# Centre for Image Analysis

Swedish University of Agricultural Sciences
Uppsala University

# ANNUAL REPORT 2006

SLU

UPPSALA UNIVERSITET

# Annual Report 2006

# Centre for Image Analysis

# Centrum för bildanalys

*Cover:* Paintings by Jakob Nisell.

**Top:**
Centre for Image Analysis' red wooden quarters during the period 1992–2006, Polacksbacken, building 17, transforming into the new premises.
**Bottom:**
Centre for Image Analysis' new premises, Polacksbacken, building 2, south entrance (to the left), floor 1. Welcome!

*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. On average we have 3–4 dissertations per year. During 2006, we did not have any dissertations. This is very unusual but due to the fact that we during 2004–2005 had a total of 10 dissertations, so they are simply not evenly distributed over time.

Also this year CBA personnel received a scientific award; Hamed Hamid Muhammed was awarded the Benzelius prize from the Royal Society of Sciences in Uppsala. Ewert Bengtsson was elected member of the Royal Swedish Academy of Engineering Sciences, IVA. He will be active in Section VII, Basic and Interdisciplinary Engineering Sciences.

A big event this year was our move to new premises. Reorganisations within IT at UU had made room available in the main buildings where almost all IT-related research groups at UU are located and after much hesitation we accepted the proposal to move there. In October, we thus left the charming old wooden building where CBA has been located since 1992. The new premises have less charm but will suit our needs well and additionally offer the advantage of being closer to all other IT-related groups at UU.

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 cooperation partners are found locally as well as nationally and internationally. For a complete list of our 34 national and 28 international cooperation 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. The move to new premises makes it possible for us to realize an old ambition, to create a visualization lab. During 2006, we started our planning and fundraising for this and the work will continue next year.

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 and some is organized through the Dept. of Mathematics at UU.

During 2006, a total of 22 persons have been working at CBA as researchers, administrators or PhD students. Additionally, 12 Master thesis students have finished their thesis work at CBA. This does, however, not mean that we have had $22 + 12$ 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 sum up the time spent at and working for CBA, we had the equivalent of about 15 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 was President of the Swedish Society for Automated Image Analysis (SSBA) until March 2006, 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.

Ingela Nyström was in September 2006 appointed Director of UPPMAX, the Uppsala Multidisciplinary Center for Advanced Computational Science, a part time position. As a consequence of this our administrator Lena Wadelius is also taking care of UPPMAX administration. We hope this may lead to increased use of high performance computing in our work in the future. Lucia Ballerini who was a visiting researcher at CBA for a number of years became docent of Computerized Image Analysis at CBA, UU.

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/AR06html/

## 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 and forestry. Since a large portion of our work deals with images with at least 3D, the research in graphics and visualization that is also part of CBA finds direct applications in our own work.

We also used to have substantial activity in remote sensing but were not able to obtain funding to replace the position held by Tommy Lindell after his retirement. He still runs a few projects but the activity is much lower than earlier. During 2006, we have had discussions with the Faculty of Science and Technology at UU about the possibility of moving the research in Geoinformatics to CBA and thus reviving the remote sensing. Hopefully, that will lead to some favourable decisions during 2007.

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, twelve Master thesis projects were completed with supervision from CBA. They covered a wide range of topics. Some projects were related to our own research while other were trying to solve problems for industry or in biomedical research, in a few of the cases the results were directly applied in new products or services. In Section 3.2, we give a presentation of the different master thesis projects.

In addition to this, our PhD students and senior researchers worked on 33 different projects as described in Section 5. In the rest of this section, we will briefly outline the different projects we have been involved with. The order follows roughly that of Section 5 and is somewhat arbitrary although we have tried to group similar projects under headings that roughly describe our different research areas starting with more theoretical work before moving on to more applied. Some projects could fit under several headings though. It is also worth noting that the projects do not cluster according to host university, there are researchers from both universities active in almost all our research areas.

### 1.2.1 Theory: discrete geometry, volumes and fuzzy methods

Our long standing work based on distance transforms and related algorithms continues, it is now mainly focussed on volume images. Robin Strand is studying distance transforms and skeletons in multi-dimensional images with more general tesselations than the common cubic one. He is PhD student at CBA funded by the Graduate School in Mathematics and Computing (FMB) at UU. Gunilla Borgefors is also main supervisor for Erik Melin who is PhD student at the Dept. of Mathematics at UU funded by the FMB. And she is assistant supervisor to Hania Uscka-Wehlou also at Dept. of Mathematics, UU. Mathematics Professor Emeritus Christer Kiselman is assistant supervisor to these students.

