

17. **Mats Lind**  
    *Host:* Ingela Nyström  
    *Address:* Dept of Information Sciences, Human-Computer Interaction  
    *Date:* 041007  
    *Topic:* Fusion of images from a view of perception psychology.
18. **Christine Johansson**  
*Host:* Maria Axelsson  
*Address:* Mid Sweden University, Dept. of Natural and Environmental Sciences / FSCN, Sundsvall  
*Date:* 041013  
*Topic:* Discussions of internal paper structure and image analysis as a tool in paper research. Possible cooperation discussed.

19. **Heads of S-faculty, SLU**  
*Hosts:* Gunilla Borgefors, Lena Wadelius  
*Address:* SLU, Umeå  
*Date:* 041028  
*Number of visitors:* 3  
*Comment:* Even though the official subject was the budget, many other things were also discussed.

20. **Lars Björklund**  
*Host:* Gunilla Borgefors  
*Address:* Swedish Timber Measurement Council (VMR), Sundsvall  
*Date:* 041102  
*Topic:* Possible future co-operation.

21. **Urban Wallin, Bo Sandhagen**  
*Host: Carolina Wahlby  
*Address:* Department of Biomedical Engineering, Uppsala University Hospital  
*Date:* 041108  
*Topic:* Methods for image analysis in fundus biomicroscopy.  
*Comment:* The discussions led to the initiation of a MSc project for Axel Hjälm, who also participated in the meeting.

22. **Catherine Östlund, Matthieu Dessaux, Hannes Vomhoff**  
*Hosts:* Maria Axelsson, Gunilla Borgefors, Stina Svensson  
*Address:* STFI-Packforsk  
Stockholm  
*Date:* 041209  
*Topic:* Cooperation on image analysis on paper structure.

### 7.11 Committees

In addition to the international and national committees we participate in (listed below), the PhDs and senior PhD students at CBA annually review a considerable number of articles for many diverse international scientific journals and conferences. These are not listed in detail, as that would violate the confidentiality of refereeing.

**Ewert Bengtsson**  
*International:*  
  *Comment:* Published by Polish Academy of Sciences  
- Editorial board member of “Computer Methods and Programs in Biomedicine”, 1995–  
  *Comment:* Published by Elsevier  
- Associate Editor for IEEE Transactions on Information Technology in BioMedicine 2002–  
- Senior member of the "Institute of Electrical and Electronics Engineers”, Inc. (IEEE) 1974–  
  *Comment:* Senior since 2004.  
- Member of "The International Society for Optical Engineering”, (SPIE)  
- Member of “Eurographics, the European Association for Computer Graphics”
Member of the Program Committee of WSCG’2004

*Comment:* International annual conference series in Computer graphics and Image Analysis held in Plzen, Czech Republic in March each year.


Expert evaluator of project proposals for “Dipartimento per la programmazione il coordinamento e gli affari economici suoi programmi di ricerca scientifica di rilevante interesse nazionale” of the Italian Ministry for Education, University, and Research, 2001–.

Chair of the Uppsala-Makerere IT cooperation project, 2000–

*Comment:* A project financed by SIDA aiming at developing IT infrastructure and competence at Makerere University, Kampala, Uganda.

National:

Member of the Royal Society of Sciences in Uppsala (Kungliga Vetenskaps-Societeten), 199809–

*Comment:* Elected member of this, the oldest scientific society in Sweden. (4 meetings.)

Chair of the Virtual Faculty of Information Technology, UU, 199807–

*Comment:* The faculty is responsible for coordinating all aspects of the information technology field at UU. The faculty board has about 15 members. (4 meetings.)

Advisor to the Rector on Information Technology at UU, 199802–

*Comment:* One of seven advisors appointed to lead the strategic planning of UU and give advice to the Rector. (5 meetings.)

Member of “Rektorsrådet” the Rector’s advisory council, 199802–

*Comment:* (6 meetings.)

Chair of the board of Uppsala Learning Lab, ULL, 199908–

*Comment:* Uppsala Learning Lab is, through the Swedish Learning Lab - network, cooperating with the Royal Institute of Technology and the Karolinska Institute and through the Wallenberg Global Learning Network also with Stanford and Learning Lab Lower Saxony. The object of the cooperation is to develop new ways of using IT support in higher education. (6 meetings.)

