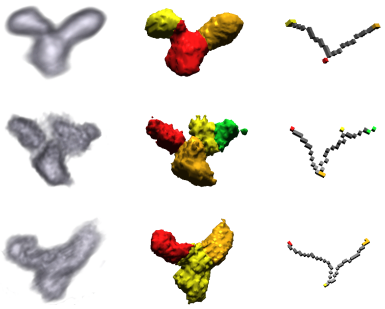
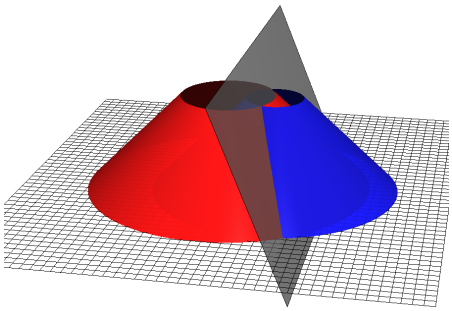
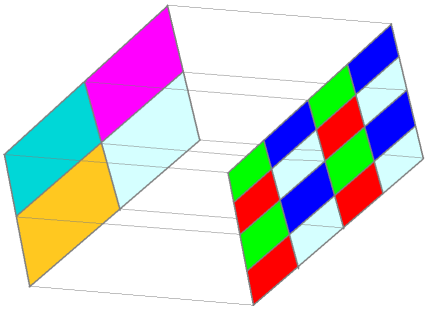
Centre for Image Analysis

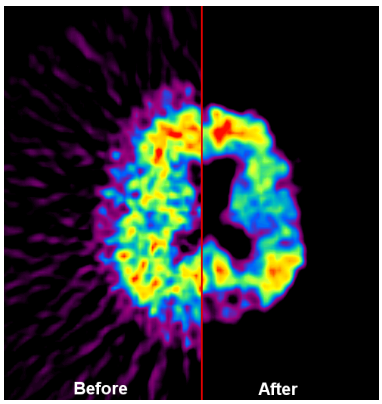
Swedish University of Agricultural Sciences
Uppsala University

ANNUAL REPORT 2005









SLU

UPPSALA UNIVERSITET

Annual Report 2005

Centre for Image Analysis

Centrum för bildanalys

Cover:
Illustrations from the six PhD theses presented at CBA during 2005. Further information in Section 4.2.

Top-left:
Ida-Maria Sintorn – Three IgG molecules from Sidec Electron Tomography (SET). Volume rendered original object (left), grey-level decomposition (middle), and medial grey-level based representation, MGR (right).

Top-right:
Ola Weistrand – The image shows an approximation of a digital voxel surface. Coordinate functions that parameterizes the surface are constructed using optimization methods. Spherical harmonics of order upto 20 are used as basis functions for the approximation.

Middle-left:
Nataša Sladoje – 3D illustrations of two intersecting fuzzy disks (red and blue). The difference sets of the disks are separated by a plane surface, which is used to prove important properties of moment-based representations of fuzzy disks.

Middle-right:
Hamed Hamid Muhammed – A multiple colour filter mosaic consisting of two overlapping mosaics, one consisting of red (R), green (G), blue (B) and transparent (T) areas, and the other consisting of cyan (C), magenta (M), yellow (Y) and transparent (T) areas.

Bottom-left:
Pasha Razifar – PIB retention showing amyloid deposition in the brain of patient with suspected Alzheimer's disease. PET image (left) and the result as a PC image using the proposed MVW-PCA.

Bottom-right:
Julia Åhlén – A colour corrected RGB colour image, the colour correction method uses point spectra from the spectrometer together with RGB colour images from a camera to find the mapping from underwater images to correct RGB images.

Edited by:
Ewert Bengtsson, Kristin Norell, Ingela Nyström, Robin Strand, Lena Wadelius
Centre for Image Analysis, Uppsala, Sweden

Contents

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 six dissertations 2005, two at SLU, Ida-Maria Sintorn and Nataša Sladoje, and four at UU, Hamed Hamid Muhammed, Pasha Razifar, Julia Åhlén, and Ola Weistrand, the latter got his PhD in mathematics, but did his work at CBA on an image analysis topic. The six theses are illustrated on the cover of this report. Together with the four theses in 2004, two thirds of the PhD students have finished their work in the last two years, this is about twice the average number per year. This reflects the more favourable financing conditions some years ago. For the next couple of years the number of theses will be much lower.

Also this year CBA personnel received two rewards; Hamed Hamid Muhammed and Fredrik Bergholm were awarded the prize for best industry-relevant paper at the national Swedish Symposium on Image Analysis, SSBA 2005, for the paper *Camera-spectrometer for multi- and hyper-spectral imaging*. The same project was awarded the prize as most innovative project of the year 2005 in the Uppsala region by ”ALMI Företagspartner”.

Image processing is highly interdisciplinary, its foundations being in mathematics, statistics, physics, signal processing, and computer science, and with applications found in many diverse fields. We are working in a wide range of application areas, most of them related to life sciences and usually in close collaboration with experts from the particular application area. Our co-operation partners are found locally as well as nationally and internationally. For a complete list of our 41 national and 20 international co-operation partners, see Section 5.2. From a methodological point of view our focus is on discrete geometry and multi-dimensional images, both spatially, 3D and 4D, and spectrally, i.e., images with many spectral channels.

Computer graphics and visualisation are different subjects than image analysis, but at UU they have both been included under the heading “image processing” and research and teaching in those topics is part of CBA’s responsibilities. Since visualisation issues are important when working with images of higher dimensions this ties in well with our general research profile.

CBA is only responsible for organising undergraduate education at SLU, but all personnel at CBA participates in undergraduate education. Most of it is organized through the large Dept. of Information Technology at UU and some is organized through the Dept. of Mathematics.

During 2005, a total of 25 persons have been working at CBA as researchers, administrators or PhD students. Additionally, 8 Master thesis students have done their work at CBA. This does, however, not mean that we have had 25+8 full time persons at CBA, many have split appointments, part time at CBA and part time elsewhere most commonly at the Dept. of Information Technolog. If we count the time spent at and working for CBA, we had the equivalent of about 16.5 full time full year equivalents including teaching and 13 excluding teaching. The employees are formally employed at either university. The whole of CBA is administrated through UU.

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 serves as Vice Chair of the Swedish Society for Computer Graphics (SIGRAD), and Gunilla Borgefors is Area Editor for the Scientific Journal Pattern Recognition Letters. Ewert Bengtsson serves as senior advisor to the Rector of UU on information technology and also as Chair of the Virtual IT Faculty, together with many other related appointments.

Since 1993/94 CBA assembles extensive annual reports such as this document that describes in some detail what we have achieved during the year. These annual reports are intended for anyone interested in

our work. 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/AR05html/

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." We are pursuing this objective by running a large number of research projects ranging from fundamental mathematical methods development to application tailored developments and tests, the latter mainly in biomedicine, forestry and remote sensing. Remote sensing has decreased over the last years since we have not been able to obtain funding to replace the position held by Tommy Lindell after his retirement. Instead visualisation and graphics has increased with two new part time senior positions.

We are 10 professors (assistant, associate and full) with PhDs who carry out our research at CBA. We are all involved with supervision of PhD and Master thesis students although to quite varying degrees. We do not have 10 distinct research groups, there is a lot of interaction between the different researchers and for each new project usually a new combination of researchers from CBA and from other collaboration partners is formed.

During this year, seven Master thesis projects were completed with supervision from CBA. They covered a wide range of topics: Kristin Norell tried to determine bark content in wood-chips for pulping using image analysis methods. Per Holting developed a new easy-to-use object selection method based on colour space projections and watershed segmentation. Mathias Klippinge investigated how fungal spores can be characterized through image analysis. Jakob Sandström and Harald Klomp worked together to improve image quality from inexpensive UAV technology by determining camera motion and 3D structure. Axel Hjälm developed new methods for registration of retinal images. Markus Hansen evaluated a vision system for inspection of infusion bags. Finally, Johan Ljung studied the state of the art for automatic content-based filtering of television news.

In addition to this, our PhD students and senior researchers worked on 40 different projects as described in Section 5. In the rest of this section, we will briefly outline the different research areas we have been involved with. The order follows roughly that of Section 5 and is somewhat arbitrary although similar projects are grouped and we start with more theoretical projects before moving on to more applied ones.

Our work on theoretical aspects of image analysis is currently mostly concentrated on general methods for volume imagery. Serbian PhD student Nataša Sladoje has been 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, analysis of shape signatures, and defuzzification based on various shape measurements, meaning that the original object is recreated not only based on grey-levels, but also on invariance of, e.g., area, perimeter length, and moments. Sladoje presented her PhD thesis this year. Ola Weistrand, who was a joint PhD student between Dept. of Mathematics at UU and CBA, also presented his thesis this year. He developed global shape descriptions for volume objects, using linear combinations of spherical harmonics. The surface of the object is first projected on a sphere. However, this projection is almost always such that computing coefficients for the harmonics become numerically unstable. Therefore, much effort have been spent on better parameterizations of the projection of the object surface. There are three other PhD students that are supervised jointly by Prof. Christer Kiselman and Borgefors. Two are at the Dept. of Mathematics, while Robin Strand is at CBA and is funded by the Graduate School in Mathematics and Computing (FMB) at UU. Strand mainly develops image processing tools for volume images digitized in the bcc and fcc grids (where voxels are not cubes, but "rounder" polyhedra). He has developed distance

transforms, skeletonization, and pyramid structures. A distance transform computes the distances to the background for all pixels in an object. Post-Doc Céline Fouard (INRIA) has, together with Strand, been working on a deep investigation into the properties of digital distance transforms. There are many different definitions and properties listed in the literature, but using the general framework of modules proves very clarifying. Strand has also, in co-operation with Benedec Nagy from University of Debrecen, Hungary, been working on computational algorithms for distance transforms based on neighbourhood sequences. Skeletonization reduces the dimensionality of data — a volume object becomes a set of surfaces or even a set of curves. Strand has worked on skeletonization in the cubic grid, as well as in the fcc and bcc grids. Previous results on digital distances transforms and 3D skeletons, produced mostly in co-operation with our long-time research partner Istituto di Cibernetica, "E. Caianiello", CNR, Pozzuoli, Italy, have this year been summaried in two chapters in the *Handbook of Pattern Recognition and Computer Vision*. Another project in collaboration with the same group is to study decomposition of 3D objects, taking the complement of the objects into account. During this year, our methods for this has been extended by fuzzy set concepts. This work is done by Stina Svensson and Magnus Gedda. An approximation of a solution to the digital "potato peeling" problem in 2D and 3D has been developed. The deceptively simple, but in reality very difficult task, is here to compute the largest inscribed convex set for an arbitrary digital set. In a nice combination between our image analysis expertise and expertise in solving large partial differential equation problems at the Dept. of Information Technology, we were able to increase the efficiency of computing gradient vector flow (GVF) fields about 50 times, making GVF based methods practical to use also in 3D. PhD student Hamed Hamid Muhammed developed new approaches to information extraction based on neuro-fuzzy systems which are directly applicable to difficult segmentation problems.

PhD student Ida-Maria Sintorn presented her theses in April. She has been working on various applications of image segmentation methods and shape description for microscopy applications, mostly in 3D, such as finding cell nuclei, finding flourescent markers in cell nuclei, classifying maturation stages of viral capsids, finding and analysing the shape of individual proteins in very noisy images, and analysing paper pore networks. She developed distance transforms for the elongated grid often resulting from various imaging methods, several specific segmention methods, e.g., based on morphological watersheds, and 3D shape matching.

During the year a new project on evaluation of the integration of bone implants has started. In an aging population it is important to study the implant/bone interface, not only in healthy bone tissue, but also in osteoporotic or otherwise affected tissue. This will be pursued together with Carina Johansson at Örebro University and a PhD student at CBA to be recruited next year.

Automated image analysis methods are indispensable for modern bioscience, understanding how genes are expressed in proteins and the role of these proteins in the life and development of cells require quantitative analysis of millions of microscopic images of different kinds. We have for many years been involved in developing image analysis tools for this. This year the work has ranged from improved methods for tracking stem cells in time lapse microscopy, segmenting fluorescent cells and detecting point-like multi-spectral signals from specific molecular stains. Carolina Wählby has with joint appointments at CBA and the Rudbeck Laboratory at UU been a key-person in this work. PhD students in the projects have been Amalka Pinidiyaarachchi, Patrick Karlsson, and Magnus Gedda.

Using Cryo-Electron Tomography 3D images of protein molecules can be obtained with voxel sizes around 2 nm. Techniques for this are developed at the Dept. of Cell and Molecular Biology, Karolinska Institutet. Stina Svensson and Magnus Gedda have worked to develop new methods for analysing these images, e.g., segmenting and decomposing the 3D "blobs".

The rapid progress in medical imaging technology generates rapidly increasing amounts of 3D image data creating a pressing need of finding efficient methods for exploring and evaluating such data. Several of our projects have addressed such problems. Pasha Razifar has investigated the noise correlation structures in PET images and come up with new ways of normalising the data so that principal compo-

nent transforms can create new images with significantly improved visual properties. His work has been carried out in close collaboration with Uppsala PET Centre/Imanet AB.

It is important to use as many information channels as possible for interaction between humans and the 3D data when difficult medical diagnostic tasks are to be carried out. We have explored the use of haptic interaction for this purpose. Earlier haptic systems have mainly been used for training purposes, but we are exploring their use for investigating actual patient data. So far MR angiographic data, CT data from the liver, and dynamic breast MR data have been used. The latter project is based on collaboration with the group at University of Queensland that hosted Bengtsson during his sabbatical stay there October 2004–March 2005. We are also looking into applying the same visualisation approaches without the haptics, both in order to see the differences and to create low cost solutions using only standard PC hardware. Ingela Nyström is heading this project with PhD students Erik Vidholm and Suthakar Somaskandan.

Bengtsson has also continued his productive collaboration with Anders Hast and Tony Barrera on fundamental graphics algorithms, e.g., for shading.

Stefan Seipel is working mainly at University College of Gävle, but 20% of his time with CBA. His research activities are in the field of "efficient visualizations" with a focus at designing expressive visualization techniques to enhance interpretation by the human observer. There are currently two projects which deal with similar aspects of this research. One project looks at new ways to visualize complex ecosystems, e.g., forests and landscapes, for the purpose of forestry and landscape planning. This research includes both the development of computationally efficient algorithms as well as the development of 3D display modalities that provide comfortable user interaction. The other project, which is carried out in collaboration with Swedish Research Defense College and perception psychologists from UU is investigating the effectiveness of various graphical cues in visualization of time varying data and 3D spatial information. Recently, this research has expanded towards empirical studies in advanced 3D and colour visualizations of thermography data. This initiative is carried out in collaboration with FLIR Systems AB, Danderyd, and Stora Enso pulp mill in Norrsund.

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 and pore networks have on paper properties. This year, we have, through co-operation with the Norwegian Pulp and Paper Research Institute got access to micro-computer tomography images of paper from the European Radiation Synchrotron in Grenoble, images that have enough resolution to follow the individual fibres. Work has mainly been done on noise and artefact removal in these images, by Stina Svensson and PhD student Maria Axelsson. In 2006, a second assistant professor and a second PhD student will start in the project. In this context, we have also done a project together with STFI-Packforsk investigating the water holding capacity of paper press felts under different compression loads.

A new project started this year, in co-operation with the Swedish Timber Measurement Council and Dept. of Forest Products and Markets, SLU. The goal is to use image analysis in the saw mills, to improve the quality of the products. So far, the new PhD student Kristin Norell has concentrated on images of log ends to find the annual ring centre (pith) and the annual ring density. We will also look at rot and blue stain. It should be pointed out that the image quality will be low in this environment, not the least because of the roughness of the log ends.

Joakim Lindblad has developed an image analysis tool for evaluating seed vitality for SeedGard, a company that treats cereal seeds thermally to kill various pathogens. As the temperature must be very precise to kill the pathogens without killing the seeds, many vitality tests needs to be done, thus the need for automation. Lindblad has also done a small project for estimation pest damage on green-house grown chrysanthemums.

When CBA was founded, remote sensing was one of the main work areas. We have continued method development for remote sensing and some application projects also during 2005 although the work in this field is decreasing. In the thesis of Hamid Muhammed, he presents a new approach to analysing

hyperspectral data and applies it to judging disease severity in wheat and the extent of pollution of lakes. The former application has been carried out in co-operation with Anders Larsolle at Dept. of Biometry and Engineering, SLU, Uppsala. The latter application ties in with work by Tommy Lindell and Petra Philipson. They have also continued their work on coral bleaching detection. And Lindell has together with Bergholm collected ground truth data for evaluating new satellite data in northern Sweden.

A problem when working with hyperspectral data is the lack of good systems for acquiring such images. We have pursued several ideas for improved hyperspectral imaging including both a new camera design (Fredrik Bergholm and Hamed Hamid Muhammed) and colour correction of underwater data (Julia Åhlén) Both projects have been successful in that they have received external rewards both last year and this year.

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 the end of 2005. If we count the time spent at CBA, we had the equivalent of about 16.5 full time persons. About half of the graduate students belong to each university. 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 2005 was 12.2 million SEK which is approximately the same as the two previous years, 41% comes from UU and 24% from SLU. Our ambitions are that at least half of our research should be funded from outside sources and we are working hard to reach that level again.

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 Sciences (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 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. 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

The current appointment period will end at the end of 2005. During 2005, there was an administrative review of all centres at UU and as a result of this some minor changes of the CBA consitution will be negotiated during 2006. Because of this the mandate for the present board has been extended for one year with some minor changes.

The executive management of CBA rests with a Director, appointed by UU, who also serves as Chairman of the board. Prof. Gunilla Borgefors served as Director from 1996 until end of June 2005 when Ewert Bengtsson took over the directorship. Dr Olle Eriksson has served as deputy Director since 1996.

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 2005. 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 total turnover is thus 12.2 million for 2005. 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, where each project is listed.

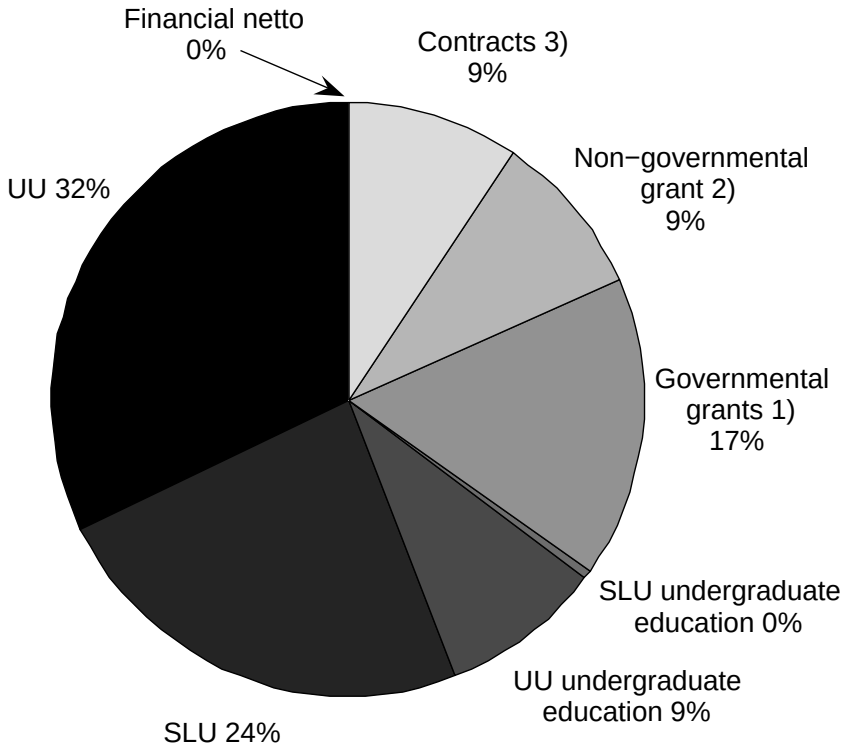
The main changes in income from last year is that overall external income has decreased with about half a million SEK, this is mainly due to a decrease in governmental grants. There has also been a decrease in contracts but a corresponding increase in non-governmental grants. The percentage of research financed from outside sources is 35% which is significantly lower than our ambitions, a few years ago it was above 50% and we are working hard to reach that level again.

The total turnover is roughly the same as the two previous years (plus 100 kSEK per year) The major costs are for personnel (salaries). The equipment cost is very low since we have been unable to invest in new equipment over the last several years due to a very tight budget. Because of this the computer equipment is becoming very old and during 2006 it will be necessary to invest in a significant renewal.

Table 1: CBA income and costs for 2005.

Income		**Costs**	
UU	3955	Personnel	7045
SLU	2908	Equipment	176
UU graduate education	1084	Operating exp. 4)	2289
SLU undergraduate education	48	Rent	973
Governmental grants 1)	2029	University overhead	1459
Non-governmental grants 2)	1091		
Contracts 3)	1150		
Financial netto	9		
Total income	**12274**	**Total cost**	**11942**

1) Sw. National Space Board, The Swedish Research Council, SIDA
2) Research foundations
3) Internal invoices and compensations
4) Including travel and conferences



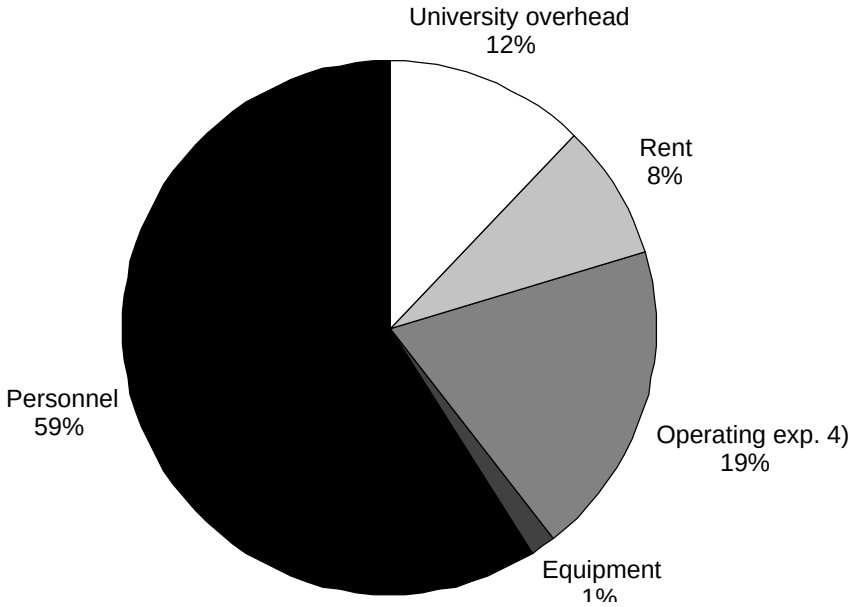


Figure 1: CBA income (top) and costs (below) for 2005.

2.3 Staff

Gunilla Borgefors, Professor, PhD, Director, SLU, –0630
Ewert Bengtsson, Professor, PhD, Director, UU, 0701–
Olle Eriksson, Lecturer, PhD, Deputy Director, (part time) UU

Maria Axelsson, Graduate Student, 0601–, SLU
Fredrik Bergholm, Researcher/Lecturer, PhD, (part time) UU
Magnus Gedda, Graduate Student, 0601–, UU
Hamed Hamid Muhammed, Graduate Student, UU, –0930
Patrick Karlsson, Graduate Student, UU
Joakim Lindblad, PhD, 0126–0302 0530–, UU
Tommy Lindell, Docent, PhD, (part time) UU
Bo Nordin, Researcher/Lecturer, PhD, (part time) UU
Ingela Nyström, Docent, PhD, (part time) UU
Amalka Pinidiyaarachchi, Graduate Student, (part time) UU and University of Perodeniya, Sri Lanka
Pasha Razifar, Graduate Student, (part time) UU and Uppsala Imanet, –1231
Ida-Maria Sintorn, Graduate Student, SLU, –0502
Stefan Seipel, Professor, (part time 20%) UU and University College of Gävle
Nataša Sladoje Matić, Graduate Student, (part time) SLU and University of Novi Sad, Serbia, –1130
Suthakar Somaskandan, Graduate Student, (part time) UU and University of Jaffna, Sri Lanka
Robin Strand, Graduate Student, UU
Stina Svensson, Researcher, PhD, SLU
Erik Vidholm, Graduate Student, UU
Ola Weistrand, Graduate Student, Dept. of Mathematics, UU, –1015
Carolina Wählby, Researcher, PhD, (part time) UU
Julia Åhlén, Graduate Student, (part time) UU and Dept. of Mathematics, Natural Sciences, and Computing, University College of Gävle, –1216

Lena Wadelius, Administration

Master Thesis students:
Axel Hjälm, Per Holting, Harald Klomp, Andreas von Knobloch, Filip Malmberg, Kristin Norell, Jakob Sandström, Johan Östrand

In addition to the above Graduate Students,
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 (in C++ and Java) and mathematics.

We offer a number of Master Thesis projects (examensarbeten) each year. Seven were completed during 2005.