By representing objects in a fuzzy rather than crisp, binary way several advantages can be obtained, albeit at the expense of increased complexity. We have been studying how to obtain more precise measurements, shape decomposition methods and methods for defuzzification which can give representations with increased resolution. By grey-weighting distance measures similar advantages can be obtained as with some fuzzy approaches and visiting researcher Céline Fouard has together with PhD student Magnus Gedda compared diffferent such measures. Also Stina Svensson looked at the possibility of improving the HCMA algorithm by adding grey-weighting. Joakim Lindblad and Ingela Nyström are also active in this area.

Although hardly a theoretical project, our long term effort of developing a well functioning general image analysis platform to be used for our research and teaching is mentioned under this heading since it is non-application specific. That project has gone on also this year with about 30% of Bo Nordin's time.

### 1.2.2 Analysis of microscopic biomedical images

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. Also in this area there is a strong trend towards 3D images with corresponding need for 3D algorithms.

A large part of our work deals with fluorescent light microscopy images, where we develop methods to detect and resolve signals from single molecules and to segment the images to find out from what structures the signals comes. Carolina Wählby has with joint appointments at CBA and the Rudbeck Laboratory at UU been a key-person in this work. The work has during the year received new funding from EU through the ENLIGHT project. Students Amalka Pinidiyaarachchi, Milan Gavrilovic and Amin Allalou has also been active in this area.

The studies of single molecules is carried to an even higher resolution level, voxel sizes around 2 nm, through our work on cryo-electron tomography images. Here, Stina Svensson and PhD student Magnus Gedda is working to recognize, decompose and analyse the shape of proteins. The work is funded by the Swedish Research Council, *Vetenskapsrådet* (VR).

In another VR funded project in collaboration with Carina Johansson at Örebro University, we are developing methods for evaluation of the integration of bone implants. Here, micro CT is a promising new imaging technique. This work is carried out by our new PhD student Hamid Sarve.

Muscle cells are the largest cells of the body and each cell can have many nuclei. The spatial distribution of these nuceli is of interest for understanding the function of the cells and some diseases, but this has previously not been studied in real 3D images. With new funding from VR PhD student Patrick Karlsson and Joakim Lindblad have recently started work on this in cooperation with the Dept. of Neuroscience at UU.

### 1.2.3 3D analysis and visualization

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. In addition to our work on microscopy as described in the previous paragraphs, we are also working more generally on visualization and interaction methods and on medical application for this. We are currently planning to expand our activites in this field by creating a visualisation lab.

Bengtsson has for several years had a 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. One of his projects deals with collaborative 3D visualization, another one with the visualisation of multivariate volume data. He has also carried out a more special project on realistic rendering of ice.

In another group of projects, we are exploring the use of haptic interaction as an added information channel in 3D medical data exploration. So far MR angiographic data, CT data from the liver, and dynamic breast MR data have been used. Ingela Nyström is heading this project with PhD students Erik Vidholm and Suthakar Somaskandan.

### 1.2.4 Forestry related applications

In addition to the biomedical field, our main application area is the forest industry. 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.

Micro CT techniques by synchrotron radiation provides new kinds of images of paper and composite materials and offer many challenging problems. PhD students Maria Axelsson and Filip Malmberg are working on this. We have also received S-faculty funding for a new assistant professor position in this field which is held by Joakim Lindblad. Before starting on this project Lindblad developed an image analysis tool for evaluating seed vitality.

In another project, we are studying the possibility of using image analysis in the saw mills, to improve the quality of the products. PhD student Kristin Norell has initially concentrated on images of log ends to find the annual ring centre (pith) and the annual ring density and to detect rot and blue stain. The project is made very hard due to the poor image quality obtainable under realistic production conditions.

### 1.2.5 Remote sensing

When CBA was founded, remote sensing was one of the main work areas. Currently, there is unfortunately very limited activity in remote sensing and geoinformatics. Tommy Lindell has in spite of his retirement a few years ago collected ground data for a remote sensing project in the arctic region and he has also explored some new camera techniques for data collection. We are actively trying to convince the TN-faculty at UU that we should receive resources to rebuild activity in this area of great and increasing interest in society.