Chair of the WWW management board of UU, 200001–

*Comment:* (4 meetings.)

Chair of the board of the UPI, the Unit for Development of Teaching and Interactive Learning of Uppsala University, 200407–

*Comment:* (6 meetings.)

Chair of Uppsala Internet Protocol Academy, UIPa, 200011–

*Comment:* A cooperation network between universities, local authorities, other education providers and companies to develop education and other kinds of cooperation on Internet technology on all levels in the Uppsala region. (3 meetings.)

Project leader for a National IT User Centre, NITA, 200008–

*Comment:* Established a Swedish national IT user centre funded by Vinnova and UU and in cooperation with industry. NITA is run by a national board where Bengtsson is not a member, but several informal meetings concerning future financing and cooperation plans took place. (5 meetings.)

Member of the reference group of the Unit for Development of Pedagogy and Interactive Learning of Uppsala University formed 200301.

*Comment:* (3 meetings + several preparatory discussions.)

Member of the Board of UpGIS, the net for Geographical Information Systems at UU, 199904–

*Comment:* Representing the virtual IT faculty, responsible for managing the economy of the network. (5 meetings.)
• Member of the virtual museums group of UU. 200109–
   Comment: This informal group works to develop how the cultural heritage treasures owned by UU can be presented on the web. (1 meeting.)

• Member of the UU student cooperation group, 200001–
   Comment: A group where the leadership of the university and the student unions meets to discuss matters of common interest. (3 meetings.)

• Member of the board of the Uppsala High Performance Computing Centre, UppMAX, 200303–
   Comment: (3 meetings.)

• Member of the Uppsala Chamber of Commerce IT board, representing UU. 200006–
   Comment: Working with various activities to promote cooperation researchers - companies. (7 meetings.)

• Member of the IT-cluster group, 200108–
   Comment: A group under the chairmanship of Uppsala municipality with the task of promoting the IT business activity in Uppsala by making the present competence and activity known to the local, national and international community. All kinds of organisations are represented on the committee. Bengtsson represents UU. (3 meetings.)

• IT Pub. 200201–
   Comment: Bengtsson is responsible for promoting participation of UU researchers in the monthly “IT-Pub” activity where actors in the IT business and research community meet in an informal setting to discuss common interests, hopefully promoting increased cooperation. (2 meetings.)

• Follow up on the IT audit of UU, 200310–
   Comment: A committee appointed by the rector to plan the projects to implement proposals made by the IT-audit conducted in 2003. (2 meetings.)

• The National Research Council (VR) committe on Medical Technology, 040601–0921
   Comment: Responsible for evaluating application about funding of research in Medical technology. Three days of meetings + 30 applications to read and grade.

• Member of the program committee of the Promote IT Conference series of the KK foundation, 2001–
   Comment: Reviewed several papers and participated in the annual conference.

• Member of the “Future Group” of SUNET, the Swedish National University Computer Network, 200309–
   Comment: (5 full day meetings.)

• The IT College Group, 040114–1231
   Comment: A group appointed to plan a new education program at UU IT College in collaboration with the Uppsala Secondary Education authorities. (6 meetings.)

• Planning group for conference on ”ICT - a Tool for Poverty Reduction?”, 040128–0927
   Comment: A group appointed to plan an international conference with the theme ”ICT - a Tool for Poverty Reduction? Challenges for development cooperation”. (10 meetings.)

• PhD half time committee, 040318
   Comment: The medical faculty at the Karolinska Institute asks for an expert committee to evaluate the progress of a PhD candidate at half time. Such a meeting took place for Zsolt Cselényi at the Department of Neuroscience.

Gunilla Borgefors
International:

• Fellow of the “International Association for Pattern Recognition” (IAPR), 1998–
   Comment: 1st Vice President 1994–1996.

• Chair of the Constitution and Bylaws Committee, International Association for Pattern Recognition (IAPR), 2000–2004

• Senior member of the “Institute of Electrical and Electronics Engineers”, Inc. (IEEE), 1998–

• Area Editor “Pattern Recognition Letters”, 200412–
   Comment: On the editorial Board since 1998. Published by Elsevier.
• Editorial board member, “Image Processing and Communications”, 1994–
  Comment: Published by the Institute of Telecommunications, Bydgoszcz, Poland.