3.1 SLU courses

1. **Digital image analysis A, 5p**
   Examiner: Gunilla Borgefors
   Lecturers: Gunilla Borgefors, Robin Strand, Stina Svensson
   Application Lecturers: Anna Rydberg, Carolina Wählby, Petra Philipson, Mats Eriksson, Anna Jonsson, Fredrik Bergholm
   Computer Exercises: Maria Axelsson
   Period: 0502–03
   Comment: A course in image analysis for undergraduate students at SLU.

3.2 UU courses

1. **Computer Graphics II, 5p**
   Fredrik Bergholm
   Period: 0501–03
   Comment: Patrick Karlsson was lab assistant.

2. **Software architecture with Java, 5p**
   Olle Eriksson
   Period: 0501–03

3. **Calculus of several variables (Analysis MN2), 10p**
   Robin Strand
   Period: 0501–05
   Comment: 18 problem sessions.

4. **Basic programming, 5p**
   Olle Eriksson
   Period: 0501–05

5. **Object oriented programming with C++, 5p**
   Bo Nordin
   Period: 0503–05
   Comment: Distance Course. C++ programming, 3rd course.

6. **Computer graphics I, 5p**
   Erik Vidholm, Ingela Nyström, Patrick Karlsson, Anders Hast, Filip Malmberg
   Period: 0504–06

7. **Computer Assisted Image Analysis, 5p**
   Carolina Wählby, Ida-Maria Sintorn, Magnus Gedda
   Period: 0504–06

8. **Medical informatics, 5p**
   Ewert Bengtsson
   Period: 0505
   Comment: Two 2 hour lectures given by Bengtsson.

9. **Internet programming, 5p**
   Bo Nordin
   Period: 0506–08
   Comment: Summer course. Olle Eriksson was involved in a part of the course.

10. **Calculus of several variables, 6p**
    Robin Strand
    Period: 0508–12
    Comment: 18 problem sessions.

11. **Computers and programming TDB1, 5p**
    Bo Nordin
    Period: 0509–11
    Comment: Distance Course. C++ programming, 1st course.

12. **Computer Assisted Image Analysis MN2, 5p**
    Joakim Lindblad, Ingela Nyström, Stina Svensson, Nataša Sladoje, Céline Fouard
    Period: 0510–12
    Comment: Erik Vidholm and Magnus Gedda assisted with the computer exercises .

    Medical engineering, 5p
    Ewert Bengtsson
    Period: 0510
    Comment: One double lecture on image analysis was given by Bengtsson.

13. **Programmeringsteknik 1, X2, 4p**
    Maria Axelsson
    Period: 0510–12
    Comment: 30 laborations in Java with students from X2. (Including two sessions with discussions at project seminars.)

14. **Computer graphics, first course, 5p**
    Patrick Karlsson
    Period: 0510–12
    Comment: Teachers: Patrick Karlsson (responsibility), Ingela Nyström, Erik Vidholm, Anders Hast, Filip Malmberg (computer exercises).

15. **Computers and programming TDB2, 5p**
    Kristin Norell
    Period: 0510–0601
    Comment: Distance Course. C++ programming, 2nd course.

16. **Advanced programming, 5p**
    Olle Eriksson
    Period: 0510–12

17. **Medical imaging and analysis, 3p**
    Ewert Bengtsson
    Period: 0511
    Comment: Bengtsson gave a four hour lecture on basic medical image analysis in this course at the Karolinska Institute.

3.3 Master theses projects

1. **Determining bark content in wood-chips for pulping with computerized image analysis**
   Student: Kristin Norell
   Supervisor: Mats Erikson
   Subject supervisor: Gunilla Borgefors
   Partner(s): Höglind Marketing HB, Örebro and StoraEnso Packanging Boards, Skoghall
   Publisher: CBA Master Thesis No. 75
   UU School of Engineering, UPTEC F05 003
   Abstract: This thesis examines the possibility to use computerized image analysis for quality control of wood-chips used for pulping. The quality control in this case means controlling the amount of bark in the chips, since bark can create damages in the finished product. At present the chips quality at Stora Enso Packaging Boards, Skoghall Mill is controlled with samples where the amount of bark is evaluated. The evaluation is done by sorting out the bark in the sample and calculating the weight percentage.
   To examine if this controll is possible to do with computerized image analysis two different sets of images were used. Image series 1 was used for developing and evaluating the method and image series 2 was used only for evaluation. The results from image series 1 are good and shows that it is possible to separate the bark from the rest of the pieces. In image series 2 the results are not quite as good. Not all bark pieces are found, and some other pieces are instead identified as bark. The reason for this is that the image material for developing the algorithm was not large enough. Continuing to develop the method with more images from different sets of wood-chips would probably give even better results.

2. **Easy-to-use object selection by color space projections and watershed segmentation**
   Student: Per Holting
   Supervisor: Carolina Wählby
   Subject supervisor: Carolina Wählby
   Partner(s): Révolte Development AB, Stockholm
   Publisher: CBA Master Thesis No. 76
   UU School of Engineering, UPTEC F05 000
   Abstract: Digital cameras are gaining in popularity, and not only experts in image analysis, but also the average users, show a growing interest in image processing. Many different kinds of software for image processing are available, but most of them require expertise knowledge, and are too advanced for the average user.
   Object segmentation is the process of finding, outlining, and extracting objects in an arbitrary digital image. Image processing software often provide a set of different tools for segmentation. Many of the tools are, however, too complicated for the average user, or leave too little freedom in expressing the desired segmentation.
   The aim of this master thesis work was to develop an easy to use tool for object segmentation in color images for the average user. The work resulted in a new color image segmentation method with little user interaction and no tuning parameters. The method is based on the Watershed segmentation algorithm, combined with seeding information given by the user, and color space projections for optimized object edge detection. The presented method can successfully segment objects in most types of color images.

3. **Characterization and differentiation of fungal spores using image analysis**
   Student: Mathias Klippinge
   Supervisors: Ola Weistrand, Ida-Maria Sintorn
   Subject supervisor: Gunilla Borgefors
   Partner(s): Jennifer Jennessen, Dept of Microbiology, SLU
   Publisher: CBA Master Thesis No. 77
   UU School of Engineering, UPTEC F05 042
   Abstract: Many fungi play important biological roles in the ecosystem. The different biological species of fungi have different chemical and biological properties, and they have been classifed based on their physical appearance in quite low levels of magnification. This thesis investigates if image analysis can be used to analyze images of fungi in high magnification, using scanning electron microscopy technology.
   An algorithm for characterization of fungal spores was developed, and it was investigated if it was possible to differentiate between different classes of fungi. The results show that it is possible to discriminate between different classes of fungi to a certain limit. This limit depends on how similar two example classes

are, but results also indicate that the better (more homogeneous) the images are, the greater the chances are of a correct diagnosis. It is concluded that it is very difficult to get a homogeneous image data base. Characterization and differentiation of fungal spores using image analysis can, however, be used when differences between classes are so signifcant that inhomogeneous factors does not matter, for example separating warty spores from smooth ones.

4. **Quality imagery and video using inexpensive UAV technology by determining camera motion and 3D structure**
   Student: Jakob Sandström, Harald Klomp
   Supervisor: Carolina Wählby
   Subject supervisor: Gunilla Borgefors
   Partner(s): Olle Hagner, Dept of Forest Resource Management and Geomatics, SLU, Umeå
   Publisher: CBA Master Thesis No. 78
   UU School of Engineering, UPTEC F05 033
   Abstract: This thesis is part of the Smartplane project, aimed at producing qualitative image output from small inexpensive unmanned aerial vechicles. Due to the small size and limited payload capability of mini-UAV systems mechanical stabilizations of sensors is often not a feasible option. Turbulence is often significant at the typical operating height of most mini-UAV systems and cost requirements usually dictate the use of non-metric cameras. By consequence the raw imagery acquired is often characterized by unstable orientation, motion blur, high noise levels and significant optical distortions. Hence, extensive processing has to be applied in order to meet the user requirement of high contrast stabilized video and high resolution image mosaics with map compatible geometry.
   The focus of this thesis is to explore methods and techniques used in Computer Vision and Photogrammetry in order to create a mosaic image from an unordered sequence of images. Relevant subjects are camera calibration feature detection, image matching and global adjustment of geometric information.

5. **Registration of retinal images**
   Student: Axel Hjälm
   Supervisor: Carolina Wählby
   Subject supervisor: Carolina Wählby
   Partner(s): Dept. of Neuroscience, UU Hospital
   Publisher: CBA Master Thesis No. 79
   Abstract: Glaucoma is one of the most common causes of blindness in the world, and is characterized by an irreversible damage to the optic nerve. Early detection and treatment of the disease is vital in order to slow down or stop the progression of the disease. In clinical practice, photographs of the optic nerve are taken at different points in time, and compared in order to find pathological changes in the optic nerve.
   In this master thesis, a computer based tool for diagnosis of glaucoma has been developed. By superimposing and flicker two images from different points in time, any changes between them will be readily visualized. As the images are taken at different points, they may be misaligned with respect to each other. By registering the images, these misalignments can be accounted for.
   The registration is performed using Mutual Information as the similarity measure between two images. Two images are considered to be registered when their Mutual Information value is at its maximum. During the registration, one of the images remains fixed while the other one is transformed using an affine transformation. To find the transformation that best registers the images, i.e., maximizes the Mutual Information, an optimization method called Simulated Annealing is used.
   Finally, methods for improving the visual quality of the images have been evaluated. This includes methods for noise reduction and contrast enhancement.

6. **Evaluation of vision system for inspection of infusion bags**
   Student: Markus Hansen
   Supervisor: Annette Gusén, Fresenius Kabi, Uppsala
   Subject supervisor: Gunilla Borgefors
   Partner(s): Fresenius Kabi, Uppsala
   Publisher: CBA Master Thesis No. 80
   UU School of Engineering, UPTEC F05 083
   Abstract: Today, inspection of intravenous nutrition bags is performed completely manually by operators. This can partly be automated by having specially designed software that inspects photographs of the bags.

Three defect criteria were analyzed: missing caps, the position of the inner bag and the so-called headspace. A vision prototype was constructed 1998–2000 but has since not been evaluated. This evaluation was the purpose of the project. The evaluation was performed in two steps of which the first was done with a test rig outside of the production. The results of this step showed that the prototype could detect missing caps with 100 % reliability and that it could check the position of the inner bag in relation to the outer bag, though not with exact precision. The result also showed that the automated measurement of headspace was not achievable.

As the results of the first step of the evaluation were partly satisfacting the second step was performed. This was done in a production line where pictures were taken and analyzed by the vision prototype. The results from this test agreed with the results from the first step showed that the system could handle missing caps and inner bags positioned in the weld of the outer bag. The advantages of implementing the vision system are that fewer bags will be wasted and that operators immediately will be informed of possible errors of bags.

A separate evaluation of inspecting headspace with sensors that measures the solution level has been performed. The results showed that there is a connection between the solution level and the headspace volume, though the reliability is not very good since the bag form differs from bag to bag.

7. **Automatic content-based filtering of television news**
   Student: Johan Ljung
   Supervisor: Daniel Grönquist, Observer AB, and Tacquin Ho, Observer AB
   Subject supervisor: Ewert Bengtsson
   Partners: Sifo Group IT&T, Stockholm and Observer AB, Stockholm
   Publisher: CBA Master Thesis No. 81
   UU School of Engineering, UPTEC F05 085
   Abstract: With the ever-increasing flow of information, the need for computer-automated tools for handling information becomes greater and greater. News shows and other television broadcasts carry vast amounts of information, but generally in forms that are not reachable through conventional information retrieval techniques. During the last couple of years, researchers around the world have given considerable attention to the problem of extracting semantic information from television and re-representing it in a form suitable for automatic indexing and searching. Detailed content information in a television broadcast is typically found in teletext subtitles (if such are available), text imbedded in the video image, and in the spoken dialogue. Extracting it involves using techniques associated with signal processing, image analysis, artificial intelligence, speech recognition, etc. A reliable filter system for use in e.g. Scandinavia, where only a few of the television broadcasts are teletext-subtitled, must take advantage of information in all three forms, or modalities. The presented report contains a survey of current research projects in this area and a theoretical design of a modular, multi-modal, content-based television filter, based on findings in the survey. A prototype of a module for extracting and recognizing image-embedded text has been designed and implemented in matlab. The prototype operates on DCT-compressed video frames (e.g. JPEG, MPEG) and uses statistics, heuristics, image processing and neural network technology. When applied to subtitles embedded in the image, the prototype outputs recognized text with a total character error rate of 5%.

4 Graduate education

This year, there were as many as six dissertations at CBA, four at UU and two at SLU. This certainly is exceptional and makes 2005 a "year of harvest." We gave two PhD courses, one for our own students and one for students in other areas that need basic knowledge about image analysis.

At the end of 2005, we were main supervisors for eight PhD students, six at UU and two at SLU. Another two at SLU were being recruited. Borgefors is also assistant supervisors for two PhD students at Dept. of Mathematics, UU, and one PhD student at Dept. of Biometry and Engineering, SLU.

4.1 Courses

1. **Modelling for image segmentation, 3p**
   Examiner: Ewert Bengtsson
   Lecturers: Ewert Bengtsson, the participants
   Period: 0509–10
   Description: Each participant selected (or was assigned) scientific papers from the general field of model based segmentation. The participants presented a summary of the papers in written form and at a seminar.
   Comment: Bengtsson organized and supervised the course and gave three lectures. The participants also each gave a lecture.

2. **Application oriented image analysis, 5p**
   Examiner: Gunilla Borgefors
   Lecturers: Ewert Bengtsson, Gunilla Borgefors, Magnus Gedda, Ingela Nyström, Robin Strand, Stina Svensson
   Computer exercises: Maria Axelsson, Kristin Norell
   Period: 0510–12
   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".

4.2 Dissertations

1. **Segmentation methods and shape descriptions in digital images —**
   Applications in 2D and 3D microscopy
   Ida-Maria Sintorn
   Date: 20050401
   Publisher: Acta Universitatis Agriculturae Sueciae 20, ISBN: 91-576-7019-6, Uppsala 2005
   Supervisor: Gunilla Borgefors
   Assistant supervisor: Ingela Nyström
   Opponent: Prof. Max Viergever, Image Sciences Institute, University Medical Center Utrecht, The Netherlands
   Committee: Gabriella Sanniti di Baja, Istituto di Cibernetica, C.N.R., Pozzuoli (Napoli), Italy
   Ulf Skoglund, Dept. of Cell and Molecular Biology, Karolinska Institute, Stockholm
   Nils Åslund, AlbaNova University Center, Royal Institute of Technology
   Abstract: Digital image analysis enables creating objective, fast, and reproducible analysis methods of objects or situations that can be imaged.
   This thesis contains theoretical work regarding distance transforms for images digitized in elongated grids. Such images are the result of many, mainly 3D, imaging devices. Local weights appropriate for different elongation factors in 2D, as well as in 3D, are presented. Methods adapted to elongated grids save time and computer memory compared to increasing the image size by interpolating to a cubic grid.

A number of segmentation methods for images in specific applications are also included in the thesis. Distance information is used to segment individual pores in paper volume images. This opens the possibility to investigate how the pore network affects the paper quality. Stable and reliable segmentation methods for cell nuclei are necessary to enable studies of tumor morphology, as well as amounts of fluorescence marked substances in individual nuclei. Intensity, gradient magnitude, and shape information is combined in a method to segment cell nuclei in 2D fluorescence and 3D confocal microscopy images of tissue sections. Two match based segmentation methods are also presented. Three types of viral capsids are identified and described based on their radial intensity distribution in transmission electron micrographs of infected cells. This can be used to measure how a potential drug affects the relative amounts of the three capsids, and possibly, the viral maturation pathway. Proteins of a specific kind in transmission electron volume images of a protein solution are identified using a shape based match method. This method reduces the amount of visual inspection needed to identify proteins of interest in the images.
Two representation schemes, developed in order to simplify the analysis of individual proteins in volume images of proteins in solution, are presented. One divides a protein into subparts based on the internal intensity distribution and shape. The other represents the protein by the maximum intensity curve connecting the centers of the subparts of the protein. These representations can serve as tools for collecting information about how flexible a protein in solution is and how it interacts with other proteins or substances. This information is valuable for the pharmaceutical industry, when developing new drugs.

2. **Hyperspectral image generation, processing and analysis**
Hamed Hamid Muhammed
Date: 20050923
Publisher: Acta Universitatis Upsaliensis, ISBN: 91-554-6318-5, Uppsala 2005
Supervisor: Ewert Bengtsson
Assistant supervisor: Tommy Lindell, Fredrik Bergholm
Opponent: Prof. Erkki Oja, HUT, Helsinki, Finland
Committee: Docent Reiner Lenz, Norrköping
Docent Hans-Eric Nilsson, Uppsala
Prof. Gunilla Borgefors, CBA, Uppsala
Abstract: Hyperspectral reflectance data are utilised in many applications, where measured data are processed and converted into physical, chemical and/or biological properties of the target objects and/or processes being studied. It has been proven that crop reflectance data can be used to detect, characterise and quantify disease severity and plant density.
In this thesis, various methods were proposed and used for detection, characterisation and quantification of disease severity and plant density utilising data acquired by hand-held spectrometers. Following this direction, hyperspectral images provide both spatial and spectral information opening for more efficient analysis.
Hence, in this thesis, various surface water quality parameters of inland waters have been monitored using hyperspectral images acquired by airborne systems. After processing the images to obtain ground reflectance data, the analysis was performed using similar methods to those of the previous case. Hence, these methods may also find application in future satellite based hyperspectral imaging systems.
However, the large size of these images raises the need for efficient data reduction. Self organising and learning neural networks, that can follow and preserve the topology of the data, have been shown to be efficient for data reduction. More advanced variants of these neural networks, referred to as the weighted neural networks (WNN), were proposed in this thesis, such as the weighted incremental neural network (WINN), which can be used for efficient reduction, mapping and clustering of large high-dimensional data sets, such as hyperspectral images.
Finally, the analysis can be reversed to generate spectra from simpler measurements using multiple colour-filter mosaics, as suggested in the thesis. The acquired instantaneous single image, including the mosaic effects, is demosaicked to generate a multi-band image that can finally be transformed into a hyperspectral image.

3. **On analysis of discrete spatial fuzzy sets in 2 and 3 dimensions**
Nataša Sladoje
Date: 20051125
Publisher: Acta Universitatis Agriculturae Sueciae 112, ISBN: 91-576-6911-2, Uppsala 2005
Supervisor: Gunilla Borgefors
Assistant supervisor: Ingela Nyström
Opponent: Prof. Isabelle Bloch, Dept. of Signal and Image Processing, Ecole Nationale Supérieure des Télécommunications, Paris, France
Committee: Prof. Ewert Bengtsson, CBA, UU
Docent Magnus Borga, Dept. of Biomedical Engineering, Linköping University
Prof. Örjan Smedby, Dept. of Medicine and Care, Linköping University Hospital
Abstract: The use of fuzzy set theoretical approaches for representing spatial relationships provides an intuitive way of expressing the diffuse localization and limits of image components. Fuzziness can be present in images as a consequence of noise introduced during the imaging process, in which case it should preferably be removed, and as imprecision inherent to the observed objects, in which case it provides important information that should be utilized during the image analysis process.
A general goal for the research presented in this thesis has been to develop shape analysis methods that can be applied to fuzzy segmented images in 2D and 3D. A demand for the developed methods has been to respect the specific nature of a fuzzy representation of the studied shapes and, especially, the consequences of discretization. We have studied representation and reconstruction of a shape by using moments of both its crisp and fuzzy discretization. We show, both theoretically and statistically, that the precision of estimation of moments of a shape is increased if a fuzzy representation of a shape is used, instead of a crisp one. The signature of a shape based on the distance from the shape centroid is studied and two approaches for its calculation for fuzzy shapes are proposed. A comparison of the performance of fuzzy and crisp approaches is carried out through a statistical study, where a higher precision of shape signature estimation is observed for the fuzzy approaches. The measurements of area, perimeter, and compactness, as well as of volume, surface area, and sphericity, are considered, too. New methods are developed for the estimation of perimeter and surface area of a discrete fuzzy shape. It is shown through statistical studies that the precision of all the observed estimates increases if a fuzzy representation is used and that the improvement is more significant at low spatial resolutions. In addition, a defuzzification method based on feature invariance is designed, utilizing the improved estimates of shape characteristics from fuzzy sets to generate crisp discrete shapes with the most similar shape characteristics. This defuzzification method, performed on a fuzzy segmentation, can be seen as an alternative to a crisp segmentation of an image.
The presented results can be applied wherever precise estimates of shape properties are required, especially in conditions of limited spatial resolution. We have showed, either theoretically, or empirically, that membership resolution available can be successfully utilized to overcome a lack of spatial resolution.

4. **Novel approaches for application of principal component analysis on dynamic PET images for improvement of image quality and clinical diagnosis**
Pasha Razifar
Date: 20051202
Publisher: Acta Universitatis Upsaliensis, ISBN: 91-554-6387-8, Uppsala 2005
Supervisor: Ewert Bengtsson, Mats Bergström
Assistant supervisor: Harald Schneider
Opponent: Prof. Habib Zaidi, PET Instrumentation and Neuroscience Laboratory, Division of Nuclear Medicine, Geneva University Hospital, Geneva, Switzerland
Committee: Docent Ingela Nyström, CBA, UU
Prof. Terry Jones, Manchester Molecular Imaging Centre, The University of Manchester, Manchester, UK
Prof. Eva Kumlien, Dept. of Neuroscience Neurology, UU
Abstract: Positron Emission Tomography, PET, can be used for dynamic studies in humans. In such studies a selected part of the body, often the whole brain, is imaged repeatedly after administration of a radiolabelled tracer. Such studies are performed to provide sequences of images reflecting the tracers kinetic behaviour, which may be related to physiological, biochemical and functional properties of tissues. This information can be obtained by analyzing the distribution and kinetic behaviour of the administered tracers in different

regions, tissues and organs. Each image in the sequence thus contains part of the kinetic information about the administered tracer.
Several factors make analysis of PET images difficult, such as a high noise magnitude and correlation between image elements in conjunction with a high level of non-specific binding to the target and a sometimes small difference in target expression between pathological and healthy regions. It is therefore important to understand how these factors affect the derived quantitative measurements when using different methods such as kinetic modelling and multivariate image analysis.
In this thesis, a new method to explore the properties of the noise in dynamic PET images was introduced and implemented. The method is based on an analysis of the autocorrelation function of the images. This was followed by proposing and implementing three novel approaches for application of Principal Component Analysis, PCA, on dynamic human PET studies. The common underlying idea of these approaches was that the images need to be normalized before application of PCA to ensure that the PCA is signal driven, not noise driven. Different ways to estimate and correct for the noise variance were investigated. Normalizations were carried out Slice-Wise (SW), for the whole volume at once, and in both image domain and sinogram domain respectively. We also investigated the value of masking out and removing the area outside the brain for the analysis.
The results were very encouraging. We could demonstrate that for phantoms as well as for real image data, the applied normalizations allow PCA to reveal the signal much more clearly than what can be seen in the original image data sets. Using our normalizations, PCA can thus be used as a multivariate analysis technique that without any modelling assumptions can separate important kinetic information into different component images. Furthermore, these images contained optimized signal to noise ratio (SNR), low levels of noise and thus showed improved quality and contrast. This should allow more accurate visualization and better precision in the discrimination between pathological and healthy regions. Hopefully this can in turn lead to improved clinical diagnosis.

5. **Global shape description of digital objects**
Ola Weistrand
Date: 20051209
Publisher: Acta Universitatis Upsaliensis, ISBN: 91-506-1833-4, Uppsala 2005
Supervisor: Christer Kiselman
Assistant supervisor: Gunilla Borgefors, Örjan Smedby
Opponent: Prof. Michael S. Floater, Dept. of Informatics, University of Oslo, Norway
Committee: Prof. Anders Heyden, School of Technology and Society, Malmö University
Docent Ingela Nyström, CBA, UU
Prof. Henrik Shahgholian, Dept. of Mathematics, Royal Institute of Technology, Stockholm
Abstract: New methods for global shape description of three-dimensional digital objects are presented. The shape of an object is first represented by a digital surface where the faces are either triangles or quadrilaterals. Techniques for computing a high-quality parameterization of the surface are developed and this parameterization is used to approximate the shape of the object. Spherical harmonics are used as basis functions for approximations of the coordinate functions. Information about the global shape is then captured by the coefficients in the spherical harmonics expansions.
For a starshaped object it is shown how a parameterization can be computed by a projection from its surface onto the unit sphere. An algorithm for computing the position at which the centre of the sphere should be placed, is presented. This algorithm is suited for digital voxel objects. Most of the work is concerned with digital objects whose surfaces are homeomorphic to the sphere. The standard method for computing parameterizations of such surfaces is shown to fail on many objects. This is due to the large distortions of the geometric properties of the surface that often occur with this method. Algorithms to handle this problem are suggested. Non-linear optimization methods are used to find a mapping between a surface and the sphere that minimizes geometric distortion and is useful as a parameterization of the surface.
The methods can be applied, for example, in medical imaging for shape recognition, detection of shape deformations and shape comparisons of three-dimensional objects.