## 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 versions), 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.

Centre for Image Analysis (Centrum för bildanalys, CBA) can be contacted in the following ways:


| | |
|---|---|
| *Visiting address:* | Lägerhyddsvägen 2<br>Polacksbacken, building 2, floor 1<br>Uppsala |
| *Postal address:* | Box 337<br>SE-751 05 Uppsala<br>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 22 at the end of 2006. If we sum up the time spent at CBA, we had the equivalent of about 15 full time full year persons. About two thirds of us belongs to UU, the other third to SLU. 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 2006 was 13.8 million SEK which is about 13% increase from the level the three previous years. A bit more than one third, 35%, comes from UU, somewhat less than one third, 31%, from SLU, and the last third from external sources. 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 took place to give us our present constitution. We are now a joint University entity (due to administrative rules, we cannot 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. CBA 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. During 2006, the board members were:

- Ewert Bengtsson TN-faculty UU
- Christer Kiselman TN-faculty UU
- Håkan Ahlström Faculty of Medicine UU
- Raili Raininko deputy UU
- Gunilla Borgefors S-faculty SLU
- Johan Fransson S-faculty SLU
- Lennart Norell Faculty of Natural Resources and Agricultural Sciences SLU
- Mats Nylinder deputy SLU
- Anders Andersson TCO
- Olle Eriksson SACO

During 2005, there was an administrative review of all centres at UU and as a result of this some minor changes of the CBA constitution were to be negotiated during 2006. The mandate for the present board ended at the end of 2006. Unfortunately, the new constitution has not yet been negotiated so the new year starts with a formally unclear situation. We do not expect that this will cause any serious problems though and hope to have the new constitution in place during spring 2007.

The executive management of CBA rests with a Director, appointed by UU, who also serves as Chairman of the Board. During 2006, Prof. Ewert Bengtsson served as Director and Dr Olle Eriksson served as deputy Director.

## 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, most of which 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 2006. 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 13.8 million SEK for 2006. The total cost was 12.1 million SEK, the surplus was mainly project money that is reserved for the next year. But for the first time in several years also our small operational budget showed a small surplus. 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 the funding from SLU has increased by 1.3 million SEK, a big part of that increase was a new position as Assistant Professor (forskarassistent) that we were rewarded. There has also been an increase in grants from the Swedish Research Council with about a million SEK, but at the same time a decrease in other grants of about half a million SEK. The percentage of research financed from outside sources is about 33%, 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 about 13% higher than the three previous years. The major costs are for personnel (salaries). The equipment cost is rather low even though we have been reneweing our computer equipment during the year. But those investments are depreciated over five years and also led to decreased maintenance costs.

A big event during last year was that we during October moved from the old wooden building, where we have been located since 1992 into new premises in the same large building as the IT-department of UU. The new premises has less character and charm than the old, but there are also advantages being located closer to other IT-based research groups. The new premises will have a somewhat higher rent but we will also get more funds to cover the rent so the move is not expected to have any major influence on our economy. The move will also make it possible to create a new visualization lab.

Table 1: CBA income and costs for 2006.

| **Income** | | **Costs** | |
|---|---|---|---|
| UU | 3999 | Personnel | 6962 |
| SLU | 4243 | Equipment | 184 |
| UU graduate education | 793 | Operating exp. 4) | 2487 |
| SLU undergraduate education | 0 | Rent | 1041 |
| Governmental grants 1) | 3171 | University overhead | 1389 |
| Non-governmental grants 2) | 670 | | |
| Contracts 3) | 948 | | |
| Financial netto | 31 | | |
| **Total income** | **13855** | **Total cost** | **12063** |