• Editorial Board, “Pattern Recognition and Image Analysis: Advances in Mathematical Theory and Applications”, 1993–
  Comment: Published by Interperiodica Publishing in cooperation with the “Cybernetics” Scientific Council, Russian Academy of Sciences.


• Steering Committee member for Discrete Geometry for Computer Imagery (DGCI) conferences, 200012–

• Member of the Program Committee of Track Two: Pattern Recognition and Neural Networks of the International Conference on Pattern Recognition, Cambridge, UK, August 23–26, 2004

• Member of the programme committee for 10th International Workshop on Combinatorial Image Analysis (IWCIA), Auckland, New Zealand, Dec. 2004, 20040101–1203

• Second opponent at the PhD dissertation of Rune Holmstad, Dept of Chemical Engineering, Norwegian University of Science and Technology, Trondheim, Norway, 20040930
  Comment: Title: Methods for paper structure characterisation by means of image analysis.

National:

• Royal Society of Sciences in Uppsala (Kungl. Vetenskaps-Societeten), Member No. 19, 200009–
  Comment: Elected member of this, the oldest scientific society in Sweden (founded 1710.)

• Royal Society of Sciences in Uppsala
  Comment: Borgefors was auditor for the fiscal year 2003.

• Member, Swedish Parliamentarians and Scientists, 1987–
  Comment: Members are elected. Only one scientist per field admitted.

• Permanent member, Appointments board, Faculty of Forest Science, SLU, 199907–
  Comment: (4 meetings.)

• Member of the Board of UpGIS, the net for Geographical Information Systems at UU, 199904–
  Comment: Representing TN-Faculty at UU. (3 meetings.)

• Recruitment group for a professor in mathematics, UU, 20041001
  Comment: (3 meetings.)

• Strategy group for research, S-fak, SLU, 200410–12
  Comment: (4 meetings.)

• Opponent at the PhD dissertation of Ulf Ekblad, Royal Institute of Technology, Stockholm, 20040603
  Comment: Title: Earth satellites and detection of air and ground based activities.

• PhD dissertation committee of Per-Erik Forssén, Dept. of Electrical Engineering, Linköping University, 20040305
  Comment: Title: Low and medium level vision using channel representations.

• PhD dissertation committee of Felix Wehrmann, CBA, UU, 20040519
  Comment: Title: On modelling nonlinear variation in discrete appearances of objects.

**Tommy Lindell**

International:

• Affiliate Associate Professor and Officer for Valle Scandinavian Exchange Program, University of Washington, Seattle, WA, USA, 1985–
Ingela Nyström
International:

- Governing Board Member, International Association for Pattern Recognition, 200203-
- Member of Track Three: Image and Signal Processing of the program committee of International Conference on Pattern Recognition 2004, Cambridge, UK
- Member of the program committee for 10th International Workshop on Combinatorial Image Analysis (IW-CIA), Auckland, New Zealand, Dec. 2004, 20040101-1203

National:

- President of Swedish Society for Automated Image Analysis (SSBA), 200203–
  Comment: Board member 200003–
- Member of the Board for Education in Natural Sciences (NUN), 200301–

Stefan Seipel
National:

- Vice-chair of the SIGRAD organisation, 200403–
- PhD dissertation committee of Kai-Mikael Jää-Aaro, KTH, Stockholm, 20040305
  Comment: Title: Reconsidering the avatar: From user mirror to interaction locus
- PhD dissertation committee of Anders Hast, UU, 20040429
  Comment: Title: Improved algorithms for fast shading and lighting
- PhD dissertation committee of Per Johansson, Linköping University, 20040604
  Comment: Title: On the use of visualisation tools in product design: exploring possibilities and problems of virtual reality techniques
- Reviewer of applications to the position as Senior Lecturer in Computer Graphics and Visualization, Uppsala University, 200405
- Reviewer of the application of Lars Kjell Dahl to the appointment as Docent in Computer Science with a focus on Human-Computer Interaction, KTH, 200406
- Host and scientific program committee chair and editor of the annual SIGRAD conference, 2004

Stina Svensson
International:

- Co-chair, International Association for Pattern Recognition (IAPR) TC 18 - Discrete Geometry, 200208–
  Comment: Founded this Technical Committee with Annick Montanvert, LIS-Grenoble, France.

National:

- Strategy group for undergraduate education, S-fak, SLU, 200410–12
  Comment: (4 meetings.)