6. **Colour correction of underwater images using spectral data**
Julia Åhlén
Date: 20051216
Publisher: Acta Universitatis Upsaliensis, ISBN: 91-554-6403-3, Uppsala 2005
Supervisor: Ewert Bengtsson
Assistant supervisor: Tommy Lindell
Opponent: Prof. Jussi Parkkinen, University of Joensuu
Committee: Prof. Björn Kruse, Linköping University, Norrköping
Docent Kerstin Malmqvist, Halmstad University College
Dr Catherine Östlund, STFI, Stockholm
Abstract: For marine sciences sometimes there is a need to perform underwater photography. Optical properties of light cause severe quality problems for underwater photography. Light of different energies is absorbed at highly different rates under water causing significant bluishness of the images. If the colour dependent attenuation under water can be properly estimated it should be possible to use computerised image processing to colour correct digital images using Beers Law.
In this thesis we have developed such estimation and correction methods that have become progressively more complicated and more accurate giving successively better correction results. A process of estimation of downwelling attenuation coefficients from multi or hyper spectral data is a basis for automatic colour restoration of underwater taken images. The results indicate that for each diving site the unique and precise coefficients can be obtained.
All standard digital cameras have built in white balancing and colour enhancement functions designed to make the images as aesthetically pleasing as possible. These functions can in most cameras not be switched off and the algorithms used are proprietary and undocumented. However, these enhancement functions can be estimated. Applying their reverse creates un-enhanced images and we show that our algorithms for underwater colour correction works significantly better when applied to such images.
Finally, we have developed a method that uses point spectra from the spectrometer together with RGB colour images from a camera to generate pseudo-hyper-spectral images. Each of these can then be colour corrected. Finally, the images can be weighted together in the proportions needed to create new correct RGB images. This method is somewhat computationally demanding but gives very encouraging results.
The algorithms and applications presented in this thesis show that automatic colour correction of underwater images can increase the credibility of data taken underwater for marine scientific purposes.

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 theoretical 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 of Forest Science at SLU).

In this section, we list the 40 research projects that were active during 2005. Some are big projects that have been active for a long time, while others are small and short-lived. We started ten new projects this year, while nine were finished.

This year, the list starts with image analysis theory; followed by medical image applications (from proteins to organs); computer graphics and visualization; forest and agricultural projects; and finish with aquatic remote sensing and some miscellaneous projects. 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 20 international groups in 13 countries and 41 national groups with which we have had active co-operation in 2005.

5.1 Current research projects

1. **The discrete potato peeling problem**
   Gunilla Borgefors, Robin Strand
   Funding: SLU, S-faculty, FMB
   Period: 0502–
   Abstract: In several application projects we have discovered the need of computing the maximal inscribed convex set of a digital shape. Finding this set turn out to be a very though problem, both in the continuous world and even more so in the discrete case. An algorithm for computing an approximate solution in 2D and 3D have been developed and presented at a conference. The main idea is to iteratively identify the deepest concavity and then remove it by cutting off as little as possible of the shape. A small example is found in the Figure 2.

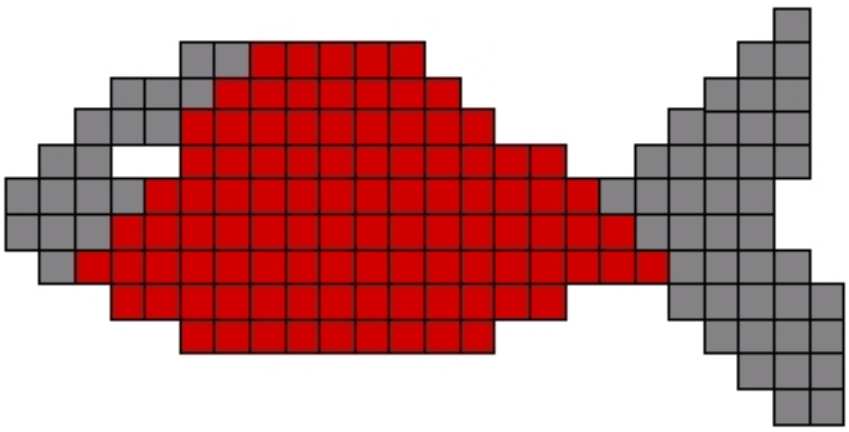


Figure 2: The approximation of the maximal inscribed convex set of the fish is shown in red.

2. **Global shape description in 2D and 3D by polynomial expansion**
   Ola Weistrand, Gunilla Borgefors
   Funding: Swedish Research Council; UU TN-faculty
   Period: 9701–0512
   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. The results were presented in the PhD thesis of Ola Weistrand which was published during 2005, see Section 4.2.

3. **Skeletonization in 3D discrete binary images**
   Ingela Nyström, Robin Strand, Gunilla Borgefors, Stina Svensson
   Funding: UU TN-faculty, Graduate School in Mathematics and Computing (FMB), SLU S-faculty
   Period: 9501–
   Partners: Gabriella Sanniti di Baja, Istituto di Cibernetica, CNR, Pozzuoli, Italy
   Abstract: Skeletonization is a way to reduce dimensionality of digital objects. A skeleton should have the following properties: topologically correct, centred within the object, thin, and fully reversible. We have been working on 3D skeletonization for the last decade. This research is summarized in a chapter in the *Handbook of Pattern Recognition and Computer Vision* published 2005. There, we present in detail an algorithm that computes the curve skeleton of a solid object, i.e., an object without cavities, in a 3D binary image. Our algorithm consists of three main steps. During the first step, the surface skeleton is detected by directly marking in the distance transform of the object, the voxels that should be assigned to the surface skeleton. Our surface skeleton fulfils the property of being fully reversible. During the second step, the curve skeleton is computed by iterative thinning of the surface skeleton, based on the detection of curves and of junctions between surfaces. Finally, the third step is performed to reduce the curve skeleton to unit width and to prune, in a controlled manner, some of its peripheral branches.

   Reversibility of a skeleton can be guaranteed by assigning the centres of maximal balls (CMBs) to the skeleton. The CMBs are local maxima in the distance transform and the original object can be obtained by taking the union of all such balls. An alternative method to decide which CMBs that should be included in surface- and curve-parts of the skeleton is described in *A classification of centres of maximal balls in* $\mathbb{Z}^3$, see 6.4.8.

4. **Distance functions and distance transforms in discrete images**
   Gunilla Borgefors, Robin Strand, Céline Fouard, Stina Svensson
   Funding: SLU S-faculty, Graduate School in Mathematics and Computing (FMB)
   Period: 9309–
   Partner: Benedek Nagy, Dept. of Computer Science, Faculty of Informatics, University of Debrecen, Debrecen, Hungary
   Abstract: The distance between any two grid points in a grid is defined by a distance function. In this project, The Euclidean metric and *path-generated* distance functions are considered. For path-generated distance functions, the distance between two points is defined as the shortest path between the points. To define paths between points, an adjacency relation and the cost (weight) for a step between two neighbouring grid points must be defined. The rotational dependency can be minimized either by using predefined weights (weighted distances) or by varying the adjacency relation along the path (distance based on neighbourhood sequences).
   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.
Methods for acquiring 3D images are usually designed to produce images on grids with cubic, or box-shaped, voxels. Many standard methods for generating 3D images can be adjusted to produce images on grids where the voxels are not box-shaped. Examples of such grids are the fcc and bcc grids, see Project 5. Results concerning weighted DTs and Euclidean DTs on these grids have been published in 2005, see 6.4.10 and 6.3.10.
A summary of DTs in 2D and 3D square/cubic grids have been published as a chapter in *Handbook of Pattern Recognition and Computer Vision*, see 6.2.3.
Weighted distance functions and distance transforms have been examined in a very general framework — modules and point-lattices, respectively. These results have been submitted for publication.
Distances based on neighbourhood sequences on the fcc and bcc grids have also been examined. This research has resulted in two manuscripts submitted for publication. The manuscripts include both results on the basic theory for such distance functions and "optimal" (minimizing the rotational dependency) neighbourhood sequences.

5. **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, e.g., 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, and in the fcc grid, the voxels consist of rhombic dodecahedra. The voxels in these grids are better approximations of Euclidean balls than the cube, a fact that is justified by looking at the neighbours of the voxels. 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 Project 4, on the fcc and bcc grids have been examined and some of the results published. A paper about resolution pyramids on these grids, Figure 3, has been published, see 6.4.9.

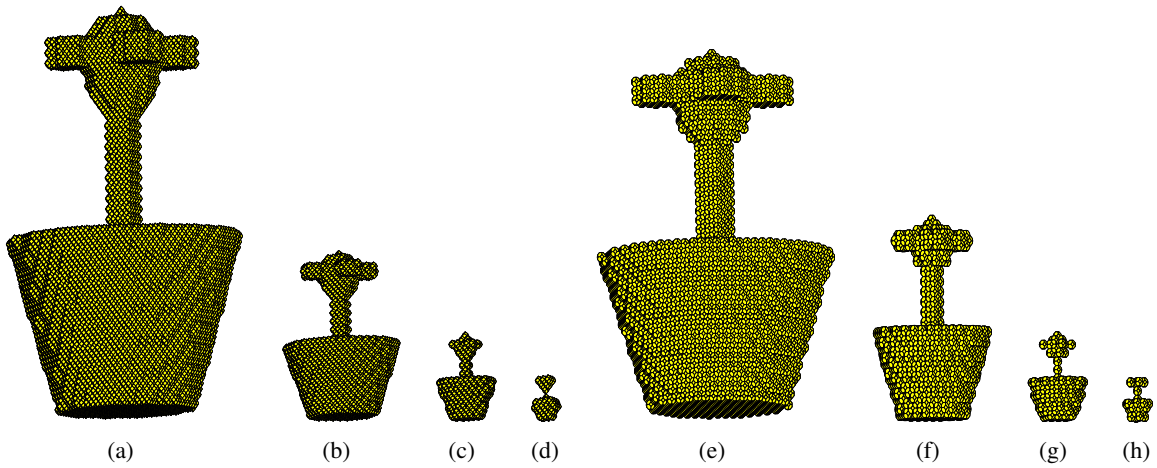


Figure 3: Resolution pyramids for a potplant on the fcc grid (a)–(d) and the bcc grid (e)–(h) using the shifting grid method.

6. **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: The advantages of representing objects in images as fuzzy spatial sets are numerous and have lead to increased interest for fuzzy approaches in image analysis. Fuzziness is an intrinsic property of images. It is additionally introduced in digital image processing by discretization and as a natural outcome of most imaging devices. Preservation of fuzziness implies preservation of important information about objects and images. Our previous results within this project show that an improved precision of shape description can be achieved if the description is based on a fuzzy shape representation, where the fuzzy membership of a point reflects the level to which that point belongs to the object. We have analysed perimeter, area, compactness measure, surface area, volume and sphericity measure, as well as the signature of a shape, for shapes resulting from area coverage fuzzification. Two journal papers covering some of these aspects were published in 2005.
During 2005, we have studied moment-based shape descriptors and derived error bounds for the estimation of moments from a fuzzy representation of a shape. We show that moments are estimated with significantly higher accuracy from a fuzzy membership function based on pixel area coverage, than from a binary Gauss digitization at the same spatial resolution. This study was presented at *ICIAP 2005*, see 6.4.14.
We also show that for a certain class of membership functions defining a fuzzy disk, there exists a one-to-one correspondence between the set of fuzzy disks and the set of their generalized moment representations. General moments were defined within this study, in order to provide this one-to-one correspondence. Theoretical error bounds for the accuracy of the estimation of moments of a continuous fuzzy disk from the moments of its digitization and, in connection with that, the accuracy of an approximate reconstruction of a continuous fuzzy disk from the moments of its digitization, were derived. A paper resulting from this study is submitted for journal publication.
The results of the research performed within this project and Project 7 are summarized in Nataša Sladoje's PhD thesis, see Section 4.2.

7. **Defuzzification of fuzzy segmented objects by feature invariance**
Nataša Sladoje (Matić), Ingela Nyström, Joakim Lindblad
Funding: SLU S-faculty, UU TN-faculty
Period: 0301–
Abstract: The defuzzification method based on invariance of feature values between fuzzy and crisp representations, that we introduced in 2004, has been further developed. The method produces crisp shapes from fuzzy shapes, by minimizing the distance between the two representations. A distance measure that we find appropriate for defuzzification incorporates selected (local and global) properties of the two sets: corresponding membership values, gradient, area, perimeter, and centre of gravity. An example of defuzzification is presented in Figure 4. We define a distance between two fuzzy sets as a distance between their feature-based representations in a defined feature space. Several existing distance measures can be adjusted and used for this purpose. We have tested some of them, being mostly interested in Minkowski distances. Our method allows to combine two defuzzification approaches, since it utilizes the information contained in the fuzzy representation both for defining a mapping from the set of fuzzy sets to the set of crisp sets, and for the approximate reconstruction of an unknown crisp original. A paper resulting from this study has been submitted for journal publication.
Further improvement of the defuzzification of fuzzy spatial sets by feature invariance is made by generating the crisp discrete representation of a fuzzy set at an increased spatial resolution, compared to the resolution of the fuzzy set. This research is in process.
The results of the research performed within this project and Project 6 are summarized in Nataša Sladoje's PhD thesis, see Section 4.2.

8. **Discrete 3D tools applied to 2D grey-level images**
Ingela Nyström, Gunilla Borgefors
Funding: UU TN-faculty, SLU S-faculty
Period: 0209–0509
Partners: Gabriella Sanniti di Baja, Istituto di Cibernetica, CNR, Pozzuoli, Italy

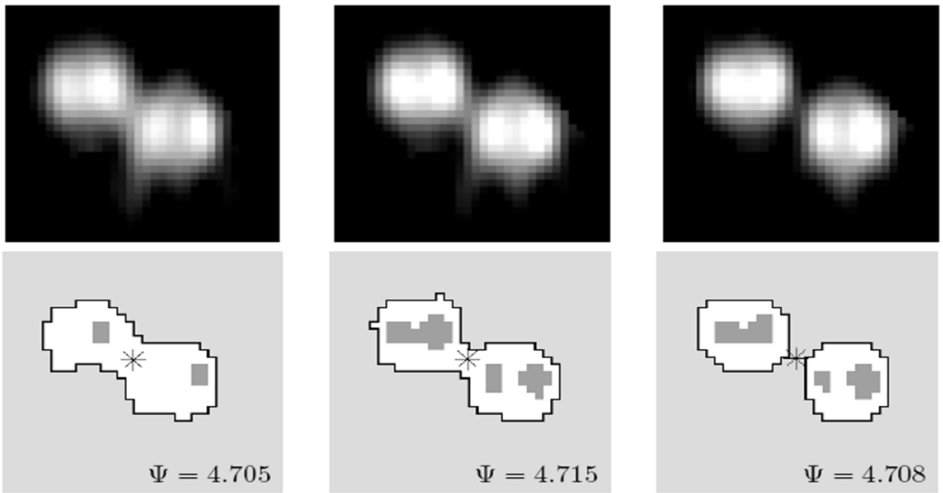


Figure 4: Fuzzy segmented vessels in a slice of a magnetic resonance angiography (MRA) image (top). Defuzzifications of the vessels based on feature invariance between the fuzzy and crisp representations (Ψ is the similarity measure) (bottom).

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. We present three such algorithms. The first algorithm smoothes a 2D grey-level image by flattening its geometrical and grey-level peaks while simultaneously filling in geometrical and grey-level valleys, regarded as non-significant in the problem domain. The second algorithm computes an approximation of the convex hull of a 2D grey-level object, by building a covering polyhedron closely fitting the corresponding object in a 3D binary image. The result obtained is convex both from the geometrical point of view and as concerns grey-levels. The third algorithm skeletonizes a 2D grey-level object by skeletonizing the top surface of the object in the corresponding 3D binary image. The algorithms can find applications in optical character recognition (OCR) or in other situations where such shape analysis is desired. These algorithms were presented at *ICIAP 2005*, Cagliari, Italy, see 6.4.20.

9. **Decomposition of 3D objects**
Stina Svensson, Magnus Gedda
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 itself. 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 was published in Image and Vision Computing in February 2005.
Methods for decomposition of 3D discrete objects as well as grey-level representations of proteins (see Project 13) have earlier been developed at CBA. During 2005, these methods have been further developed by utilising the concept of fuzzy sets. The application in mind is Cryo-ET data of proteins, but the method is general and can be used as a blob separation algorithm for 2D or 3D grey-level images in applications where grey-levels are increasing towards the internal parts of the blobs. By using fuzzy sets, the inner properties of the structure is enhanced, thus, aiding decomposition. The decomposition scheme combines fuzzy distance information from the fuzzy object and hierarchical clustering of local maxima with a region growing process to identify the parts of the fuzzy object. This approach shows promising results and several manuscripts describing the work was prepared and submitted during 2005.

10. **New techniques for information extraction by using new neuro-fuzzy systems**
Hamed Hamid Muhammed, Ewert Bengtsson
Funding: UU TN-faculty, Swedish National Space Board
Period: 0201–0509
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 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. 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 distributed 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.
    - Weighted Incremental Neural Networks (WINN): The model is built by successive addition, adaptation, 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.

    Results from this project have been documented in two conference papers and two journal papers as well as in the PhD thesis of Muhammed which was published during 2005, see Section 4.2.

11. **Accelerating the computation of 3D gradient vector flow (GVF) fields**
Erik Vidholm, Ingela Nyström, Ewert Bengtsson
Funding: Swedish Research Council
Period: 0508–
Partners: Per Sundqvist, Dept. of Information Technology, UU
Abstract: In our work on interactive 3D segmentation, see Project 20, we have been working on methods to facilitate initialization of our segmentation algorithms. One way is to 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 GVF field can also be used to drive a deformable model, and then we get an intuitive connection between the model and the interaction.
The computation of a GVF field consists mainly of solving a huge discretized system of elliptical partial differential equations (PDEs). The convergence rate of the commonly used numerical scheme to compute GVF does not allow for practical use in 3D applications. This project aims at presenting alternative computation schemes to speed up the computation. The discrete equations have several properties that can be utilized to accelerate the process of finding an approximate solution. We investigate how stationary iterative methods, preconditioned conjugate gradient methods, and multigrid methods can be tuned to solve our problem.

    Our results show that it is possible to obtain much better performance by only small modifications of the original scheme. The results also show that the multigrid algorithm is the fastest and allows us to compute the GVF field in the order of one minute for a standard medical image on a standard computer (compared to approximately one hour with the commonly used approach). The results are summarized in a manuscript submitted to an international conference.

12. **Evaluation of bone implants**
Gunilla Borgefors
Funding: SLU, S-faculty
Partner: Carina Johansson, Dept. of Technology, Örebro University
Period: 0505–

Abstract: In an aging population the use of bone anchored spare parts in them form of bone implants becomes more and more usual and important, e.g., orthopedic and dental implants. It is important to study the interface between the biomaterial and the bone tissue, to be able to develop implants with optimal properties. The implants should work also in not completely healthy tissues, where the acceptance of biomaterials is complex. We can use images from light microscope, confocal microscope and micro computer tomography. Our task is to develop automatic image analysis methods for evaluations of these two or three dimensional images. This project is just starting, but will have funding from the Swedish Research Council from 2006.

13. **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: Dept. of Cell and Molecular Biology (CMB), Karolinska Institutet, Stockholm; Susana Mata, Rey Juan Carlos University, Madrid, Spain; Sidec Technologies AB, Stockholm.
Abstract: ryo-Electron Tomography (Cryo-ET) is a technique for 3D structure visualisation. Standard reconstruction tools can be complemented by the COnstrained Maximum Entropy Tomography, a refinement procedure developed at CMB which has been shown to reduce the degenerative effect of noise, thus allowing more details to be included in the tomograms. This procedure allows reconstruction of the 3D profile of individual proteins in solution to about 2nm resolution. Thus Cryo-ET allows to inspect qualitatively the inherent, large-scale flexibility of various domains. Each 3D tomogram can seen as an instantaneous snapshot of the protein dynamics. Computerized image analysis plays an essential role to extract a quantitative estimate of the relevant structural parameters.
During 2005, a cooperation was initiated with Department of Cell and Molecular Biology, Karolinska Institutet, Stockholm, Sweden and Department of Energetic "S. Stecco", University of Florence, Florence, Italy. This resulted in an approved application to The Swedish Research Council for a three years project that will start 2006. Some initial results were presented on Medicintekniskdagarna in Södertälje, Sweden.
The resolution in Cryo-ET data 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 have developed several methods related to the analysis of such images.
The segmentation method used at CMB so far for identifying proteins in Cryo-ET data consists of grey-level thresholding together with size discrimination and visual inspection. The visual inspection is very time consuming and varying background makes it difficult to find a suitable threshold. During 2005, we have developed a shape based method for automatic detection of proteins in Cryo-ET data which combines intensity and gradient magnitude information to extract stable borders of the proteins and then use a template to search for borders corresponding to proteins of interest. The method uses the hierarchical chamfer matching algorithm, which matches a binary edge template to a distance transform of a binary edge image. The matching is embedded in a resolution pyramid to speed up the calculations and avoid getting stuck in false local minima. The method was evaluated on images containing the antibody Immunoglobulin G. The results were presented at (and published in proceedings of) SCIA in June 2005 as well as in the PhD thesis of Ida-Maria Sintorn which was published during 2005.
To facilitate the recognition and analysis of proteins in Cryo-ET data, focus has been put on the development of two different representation schemes which are described in the following.
One 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, making use of both grey-level as well as shape information without the need of an initial segmentation of the object. Since the grey-level distribution within a protein is of great importance for function, this medial surface representation was adapted to suit proteins in volume images giving a curve connecting the locii of the different parts of the protein as a medial representation. The medial grey-level based representation was presented at (and published in proceedings of) the IbPRIA conference in June 2005 as well as in the PhD thesis of Ida-Maria Sintorn which was published during 2005.
Another way of representing an object is to use decomposition into significant parts. This is of interest as the parts and their relative position is the key to understanding how flexible a protein is and how it can interact with, or bind to, other proteins or substances. Methods for decomposition of binary and grey-level representations of proteins have earlier been developed at CBA. During 2005 these methods have been further developed by utilising the concept of fuzzy sets. By using fuzzy sets in the protein representation, the

inner properties of the protein structure is enhanced, thus, aiding decomposition of the protein into parts. This approach is described in Project 9. Some inital results can be seen in Figure 5, where three antibodies Immunoglobulin G imaged by Cryo-ET and their decomposed representations are shown.

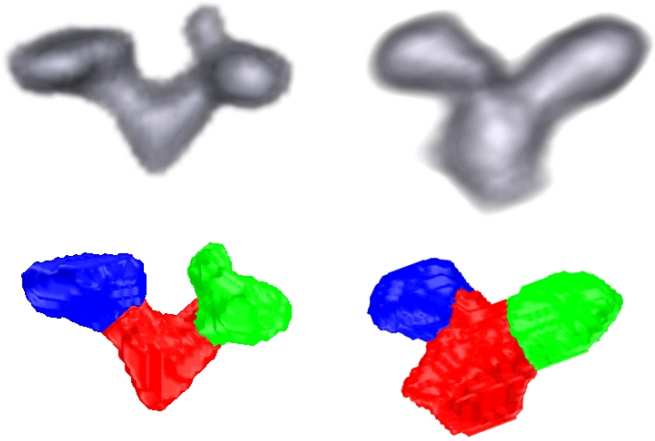


Figure 5: Volume rendered antibodies in set images (top) and decomposed representation (bottom).

14. **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.
    The results were presented in the PhD thesis of Ida-Maria Sintorn which was published during 2005, see Section 4.2.

15. **Segmentation and analysis of point-like fluorescent signals in 2D and 3D images of cells**
    Amalka Pinidiyaarachchi, Patrick Karlsson, Carolina Wählby, Ewert Bengtsson
    Funding: UU TN-faculty
    Period: 0305–
    Partners: Mats Nilsson and Chatarina Larsson, Dept. of Genetics and Pathology, UU
    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. 3D images are acquired by making non-invasive serial optical sections of the object. Analysis of spatial relationships in 2D and 3D 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 spatial relationships and non-random patterns in the blob distribution. See Figure 6.

16. **Time-lapse microscopy and cell migration modeling**
    Carolina Wählby, Amalka Pinidiyaarachchi, Magnus Gedda, Patrick Karlsson, Ewert Bengtsson
    Funding: Swedish Research Council; UU TN-faculty;

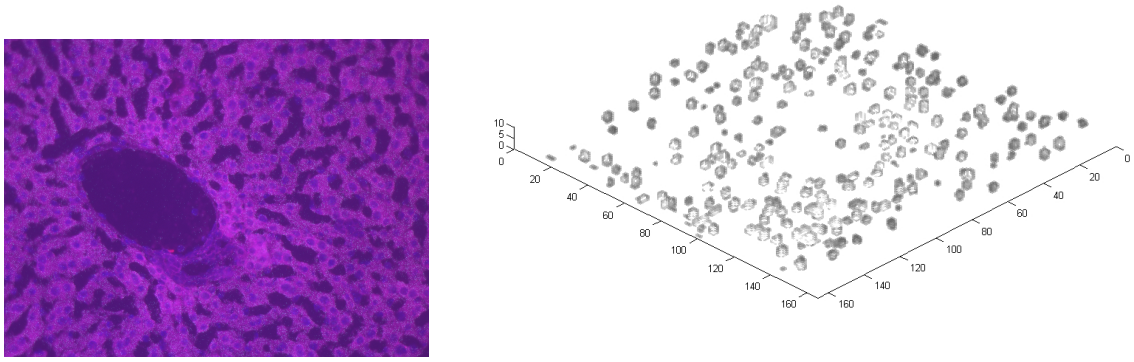


Figure 6: A liver tissue image where mitochondrial DNA has been visualized using padlock probes (left). (Image by Chatarina Larsson, Dept. of Genetics and Pathology.) Segmented fluorescence spots of a selected region for 10 image slices (right).