1) Sw. National Space Board, The Swedish Research Council, SIDA

2) Research foundations

3) Internal invoices and compensations

4) Including travel and conferences

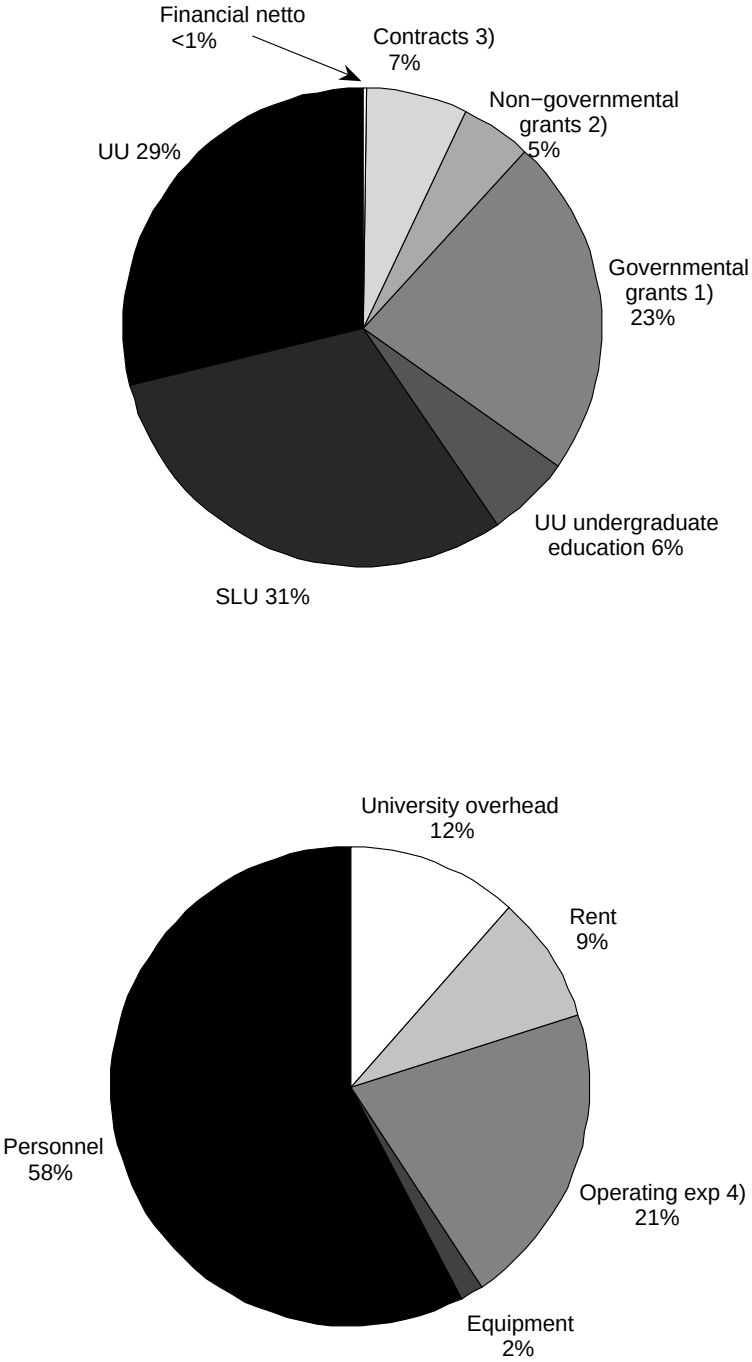



Figure 1: CBA income (top) and costs (below) for 2006.

## 2.3 Staff

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

Maria Axelsson, Graduate Student, SLU
Milan Gavrilovic, Research Assistant, 1204–
Magnus Gedda, Graduate Student, UU
Patrick Karlsson, Graduate Student, UU
Joakim Lindblad, Researcher, 0501–, UU
Tommy Lindell, Docent, PhD, (part time) UU
Filip Malmberg, Graduate student, 0213–, SLU
Bo Nordin, Researcher/Lecturer, PhD, (part time) UU
Kristin Norell, Graduate Student, SLU
Ingela Nyström, Docent, PhD, (part time) UU
Amalka Pinidiyaarachchi, Graduate Student, (part time) UU and University of Perodeniya, Sri Lanka
Hamid Sarve, Graduate student, 0320–, SLU
Stefan Seipel, Professor, (part time 20%) UU and University College of Gävle
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
Lars Winkler Pettersson, Graduate student, 1016–, UU
Carolina Wählby, Researcher, PhD, (part time) UU

Lena Wadelius, Administration

Master Thesis students:
Amin Allalou, Anders Berggren, Åsa Berglund, Tomas Björklund, Daniel Fransson, Qing Gu, Petter Holmberg, Jonas Jämtberg, Mikael Lönnberg, Filip Malmberg, Björn Nilsson, Carl Johan Otterheim, Jesper Renck, Olena Tankyevych, Per Uddholm, Yao Wang, 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 an appreciated course in basic image analysis. However, in 2006 the course was cancelled due to too few applicants. We took the opportunity to adjust the course according to the Bologna proposition. Now, the course fits better with a number of educations and should then attract more students in the future.