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. Variance filtering and seeded watershed segmentation as well as methods based on mean-shift segmentation have been explored. See Figure 7.

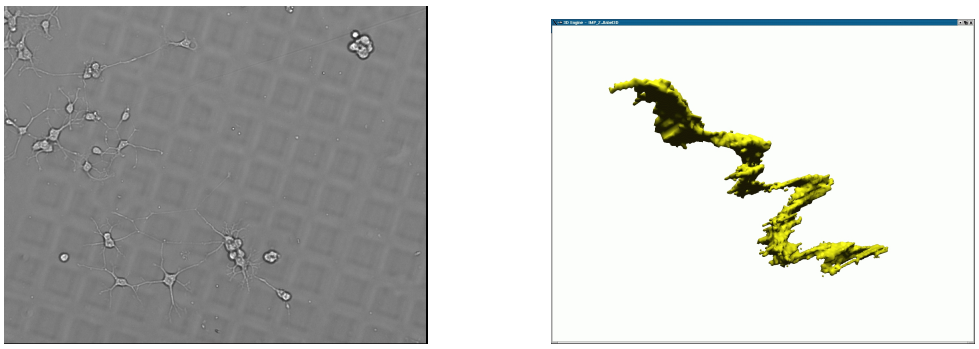


Figure 7: One single original time-lapse image of a stem cell culture, from a sequence of 273 image frames (left). A mean shift segmented cell in space, and time (right). The mean shift method allows for simultaneous segmentation and tracking of individual stem cells, by a form of adaptive hill climbing on the four dimensional density space defined by the joint spatial/spectral/temporal domain of the time-lapse microscopy sequences.

17. **Segmentation of 2D and 3D images of tissue**
Carolina Wählby, 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: 0209–0504
Partners: Fredrik Erlandsson, Dept. of Oncology/Pathology, Karolinska Institute, Stockholm
Abstract: Shape and distribution of various sub-cellular structures and components can be observed by immunostaining 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. The results were presented in the PhD thesis of Sintorn which was published during 2005, see Section 4.2.

18. **Analysis of random array data**
Carolina Wählby
Funding: Uppsala BioX
Period: 0501–
Partners: Mats Nilsson, Jenny Göransson and Mathias Howell, Dept. of Genetics and Pathology, UU
Abstract: Nilsson et al are developing new concepts for molecular analyses that allow analysis at the ultimate level of single bio-molecules through padlock- and proximity probing coupled to rolling-circle amplification. Rolling-circle products spontaneously form micron-sized coils (blobs) that can be immobilized randomly on a glass surface, referred to as a random blob array, and identified by hybridization of fluorescence labelled tag-oligonucleotides. Therefore, individual detection oligonucleotides act as biotransistors that convey and amplify the information from the nanometer-sized probe molecules to observable micron-sized products. In this project, the goal is to use combinations of fluorescent molecules on single detection oligonucleotides, as well as repeated staining and de-staining, in order to create image data that can be analysed for increase of the multiplexity of DNA, transcript, and protein detection. The position of the reaction sites of a random blob array are random. Standard methods for spectral analysis require known reaction sites, and can therefore not be applied to this type of image data. We develop new methods for bilateral (spatial and spectral) clustering and analysis of image data to describe the bio-molecular composition of biological samples.

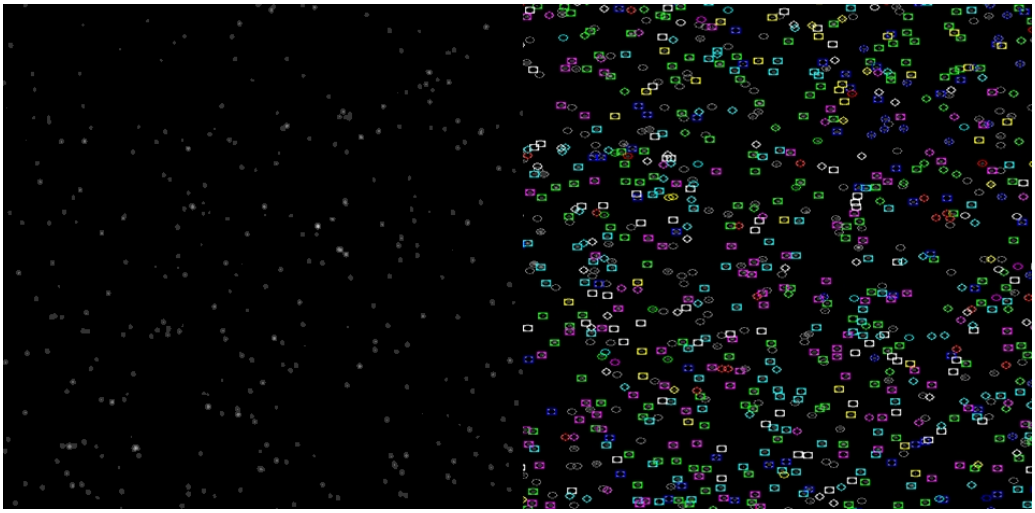


Figure 8: One of several spectral images of a random blob array (left). Color coded result of random blob classification (right).

19. **Simultaneous visualization of 3D anatomical and multi-dimensional physiological information — with application to positron emission tomography**
Pasha Razifar, Ewert Bengtsson
Period: 0110–
Fundig: 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 the first part of this 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 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.
This was followed by proposing and implementing three novel approaches for application of Principal Component Analysis (PCA) on dynamic human PET studies. The common underlying idea of these approaches was that the images need to be normalized before application of PCA to ensure that the PCA is signal driven, not noise driven. Different ways to estimate and correct for the noise variance were investigated. Normalizations were carried out Slice-Wise (SW), for the whole volume at once, and in both image domain and sinogram domain, respectively. We also investigated the value of masking out and removing the area outside the brain for the analysis.
The results were very encouraging. We could demonstrate that for phantoms as well as for real image data, the applied normalizations allow PCA to reveal the signal much more clearly than what can be seen in the original image data sets. Using our normalizations, PCA can thus be used as a multivariate analysis technique that without any modelling assumptions can separate important kinetic information into different component images. Furthermore, these images contained optimized signal to noise ratio (SNR), low levels of noise and thus showed improved quality and contrast. This should allow more accurate visualization and better precision in the discrimination between pathological and healthy regions. The results were published in the PhD thesis of Pasha Razifar, see Section 4.2, as well as in two journal papers published during 2005, see Section 6.3. Additional papers have been submitted for publication.

20. **Improved interactive medical image analysis through 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 developed methods are tested on real medical application data.
In March 2005, we presented a paper about haptic volume rendering based on gradient diffusion at World-

Haptics 2005, Pisa, Italy, see 6.4.21, a work that has continued during the year, see Project 11. Another sub-project has been on liver segmentation from CT images, see Project 21. Two MSc projects are under finalizing: Filip Malmberg, *3D live-wire: Semi-automatic segmentation of volume images in a haptic environment* and Andreas von Knobloch, *Segmentation by deformable models in a haptic environment*. Both of these works deal with interactive segmentation facilitated by haptic feedback. In additon to this, we are working on haptic interaction with 3D deformable surface meshes and hardware assisted visualization of breast MR images, see Project 22.

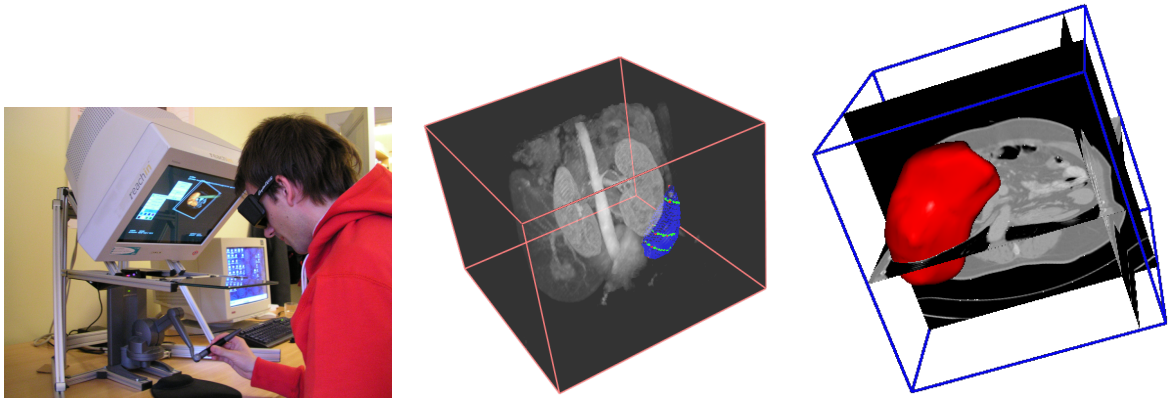


Figure 9: A user working with the haptic display (left). A screenshot from the 3D live-wire application (middle). A screenshot from the deformable model application (right).

21. **Interactive segmentation of CT images for liver metastasis quantification**
Erik Vidholm, Ingela Nyström, Ewert Bengtsson
Funding: Swedish Research Council
Period: 0501–
Partners: Sven Nilsson, Hans Frimmel, Dept. of Oncology, Radiology, and Clinical Immunology, UU
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 segmentation algorithm. We investigate how such initialization tasks can be facilitated by using haptic feedback.
In this project, we want to segment the liver from CT scans of patients with neuroendocrine tumors. The aim is to compute the liver volume and metastasis volume. We have used the fast marching algorithm, and we use haptics to make the initialization of the algorithm easier and more efficient. Two users placed initializations in 52 datasets (26 patients at two different occasions) using the haptic user interface. The mean interaction time is about 45 seconds per dataset and the resulting segmentations highly correlate between the users. The next step is to study how well the computed volumes correlate with the level of a biochemical marker acquired at the same time as the scan. This project builds on Project 20.

22. **Analysis of dynamic breast MRI**
Ewert Bengtsson, Erik Vidholm, Ingela Nyström
Funding: UU TN Faculty, The Australian Research Council
Period: 0503–
Partners: Stuart Crozier, Andrew Mehnert and co-workers at ITEE department, University of Queensland, Brisbane, Australia;
Ivo Hanak, Dept. of Computer Science, University of West Bohemia, Czech Republic
Abstract: The pattern of change of signal intensity over time in contrast enhanced magnetic resonance (MR) images of the breast is a useful indicator of malignancy. The methods used for assesing and visualising this in current clinical practice are rather tedious; it is difficult to visualise and evaluate 4D (3D volumes over time) data effectively. In this project, we are developing and evaluating improved methods for such visualisation and evaluation. The project started during Bengtssons sabbatical at the University of Queensland in 2004–2005 and continued as a joint project after his return to CBA. Preliminary results were presented at two conferences, one in Brisbane in February and one in Sweden in March 2005. In August

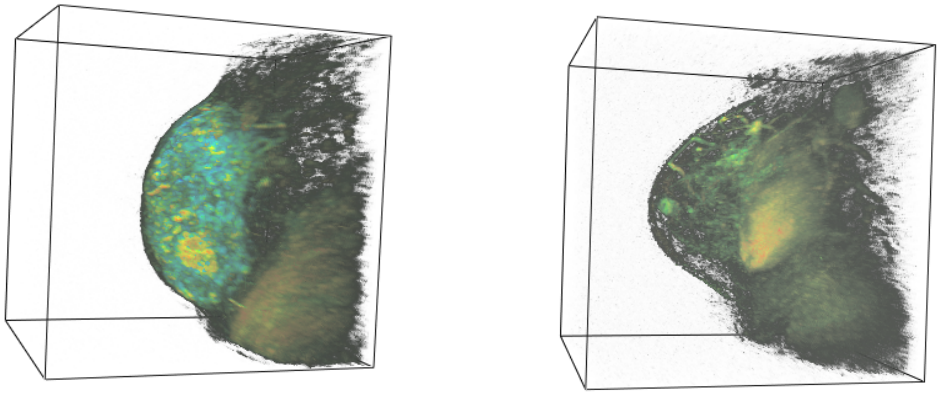


Figure 10: The uptake of MR contrast medium over time in each voxel of the breast volume images is converted to a colour coded MIP, which can be rotated and explored dynamically giving a direct overview of points of interest, where there is a potential small malignant lesion.

2005, a small grant was awarded for this work from the Australian Research Council. During the fall, a new method for dynamic visualisation of colour maximum intensity projections (MIPs) has been developed and implemented in a graphics processor in cooperation with Ivo Hanak. See Figure 10.

23. **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. However, to reach a diagnostic conclusion, the 3D images need to be projected onto the 2D computer screens in more sophisticated ways than slice by slice projections.
It is particularly useful to device methods where the user interactively can explore the 3D information in the images. Earlier, allowing dynamic interaction with medical volume images 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 (mass produced for the game market) can be used quite effectively for the purpose of medical visualization. Still much research work is needed to find out the most effective way of using such display facilities for exploring medical data. The research task in this project is to develop such display methods, e.g., by utilizing the programmability of today's graphics cards.

24. **Efficient algorithms for computer graphics**
Ewert Bengtsson
Funding: UU TN Faculty
Period: 9911–
Partners: Anders Hast, Dept. of Mathematics, Natural Sciences, and Computing, University College of Gävle;
Tony Barrera, Barrera Kristiansen AB, Uppsala
Abstract: Computer graphics is increasingly being used to create ealistic 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.
The project is carried out in close collaboration with Tony Barrera. It has been running since 1999 and

resulted in 2004 in a PhD thesis by Anders Hast. By that time it had produced 20 international publications. The work has continued after the dissertation and has during 2005 resulted in another book chapter and two reviewed conference papers, see Section 6.

25. **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, it is not sufficient to provide high detailed models. In addition to geometric detail, motion of foliage and twigs is an essential visual cue. Traditional techniques for animation of complex plant 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.

26. **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: Norwegian Pulp and Paper Research Institute (PFI), Trondheim, Norway, STFI-Packforsk, Stockholm, StoraEnso, Falun
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. 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. The developed methods are also intended for other fibrous and porous structures and materials.
In this project, both segmentation algorithms for individual fibres and for the porous structure are investigated. A method for segmenting the porous structure into individual pores using distance transforms and the watershed algorithm was published in Nordic Pulp and Paper Research Journal in 2005, see 6.3.9. See Figure 11 for an example segmentation of the pore structure with this method.
In this project, different volume images of paper are available for the studies. One volume created from a series of 2D scanning electron microscopy (SEM) images at StoraEnso in Falun, and three-dimensional X-ray microtomography images of paper samples, from the European Radiation Syncrotron Facility in Grenoble. Furthermore, methods for creating other sample volume images are investigated.
Ida-Maria Sintorn presented some of these results in her PhD thesis, which was published during 2005, see Section 4.2.

27. **Estimation of the water holding capacity of press felts**
Maria Axelsson, Stina Svensson, Gunilla Borgefors
Funding: SLU S-faculty
Period: 0501–
Partners: STFI-Packforsk, Stockholm

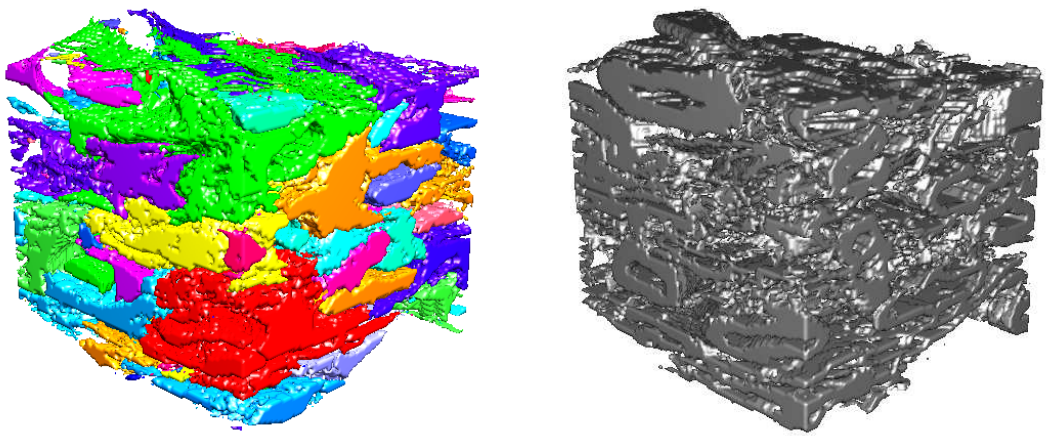


Figure 11: A 3D rendering of the segmentation result where the void space is divided into individual pores (left). The corresponding fibre network (right).

Abstract: Press felts are used in the manufacturing of paper to press out as much water as possible from the paper web after the sheet formation in a number of press nips. The press felt surface is a non uniform porous structure. The amount of water that can be pressed out of the paper web and how much of the water that is transfered back to the fibre web in the separation rewetting depends on the structure of the press felt surface. In this project the amount of water found in the interface pores between the press felt surface and the fibre web is estimated. The felts are compressed to different degrees and imaged in a Confocal Laser Scanning Microscope. A method for estimating the interface pores was developed during 2005. The method was presented in an internal report at STFI-Packforsk and a journal paper is submitted for publication. For an example of 3D renderings of a press felt surface under load, see Figure 12.

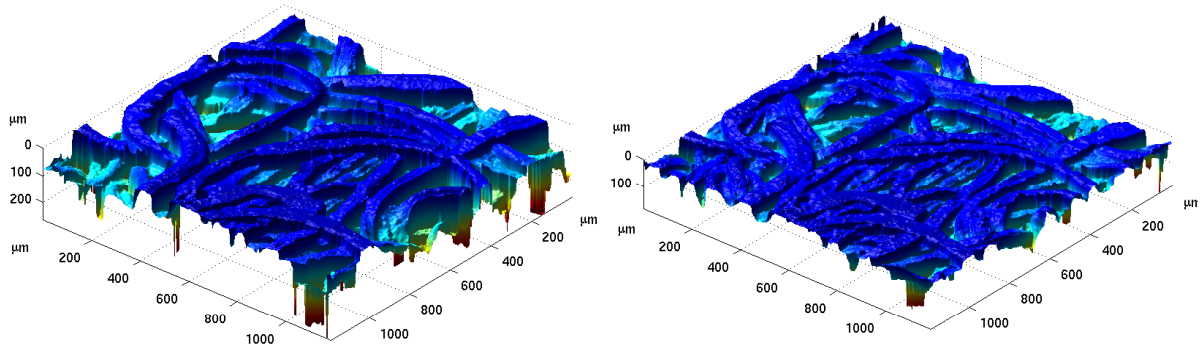


Figure 12: The surface of the press felt observed with a Confocal Laser Scanning Microscope. Load of 1 MPa (left). Load of 10 MPa (right).

28. **Log end feature extraction of untreated wood logs in saw mill environment**
Kristin Norell, Gunilla Borgefors
Funding: The Swedish Timber Measurement Council (VMR), SLU S-faculty
Period: 0505–
Partners: The Swedish Timber Measurement Council (VMR), Dept. of Forest Products and Markets, SLU
Abstract: Wood quality can be analyzed by examining features of log ends. This is sometimes done manually today, but an automatic measurement could be valuable at a saw mill since it would not only be faster than manual inspection but also more robust. In this project the possibilities to measure important log end properties of logs in saw mill environment using computerized image analysis is examined.
Some interesting measurements are:

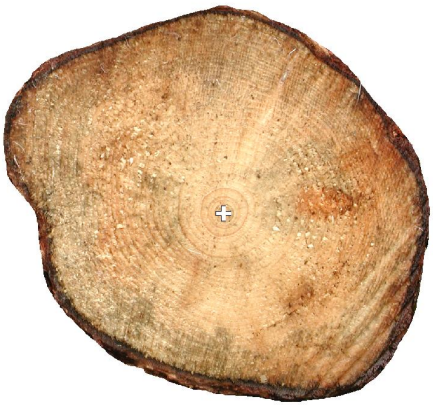


Figure 13: A typical image showing the log end of a spruce. The result is seen as a white +-sign.

- position of the center of the annual rings (pith)
- shape
- annual ring density item rot
- blue stain

The images used in this project are images of untreated log ends taken in a saw mill environment. The logs are sawn with a regular harvester or chain saw and not treated in any way. The images used so far are picked to represent a large variety of features that can occur.
Pith position is found using standard and special filters, Hough transform, and a final adjustment technique. Once the pith is found some other measurements will be easy, and others will be facilitated. Figure 13 shows a typical image. The result is seen as a white +-sign.

29. **Image analysis for quantitative estimation of seed vitality**
Joakim Lindblad, Gunilla Borgefors
Funding: The Swedish Farmers Foundation for Agricultural Research (SLF)
Period: 0509–
Partners: AnalyCen Nordic AB, Lidköping; SeedGard AB (prev. Acanova), Uppsala; Anders Larsolle, Dept. of Biometry and Engineering, SLU, Uppsala
Abstract: ThermoSeed cereal seed treatment is a new method for thermal seed treatment developed by SeedGard AB (prev. Acanova). The method makes it possible to produce seed free from seed-borne pathogens without using chemical seed dressing. By exposing seeds for precisely conditioned hot humid air, pathogens are rendered harmless without affecting seed germinability.
It is of interest to facilitate objective and accurate monitoring of how different treatments and different types of stress affects the vitality of seeds. During the autumn of 2005 a project was initiated to develop methods for objective quantification of seed vitality by measuring relevant parameters of plants grown in a controlled environment. Computer software for automatic segmentation and separation of the individual plants as well as to measure relevant parameters, such as area and length, of the plants has been developed at the Centre for Image Analysis. What follows in 2006 is a statistical study to evaluate the performance of the method.

30. **Image analysis for estimation of pest damage on greenhouse grown chrysanthemum**
Joakim Lindblad
Funding: SLU LTJ-faculty
Period: 0510–0601
Partners: Margit Nothnagl, Dept. of Crop Science, SLU, Alnarp

Abstract: Chemical control of pests in greenhouse crop production causes many environmental problems that could be minimized with frequent biological control. Unfortunately most of the biological control methods that are used today are still ineffective, especially in pot plant production, where the appearance of the plant is the most important quality aspect.
During autumn 2005, we developed a software tool for the estimation and quantification of pest damage on chrysanthemum leaves. The results are to be used in a larger study aimed at providing better understanding of the interaction between greenhouse climate, the host plant, a pest and a predator, with the final goal of more efficient pest control with a minimal environmental impact.

31. **Colour correction of underwater multi- or hyper-spectral data**
Julia Åhlén, Tommy Lindell, Ewert Bengtsson
Funding: The Knowledge Foundation
Period: 0102–
Abstract: Colour restoration 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. The work has resulted in a PhD thesis by Julia Åhlén in December of 2005.

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: 9701–0512
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 Dept. 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: 0001–0509

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-FeatureVector 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 been documented as part of the PhD thesis of Hamed Hamid Muhammed in 2005 and also submitted for publication.

34. **Nordkalotten Satellite Evaluation co-operation Network (NorSEN)**
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: Field measurements has been performed on Lake Torneträsk, and near Abisko. From June 20 to July 2, 2004, spectrometer measurements were performed by Fredrik Bergholm, in birch forest around Abisko Naturvetenskapliga Station (ANS), and spectral measurements were performed by Tommy Lindell and Kai Sörensen, on Lake Torneträsk. These field measurements will be part of data base, for the Scandinavian NorSEN project, wich formally started in 2005. The project deals with validation of satellite images, and build-up of ground-based spectral sensors around ANS.

35. **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 Bisceyne National Park. Recently, tests of the usefulness of those images have been performed for the classification of the Swedish coastline. The system has been further used for the classification of the Swedish coastline.

36. **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 and in cooperation with Tiit Kutser and Italian partners.

37. **Open boundary conditions: shallow water waves**
Fredrik Bergholm
Funding: UU TN-faculty
Period: 0207–0512
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.

38. **New approach to multi- and hyper-spectral imaging**
Hamed Hamid Muhammed, Fredrik Bergholm
Funding: UU TN-faculty, Swedish National Space Board
Period: 0306–0509
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 authors were awarded a prize for best industry-relevant paper, see 1, at SSBA 2005 for the paper *Camera-spectrometer for multi- and hyper-spectral imaging* (see Section 6.5, paper 3). Also, the project was awarded the prize as most innovative project of te year 2005 in the Uppsala region by "ALMI Företagspartner". The results were presented in the PhD thesis of Muhammed which was published during 2005, see Section 4.2.

39. **New techniques for information extraction from hyper-spectral crop reflectance data**
Hamed Hamid Muhammed
Funding: UU TN-faculty, Swedish National Space Board
Period: 0201–0509
Partners: Anders Larsolle, 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. The results were presented in the PhD thesis of Muhammed which was published during 2005, see Section 4.2.

40. **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. A first test version of Pixy was released internally at CBA during 2003 and a more complete version will be released externally during 2006.

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 2005.

International

Centre for Sensor Signal and Information Processing, University of Queensland, Brisbane, Australia

Greenslopes Private Hospital, Queensland X-ray, Brisbane, Australia

School of ITEE, University of Queensland, Brisbane, Australia

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

Dept. of Computer Science, University of West Bohemia, Czech Republic

EPIDAURE project, INRIA, Sophia Antipolis, France

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

Dept. of Computer Science, University of Hamburg, Germany

Dept. of Computer Science, Faculty of Informatics, University of Debrecen, Hungary

Dept. of Electronics and Telecommunications, University of Florence, Italy

National Research Council, Milan, Italy

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

VU University Medical Centre, PET Centre, Amsterdam, 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

University of Jaffna, Sri Lanka

University of Perodeniya, Sri Lanka

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

Dept. of Radiology, University of Pennsylvania, Philadelphia, PA, USA

National

Abisko Scientific Research Station, Abisko

AnalyCen Nordic AB, Lidköping

Barrera Kristiansen AB, Uppsala

Creative Media Lab, University of Gävle

Fresenius Kabi, Uppsala

GE Health care, Uppsala/London

Höglind Marketing HB, Örebro

Imanet AB, Uppsala

Révolte Development AB, Stockholm

SeedGard AB (prev. Acanova), Uppsala
Sidec Technologies AB, Stockholm
StoraEnso Packaging Boards, Skoghall
StoraEnso Research, Falun
Swedish Defense College, Stockholm
Swedish Pulp and Paper Research Institute (STFI), Stockholm
Swedish Timber Measurement Council (VMR), Sundsvall
Dept. of Evolutionary Biology, Limnology, UU
Dept. of Genetics and Pathology, UU
Dept. of Hospital Physics, UU Hospital
Dept. of Information Technology, UU
Dept. of Mathematics, UU
Dept. of Medical Sciences, UU Hospital
Dept. of Neuroscience, UU Hospital
Dept. of Oncology, Radiology, and Clinical Immunology, UU Hospital
Dept. of Pharmaceutical Biosciences, UU
Dept. of Psychology, UU
Dept. of Biometry and Engineering, SLU, Uppsala
Dept. of Forest Products and Markets, SLU, Uppsala
Dept. of Microbiology, 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 Medicine and Care, Linköping University Hospital, Linköping
Dept. of Cell and Molecular Biology (CMB), Karolinska Institute, Stockholm
Dept. of Medicine, Karolinska Institute, Stockholm
Dept. of Oncology-Pathology (CCK), Karolinska Institute/Hospital, Stockholm
Dept. of Computer and Systems Science, Royal Institute of Technology, Stockholm
Dept. of Meteorology, Stockholm University, Stockholm
Dept. of Mathematics, Umeå University, Umeå
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." Therefore, we 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 also aim to produce some popular articles, but are less successful in this respect. However, we give a number of such seminars each year.

This list covers all publications with publication date in 2005. We have authored two book chapters (in the same book) and edited two special issues, one for the journal *Image and Vision Computing* and one for the journal *Discrete Applied Mathematics*. We have published eleven journal articles and as many as 24 articles in refereed international conference proceedings. In addition, we published seven papers in non-refereed or abstract refereed conference proceedings and six CBA reports. Similarly as 2004, we also have a patent application this year. These numbers indicate that we have had a productive year.

6.1 Patent application

A system for multi- and hyperspectral imaging
Inventors: Bergholm, F.; Hamid Muhammed, H.
Abstract: The present invention relates to the production of instantaneous or non-instantaneous multi-band images, to be transformed into multi- or hyperspectral images, comprising light collecting means, an image sensor with at least one two dimensional sensor array, and an instantaneous colour separating means, positioned before the image sensor array in the optical path of the arrangement, and first uniform spectral filters in the optical path, with the purpose of restricting imaging to certain parts of the electromagnetic spectrum. The present invention specifically teaches that a filter unit comprising colour or spectral filter mosaics and/or uniform colour or spectral filters mounted on filter wheels or displayed by transmissive displays, is either permanently or interchangeably positioned before the colour separating means in the optical path in, or close to, converged light. Each colour or spectral filter mosaic consists of a multitude of homogeneous filtering regions. The transmission curves of the filtering regions of a colour or spectral filter mosaic can be partly overlapping, in addition to overlap between these transmission curves and those belonging to the filtering regions of the colour separating means. The transmission curves of the colour or spectral filter mosaics and the colour separating means are suitably spread out in the intervals of a spectrum to be studied. The combination of the colour separating means and the spectral or colour or spectral filter mosaics produces different sets of linearly independent transmission curves. The multiple-filter image captured by the image sensor is demosaicked by identifying and segmenting the image regions that are affected by the regions of the multiple filter mosaic, and after an optional interpolation step, a multi-band image is obtained. The resulting multi-band image is transformed into a multi- or hyperspectral image.

6.2 Book chapters and special issues

1. **Minimal acceleration Hermite curves**
   Authors: Barrera, T. (1); Hast, A. (2); Bengtsson, E.
   (1) Barrera-Kristiansen AB, Uppsala
   (2) University of Gävle, Creative Media Lab
   Editors: Pallister, C.
   Publisher: Charles River Media, Hingham, Massachusetts
   Comment: pp. 225–231 in "Game Programming Gems 5".
   Abstract: This gem shows how a curve with minimal acceleration can be obtained using Hermite splines [Hearn04]. Acceleration is higher in the bends and therefore this type of curve is a minimal bending curve. This type of curve can be useful for subdivision surfaces when it is required that the surface has this property,

which assures that the surface is as smooth as possible. A similar approach for Bézier curves and subdivision can be found in [Overveld97]. It could also be very useful for camera movements [Vlachos01] since it allows that both the position and the direction of the camera can be set for the curve. Moreover, we show how several such curves can be connected in order to achieve continuity between the curve segments.

2. **Skeletonization in 3D discrete binary images**
   Authors: Nyström, I.; Sanniti di Baja, G.(1)
   (1) Istituto di Cibernetica, National Research Council of Italy (CNR) Napoli, Italy
   Editors: Chen, C. H.; Wang, P. S. P.
   Publisher: World Scientific, Singapore
   Comment: Chapter 2.3 (pp. 137–156) in "Handbook of Pattern Recognition and Computer Vision, 3rd ed."
   Abstract: Skeletonization is a way to reduce dimensionality of digital objects. Here, we present in detail an algorithm that computes the curve skeleton of a solid object, i.e., an object without cavities, in a 3D binary image. The algorithm consists of three main steps. During the first step, the surface skeleton is detected, by directly marking in the distance transform of the object the voxels that should be assigned to the surface skeleton. The curve skeleton is then computed by iteratively thinning the surface skeleton, during the second step. Finally, the third step is performed to reduce the curve skeleton to unit width and to prune, in a controlled manner, some of its peripheral branches.

3. **Digital distance transforms in 2D, 3D, and 4D**
   Author: Borgefors, G.
   Editors: Chen, C. H.; Wang, P. S. P.
   Publisher: World Scientific, Singapore
   Comment: Chapter 2.4 (pp. 157–176) in "Handbook of Pattern Recognition and Computer Vision, 3rd ed."
   Abstract: Digital distance transforms have been used in image processing and analysis since the 1960s. Distance transforms are excellent tools for all applications regarding shape. They are, in fact, extensively used, especially in industrial and medical applications. At the same time, from the mid 1980s until today, there has been a rich literature that investigates distance transforms theoretically, constructs new ones, and improves computation algorithms. Despite this, distance transforms have not really been incorporated into the general image analysis toolbox. They are usually not mentioned at all — or the oldest ones (e.g., City block and Chessboard) are mentioned very briefly — in the basic books on image analysis used in education. One reason for the under-use of distance transforms could be that the oldest distance transforms are very rotation dependent, giving quite different results depending of the position of an object. The Euclidean distance transform is rotation independent up to digitisation effects, but often leads to complex algorithms where it is used. The compromise is the integer weighted distance transforms, that combines the simplicity of the old distance transforms with a reasonable rotation independence. Here, a large number of distance transforms will be described, with some of their properties and the simplest computation algorithms.

4. **Image and Vision Computing 23(2):87-269, 2005**
   Special issue on Discrete Geometry for Computer Imagery
   Guest Editors: Nyström, I.; Sanniti di Baja, G.(1); Svensson, S. (1) Istituto di Cibernetica, National Research Council of Italy (CNR), Napoli, Italy

5. **Discrete Applied Mathematics, 147(2-3):147-361, 2005**
   Special issue on Discrete Geometry for Computer Imagery
   Guest Editors: Nyström, I.; Sanniti di Baja, G.(1); Svensson, S. (1) Istituto di Cibernetica, National Research Council of Italy (CNR), Napoli, Italy

6.3 Journal articles

1. **Computing and analysing convex deficiencies to characterise 3D complex objects**
   Authors: Arcelli, C.; Sanniti di Baja, G.(1); Svensson, S.
   (1) Istituto di Cibernetica, National Research Council of Italy (CNR) Napoli, Italy
   Journal: Image and Vision Computing: Discrete Geometry for Computer Imagery 23(2):203–211, 2005
   Abstract: Entities such as object components, cavities, tunnels and concavities in 3D digital images can be useful in the framework of object analysis. For each object component, we first identify its convex deficiencies, by subtracting the object component from a covering polyhedron approximating the convex

hull. Watershed segmentation is then used to decompose complex convex deficiencies into simpler parts, corresponding to individual cavities, concavities and tunnels of the object component. These entities are finally described by means of a representation system accounting for the shape features characterising them.

2. **Comparison of three individual tree crown detection methods**
   Authors: Erikson, M.; Olofsson, K. (1)
   (1) Remote Sensing Laboratory, Dept. of Forest Resource Management and Geomatics, SLU, Umeå
   Journal: Machine Vision and Applications: 16(4):258–265
   Abstract: Three image processing methods for single tree crown detection in high spatial resolution aerial images are presented and compared using the same image material and reference data. The first method uses templates to find the tree crowns. The other two methods uses region growing. One of them is supported by fuzzy rules while the other uses an image produced by Brownian motion. All three methods detect around 80%, or more, of the visible sunlit trees in two pine (*Pinus Sylvestris* L.) and two spruce stands (*Picea abies* Karst.) in a boreal forest. For all methods, large tree crowns are easier to detect than small ones.

3. **Hyperspectral crop reflectance data for characterising and estimating fungal disease severity in wheat**
   Authors: Hamid Muhammed, H.
   Journal: Biosystems Engineering 91(1):9–20, 2005
   Abstract: Many studies have shown the usefulness of hyperspectral crop reflectance data for detecting plant pathological stress. However, there is still a need to identify unique signatures for specific stresses amidst the constantly changing background associated with normal crop growth and development. Comparing spatial and temporal patterns in crop spectra can provide such signatures. This work was concerned with characterising and estimating fungal disease severity in a spring wheat crop. This goal can be accomplished by using a reference data set consisting of hyperspectral crop reflectance data vectors and the corresponding disease severity field assessments. The hyperspectral vectors were 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 hyperspectral data, a nearest-neighbour classifier was used to classify the new data against the reference data. Finally, the corresponding stress signatures were computed using a linear transformation model. High correlation was obtained between the classification results and the corresponding field assessments of fungal disease severity, confirming the usefulness and efficiency of this approach. The effects of increased disease severity could be characterised by analysing the resulting disease signatures obtained when applying the different normalisation procedures. The low computational load of this approach makes it suitable for real-time on-vehicle applications.

4. **Measurements of digitized objects with fuzzy borders in 2D and 3D**
   Authors: Sladoje, N.; Nyström, I.; Saha, P. K. (1)
   (1) Dept. of Radiology, University of Pennsylvania, Philadelphia, PA, USA
   Journal: Image and Vision Computing 23(2):123–132
   Abstract: The results of our investigation of several measurements on digitized 2D and 3D objects with fuzzy borders are presented. The performance of surface area, volume, and roundness measure estimators for digitized balls with fuzzy borders is analyzed. The method we suggest provides significant improvement in precision, compared to analogous estimation results obtained on a crisp (hard) segmentation, especially in the case of low resolution images.

5. **Shape signatures of fuzzy star-shaped sets based on distance from the centroid**
   Authors: Chanussot, J. (1); Nyström, I.; Sladoje, N.
   (1) Signal and Image Laboratory (LIS), INPG, Grenoble, France
   Journal: Pattern Recognition Letters 26(6):735–746, 2005
   Abstract: We extend the shape signature based on the distance of the boundary points from the shape centroid, to the case of fuzzy sets. The analysis of the transition from crisp to fuzzy shape descriptor is first given in the continuous case. This is followed by a study of the specific issues induced by the discrete representation of the objects in a computer.We analyze two methods for calculating the signature of a fuzzy shape, derived from two ways of defining a fuzzy set: first, by its membership function, and second, as a stack of its a-cuts. The first approach is based on measuring the length of a fuzzy straight line by integration of the fuzzy membership function, while in the second one we use averaging of the shape signatures obtained for the individual a-cuts of the fuzzy set. The two methods, equivalent in the continuous case for the studied class of fuzzy shapes, produce different results when adjusted to the discrete case. A statistical study, aiming at characterizing the performances of each method in the discrete case, is done. Both methods are shown

to provide more precise descriptions than their corresponding crisp versions. The second method (based on averaged Euclidean distance over the a-cuts) outperforms the others.

6. **Real-time visualization of animated trees**
Authors: Wesslén, D.(1); Seipel, S.
(1) Dept. of Mathematics, Natural Sciences and Computing, University College of Gävle
Journal: Visual Computing 21:397–405, 2005
Abstract: Realistic visualization of plants and trees has recently received increased interest in various fields of applications. Limited computational power and the extreme complexity of botanical structures have called for tradeoffs between interactivity and realism. In this paper we present methods for the creation and realtime visualization of animated trees. In contrast to other previous research, our work is geared toward near-field visualization of highly detailed areas of forestry scenes with animation. We describe methods for rendering and shading of trees by utilizing the programmable hardware of consumer-grade graphics cards. We then describe a straightforward technique for animation of swaying stems and fluttering foliage that can be executed locally on a graphics processor. Our results show that highly detailed tree structures can be visualized at real-time frame rates and that animation of plant structures can be accomplished without sacrificing performance.

7. **Noise correlation in PET, CT, SPECT and PET/CT data evaluated using autocorrelation function: a phantom study on data, reconstructed using FBP and OSEM**
Authors: Razifar, P.; Sandström, M.(2); Schneider, H.(1); Långström, B.(1); Maripuu, E.(2); Bengtsson, E.; Bergström, M.(1,3)
(1) Uppsala Imanet AB, Uppsala
(2) UU Hospital, Dept. of Hospital Physics
(3) Dept. of Pharmaceutical Biosciences, UU
Journal: Bio Medical Central (BMC): Medical Imaging 5(5)
Abstract: BACKGROUND: Positron Emission Tomography (PET), Computed Tomography (CT), PET/CT and Single Photon Emission Tomography (SPECT) are non-invasive imaging tools used for creating two dimensional (2D) cross section images of three dimensional (3D) objects. PET and SPECT have the potential of providing functional or biochemical information by measuring distribution and kinetics of radiolabelled molecules, whereas CT visualizes X-ray density in tissues in the body. PET/CT provides fused images representing both functional and anatomical information with better precision in localization than PET alone.Images generated by these types of techniques are generally noisy, thereby impairing the imaging potential and affecting the precision in quantitative values derived from the images. It is crucial to explore and understand the properties of noise in these imaging techniques. Here we used autocorrelation function (ACF) specifically to describe noise correlation and its non-isotropic behaviour in experimentally generated images of PET, CT, PET/CT and SPECT. METHODS: Experiments were performed using phantoms with different shapes. In PET and PET/CT studies, data were acquired in 2D acquisition mode and reconstructed by both analytical filter back projection (FBP) and iterative, ordered subsets expectation maximisation (OSEM) methods. In the PET/CT studies, different magnitudes of X-ray dose in the transmission were employed by using different mA settings for the X-ray tube. In the CT studies, data were acquired using different slice thickness with and without applied dose reduction function and the images were reconstructed by FBP. SPECT studies were performed in 2D, reconstructed using FBP and OSEM, using post 3D filtering. ACF images were generated from the primary images, and profiles across the ACF images were used to describe the noise correlation in different directions. The variance of noise across the images was visualised as images and with profiles across these images. RESULTS: The most important finding was that the pattern of noise correlation is rotation symmetric or isotropic, independent of object shape in PET and PET/CT images reconstructed using the iterative method. This is, however, not the case in FBP images when the shape of phantom is not circular. Also CT images reconstructed using FBP show the same non-isotropic pattern independent of slice thickness and utilization of care dose function. SPECT images show an isotropic correlation of the noise independent of object shape or applied reconstruction algorithm. Noise in PET/CT images was identical independent of the applied X-ray dose in the transmission part (CT), indicating that the noise from transmission with the applied doses does not propagate into the PET images showing that the noise from the emission part is dominant. The results indicate that in human studies it is possible to utilize a low dose in transmission part while maintaining the noise behaviour and the quality of the images. CONCLUSION: The combined effect of noise correlation for asymmetric objects and a varying noise variance across the image field significantly complicates the interpretation of the images

when statistical methods are used, such as with statistical estimates of precision in average values, use of statistical parametric mapping methods and principal component analysis. Hence it is recommended that iterative reconstruction methods are used for such applications. However, it is possible to calculate the noise analytically in images reconstructed by FBP, while it is not possible to do the same calculation in images reconstructed by iterative methods. Therefore for performing statistical methods of analysis which depend on knowing the noise, FBP would be preferred.

8. **Non-isotropic noise correlation in PET data reconstructed by FBP but not by OSEM demonstrated using auto-correlation function**
   Authors: Razifar, P.; Lubberink, M. (1,2); Schneider, H. (1); Långström, B. (1); Bengtsson, E.; Bergström, M. (1,3)
   (1) Uppsala Imanet AB, Uppsala
   (2) VU University Medical Centre, PET Centre, Amsterdam, The Netherlands
   (3) Dept. of Pharmaceutical Biosciences, UU
   Journal: Bio Medical Central (BMC): Medical Imaging 5(3)
   Abstract: BACKGROUND: 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 modelling to extract quantitative values of a desired physiological, biochemical or pharmacological entity. Because such images are generally noisy, 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. METHODS: In this paper we explored the pattern of noise correlation in experimentally generated PET images, with emphasis on the angular dependence of correlation, using the autocorrelation function (ACF). Experimental PET data were acquired in 2D and 3D acquisition mode and reconstructed by analytical filtered back projection (FBP) and iterative ordered subsets expectation maximisation (OSEM) methods. The 3D data was rebinned to a 2D dataset using FOurier REbinning (FORE) followed by 2D reconstruction using either FBP or OSEM. In synthetic images we compared the ACF results with those from covariance matrix. The results were illustrated as 1D profiles and also visualized as 2D ACF images. RESULTS: We found that the autocorrelation images from PET data obtained after FBP were not fully rotationally symmetric or isotropic if the object deviated from a uniform cylindrical radioactivity distribution. In contrast, similar autocorrelation images obtained after OSEM reconstruction were isotropic even when the phantom was not circular. Simulations indicated that the noise autocorrelation is non-isotropic in images created by FBP when the level of noise in projections is angularly variable. Comparison between 1D cross profiles on autocorrelation images obtained by FBP reconstruction and covariance matrices produced almost identical results in a simulation study. CONCLUSION: With asymmetric radioactivity distribution in PET, reconstruction using FBP, in contrast to OSEM, generates images in which the noise correlation is non-isotropic when the noise magnitude is angular dependent, such as in objects with asymmetric radioactivity distribution. In this respect, iterative reconstruction is superior since it creates isotropic noise correlations in the images.

9. **Segmentation of individual pores in 3D paper images**
   Authors: Sintorn, I.-M.; Svensson, S.; Axelsson, M.; Borgefors, G.
   Journal: Nordic Pulp & Paper Research Journal 20(3):316–319
   Abstract: In this paper, we show that the void space in 3D images of paper can be successfully divided into subspaces using digital volume image analysis. The subspaces are denoted pores, which are connected to each other by contractions or narrowings, throats. This division of the void space into individual pores opens the possibility of extracting geometrical features as well as localising where pores with a certain feature are located in the paper. The method is illustrated on a 3D reconstruction from 2D Scanning Electron Microscopy images of a five layered duplex board. Examples of easily extracted features for the segmented pores and plots for some pore features versus the position in the paper are presented.

10. **Distance transforms for three-dimensional grids with non-cubic voxels**
    Authors: Strand, R.; Borgefors, G.
    Journal: Computer Vision and Image Understanding 100(3):294–311
    Abstract: Distance transforms on the face-centered cubic (fcc) grid and the body-centered cubic (bcc) grid are examined. Since the voxels on the fcc and bcc grids are better approximations of a Euclidean ball than the cube, the distance transforms (DTs) on these grids can be less rotation dependent than those in ,

which is a desirable feature. Optimal (according to the error function) weights are calculated and integer approximations of these weights are found. Also, the two-dimensional city block distance is generalized to the fcc and bcc grids by considering a unit distance between gridpoints whose corresponding voxels share a face. A method to compute the DTs is presented. The results are evaluated both theoretically and by actually computing some DTs.

11. **Surface area estimation of digitized 3D objects using weighted local configurations**
Authors: Lindblad, J.
Journal: Image and Vision Computing 23(2):111–122
Abstract: We present a method for estimating surface area of three-dimensional objects in discrete binary images. A surface area weight is assigned to each $2\times2\times2$ configuration of voxels. The total surface area of a digital object is given by a summation of the local area contributions. Optimal area weights are derived in order to provide an unbiased estimate with minimum variance for randomly oriented digitized planar surfaces. Due to co-appearance of certain voxel combinations, the optimal solution is not uniquely defined for planar surfaces. A Monte Carlo-based optimization of the estimator performance on the distribution of digitized balls of increasing radii is performed in order to uniquely determine the optimal surface area weights. The method is further evaluated on various objects in a range of sizes. A significant reduction of the error for small objects is observed. The algorithm is appealingly simple; the use of only a small local neighborhood enables efficient implementations in hardware and/or in parallel architectures.

6.4 Refereed conference proceedings

1. **Connected minimal acceleration trigonometric curves**
Authors: Barrera, T. (1); Hast, A. (2); Bengtsson, E.
(1) Barrera-Kristiansen AB, Uppsala
(2) University of Gävle, Creative Media Lab
Conference: SIGRAD 2005 The Annual SIGRAD Conference Special Theme Mobile Graphics November 23–24, 2005 Lund, Linköping electronic conference proceedings, vol. 15, pp. 1650–3686
Editor: Akenine Möller, T.
Abstract: We present a technique that can be used to obtain a series of connected minimal bending trigonometric splines that will intersect any number of predefined points in space. The minimal bending property is obtained by a least square minimization of the acceleration. Each curve segment between two consecutive points will be a trigonometric Hermite spline obtained from a Fourier series and its four first terms. The proposed method can be used for a number of points and predefined tangents. The tangent length will then be optimized to yield a minimal bending curve. We also show how both the tangent direction and length can be optimized to give as smooth curves as possible. It is also possible to obtain a closed loop of minimal bending curves. These types of curves can be useful tools for 3D modelling, etc.

2. **Computerized cell image processing in healthcare**
Authors: Bengtsson, E.
Conference: Healthcomm2005, pp. 11–17
Editor: Choi, H.-K.
Publisher: IEEE Technical Activities, Piscataway NJ
Abstract: The visual interpretation of images is at the core of most medical diagnostic procedures and the final decision for many diseases, including cancer, is based on microscopic examination of cells and tissues. Through screening of cell samples the incidence and mortality of cervical cancer have been reduced significantly. The visual interpretation is, however, tedious and in many cases error-prone. Therefore many attempts have been made at using the computer to supplement or replace the human visual inspection by computer analysis and to automate some of the more tedious visual screening tasks. The computers and computer networks have also been used to manage, store, transmit and display images of cells and tissues making it possible to visually analyze cells from remote locations. In this presentation these developments are traced from their very beginning through the present situation and into the future.

3. **A new evolutionary algorithm for image segmentation**
Authors: Bocchi, L. (1); Ballerini, L.; Hässler, S. (2)
(1) Dept. of Electronics and Telecommunications, University of Florence, Italy
(2) Dept. of Medical Sciences, UU Hospital

Conference: Applications of evolutionary computing, pp. 264–273
Editor: Rothlauf, F.; Branke, J.; Cagnoni, S.; Corne, D.; Drechsler, R.; Jin, Y.; Machado, P.; Marchiori, E.; Romero, J.; Smith, G.; Squillero, G.
Publisher: Springer-Verlag GmbH
Abstract: This paper describes a new evolutionary algorithm for image segmentation. The evolution involves the colonization of a bidimensional world by a number of populations. The individuals, belonging to different populations, compete to occupy all the available space and adapt to the local environmental characteristics of the world. We present experiments with synthetic images, where we show the efficiency of the proposed method and compare it to other segmentation algorithm, and an application to medical images. Reported results indicate that the segmentation of noise images is effectively improved. Moreover, the proposed method can be applied to a wide variety of images.