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. Twelve were completed during 2006.

## 3.1 Undergraduate Courses

1. **Calculus of several variables (Analys MN2), 10p**
   Robin Strand
   *Period:* 0601–05
   *Comment:* 18 problem sessions.

2. **Software architecture with Java, 5p**
   Olle Eriksson
   *Period:* 0601–03

3. **OOP with C++, 5p**
   Bo Nordin
   *Period:* 0603–05
   *Comment:* Distance course: C++ programming, 3rd course

4. **Programming techniques 1, 4p**
   Maria Axelsson
   *Period:* 0603–06
   *Comment:* Teaching $32 \times 2$ hours of laborations in Java and correction of home assignments and projects in one group of students.

5. **Scientific programming, 5p**
   Olle Eriksson
   *Period:* 0603–05

6. **Computer assisted image analysis MN1, 5p**
   Magnus Gedda, Patrick Karlsson
   *Period:* 0603–05
   *Comment:* Hamid Sarve was teaching the computer exercises.

7. **Advanced computer graphics and visualization, 5p**
   Ingela Nyström, Erik Vidholm
   *Period:* 0603–06
   *Commment:* New course Spring 2006. Stefan Seipel, Daniel Wesslén, and Mats Lind giving guest lectures.

8. **Computers and programming TDB2, 5p**
   Kristin Norell
   *Period:* 0604–06
   *Comment:* Distance course: C++ programming, 2nd course

9. **Computers and programming TDB1, 5p**
   Bo Nordin
   *Period:* 0609–11

10. **Computer graphics, first course, 5p**
    Ingela Nyström, Erik Vidholm
    *Period:* 0610–12
    *Comment:* Teachers: Ingela Nyström (responsibility), Erik Vidholm, Patrick Karlsson, Anders Hast, Filip Malmberg (computer exercises)

11. **Programming techniques 2, 4p**
    Olle Eriksson
    *Period:* 0610–12

12. **Computers and programming TDB2, 5p**
    Bo Nordin
    *Period:* 0611–0701

## 3.2 Master theses

1. **3D live-wire: Semi-automatic segmentation of volume images in a haptic environment**
   *Student:* Filip Malmberg
   *Supervisor:* Ingela Nyström
   *Subject supervisor:* Ewert Bengtsson
   *Publisher:* CBA Master Thesis 82
   *Abstract:* In computerized image analysis, most applications require the images to be segmented into objects of interest at some stage in the process. Segmentation is a difficult task, and sometimes it is not possible to achieve a good segmentation using automatic methods alone. In such cases, it might be necessary to utilize interactive, semi-automatic methods.

   As volume images become increasingly common there is a need to extend existing image analysis tools to also handle 3D images. Segmenting volume images with interactive methods is difficult, mainly because efficient interaction with a 3D image is much harder to achieve than interaction with 2D images. We have used a system that uses stereo graphics and haptic feedback to facilitate efficient 3D interaction.

   We propose a new method, based on the 2D live-wire method, for segmenting volume images. Our method consists of two parts: an interface for drawing 3D live-wire curves onto a surface in a volume image, and an algorithm for connecting two such curves to create a surface. We also discuss some problems encountered with our method, and possible ways of solving them.

2. **Non-contact quality measurements of open die forging – development of a laser triangulation system**
   *Student:* Björn Nilsson
   *Supervisor:* Jan Wipenmyr, IMEGO AB, Göteborg
   *Subject supervisor:* Gunilla Borgefors
   *Partner:* IMEGO AB, Göteborg
   *Publisher:* CBA Master Thesis 83
   UU School of Engineering, UPTEC F06 002
   *Abstract:* A demo system for non-contact measurements of dimensions on open die forging has been developed by IMEGO AB, Göteborg and SINTEF, Olso, on comission of the steel industry companies: Scana Steel Björneborg AB, Uddeholm Tooling AB and Sandvik Materials Technology AB.

   The concept for the demo system is based on the principle of triangulation for measuring and composing cross-sections of wrought-iron goods. When used for reference measurements the system has proved to be accurate with millimetre precision.

   In this thesis, software for collecting and processing of measurement data have been proposed and integrated into two graphical user interfaces. One program was developed for presentation purposes and one for management of measurements.