4. **An approximation of the maximal inscribed convex set of a digital object**
Authors: Borgefors, G.; Strand, R.
Conference: International Conference on Image Analysis and Processing (ICIAP'05), pp. 438–445
Editors: Roli, F.; Vitulano, S.
Publisher: Springer, Berlin
Abstract: In several application projects we have discovered the need of computing the maximal inscribed convex set of a digital shape. Here we present an algorithm for computing a reasonable approximation of this set, that can be used in both 2D and 3D. The main idea is to iteratively identify the deepest concavity and then remove it by cutting off as little as possible of the shape. We show results using both synthetic and real examples.

5. **Automatic tracking of neural stem cells**
Authors: Chunming, T.(1); Bengtsson, E.
(1) Information and Communication Institute, Harbin Engineering University, China
Conference: WDIC 2005, pp. 61–66
Editors: Lovell, B.
Publisher: The University of Queensland , Brisbane, Australia
Abstract: In order to understand the development of stem-cells into specialized mature cells it is necessary to study the growth of cells in culture. For this purpose it is very useful to have an efficient computerized cell tracking system. In this paper a prototype system for tracking neural stem cells in a sequence of images is described. The system is automatic as far as possible but in order to get as complete and correct tracking results as possible the user can interactively verify and correct the crucial starting segmentation of the first frame and inspect the final result and correct errors if necessary. All cells are classified into inactive, active, dividing and clustered cells. Different algorithms are used to deal with the different cell categories. A special backtracking step is used to automatically correct for some common errors that appear in the initial forward tracking process.

6. **Shading by quaternion interpolation**
Authors: Hast, A. (1)
(1) University of Gävle, Creative Media Lab
Conference: Computer Graphics, Visualization and Computer Vision (WSCG 2005), pp. 53–56
Editor: Skala, V.
Abstract: The purpose of this paper is to show that linear interpolation of quaternions can be used for true Phong shading and also for related techniques that use frames, like bump mapping and anisotropic shading. Quaternion interpolation for shading has not been proposed in literature and the reason might be that it turns out to be mostly of academic interest, and it will here be explained why. Furthermore some pros and cons of interpolation using quaternions will be discussed. The effect of using this approach is that the square root in the normalization process disappears. The square root is now implemented in modern graphics hardware in such way that it is very fast. However for other types of platforms, especially hand held devices, the square root is computationally expensive and any software algorithm that could produce true Phong shading without the square root might turn out to be useful. It will be shown that linear interpolation of quaternion could be useful for bump mapping as well. However, quaternion arithmetic operations are not implemented in modern graphics hardware, and are therefore not useful until this is done.

7. **Visualisation of the pattern of contrast enhancement in dynamic breast MRI**
Authors: Mehnert, A. (1); Bengtsson, E; McMahon, K. (2); Kennedy, D. (2); Wilson, S. (3); Crozier, S. (3)
(1) Centre for Sensor Signal and Information Processing, Univ. of Queensland, Brisbane, Australia
(2) Queensland X-ray, Greenslopes Private Hospital, Brisbane, Australia
(3) School of Information Technology and Electrical Engineering, Univ. of Queensland, Brisbane, Australia
Conference: Workshop on Digital Image Computing (WDIC 2005)
Editors: Lovell, B
Publisher: The University of Queensland, Brisbane, Australia
Abstract: A new pixel-mapping method for visualising contrast uptake in dynamic MR images of the breast is presented. The method reduces the sequence of images of a single spatial slice over time to a single colour-coded image. This is achieved by fitting a linear-slope model pixel-wise to the slice time series and using the fitted parameters to define HSV colour space coordinates. The model parameters are related to the shape of the signal intensity-time curve at each pixel. The effect is that pixels with rapid and significant initial postcontrast enhancement appear brighter and more saturated, whilst the nature and degree of intermediate and late postcontrast enhancement is reflected in the colour hue. Preliminary results are reported for six subjects with suspicious MRI findings subsequently confimed by pathology. The results suggest that the method shows promise as a replacement for, or adjunct to, the review of the raw time series data and/or associated difference images in the clinical setting.

8. **A classification of centres of maximal balls in $\mathbb{Z}^3$**
Authors: Strand, R.
Conference: Scandinavian Conference on Image Analysis (SCIA 2005), pp. 1057–1065
Editor: Kalvainen, H.; Parkkinen, J.; Kaarna, A.
Publisher: Springer, Berlin
Abstract: A classification of centres of maximal balls (CMBs) in $\mathbb{Z}^3$ derived from generalizations of the chessboard and city block metrics to 3D, a weighted metric, and the Euclidean metric is presented. Using these metrics, the set of CMBs (the medial axis) can be extracted. One difficulty with skeletonization in 3D is that of guaranteeing reversibility. A reversible skeleton generally consists of both surfaces and curves. Previous attempts to construct connected skeletons including the CMBs uses conditions based on local neighbourhood configurations. However, a local neighbourhood might be too small and, most important, does not allow a consistent definition for surface- and curve-parts of the skeleton. The classification of the CMBs presented in this paper will be a tool for defining which parts of a 3D skeleton are surfaces and curves.

9. **Resolution pyramids on the FCC and BCC grids**
Authors: Strand, R.; Borgefors, G.
Conference: Discrete Geometry for Computer Imagery (DGCI 2005), pp. 68–78
Editor: Andres, E.; Guillaume, D.; Lienhardt, P.
Publisher: Springer, Berlin
Abstract: Partitionings on the face-centered cubic grid and the body-centered cubic grid that are suitable for resolution pyramids are found. The partitionings have properties similar to a partitioning that has been used for the resolution pyramids on the cubic grid. Therefore, they are well-suited for adapting methods to construct multiscale representations developed for the cubic grid. Multiscale representations of images are constructed using different methods.

10. **The Euclidean distance transform applied to the FCC and BCC grids**
Authors: Strand, R.
Conference: Iberian Conference on Pattern Recognition and Image Analysis (IbPRIA 2005), Vol. 1, pp. 243–250
Editor: Marques, J.; de la Blanca, N.; Pina, P.
Publisher: Springer, Berlin
Abstract: The discrete Euclidean distance transform is applied to grids with non-cubic voxels, the face-centered cubic (fcc) and body-centered cubic (bcc) grids. These grids are three-dimensional generalizations of the hexagonal grid. Raster scanning and contour processing techniques are applied using different neighbourhoods. When computing the Euclidean distance transform, some voxel configurations produce errors. The maximum errors for the two different grids and neighbourhood sizes are analyzed and compared with the cubic grid.

11. **Seeded watersheds for combined segmentation and tracking of cells**
Authors: Pinidiyaarachchi, A.; Wählby, C.
Conference: International Conference on Image Analysis and Processing (ICIAP'05), pp. 336–343
Editors: Roli, F.; Vitulano, S.
Publisher: Springer, Berlin
Abstract: Watersheds are very powerful for image segmentation, and seeded watersheds have shown to be useful for object detection in images of cells in vitro. This paper shows that if cells are imaged over time, segmentation results from a previous time frame can be used as seeds for watershed segmentation of the current time frame. The seeds from the previous frame are combined with morphological seeds from the current frame, and over-segmentation is reduced by rule-based merging, propagating labels from one time-frame to the next. Thus, watershed segmentation is used for segmentation as well as tracking of cells over time. The described algorithm was tested on neural stem/progenitor cells imaged using time-lapse microscopy. Tracking results agreed to 71% to manual tracking results. The results were also compared to tracking based on solving the assignment problem using a modified version of the auction algorithm.

12. **Easy-to-use object selection by color space projections and watershed segmentation**
Authors: Holting, P; Wählby, C.
Conference: International Conference on Image Analysis and Processing (ICIAP'05), pp. 269–276
Editors: Roli, F.; Vitulano, S.
Publisher: Springer, Berlin
Abstract: Digital cameras are gaining in popularity, and not only experts in image analysis, but also the average users, show a growing interest in image processing. Many different kinds of software for image processing offer tools for object selection, or segmentation, but most of them require expertise knowledge, or leave too little freedom in expressing the desired segmentation. This paper presents an easy to use tool for object segmentation in color images. The amount of user interaction is minimized, and no tuning parameters are needed. The method is based on the watershed segmentation algorithm, combined with seeding information given by the user, and color space projections for optimized object edge detection. The presented method can successfully segment objects in most types of color images.

13. **Medial grey-level based representation for proteins in volume images**
Authors: Sintorn, I.-M.; Gedda, M.; Svensson, S.; Mata, S.(1)
(1)Rey Juan Carlos University, Madrid, Spain
Conference: Iberian Conference on Pattern Recognition and Image Analysis(IbPRIA 2005), volume 2, pp. 421–428
Editor: Marques, J.; de la Blanca, N.; Pina, P.
Publisher: Springer, Berlin
Abstract: We present an algorithm to extract a medial representation of proteins in volume images. The representation (MGR) takes into account the internal grey-level distribution of the protein and can be extracted without first segmenting the image into object and background. We show how MGR can facilitate the analysis of the structure of the proteins and thereby also classification. Results are shown on two types of protein images.

14. **Estimation of moments of digitized objects with fuzzy borders**
Authors: Sladoje, N.; Lindblad, J.
Conference: International Conference on Image Analysis and Processing (ICIAP'05), pp. 188–195
Editors: Roli, F.; Vitulano, S.
Publisher: Springer, Berlin
Abstract: Error bounds for estimation of moments from a fuzzy representation of a shape are derived, and compared with estimations from a crisp representation. It is shown that a fuzzy membership function based on the pixel area coverage provides higher accuracy of the estimates, compared to binary Gauss digitization at the same spatial image resolution. Theoretical results are confirmed by a statistical study of disks and squares, where the moments of the shape, up to order two, are estimated from its fuzzy discrete representation. The errors of the estimates decrease both with increased size of a shape (spatial resolution) and increased membership resolution (number of available grey-levels).

15. **Clustering of objects in 3D electron tomography reconstructions of protein solutions based on shape measurements**
Authors: Gedda, M.
Conference: International Conference on Advances in Pattern Recognition (ICAPR 2005), Proceedings, Part II, pp. 377–383
Editor: Singh, S.; Singh, M.
Publisher: Springer, Berlin
Abstract: This paper evaluates whether shape features can be used for clustering objects in Sidec (tm), Electron Tomography (SET) reconstructions. SET reconstructions contain a large number of objects, and only a few of them are of interest. It is desired to limit the analysis to contain as few uninteresting objects as possible. Unsupervised hierarchical clustering is used to group objects into classes. Experiments are done on one synthetic data set and two data sets from a SET reconstruction of a human growth hormone (1hwg) in solution. The experiments indicate that clustering of objects in SET reconstructions based on shape features is useful for finding structural classes.

16. **Visualizations of symbols in a horizontal multiple viewer 3D display environment**
Authors: Pettersson, L: W.(1); Lind, M.(1); Spak, U(2); Seipel, Stefan
(1) Division of Human-Computer Interaction, Dept. of Information Technology, UU
(2) Swedish National Defence College
Conference: International Conference on Information Visualization (IV 2005), pp. 357–362
Publisher: IEEE Computer Society, Washington DC, USA
Abstract: In this paper we present a visualization environment for collaborative and co-located displays of geospatially related data for command and control. We first describe the working principle of a novel horizontal display that is aimed at providing high resolution stereoscopic 3D visualizations simultaneously to a group of up to four observers. This display environment opens up new ways to present view-dependent visual content within a shared workspace. For this environment we propose frontoparallel presentations of conventional symbols that are 3D presentations of 2D symbols which appear virtually oriented towards the line of sight of the observer. In an experiment we compare frontoparallel symbols with flat symbols i.e. symbols that are presented in the horizontal plane of the display. The results of our study indicate that frontoparallel symbols in a stereoscopic view are perceived and identified faster than symbols presented flat in relation to the plane of the display.

17. **Simple 3D glyphs for spatial multivariate data**
Authors: Forsell, C(1); Seipel, S.; Lind, M.(1)
(1) Division of Human-Computer Interaction, Dept. of Information Technology, UU
Conference: IEEE Symposium on Information Visualization (INFOVIS'05), pp. 119–124
Publisher: IEEE Computer Society, Washington DC, USA
Abstract: We present an effort to evaluate the possible utility of a new type of 3D glyphs intended for visualizations of multivariate spatial data. They are based on results from vision research suggesting that our perception of metric 3D structure is distorted and imprecise relative to the actual scene before us (e.g., [1]); only a class of qualitative properties of the scene is perceived with accuracy. These properties are best characterized as being invariant over affine but not Euclidean transformations. They are related, but not identical to, the non-accidental properties (NAPs) described by Lowe [2] on which the notion of geons is based [3]. A large number of possible 3D glyphs for the visualization of spatial data can be constructed using such properties. One group is based on the local sign of surface curvature. We investigated these properties in a visualization experiment. The results are promising and the implications for visualization are discussed.

18. **An augmented-reality approach to co-located visual exploration of indoor climate data in real rooms**
Authors: Forsberg, A.-K.(1); Pettersson, L: W.(2); Lindén, E.(1); Sandberg, M.(1); Seipel, S.
(1) University College of Gävle
(2) Division of Human-Computer Interaction, Dept. of Information Technology, UU
Conference: International Conference on Indoor Air Quality and Climate: Indoor Air, pp. 2860–2864
Abstract: We live in two spaces, the visible space and the non-visible but otherwise sensed space. Both spaces must satisfy our needs and there is a relation between them. If parts of the room are too cold this will lead to a restriction of the use of the room. We cannot endure draft for any longer time. Draft caused by a ventilation supply frequently leads to blockage of the supply device, which in turn gives rise to a reduction

of the ventilation rate. The final result may be a deterioration of the air quality. Therefore, to be able to guarantee the air quality it is necessary to make the invisible thermal climate visible. In this paper a method based on Augmented Reality for presenting the thermal climate is presented and discussed. Several people can walk around in a real room and see on a screen where the hot and/or cold spots may appear. Different ventilation solutions could in that way be compared in a dialogue between different actors in the building process.

19. **Shape based identification of proteins in volume images**
Authors: Sintorn, I.-M.; Borgefors, G.
Conference: Scandinavian Conference on Image Analysis (SCIA 2005), pp. 253–262
Editor: Kalvainen, H.; Parkkinen, J.; Kaarna, A.
Publisher: Springer, Berlin
Abstract: A template based matching method, adapted to the application of identifying individual proteins of a certain kind in volume images, is presented. Grey-level and gradient megnitude information is combined in the watershed algorithm to extract stable borders. These are used in a subsequent hierarchical matching algorithm. The matching algorithm uses a distance transform to serach for local best fits between the edges of a template and edges in the underlying image. It is embedded in a resolution pyramid to decrease the risk of getting stuck in false local minima. This method makes it possible to find proteins attached to other proteins, or proteins appearing as split into parts in the images. It also decreases the amount of human interaction mÂ´needed for identifying individual proteins of the searched kind. The method is demonstrated on a set of three volume images of the antibody IgG in solution.

20. **Discrete 3D tools applied to 2D grey-level images**
Authors: Sanniti di Baja, G.(1); Nyström, I.; Borgefors, G.
(1) Istituto di Cibernetica, National Research Council of Italy (CNR) Napoli, Italy
Conference: International Conference on Image Analysis and Processing (ICIAP 2005), pp. 229–236
Editor: Roli, F.; Vitulano, S
Publisher: Springer, Berlin
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. Here, we present three such algorithms. The first algorithm smoothes a 2D grey-level image by flattening its geometrical and grey-level peaks while simultaneously filling in geometrical and grey-level valleys, regarded as non significant in the problem domain. The second algorithm computes an approximation of the convex hull of a 2D grey-level object, by building a covering polyhedron closely fitting the corresponding object in a 3D binary image. The result obtained is convex both from the geometrical point of view and as concerns grey-levels. The third algorithm skeletonizes a 2D grey-level object by skeletonizing the top surface of the object in the corresponding 3D binary image.

21. **A haptic interaction technique for volume images based on gradient diffusion**
Authors: Vidholm, E.; Nyström, I.
Conference: World Haptics, pp. 336–341
Editor: Barbagli, F.
Publisher: IEEE Computer Society
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. This paper describes a haptic interaction technique based on gradient vector flow (GVF) that allows a user to feel object boundaries while still being centered inside the object. Our method is not limited to elongated structures, which is a common restriction for other approaches. Initial tests of the method shows encouraging results for differently shaped objects.

22. **Surface volume estimation of digitized hyperplanes using weighted local configurations**
Authors: Lindblad, J.
Conference: Discrete Geometry for Computer Imagery (DGCI 2005), pp. 252–262
Editor: Andres, E.; Guillaume, D.; Lienhardt, P.
Publisher: Springer, Berlin
Abstract: We present a method for estimating the surface volume of four-dimensional objects in discrete binary images. A surface volume weight is assigned to each $2\times2\times2\times2$ configuration of image elements.

The total surface volume of a digital 4D object is given by a summation of the local volume contributions. Optimal volume weights are derived in order to provide an unbiased estimate with minimal variance for randomly oriented digitized planar hypersurfaces. Only 14 out of 64 possible boundary configurations appear on planar hypersurfaces. We use a marching hypercubes tetrahedrization to assign surface volume weights to the non-planar cases. The correctness of the method is verified on four-dimensional balls and cubes digitized in different sizes. The algorithm is appealingly simple; the use of only a local neighbourhood enables efficient implementations in hardware and/or in parallel architectures.

23. **Dissolved Organic Matters Impact on Colour Reconstruction in Underwater Images**
Authors: Åhlén, J., Sundgren, D. (1), Lindell, T., Bengtsson, E.
(1) Dept. of Computer and Systems Sciences, Royal Institute of Technology, Stockholm
Conference: Scandinavian Conference on Image Analysis (SCIA 2005), pp. 1148–1156
Editor: Kalvainen, H.; Parkkinen, J.; Kaarna, A.
Publisher: Springer, Berlin
Abstract: The natural properties of water column usually affect underwater imagery by suppressing high-energy light. In application such as color correction of underwater images estimation of water column parameters is crucial. Diffuse attenuation coefficients are estimated and used for further processing of underwater taken data. The coefficients will give information on how fast light of different wavelengths decreases with increasing depth. Based on the exact depth measurements and data from a spectrometer the calculation of downwelling irradiance will be done. Chlorophyll concentration and a yellow substance factor contribute to a great variety of values of attenuation coefficients at different depth. By taking advantage of variations in depth, a method is presented to estimate the influence of dissolved organic matters and chlorophyll on color correction. Attenuation coefficients that depends on concentration of dissolved organic matters in water gives an indication on how well any spectral band is suited for color correction algorithm.

24. **Pre-Processing of Underwater Images Taken in Shallow Water for Color Reconstruction Purposes**
Authors: Åhlén, J., Sundgren, D. (1), Bengtsson, E.
(1) Dept. of Computer and Systems Sciences, Royal Institute of Technology, Stockholm
Conference: International Conference on Signal and Image Processing (SIP 2005)
Editor: Marcellin, M. W.
Comment: Proceedings on CDROM.
Abstract: Coral reefs are monitored with different techniques in or der to examine their health. Digital cameras, which pro vide an economically defendable tool for marine scientists to collect underwater data, tend to produce bluish images due to severe absorption of light at longer wavelengths. In this paper we study the possibilities of correcting for this color distortion through image processing. The decrease of red light by depth can be predicted by Beers Law. An other parameter that has been taken into account is the image enhancement functions built into the camera. We use a spectrometer and a reflectance standard to obtain the data needed to approximate the joint effect of these func tions. 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 Beers Law. This process is fully automatic and the amount of processed images is limited only by the speed of computer system. Experimental re sults show that the proposed method works well for cor recting images taken at different depths with two different cameras.

6.5 Non-refereed conferences and workshops

1. **Individual pore segmentation in 3D volumes of fibrous materials**
Author: Axelsson, M.; Sintorn, I.-M.; Svensson, S.; Borgefors, G.
Conference: Swedish Society for Automated Image Analysis Symposium (SSBA 2005)
Editors: Heyden, A.
Publisher: Applied mathematics group, Malmö university, Malmö

2. **Camera-spectrometer for instantaneous multi- and hyperspectral imaging**
Authors: Hamid Muhammed, H.; Bergholm, F.
Conference: European Conference on Precision Agriculture (5ECPA)
Editor: Stafford, J.V.
Publisher: Wageningen Academic Publishers, The Netherlands

3. **Camera-spectrometer for multi- and hyperspectral imaging**
   Authors: Hamid Muhammed, H.; Bergholm, F.
   Conference: Swedish Society for Automated Image Analysis Symposium (SSBA 2005)
   Editors: Heyden, A.
   Publisher: Applied mathematics group, Malmö university, Malmö

4. **Measuring crop status using multivariate analysis of hyperspectral field reflectance with application on disease severity and amount of plant densityCamera-spectrometer for instantaneous multi- and hyperspectral imaging**
   Authors: Larsolle, A(1); Hamid Muhammed, H.
   (1) Dept. of Biometry and Engineering, SLU
   Conference: European Conference on Precision Agriculture (5ECPA)
   Editor: Stafford, J.V.
   Publisher: Wageningen Academic Publishers, The Netherlands

5. **Dynamic breast MRI visualised through colour mapping**
   Authors: Mehnert, A. (1); Bengtsson, E; McMahon, K. (2); Kennedy, D. (2); Wilson, S. (3); Crozier, S. (3)
   (1) University of Queensland, Brisbane, Australia. Centre for Sensor Signal and Information Processing
   (2) Greenslopes Private Hospital, Brisbane, Australia. Queensland X-ray
   (3) University of Queensland, Brisbane, Australia. School of Information Technology and electrical engineering
   Conference: Swedish Society for Automated Image Analysis Symposium (SSBA 2005), pp. 9–12
   Editors: Heyden, A.
   Publisher: Applied mathematics group, Malmö university, Malmö

6. **Haptic volume rendering based on gradient vector flow**
   Author: Vidholm, E.; Nyström, I.
   Conference: Swedish Society for Automated Image Analysis Symposium (SSBA 2005), pp.97–100
   Editors: Heyden, A.
   Publisher: Applied mathematics group, Malmö university, Malmö

7. **Digital image processing for multiplexing of single molecule detection**
   Author: Pinidiyaarachchi, A; et al.
   Conference: Medicintekninkdagarna 2005
   Comment: Medicinteknikdagarna is a yearly conference on medical devices for actors within research, health, and the biotech and pharma industry. One of this years topics is the interdisciplinary overlap between medtech and IT.

6.6 Other publications

See also Section 4.2 where the Doctoral theses presented during 2005 are listed and Section 3.3 for Master theses finished during 2005.

1. **CBA annual report 2004**
   Editors: Borgefors, G.; Sintorn, I.-M.; Strand, R.; Wadelius, L.
   Publisher: Centre for Image Analysis, 75 pages

2. **Review of scientific papers on fuzzy shape analysis**
   Editors: Sladoje, N.
   Publisher: CBA Internal report no. 32, 48 pages

3. **Spectral camera design options**
   Editors: Ewert Bengtsson
   Publisher: CBA Internal report no. 33, 11 pages

4. **Discrete skeletons from distance transforms in 2D and 3D**
   Editors: Borgefors, G.; Nyström, I.; Sanniti di Baja, G.(1)
   (1) Istituto di Cibernetica, National Research Council of Italy (CNR) Napoli, Italy
   Publisher: CBA Internal report no. 34, 47 pages

5. **The face-centered cubic grid and the body-centered cubic grid: a literature survey**
   Editors: Strand, R.
   Publisher: CBA Internal report no. 35, 24 pages

6. **A brief review on Benno Artman's "Euclid - the creation of mathematics"**
   Editors: Sladoje, N.
   Publisher: CBA Internal report no. 36, 40 pages

7. **Bildanalys och bildförbättring**
   Authors: Wallin, H.(1); Borgefors, G.
   Editor: Wallin, H.(1)
   (1) Dept. of Mathematics, Umeå University
   Publisher: Liber Ab, Stockholm
   Comment: Pages 114–115 in "Den osynliga matematiken"

8. **UPPMAX progress report**
   Editors: Nyström, I.; Holmgren, S.(1)
   (1) Dept. of Information Technology, UU

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 Section, we have listed these activities for the year 2005. 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 awards: Hamed Hamid Muhammed and Fredrik Bergholm got the "Best Industry-Relevant Paper Award" at the Swedish Symposium on Image Analysis 2005. The paper is selected from all presented at the Symposium by a committee from the industry. In addition, Muhammed and Bergholm received an innovation award.

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 is one of three Area Editors for the Journal "Pattern Recognition Letters".

To give some figures: We held 13 seminars outside CBA, most in the Uppsala area, but some in Korea and China. We had eight invited seminars at CBA, from Finland, France, Germany, USA, Sri Lanka, and Sweden. In addition, we held 33 seminars in our "Monday seminar series", of which seven were Master Thesis presentations. We gave one special invited talk, five oral and nine poster presentations at international fully reviewed conferences, and seven other oral conference presentations. We had two long term visitors from abroad, both from France. 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 47 national "committees" of the most varying types in which we have served.

7.1 Awards

1. **Hamed Hamid Muhammed, Fredrik Bergholm**
   Award: Best industry-relevant paper award, Swedish Symposium on Image Analysis 2005, Malmö, for their paper *Camera-spectrometer for multi- and hyperspectral imaging*.

2. **Hamed Hamid Muhammed, Fredrik Bergholm**
   Award: ALMIs regional price for innovation 2005 in Uppsala.

7.2 Organised conferences and workshops

1. **UPPMAX Visualization Meeting**
   Organisers: Ingela Nyström
   Address: The Ångström Laboratory
   Date: 050531
   Attendees: 20 researchers from areas varying from radiation science to geosciences attended.
   Topic: The common topic was interest in scientific visualization.

2. **Uppsala ICT Business and science**
   Organisers: Local Uppsala authorities and UU
   Address: Stockholm International Fairs, Älvsjö
   Date: 050914
   Comment: Part of the large Sweden ICT Week Exhibit and show. Bengtsson was coordinating Uppsala University part of the conference.

3. **UPPMAX: Scientific Visualization with VTK**
   Organisers: Ingela Nyström
   Address: MIC, UU
   Date: 051213
   Attendees: 14 participants. Instructors: Filip Malmberg, Erik Vidholm, and Ingela Nyström
   Topic: The common topic was interest in scientific visualization and especially how to visulaize with VTK.

7.3 Seminars held outside CBA

1. **Ewert Bengtsson**
   Date: 050317
   Address: Uppsala Science Park
   Title: Visualization work at CBA.
   Comment: An IT&BIO arrangement of the Industrial Academy

2. **Ingela Nyström**
   Date: 050504
   Address: Dept. of Information Technology, Div. of Scientific Computing
   Title: Interactive medical image analysis through haptic visualization
   Comment: TDB seminar.

3. **Ewert Bengtsson**
   Date: 050627
   Address: Inje University, Kimhae, Korea
   Title: Methods and applications of image analysis in medicine
   Comment: Invited presentation to researchers at Inje University.

4. **Ewert Bengtsson**
   Date: 050627
   Address: Neuroscience Research Institute, Incheon, Korea
   Title: Methods and Applications of Image Analysis in Medicine and Cell Image Analysis
   Comment: Two presentations in special seminar after invitation by the head of the instute professor Zang-Hee Cho.

5. **Ewert Bengtsson**
   Date: 050629
   Address: Harbin Engineering University, Harbin, China
   Title: Methods and Applications of Image Analysis in Medicine
   Comment: Invited lecture presented to researchers and students.

6. **Ewert Bengtsson**
   Date: 050630
   Address: Harbin Engineering University, Harbin, China
   Title: Cell image analysis
   Comment: Invited lecture presented to researchers and students.

7. **Ewert Bengtsson**
   Date: 050701
   Address: Harbin Institute of Technology, Institute of Ultra-precision Optoelectronic Instrument Engineering
   Title: Cell image analysis
   Comment: Invited to give a lecture to staff and students. Host Wu Liying, Peng Jin and Cui Ji-wen.

8. **Ewert Bengtsson**
   Date: 050704
   Address: Dept. of Agricultural Engineering, University of Peradeniya
   Title: Cell image analysis
   Comment: Invited to give a lecture to staff and students. Host prof. Vijaya Kumar and P.M.K. Alahakoon.

9. **Ingela Nyström**
   Date: 051101
   Address: Dept. of Mathematics
   Title: How to measure perimeter and area in digital images
   Comment: Invited lecture at Prof. Kiselman's course for young scientists.

10. **Kristin Norell**
    Date: 051110
    Address: Dept. of Wood Science, SLU, Uppsala
    Title: Log quality control using image analysis
    Comment: PhD student day for SLU PhD students in forestry.

11. **Maria Axelsson**
    Date: 051110
    Address: Dept. of Wood Science, SLU, Uppsala
    Title: Image analysis of 3D images of paper
    Topic: PhD student day for SLU PhD students in forestry.

12. **Patrick Karlsson**
    Date: 051119
    Address: Skandinaviska Magasin1, Uppsala
    Title: Color - Physics, Physiology, Psycology
    Comment: A short popular lecture on color, from a physical, physiological, and psychological point of view. The lecture was given to a audience of 20 from the company Skandinaviska Magasin1 AB.

13. **Magnus Gedda**
    Date: 051119
    Address: Skandinaviska Magasin1, Uppsala
    Title: The basics of digital image analysis
    Comment: A short popular lecture on the basics of digital image analysis. The lecture was given to a audience of 20 from the company Skandinaviska Magasin1 AB.

7.4 Seminars at CBA with invited guest lecturers

1. **Damien Jamet**
   Date: 050223
   Title: On the language of discrete planes and surfaces

2. **Magnus Evestedt**
   Date: 050314
   Title: Gas jet impinging on liquid surface: Cavity shape modelling and video-based estimation

3. **Jocelyn Chanussot**
   Date: 050425
   Title: Mathematical morphology for the classification of remote sensing images from urban images

4. **Rangachar Kasturi**
   Date: 050523
   Title: Object detection and tracking in video

5. **Erkki Oja**
   Date: 050922
   Title: Independent Component Analysis - Algorithms and applications

6. **Ullrich Köthe**
   Date: 051013
   Title: Towards reliable low-level image analysis

7. **Dr. P.M.K. Alahakoon**
   Date: 051123
   Title: Digital imaging and instrumentation applications in agriculture - Sri Lankan perspective

8. **Jussi Parkkinen**
   Date: 051215
   Title: Applications of spectral color imaging

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. **Kristin Norell**
   Date: 050110
   Title: Determining bark content in wood-chips for pulping with computerized image analysis
   Comment: Master thesis presentation.

2. **Ida-Maria Sintorn**
   Date: 050117
   Title: A medial grey-level based representataion for molecules in volume images

3. **Hania Uscka-Wehlou**
   Date: 050124
   Title: Digital lines with irrational slope - theory

4. **Per Holting**
   Date: 050131
   Title: Object segmentation in color images
   Comment: Master thesis presentation.

5. **Robin Strand**
   Date: 050207
   Title: The Euclidean distance transform applied to the fcc and bcc grids

6. **Erik Vidholm**
   Date: 050214
   Title: Haptic volume rendering based on gradient vector flow

7. **Patrick Karlsson**
   Date: 050221
   Title: Mean shift filtering

8. **Julia Åhlén**
   Date: 050228
   Title: Suspended matters impact on color reconstruction in underwater images

9. **Hamed Hamid Muhammed**
   Date: 050307
   Title: Converting a digital camera into a spectrometer

10. **Stina Svensson**
    Date: 050404
    Title: Analysing the void space of porous material (for example paper)

11. **Magnus Gedda**
    Date: 050411
    Title: Introduction to CVS

12. **Ewert Bengtsson**
    Date: 050418
    Title: Research during my sabdathical at University of Queensland.

13. **Carolina Wählby**
    Date: 050502
    Title: Spatial and spectral analysis of fluorescing blobs

14. **Maria Axelsson**
    Date: 050509
    Title: Imaging paper with X-ray microtomography

15. **Pasha Razifar**
    Date: 050530
    Title: A new and more appropriate application of principal component analysis for improvement of image quality and clinical diagnosis of human brain in PET studies

16. **Harald Klomp, Jakob Sandström**
    Date: 050613
    Title: Creating quality imagery and video from inexpensive UAV - through determining camera motion and 3D structure
    Comment: Master thesis presentation.

17. **Axel Hjälm**
    Date: 050822
    Title: Registration of fundus images

18. **Robin Strand**
    Date: 050829
    Title: Distances generated by neighbourhood sequences applied to 3D grids with non-cubic voxels

19. **Joakim Lindblad**
    Date: 050905
    Title: Classifying segmented bronchial epithelial cells in H & E stained sections

20. **Céline Fouard**
    Date: 050912
    Title: Morphometrical parameters extraction for the study of the brain micro-vascular network

21. **Hamed Hamid Muhammed**
    Date: 050919
    Title: Hyperspectral image generation, processing and analysis

22. **Filip Malmberg**
    Date: 050926
    Title: 3D live-wire: Semi-automatic segmentation of volume images in a haptic environment *Comment:* Master thesis presentation.

23. **Erik Melin**
    Date: 051003
    Title: Partial orders and topological spaces

24. **Marcus Hanssen**
    Date: 051010
    Title: Evaluation of the TPN image analysis system
    Comment: Master thesis presentation.

25. **Patrick Karlsson**
    Date: 051017
    Title: Image filtering - Using probability density functions and spline approximations

26. **Andreas von Knobloch**
    Date: 051024
    Title: Segmentation by deformable models in a haptic environment
    Comment: Master thesis presentation.

27. **Gunilla Borgefors**
    Date: 051031
    Title: An approximate solution to the potato peeling problem

28. **Erik Vidholm**
    Date: 051107
    Title: Liver segmentation from CT images using fast marching and deformable surfaces

29. **Nataša Sladoje**
    Date: 051121
    Title: On analysis of discrete spatial fuzzy sets in 2 and 3 dimensions

30. **Pasha Razifar**
    Date: 051128
    Title: Novel approaches for application of principal component analysis on dynamic PET images for improvement of image quality and clinical diagnosis

31. **Johan Ljung**
    Date: 051205
    Title: Automatic content-based filtering of television news
    Comment: Master thesis presentation.

32. **Julia Åhlén**
    Date: 051212
    Title: Colour correction of underwater images using spectral data

33. **Céline Fouard**
    Date: 051219
    Title: Weighted distance properties

7.6 Conference participation

7.6.1 Special invited speakers

1. *Conference:* Healthcomm 2005
   Ewert Bengtsson
   Date: 050623–25
   Address: Haeundae Grand Hotel, Busan, Korea
   Title: Computerized cell image processing in healthcare

7.6.2 Oral presentations - refereed conferences

1. *Conference:* Workshop on Digital Image Computing (WDIC 2005)
   Ewert Bengtsson
   Date: 050221
   Address: Griffith University, Southbank, Brisbane, Australia
   Title: Automatic tracking of neural stem cells
   Comment: Organized by the Australian Pattern Recognition Society.

2. *Conference:* WorldHaptics 2005
   Erik Vidholm, Ingela Nyström
   Date: 050318–20
   Address: Pisa, Italy
   Title: A haptic interaction technique for volume images based on gradient diffusion

3. *Conference:* 14th Scandinavian Conference on Image Analysis (SCIA 2005)
   Gunilla Borgefors
   Date: 050619–22
   Address: Joensuu, Finland
   Title: Shape based identification of proteins in volume images

4. *Conference:* 3rd International Conference on Advances in Pattern Recognition (ICAPR 2005)
   Magnus Gedda
   Date: 050822–25
   Address: Bath, Great Britain
   Title: Clustering of objects in 3D electron tomography reconstructions of protein solutions based on shape measurements

5. *Conference:* 13th International Conference on Image Analysis and Processing (ICIAP 2005)
   Gunilla Borgefors
   Date: 050906–08
   Address: Cagliari, Sardinia, Italy
   Title: An approximation of the maximal inscribed convex set of a digital
   Comment: Borgefors was (only non-Italian) session Chair.

7.6.3 Poster presentations - refereed conferences

1. *Conference:* Discrete Geometry for Computer Imagery (DGCI 2005)
   Joakim Lindblad
   Date: 050413–15
   Address: Poitiers, France
   Title: Surface volume estimation of digitized hyperplanes using weighted local configurations

2. *Conference:* Discrete Geometry for Computer Imagery (DGCI 2005)
   Robin Strand
   Date: 050413–15
   Address: Poitiers, France
   Title: Resolution pyramids on the FCC and BCC grids

3. *Conference:* Discrete Geometry for Computer Imagery (DGCI 2005)
   Gunilla Borgefors
   Date: 050413–15
   Address: Poitier, France
   Title: Resolution pyramids on the FCC and BCC grids
   Comment: Borgefors was session Chair.

4. *Conference:* 2nd Iberian Conference on Pattern Recognition and Image Analysis (IbPRIA 2005)
   Robin Strand
   Date: 050607–09
   Address: Estoril, Portugal
   Title: The Euclidean distance transform applied to the FCC and BCC grids

5. *Conference:* 2nd Iberian Conference on Pattern Recognition and Image Analysis (IbPRIA 2005)
   Stina Svensson
   Date: 050607–09
   Address: Estoril, Portugal
   Title: Medial grey-level based representation for proteins in volume images

6. *Conference:* 14th Scandinavian Conference on Image Analysis (SCIA 2005)
   Robin Strand
   Date: 050619–22
   Address: Joensuu, Finland
   Title: A classification of centres of maximal balls in $\mathbb{Z}^3$

7. *Conference:* 14th Scandinavian Conference on Image Analysis (SCIA 2005)
   Julia Åhlén, Ewert Bengtsson
   Date: 050619–22
   Address: Joensuu, Finland
   Title: Dissolved organic matters impact on colour reconstruction in underwater images
8. *Conference:* 13th International Conference on Image Analysis and Processing (ICIAP 2005)
   Amalka Pinidiyaarachchi
   Date: 050906–08
   Address: Cagliari, Sardinia, Italy
   Title: Seeded watersheds for combined segmentation and tracking of cells *Comment:* Spot-light presentation.
9. *Conference:* 13th International Conference on Image Analysis and Processing (ICIAP 2005)
   Nataša Sladoje
   Date: 050906–08
   Address: Cagliari, Sardinia, Italy
   Title: Estimation of moments of digitized objects with fuzzy borders
   Comment: Spot-light presentation.

7.6.4 Oral presentations

1. *Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA 2005)
   Ewert Bengtsson
   Date: 050310–11
   Address: Malmö University
   Title: Dynamic breast MRI visualised through colour mapping
2. *Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA 2005)
   Erik Vidholm
   Date: 050310–11
   Address: Malmö University
   Title: Haptic volume rendering based on gradient vector flow
3. *Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA 2005)
   Hamed Hamid Muhammed
   Date: 050310–11
   Address: Malmö University, Sweden
   Title: Camera-spectrometer for multi- and hyperspectral imaging
4. *Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA 2005)
   Maria Axelsson
   Date: 050310–11
   Address: Malmö University
   Title: Individual pore segmentation in 3D volumes of fibrous materials
5. *Conference:* Swedish Medical Engineering Conference 2005, Medicinteknikdagarna
   Ewert Bengtsson
   Date: 050927–28
   Address: Hotell Skogshöjd, Södertälje
   Title: Computerized analysis of cell images in medicine and bioscience (in Swedish)
   Comment: Invited overview of our current research on cell images.
6. *Conference:* Ping Pong Academic User Group Workshop (PAUG)
   Ewert Bengtsson
   Date: 051010
   Address: Auditorium Minus, Gustavianum, Uppsala
   Title: Welcoming adress
   Comment: Bengtsson gave the welcoming adress to this national workshop for the Ping Pong Academic User Group.

7. *Conference:* Open Source Software
   Ewert Bengtsson
   Date: 051121–22
   Address: Main University building, UU
   Title: Welcoming and introductory adress
   Comment: This was a national conference on the use of OS software in learning. In the invited conference opening speech Bengtsson spoke about the UU policy on IT support in education.

7.6.5 Poster presentations

1. *Conference:* 5th European Conference on Precision Agriculture (5ECPA)
   Hamed Hamid Muhammed
   Date: 050609–12
   Address: SLU, Uppsala
   Title: Camera-spectrometer for instantaneous multi- and hyperspectral imaging

2. *Conference:* Swedish Medical Engineering Conference 2005, Medicinteknikdagarna
   Axel Hjälm
   Date: 050927–28
   Address: Hotell Skogshöjd, Södertälje
   Title: A computer based tool for diagnostics of glaucoma

3. *Conference:* Swedish Medical Engineering Conference 2005, Medicinteknikdagarna
   Hamed Hamid Muhammed
   Date: 050927–28
   Address: Hotell Skogshöjd, Södertälje
   Title: Cost effective instant hyperspectral medical images for telemedicine and electrical registration

4. *Conference:* Swedish Medical Engineering Conference 2005, Medicinteknikdagarna
   Stina Svensson
   Date: 050927–28
   Address: Hotell Skogshöjd, Södertälje
   Title: Computerized image analysis as an essential tool for studying protein dynamics from cryo electron tomographic data

5. *Conference:* Swedish Medical Engineering Conference 2005, Medicinteknikdagarna
   Erik Vidholm
   Date: 050927–28
   Address: Hotell Skogshöjd, Södertälje
   Title: Interactive medical image analysis through haptic visualization

6. *Conference:* Swedish Medical Engineering Conference 2005, Medicinteknikdagarna
   Carolina Wählby
   Date: 050927–28
   Address: Hotell Skogshöjd, Södertälje
   Title: Digital image processing for multiplexing of single molecule detection
   Comment: Coauthors from the Dept. of Genetics and Pathology, Rudbeck laboratory

7.6.6 Attendee

1. *Conference:* The Natural Scientist in Focus
   Ingela Nyström
   Date: 050202
   Address: The Ångström Laboratory
   Comment: A NUN arrangement.

2. *Conference:* IT strategies in companies
   Ingela Nyström

Date: 050203
Address: Uppsala Science Park
Comment: An IT&BIO arrangement of the Industrial Academy.

3. Seminar for Appointments Boards at SLU
Gunilla Borgefors
Host: SLU
Address: Atrium, Uppsala
Date: 050208
Comments: A one-day seminar for all Appointment Boards' members at SLU faculties (and some others).

4. *Conference:* Remote Sensing of Environment
Tommy Lindell
Date: 050210–11
Address: Skåsjöholm, Åkersberga
Comment: Swedish National Space Board.

5. *Conference:* Workshop on Simulations for Industry
Ingela Nyström
Date: 050210
Address: The Ångström Laboratory
Comment: An IT&BIO arrangement of the Industrial Academy.

6. SSBA PhD student day 2005
Maria Axelsson, Magnus Gedda, Patrick Karlsson, Ida-Maria Sintorn, Robin Strand, Erik Vidholm
Date: 050309
Description: PhD student day in Malmö in connection with SSBA 2005.

7. *Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA 2005)
Gunilla Borgefors, Magnus Gedda, Patrick Karlsson, Tommy Lindell, Ingela Nyström, Ida-Maria Sintorn, Robin Strand, Stina Svensson, Carolina Wählby
Date: 050310–11
Address: Malmö University

8. *Conference:* International Symposium on Mathematical Morphology
Gunilla Borgefors
Date: 050418–20
Address: Paris, France
Comment: Borgefors was session Chair.

9. *Conference:* Rules in Life Sciences and their implications on IT
Ewert Bengtsson, Ingela Nyström
Date: 050428
Address: Uppsala Science Park
Comment: An IT&BIO arrangement of the Industrial Academy.

10. *Conference:* SICS 20 years
Ewert Bengtsson
Date: 050512
Address: Swedish Institute of Computer Science, Kista
Comment: A seminar and open house exhibit to celebrate the anniversary.

11. *Conference:* 14th Scandinavian Conference on Image Analysis (SCIA 2005)
Ingela Nyström
Date: 050619–22
Address: Joensuu, Finland
Comment: Member of the best nordic thesis committee.

12. *Conference:* 14th Scandinavian Conference on Image Analysis (SCIA 2005)
Maria Axelsson
Date: 050619–22
Address: Joensuu, Finland

13. *Workshop:* Strategic Research Agenda
Stina Svensson
Date: 050621
Address: STFI, Stockholm
Topic: Forest Based Sector Technology Platform, FTP, National Support Group - Sweden

14. *Summer school:* Level sets and ITK, 2p
Maria Axelsson, Patrick Karlsson, Filip Malmberg, Kristin Norell, Amalka Pinidiyaarachchi, Stina Svensson, Erik Vidholm, Ola Weistrand
Examiner: Hans Knutsson (IMT).
Lecturer(s): Ken Museth (Graphics Group, Norrkoping), and Karl Krissian (Harvard Medical School).
Period: 050822–24
Description: Summer school at IMT (Linkoping) with lectures on level set theory for applications in visualization and medical image segmentation. The course also contained an introduction to the ITK framework with some hands-on experience included. A small project (1 credit) was part of the course curriculum.
Comment: Course also included a talk by Dr. Byung-Woo Hong, and a visit to the CMIV research facilities.

15. *Conference:* International Seminar on Medical Image Computing and Computer Assisted Intervention
Ingela Nyström
Date: 050825
Address: IT University of Copenhagen, Denmark

16. *Conference:* UPPMAX Inauguration of the Super-Computer Ra
Ingela Nyström, Ewert Bengtsson
Date: 050908
Address: The Ångström Laboratory

17. *Conference:* WURC seminar
Stina Svensson, Maria Axelsson
Date: 050921
Address: Ultuna, SLU, Uppsala
Comment: Wood Ultrastructure Research Centre annual seminar.

18. *Conference:* Swedish Medical Engineering Conference 2005, Medicinteknikdagarna
Amalka Pinidiyaarachchi
Date: 050927–28
Address: Hotell Skogshöjd, Södertälje

19. *Conference:* WSIS, Internet Governance and Human Rights
Ewert Bengtsson
Date: 051003
Address: Hammarskog Conference Centre, Uppsala

20. *Conference:* 2nd User Meeting for Swedish National Infrastructure for Computing
Ingela Nyström
Date: 051018–19
Address: National Supercomputer Centre (NSC), Linköping University
Comment: UPPMAX SNIC interaction.

21. *Conference:* Brain, Vision & Artificial Intelligence (BV&AI)
Gunilla Borgefors
Date: 051018–21
Address: Naples, Italy

22. *Conference:* System Pathology
Ewert Bengtsson
Date: 051122
Address: Fåhreus lecture hall, Dept. of Pathology, Rudbecks lab
Comment: Listened to presentation and discussed with researchers in quantitative pathology

23. *Conference:* SUNET Forum
    Ewert Bengtsson
    Date: 051219
    Address: Arlanda Conference Centre
    Comment: The annual national conference about the Swedish university network.

7.7 Visiting scientists (staying at least 2 weeks)

1. **Jocelyn Chanussot**
   Address: Signal and Image Laboratory (LIS), Institut National Polytechnique de Grenoble (INPG), Grenoble, France
   Host: Ingela Nyström
   Date: 050419–0519
   Number of visitors: 1
   Topic: Collaboration on fuzzy shape analysis.

2. **Céline Fouard**
   Address: EPIDAURE project, INRIA, Sophia Antipolis, France
   Host: Gunilla Borgefors
   Date: 050815–
   Number of visitors: 1
   Topic: Weighted distance transforms and fuzzy sets.

7.8 Short visits to other research groups and meetings outside CBA

Note: Meetings occassioned by permanent appointments are listed in section 7.10

1. **Erik Vidholm**
   Host: Hans Frimmel, Tomas Bjerner
   Address: Dept . of Radiology, UU hospital
   Date: 050119, 050202, 050216, 050616
   Topic: Project meeting, haptic guided liver-surgery planning.

2. **All personnel at CBA**
   Host: Stefan Seipel
   Address: Dept. of Mathematics, Natural and Computer Sciences, University of Gävle
   Date: 050120
   Topic: Presentation of computer graphics activities at University of Gävle
   Comments: This was the Lucia trip of 2004.

3. **Gunilla Borgefors**
   Address: Dept. of Forest Mycology and Pathology, SLU, Uppsala
   Date: 050121
   Topic: Meeting on forest research following the storm “Gudrun”.

4. **Maria Axelsson**
   Host: Gary Chinga, Per Nygård
   Address: PFI, Trondheim, Norway
   Date: 050131–0201
   Topic: Possible cooperation between CBA and PFI
   Comments: Discussions about possible cooperation and joint papers.

5. **Ewert Bengtsson**
   Host: Denise Chalmers, director
   Address: Teaching & Educational Development Institute, University of Queensland, Ipswitch, Queensland, Australia
   Date: 050201
   Topic: Multimedia support
   Comments: Discussions on how to support technology use in higher education.

6. **Ewert Bengtsson**
   Host: Anthony Maeder
   Address: Queensland EHealth Research Centre
   Date: 050202
   Topic: Discussion about EHealth

7. **Gunilla Borgefors**
   Host: Lars Roepsdorff
   Address: Dept. of Equine Studies, SLU, Uppsala
   Date: 050204
   Topic: Gair qulatity of Icelandic horses using image analysis
   Comments: Formulation of a master thesis project.

8. **Tommy Lindell**
   Host: Julia Åhlén
   Address: University of Gävle
   Date: 050204
   Topic: Student supervision
   Comments: Discusion of content of thesis.

9. **Ingela Nyström**
   Host: Anders Heyden
   Address: School of Technology and Society, Malmö University
   Date: 050224
   Topic: SSBA Board meeting

10. **Stina Svensson**
    Host: Prof. Albert Alm
    Address: Dept. of Neuroscience, Ophthalmology, UU
    Date: 050408
    Topic: Discussion about a common project on automatic change detection of the optical nerve head from confocal scanning laser images
    Comments: Also present: Olav Mäepea, Research Engineer.