3. **An optical character recognition method for an automatic number plate recognition application applied to Swedish number plates**
   *Student:* Johan Östrand
   *Supervisor:* Pär Dahlund, KFG AB, Sandviken
   *Subject supervisor:* Patrick Karlsson
   *Partner:* KFG AB, Sandviken
   *Publisher:* CBA Master Thesis No. 84
   UU School of Engineering, UPTEC F06 026
   *Abstract:* The use of automatic number plate recognition (ANPR) is crucial in many traffic surveillance applications. One step in an ANPR application is the optical character recognition (OCR) where a computer interprets images of characters as text. This master thesis presents an OCR method for an ANPR application on Swedish number plates. In this application the assumption is made that the position of the number plate in the image is known. Character recognition was achieved by applying template matching on the greylevel of the original image. The method was implemented and tested on 217 images from nine datasets with different characteristics. The percentage of correctly read number plates, assuming a standard number plate context, i.e., three letters and then three digits, was 48%. When not assuming a standard number plate context, i.e., including the letters Å, Ä and Ö and allowing 2 to 7 characters, the accuracy was 24%. Some characters were found to be difficult for the method to differentiate between when using a standard number plate context, e.g., 6, 5 and 8, D and O, and F and E. When not assuming standard number plate context also the character sets A and Ä and, D, O and 0 were hard for the method to separate.

4. **Automatic camera-surveillance of the dried river-bed for increased public safety**
   *Student:* Jesper Renck
   *Supervisor:* Daniel Nordgren, Vattenfall Utveckling AB
   *Subject supervisor:* Gunilla Borgefors
   *Partner:* Vattenfall Utveckling, Älvkarleby
   *Publisher:* CBA Master Thesis No. 85
   UU School of Engineering, IT 06 016
   *Comment:* In Swedish
   *Abstract:* This thesis was partly aimed at surveying possible applications for image analysis within hydropower and partly to designing and developing a prototype for one application. The survey shows that, for most of the propositions, the need is too small compared to the possible failure rate of the advanced technical equipment. From the eleven evaluated proposals one of them, automatic camera-surveillance of the dried river-bed for increased public safety, was selected for further work. The further work included a preliminary study which led to a specification for the system. This study found that the risks where not very high but that surveillance could be motivated for 23 of Vattenfall's 53 hydropower plants. After this a prototype was developed, based on segmentation of movement in the image-sequence, analysis of the movements based on shape, size and speed were used to separate movement of interesting objects from movement in background of the scene. The evaluation of the system shows the performance for a few representative test-cases. The result is well acceptable under good to medium light conditions and normal visibility. The algorithm detect and track the interesting object both moving and when standing still. False alarms appear but are few and mainly appear in connection with the interesting object.

5. **Image segmentation for Alcro colouring program/Becker's Painter**
   *Student:* Carl Johan Otterheim
   *Supervisor:* Caroline Staedler, MRM Worldwide, Stockholm
   *Subject supervisor:* Gunilla Borgefors
   *Partner:* MRM Worldwide, Stockholm
   *Publisher:* CBA Master Thesis No. 86
   UU School of Engineering, UPTEC IT 06 029
   *Comment:* In Swedish
   *Abstract:* Image analysis is a topic of ever growing popularity around the globe. Nowadays it affects not only corporations using it within an economic interest, but also the average user who for example uses a digital camera. Object segmentation is the process of finding, outlining and extracting objects in an arbitrary digital image. This process can be done with a variety of tools, but most of the time these are too complicated for the inexperienced user to handle. The object of this master thesis work is to identify and implement a solution for segmenting an image and to be able to use the result with an already existing

application made by MRM Worldwide. The application is made to let users repaint areas of a house on a digital image. The solution identified requires a very small amount of interaction from the user to make it as easy as possible. The method is a combination of different techniques based on colour space projections and watershed segmentation combined with seeding information given by the user.

6. **Estimation of local fibre orientation in paper using steerable filters**
   *Student:* Per Uddholm
   *Supervisor:* Fredrik Rosén, STFI-Packforsk AB, Stockholm
   *Subject supervisor:* Gunilla Borgefors
   *Partner:* STFI-Packforsk AB, Stockholm
   *Publisher:* CBA Master Thesis No. 87
   *Abstract:* Steerable filters are evaluated as tools for determining the fibre orientation in paper. Filters due to Freeman and Adelson and to Jacob and Unser are presented and compared. Both are compared with a simple gradient filter. Several model fibre orientation probability distributions are compared. The effects of the filter parameters, e.g., filter order and filter kernel width are studied. The filters' noise properties and their ability to reproduce known (synthetic) fibre orientations are also investigated. In addition, the effect of the use of a rectilinear co-ordinate system, which introduces preferred directions, and the subarea size are considered. Steerable filters, as well as the gradient filter, seem to reproduce the fibre orientation angle well. Estimating the fibre orientation anisotropy is considerably more difficult, and requires careful calibration. Jacob and Unser filters are observed to have better noise properties than the gradient filter, while those of the Freeman and Adelson filter are inferior. Steerable filters, however, are much slower than the gradient filter. Some modifications to Jacob and Unser's original work is also suggested.

7. **Automated abdominal tissue segmentation of multicontrast magnetic resonance images**
   *Student:* Olena Tankyevych
   *Supervisor:* Joel Kullberg, Dept. of Oncology, Radiology and Clinical Immunology; Ingela Nyström
   *Subject supervisor:* Ewert Bengtsson
   *Partner:* Dept. of Oncology, Radiology and Clinical Immunology, UU
   *Publisher:* CBA Master Thesis No. 88
   *Abstract:* Abdominal fat tissue and liver volume are interesting in studies of many diseases, e.g. cardiovascular, diabetes, obesity. Although there have been only few works which developed automated or semi-automated abdominal tissue segmentation.

   Magnetic Resonance Imaging (MRI) is a medical imaging technology that provides rich information about soft body tissues. Properties of MRI can give complementary contrast information from the body tissues.

   Fuzzy c-means (FCM) clustering method assigns pixels of the image to different clusters according to their distance to the cluster centres in a feature space. But the original FCM does not utilize any spatial information for the segmentation, which is crucial in many cases, and especially in medical images.

   In this master thesis we have acquired different MRI sequences and combined them in order to form an intensity feature space for an unsupervised spatial and original FCM classification.

8. **Image analysis of current collectors**
   *Student:* Jonas Jämtberg
   *Supervisor:* Kjell Wallin, Sensys Traffic
   *Subject supervisor:* Ewert Bengtsson
   *Partner:* Sensys Traffic, Uppsala
   *Publisher:* CBA Master Thesis No. 89
   UU School of Engineering, UPTEC IT06 008
   *Comment:* In Swedish
   *Abstract:* The goal of this project was to develop a technology trial for automatic identification of current collectors on locomotives. The project was carried out at Sensys Traffic AB in Uppsala and Banverket. Sensys has developed KIKA on commission from Banverket. KIKA is a system that automatically detects damages using photographs of current collectors and reports them to the nearest control center. This project may in the future add automatic identification to KIKA's functionality. Identification is done by comparing the photographs of passing current collectors to a library of CAD-models of the same. In order to get the CAD-model in proper perspective the system is required to have good knowledge of the surrounding environment. The system is able to lock on to a current collector and calculate a fidelity value in about 40 seconds.

9. **Skanner som detektionsinstrument**
*Student:* Mikael Lönnberg
*Supervisor:* Dept. of Physical & Analytical Chemistry, UU
*Subject supervisor:* Ewert Bengtsson
*Partner:* Surface Biotechnology, Dept. of Physical & Analytical Chemistry, UU
*Publisher:* CBA Master Thesis No. 90
*Comment:* In Swedish
*Abstract:* En bildskanner kan kvantifiers mängden svärta på en mätyta och skapa en bild med ett numeriskt värde för varje pixel. Detta kan användas för att mäta svärtningsstyrkan i detektionszonen på tunna membranbitar som bearbetas i immunokromatografiska tester. Ett bra detektionsinstrument ska bestämma svärtingsstyrkan med god mätprecision och ha tillräcklig känslighet för att urskilja en knappt synlig svärtning i detektionszonen.

I detta examensarbete identifieras skanneregenskaper och mätförhållanden som påverkar resultatet av mätningarna. Prestanda för tre olika skannrar i varierande prisklass har jämförts och optimala mätbetingelser har utarbetats. Skannrar som används med noga uppstyrd mätprocedur fungerar utmärkt som detektionsinstrument. Samtliga skannrar uppvisar en mätprecision på mindre än en procent i variationskoefficient vid mätning av svagt synliga ljusgrå band.