11. **Stina Svensson**
    Host: Prof. Ulf Skoglund
    Address: Dept. of Cell and Molecular Biology (CMB), Karolinska Institute, Stockholm
    Date: 050408
    Topic: Discussion about a common project on automatic extraction of geometrical features from cryo elecron microscope data
    Comments: Also present: Duccio Fanelli researcher at CMB and associate professor at Dept. of Energetic "S. Stecco", Univeristy of Florence, Florence, Italy.

12. **Ewert Bengtsson**
    Address: MIC
    Date: 050411
    Topic: Meeting about Centre for Applied Mathematics at UU
    Comment: About 20 others present.

13. **Magnus Gedda, Ida-Maria Sintorn, Stina Svensson**
    Host: Sidec Technologies AB
    Address: Sidec Technologies AB, Stockholm
    Date: 050413
    Topic: Discussion about collaboration regarding analysis of proteins in volume images
    Comments: Visiting Sidec in their new premises.

14. **Maria Axelsson, Stina Svensson**
    Host: Catherine Östlund
    Address: STFI-Packforsk, Stockholm
    Date: 050413

Topic: Discussion about on-going project on analysis of the pore structure of press felt
Comments: Hannes Vomhoff, STFI-Packforsk also participated on the meeting.

15. **Gunilla Borgefors**
    Address: Futuroscope, Poitiers, France
    Date: 050414
    Topic: DGCI Steering committee meeting

16. **Maria Axelsson**
    Host: ESRF representative; Xavier Thibault
    Address: European Radiation Syncrotron Facility, ESRF, Grenoble, France
    Date: 050427–0503
    Topic: Scanning X-ray microtomograpic volumes of paper at ESRF
    Comments: Imaging paper volumes in 3D at the syncrotron facility in Grenoble. Joint project with researchers from Norway, Sweden, France, USA and Finland. First visit.

17. **Ewert Bengtsson**
    Address: Uppsala Learning Lab
    Date: 050519
    Topic: Discussion with Jan Johansson about a possible Master Thesis project on water mark scanning and matching for old music manuscripts

18. **Stina Svensson**
    Host: Prof. Ulf Skoglund
    Address: Dept. of Cell and Molecular Biology (CMB), Karolinska Institute, Stockholm
    Date: 050602
    Topic: Discussion about a common project on automatic extraction of geometrical features from cryo elecron microscope data
    Comments: Also present: Duccio Fanelli researcher at CMB and associate professor at Dept. of Energetic "S. Stecco", Univeristy of Florence, Florence, Italy.

19. **Gunilla Borgefors**
    Host: Gustaf Forsberg
    Address: Dept. of Biometry and Engineering
    Date: 050607
    Topic: Seed vitality
    Comments: Start meeting for a project measuring the vitality of grain seeds after steam treatment.

20. **Kristin Norell**
    Host: Maria Jonsson
    Address: Dept. of Forest Products and Markets, SLU Uppsala
    Date: 050613
    Topic: Wood logs at Ultuna
    Comments: Meeting about the log end images at Ultuna.

21. **Kristin Norell**
    Host: Fredrik Nylund, ADEC Automation AB
    Address: Forssjö saw mill, Forssjö, Katrineholm
    Date: 050622
    Topic: Log images, Forssjö
    Comments: Also present Magnus Jansson, ADEC and Lars Björklund, VMR.

22. **Stina Svensson, Magnus Gedda**
    Host: Sidec Technologies AB
    Address: Sidec Technologies AB, Kista
    Date: 050622
    Topic: Open House at Sidec Technologies
    Comments: New microscope and new location.

23. **Ewert Bengtsson**
Host: Changmo Sung, president, Sang Hee Nam, dean, Heung-Kook Choi, Hee-Cheol Kim, Won Joo Hwang, Charles Kim
Address: Inje university
Date: 050627
Topic: Discussions about continued cooperation.

24. **Ewert Bengtsson**
Host: Zang-Hee Cho, director, Seong Jong Hong, Jong-Soo Kim, Jonghoe Byun, Dong-Pyo Jang, Chul-Ock Lee, Sung-Woon Kim, Sang-Hyun Ahn.
Address: Neuroscience Research Institute
Date: 050627
Topic: Scientific discussions.

25. **Stina Svensson, Magnus Gedda**
Host: Ulf Skoglund, Duccio Fanelli
Address: Dept. of Cell and Molecular Biology, Karolinska Institute, Stockholm
Date: 050629, 050930, 051006, 051220
Topic: CMB, Karolinska Institute
Comments: Discussions and information on further collaboration.

26. **Ewert Bengtsson**
Host: Guo Lili, dean, Zhao Danfeng, Zhao Chunhui, Diao Ming, Chunming Tang
Address: Harbin engineering University, College of information and communication, Harbin, China
Date: 050630
Topic: Discussion about possible collaboration.

27. **Ewert Bengtsson**
Host: P.M.K. Alahakoon and Amalka Pinidiyarachchi
Address: Dept. of Agricultural Engineering, Univ of Peradeniya
Date: 050704–05
Topic: Discussion about collaboration

28. **Ewert Bengtsson**
Host: Kasun De Zoysa, Prasad Wimalaratne, Ruvan Weerasinghe
Address: University of Colombo, School of Computing, Sri Lanka
Date: 050704–05
Topic: Discussion about collaboration
Comments: Locally responsible for Suthakar's supervision.

29. **Erik Vidholm**
Host: Daniel Evestedt, Mark Dixon, Johan Beskow, Tommy Forsell
Address: SenseGraphics AB, Kista, Stockholm
Date: 050818
Topic: Visit at SenseGraphics AB in Kista to look at the new large-scale haptic display and discuss the H3D API.

30. **Ingela Nyström**
Host: Sven Nilsson
Address: Dept. of Oncology, Radiology and Clinical Immunology, UU
Date: 050902
Topic: Study of CT liver data

31. **Ingela Nyström**
Host: Nataša Sladoje
Address: Faculty of Engineering, University of Novi Sad, Serbia and Montenegro
Date: 051002–09
Topic: Continued project on fuzzy shape analysis.

32. **Gunilla Borgefors, Joakim Lindblad**
Host: Gustaf Forsberg
Address: SeedGard AB, Ultuna, Uppsala
Date: 051004
Topic: Seed vitality
Comments: Planning meeting for the seed vitality project.

33. **Kristin Norell**
Host: Lars Björklund
Address: Nyby saw mill, Björklinge
Date: 051007
Topic: Log images, Nyby
Comments: Ari Karjula was also present.

34. **Maria Axelsson**
Host: ESRF representative; Xavier Thibault
Address: European Radiation Syncrotron Facility, ESRF, Grenoble, France
Date: 051115–21
Topic: Scanning X-ray microtomograpic volumes of paper at ESRF
Comments: Imaging paper volumes in 3D at the syncrotron facility in Grenoble. Joint project with researchers from Norway, Sweden, France, USA and Finland. Also research meetings on image processing with the PhD students working with the volumes.
Second visit.

35. **Ingela Nyström**
Host: Magnus Borga
Address: Div. of Medical Informatics (IMT), Dept. of Biomedical Engineering, Linköping University
Date: 051117
Topic: SSBA Board meeting

36. **Maria Axelsson**
Host: Stefan Gunnarsson
Address: Evolutionsbiologiskt Centrum, Biologisk strukturanalys, Uppsala Universitet
Date: 051122
Topic: Imaging paper with confocal microscopy
Comments: Discussions on sample preparation and imaging methods for paper in 3D with CLSM.
Various other visits to EBC for discussions on the topic was also conducted.

37. **Maria Axelsson**
Host: Örjan Sävborg, Olle Henningsson
Address: Stora Enso Research, Falun
Date: 051123
Topic: Sample preparation and discussions of imaging methods
Comments: Visit to Stora Enso for discussions on imaging methods for volume images of paper. Sample preparation and demonstration of methods.

38. **Ewert Bengtsson**
Host: Ulf Göransson
Address: Carolina University Library, Uppsala
Date: 051214
Topic: Future strategy for development of digital publishing and archiving at UU. Also present: Eva Müller and Lars-Elve Larsson

7.9 Other visitors

1. **KG Paulsson(1), Ulf Höglind(1), Lars Björklund(2)**
Address: 1. Höglind Marketing HB, 2. VMR, Sundsvall
Host: Gunilla Borgefors
Date: 050110

Number of visitors: 3
Topic: Presentation of Norell's Master thesis.

2. **Gabriella Sanniti di Baja**
Address: Istituto di Ciberbnetica "E. Caianello", CNR, Pozzuoli (Napoli), Italy
Host: Gunilla Borgefors, Ingela Nyström
Date: 050117–23
Number of visitors: 1
Topic: Preparing contribution to ICIAP 2005 and othe research co-operation.

3. **Christian Ronse**
Address: LSIIT, Université Louis Pasteur, Strassbourg, France
Host: Gunilla Borgefors
Date: 050119
Number of visitors: 1
Topic: Presentation of CBA
Comments: Ronse was Licentiate opponent for Erik Melin.

4. **Hans Wallin**
Host: Gunilla Borgefors
Date: 050201
Number of visitors: 1
Topic: Image analysis and mathematics
Comments: Telephone interview for a coming book on "Invisible Mathematics".

5. **Klas Eriksson**
Address: Teknikbrostiftelsen, Uppsala
Host: Gunilla Borgefors
Date: 050201
Number of visitors: 1
Topic: Commersialisation of CBA research

6. **Students from Uppsala IT-gymnasiet**
Address: IT-Gymnasiet, Uppsala.
Host: Gunilla Borgefors and Patrick Karlsson
Date: 050211
Number of visitors: 60
Topic: Gunilla Borgefors: "Chain coding - a way to describe shape in digital images", Patrick Karlsson: "Stem cell research using image analysis".
Comments: Study visit arranged by IT-Amanuens Karl Nilvér.

7. **Artem Kashubin**
Address: Dept. of Earth Sciences/Geophysics, Uppsala
Host: Patrick Karlsson, Erik Vidholm
Date: 050224
Number of visitors: 1
Topic: Scientific volume visualization
Comments: Mr. Kashubin is a Ph.D. student, specialized in controlled source seismology at the department of Earth sciences.

8. **Damien Jamet**
Address: LIRMM, Montpellier, France
Host: Gunilla Borgefors
Date: 050224
Number of visitors: 1
Topic: Presentation of CBA

9. **Catherine Östlund**
Address: STFI-Packforsk, Stockholm
Host: Maria Axelsson, Stina Svensson

Date: 050307
Number of visitors: 1
Topic: Discussions of image analysis methods developed at CBA for characterization of press felt surfaces

10. **Gabriella Sanniti di Baja**
Address: Istituto di Ciberbnetica ”E. Caianello”, CNR, Pozzuoli (Napoli), Italy
Host: Gunilla Borgefors
Date: 050330–0405
Number of visitors: 1
Topic: Dissertation of Sintorn and research co-operation
Comments: Sanniti di Baja was member of Sintorn’s dissertation committee.

11. **Lennart Thurfjell**
Address: GE Healthcare
Host: Ewert Bengtsson
Date: 050401
Topic: Meeting about possible joint VR application and future cooperation CBA - GE Medical.

12. **Stefan Seipel (1), Lennart Thurfjell (2), Gunnar Jansson (3)**
Address: (1) Dept. of Mathematics, Natural and Computer Sciences, University of Gävle; (2) GE Healthcare, Uppsala; (3) Dept. of Psychology, UU
Host: Ewert Bengtsson, Ingela Nyström, Erik Vidholm
Date: 050412, 050906
Topic: Haptik project reference group

13. **Albert Alm**
Address: Dept. of Neuroscience, Ophthalmology, UU
Host: Ewert Bengtsson, Carolina Wählby, Stina Svensson, Axel Hjälm
Date: 050414
Number of visitors: 1
Topic: Discussion about a common project on automatic change detection of the optical nerve head from confocal scanning laser images.

14. **SSBA Board**
Address: Umeå, Linköping, Göteborg, Malmö
Host: Ingela Nyström
Date: 050427
Number of visitors: 5
Topic: SSBA Board Meeting

15. **Several industrial and regulatory experts**
Date: 050428
Address: Mellanskog, Uppsala Science Park
Title: Industriakademin ITnB ”Regelverk, myndighet och verkligheten
Comment: Part of the series of seminars invesstigating possible collaboration UU IT and industry.

16. **Lars Jonsson**
Address: Uppsala universitets utveckling AB, Uppsala Science Park
Host: Ewert Bengtsson
Date: 050511
Number of visitors: 1
Topic: Hyperspectral cameras
Comments: Jonsson came to see Bengtsson to discuss the business prospects of hyperspectral cameras based on research at CBA by Muhammed and Bergholm.

17. **Prof. Eric H. Karunanayake**
Address: Institute of Biochemistry, Molecular Biology and Biotechnology, University of Colombo, Sri Lanka
Host: Ewert Bengtsson
Date: 050523

Number of visitors: 1
Topic: Contact in relation to our cooperation with Sri Lanka.

18. **Ola Ljunggren (1), Tom Smedsaas (2), Bengt Kylberg (3), Anders Ullstrand (4), Stefan Pålsson (2), Roland Bol (2)**
Address: (1) Biology Education Centre, UU; (2) Dept. of Information Technology, UU; (3) Apropos IT - B. Kylberg, Uppsala; (4) IT&BIO Academy, Uppsala
Host: Ewert Bengtsson, Olle Eriksson
Date: 050523
Topic: Discussion about need to teach students about industrial requirements on software development.

19. **Rangachur Kasturi**
Address: Dept. of Computer Science and Engineering, University of South Florida
Tampa, FL, USA
Host: Gunilla Borgefors, Ingela Nyström
Date: 050523
Number of visitors: 1
Topic: Visit in connection with Sweden trip
Comments: Kasturi met with and had project discussions with Erik Vidholm, Stina Svensson, and Maria Axelsson.

20. **Gary Chinga**
Address: PFI, Trondheim, Norway
Host: Gunilla Borgefors, Stina Svensson, Maria Axelsson
Date: 050530
Number of visitors: 1
Topic: Co-operation on paper volume research.

21. **Anne Gelb**
Address: Dept. of Mathematics and Statistics, Arizona State University, Tempe, AZ, USA
Host: Ingela Nyström, Erik Vidholm
Date: 050602
Number of visitors: 1
Topic: Discussion on common problems with image filtering and PDE solutions
Comments: Anne Gelb was here on a 2-week visit to Dept. of Scientific Computing (TDB).

22. **Carl von Linné (alias Hans Odöö)**
Host: Ingela Nyström
Date: 050607
Number of visitors: 1
Topic: Planning of Prof. Linné's performance at the inauguration of the super-computer Ra (20050908).

23. **Lars Björklund(1), Fredrik Nylund(2), Magnus Jansson(2)**
Address: 1. The Swedish Timber Measurement Council, Skellefteå
2.ADEC Automation AB, Nyköping
Host: Gunilla Borgefors, Kristin Norell
Date: 050609
Topic: Discussion about log end images at Forssjö saw mill.

24. **Anthony Maeder**
Address: E Health Reserach Centre, Brisbane, Australia
Host: Ewert Bengtsson, Gunilla Borgefors
Date: 050823
Number of visitors: 1
Topic: Discussion of possible cooperation
Comments: Sabine Koch also attended the meeting.

25. **Hannes Vomhoff and Catherine Östlund**
Address: STFI-Packforsk, Stockholm
Host: Maria Axelsson, Stina Svensson, Gunilla Borgefors

Date: 050826
Number of visitors: 2
Topic: Evaluation and discussions of image analysis methods developed at CBA for characterization of press felt surfaces.

26. **Björn Hannrup**
Address: SkogForsk, Uppsala
Host: Gunilla Borgefors, Kristin Norell
Date: 050830
Number of visitors: 1
Topic: Joint application
Comments: Mikael Andersson, Skogforsk, and Johan Oja, SP Trätek, participated on phone. CBAs part would be log inspection.

27. **Patrik Ring**
Address: Dept. of Radiology, UU hospital
Host: Ewert Bengtsson
Date: 050907
Number of visitors: 1
Topic: Possible new cooperation on MRI analysis
Comments: The visitor is starting a new research where quantitative volume measurements of brain tumours in MRI images will be needed, this leads to interesting segmentations problems. A possible future joint project?

28. **Sven Nilsson**
Address: Dept. of Oncology, Radiology, and Clinical Immunology, UU
Host: Ingela Nyström, Erik Vidholm
Date: 051011, 051108
Topic: Project meeting, liver segmentation with haptic enhanced seeding.

29. **Ullrich Köthe**
Address: Computer Science Department, University of Hamburg, Germany
Host: Ingela Nyström
Date: 051012–14
Number of visitors: 1
Topic: Supervision of MSc student Andreas von Knobloch.

30. **Ingrid Carlbom**
Address: 21 Oakley Ave, Summit, NJ 07901, USA
Host: Ewert Bengtsson
Date: 051012
Number of visitors: 1
Topic: Future cooperation project ideas.

31. **Prof Britt Östlund**
Address: Swedish Science Council and Lund University
Host: Ewert Bengtsson
Date: 051118
Number of visitors: 1
Topic: The organisation of IT-coordination at UU
Comments: Östlund has been appointed by the rektor to evaluate the UU IT-coordination of IT that Bengtsson has been responsible for and to propose its future organisation. In this meeting she interviewed Bengtsson about his views.

32. **PMK Alahakoon, Prof Walgama**
Address: University of Peradeniya, Sri Lanka
Host: Ewert Bengtsson
Date: 051121–26
Number of visitors: 2

Topic: Cooperation in realtion to PhD position at CBA of Amalka P.
Comments: Several meetings and seminars took place during the week long visit.

33. **Jonas Brändström**
Address: Dept. of Wood Science, SLU, Uppsala
Host: Stina Svensson, Gunilla Borgefors
Date: 051207
Number of visitors: 1
Topic: Discussion about possible cooperation
Comments: Jonas Brändström is working at Wood Ultrastructure Research Centre (WURC), SLU.

34. **Per Hisisng**
Address: Innovationsbron Uppsala AB
Host: Ewert Bengtsson
Date: 051215
Number of visitors: 1
Topic: Possible exploration of hyperspectral imaging ideas.

7.10 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:

- Editorial board member of "Machine Graphics & Vision", 1994–
  Comment: Published by Polish Academy of Sciences
- Editorial board member of "Computer Methods and Programs in Biomedicine", 1995–
  Comment: Published by Elsevier
- Senior member of the "Institute of Electrical and Electronics Engineers", (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'2005
  Comment: International annual conference series in Computer graphics and Image Analysis held in Plzen, Czech Rèpublic in February each year
- Expert evaluator of project proposals for the European Community 6th Framework Human Frontier Science Program Organization 200510-
- Expert evaluator of project proposals for "Dipartimento per la programmazione il coordinamento e gli affair economici saus programmi diricerca scientifica di rilevante intresse nazionale" of the Italian Ministry for Education, University, and Research, 2001–
- Chair of the Uppsala-Makerere IT cooperaton project, 2000–
  Comment: A project financed by SIDA aiming at developing IT infrastructure and competence at Makerere University, Kampala, Uganda. (2 meetings)

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. (1 meeting.)

- 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.) Additionally there has been about 15 preparatory and follow up metings.
- 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. (3 meetings.)
- Member of "Rektorsrådet" the Rector's advisory council, 199802–
  Comment: (7 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. (1 meeting.)
- 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: (5 meetings)
- 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. (7 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: (4 meetings.)
- Member of the Uppsala Chamber of Commerce IT board, representing UU. 200006–
  Comment: Working with various activities to promote cooperation researchers - companies. (1 meeting.)
- 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. (12 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.)
- 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.

- Expert evaluator of project proposals for Council of physical Sciences of the Netherlands Organization for Scientific Research, 200510–
- Expert evaluator of applications to European Yong Investigators Awards, 200512–
- SUSAM IT group, 050301
  Comment: Representing Uppsala University on the group for cooperation between universities in the Stockholm region in the IT field. (2 meetings)
- PhD dissertation committee for Gustav Tolt, 050407
  Comment: Title of thesis: Fuzzy similarity-based Image Processing, Örebro University
- Licentiate seminar discussant at University of Umeå, 050520
  Comment: Bengtsson acted as faculty appointed discussant at the licentiate seminar by Christina Olsén at the Department of computing Science, University of Umeå.
  The title of the thesis: Automatic Assessment of Mammogram Adequacy
- PhD dissertation committee of Kenneth Nilsson, Halmstad university college, 050527
  Comment: Title of thesis: Symmetry filters applied to fingerprints. Representation, feature extraction and registration.
- Licentiate seminar discussant at Chalmers University of Technology., 050531
  Comment: For thesis of Johan Degerman: Time-lapse bright-field microscopy and image acquisition of in-vitro neural stem cells
- PhD dissertation committee of Jelena Krjukova, Department of Neuroscience, Uppsala University, 050605
  Comment: Title of thesis: Investigation on Pre- and Postsynaptic Ca2+ Signaling in Neuronal Model Systems
- Board of EHealth Centre at Uppsala University, 050817
  Comment: Appointed to the board of this new Centre to represent faculty of Science and Technology. (4 meetings)
- Swedish Science Council Prioritization Committee for Medical Engineering, 050901–050902
  Comment: The actual committee meeting was the specified dates, reading the 30 assigned applications and taking part in email discussions took place during several months from June through October
- IT in university learning, 051007
  Comment: Chair of this committee charged with the task of proposing how the work to develop and support the use of IT in Uppsala university undergraduate education should be coordinated between the faculty and the central levels. To deliver final report in end of January 2006. (5 meetings)
- PhD Dissertation Committee for Nataša Sladoje, 051125
  Comment: Thesis: On analysis of discrete spatial fuzzy sets in 2D and 3D

Gunilla Borgefors
International:

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

- Editorial Board of the book series "Computational Imaging and Vision", published by Kluwer Academic Publishers, 200301–
- Steering Committee member for Discrete Geometry for Computer Imagery (DGCI) conferences, 200012–
- Program Committee member for 12th Int. Conference in Discrete Geometry for Computer Imagesry (DGCI 2005), Poitier, France, April 2005
- Program Committee member for Int. Symposium on Mathematical Morphology: 40 years on (ISMM 2005), Paris, France, April 2005
- Promgram Committee member for IAPR Conference on Machine Vision Applications (MVA 2005), Tskuba Science City, Japan, May 2005
- Program Committee member for 8th Int. Conference on Pattern Recognition and Information Processing (PRIP 2005), Minsk, Belarus, May 2005
- Programme Committee member for 1st Int. Symopsium on Brain, Vision & Artifical Intelligence (BVAI 2005), Naples, Italy, 050101–051030
  Comment: Proceedings LNCS 3704

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). (3 meetings)
- 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.)
- Deputy member, Advisory committee for new Rector of SLU, 20050901–20060630
  Comment: (1 meeting)
- Nomination Committee member, Swedish Society for Automated Image Analysis
- PhD dissertation committee of Baran Çürüklü, Dept of Computwer Science and Electronics, Mälardalen University, Västerås, 20050426
  Comment: Title: A canonical model of the primary visual cortex
- PhD dissertation committee of Hemakumar Lalith Premaratne, Dept of Signals and Systems, Chalmers University of Technology, Halmstad, 20050520
  Comment: Title: Recognition of printed Sinhala characters by direction fields
- PhD dissertation committee of Hamed Hamid Muhammed, CBA, UU, 20050923
  Comment: Title: Hyperspectral image generation, processing and analysis
- PhD dissertation committee of Göran Hamrin, Dept of Mathematics, UU, 20050929
  Comment: Title: Effective domains and admissible domain representation

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 (IAPR), 200203-
- Member of Nominating Committee for IAPR Executive Committee, 2004–2006
- Member of the committee for "Best Nordic Thesis in Pattern Recognition", 2003–
  Comment: Award appointed at SCIA.
- Program committee member of Discrete Geometry and Computer Imagery 2005 (DGCI 2005), Poitiers, France, 050101–050415
  Comment: Proceedings LNCS 3429
- Program committee member of Scandinavian Conference on Image Analysis (SCIA 2005), Joensuu, Finland, 050101–050622
  Comment: Proceedings LNCS 3540

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), 20030101–20050630
- Special adviser in Docent committee for Per Eksell, Dept. of Clinical Radiology, SLU, 050420
- PhD Dissertation Committee for Karin Althoff, Dept. of Signals and Systems, Chalmers University of Technology, Göteborg, 050603
  Comment: Title: Segmentation and Tracking Algorithms for In Vitro Cell Migration Analysis
- PhD Dissertation Committee for Pasha Razifar, 051202
  Comment: Title: Novel Approaches for Application of Principal Component Analysis on Dynamic PET Images for Improvement of Image Quality and Clinical Diagnosis
- PhD Dissertation Committee for Ola Weistrand, Dept. of Mathematics, Uppsala University, 051209
  Comment: Title: Global Shape Description of Digital Objects

Stefan Seipel
National:

- PhD dissertation committee of Per Persson, Linköping University, 0509
- Program committee member of the annual SIGRAD conference, 2005