10. **The impact of NEQ on detectability of microcalcifications in mammography**
*Student:* Åsa Berglund
*Supervisor:* Mats Danielsson, Sectra Imtec AB
*Subject supervisor:* Carolina Wählby
*Partner:* Sectra Imtec AB, Kista
*Publisher:* CBA Master Thesis No. 91
UU School of Engineering, UPTEC F06 063
*Abstract:* In mammography it is very important to be able to identify so called microcalcifications in the breast, since they may be an early sign of cancer. This work investigates how the visibility of microcalcifications is affected when certain parameters in the mammography system are changed.

An existing model of the Sectra MDM D40 system was further developed and verified against experimental measurements. Software was developed for simulating mammography images with microcalcifications, based on the system model. Different system settings were investigated to obtain the best system parameters for detection of 100 micrometer microcalcifications.

To evaluate the visibility of microcalcifications a human observer study was performed, and a mathematical model observer was implemented and compared to human performance.

The studies showed that increasing the slit width resulted in better visibility of the microcalcifications, if maximum dose was used for all slit widths. However, the clinical benefit has to be weighed against the dangers with increased dose to the patient. A slit width of around 100 micrometer is proposed as the best trade-off between image quality and patient dose.

The use of a micro focal spot results in somewhat better visibility, if the same dose as for the normal focal spot is achieved. But the time needed for the image acquisition then becomes so long that this approach is not recommended. Using a system with normal focal spot and narrower slit width results in the same visibility without increasing the scan time as much.

11. **Contour extraction and modelling of horses using background subtraction and active shape models**
*Student:* Petter Holmberg
*Supervisor:* Joakim Lindblad
*Subject supervisor:* Gunilla Borgefors
*Publisher:* CBA Master Thesis No. 92
*Abstract:* Anatomical information about horses can be extracted from still images, using markers placed on the horse and manual inspection of marker positions. However, it is a time-consuming process both to place markers and to extract coordinate data from them manually. It is therefore of interest to study if computerized image analysis can be used to extract the contour of horses from images taken without too strict limitations on the setup, and if contour features can be extracted and used to obtain reliable anatomical measurements, thereby reducing the amount of manual work needed to collect the data.

In this master's thesis, we propose a segmentation method based on background subtraction for finding the contour of horses (and other objects) with consideration to noise and shadows, and use active shape models

to locate and identify contour features. The methods are implemented as a MATLAB program. We also discuss problems and limitations of the methods, as well as possible future extensions of the project.

12. **Improved segmentation and classification of seeds**
*Student:* Yao Wang
*Supervisor:* Jan Luup, Maxx Automation AB
*Subject supervisor:* Ewert Bengtsson
*Partner:* Maxx Automation AB, Uppsala
*Publisher:* CBA Master Thesis No. 93
*Abstract:* Improvements on segmentation and classification of seeds were done for the automatic seed analyzer *Seedscanner2003* in both hardware and software aspects. The segmentation improvements were achieved by using a new plate as background which enables segmentation of seeds with various color ranges. Classification was based on 26 morphological, color, edge and texture features using Mahalanobis distance method. Features importance is analyzed. Cracked barley detection was accomplished using color and edge analysis. Wheat varieties discrimination issue was not successfully solved with several tested methods presented and discussed. The final experiments illustrate that a satsifactory high classification accuracy is achieved among all seed species included in the machine. Classification performance between wheat and triticale was greatly enhanced.

# 4 Graduate education

We had no exams at CBA in 2006. However, this is not unexpected since 2005 was a "year of harvest"; there were as many as six dissertations, four at UU and two at SLU. We gave one PhD course for our own students, while the application-oriented course for students in other areas that need basic knowledge about image analysis was at rest.

At the end of 2006, we were main supervisors for nine PhD students, six at UU and three at SLU. Another three at UU were being recruited. Borgefors is also assistant supervisor for two PhD students at Dept. of Mathematics, UU, and one PhD student at Dept. of Biometry and Engineering, SLU.

## 4.1 Graduate Course

1. **Recent Results in Pattern Recognition and Computer Vision, 3p**
   *Examiner:* Gunilla Borgefors
   *Lecturer(s):* Gunilla Borgefors, Ingela Nyström, participants
   *Period:* 20060419–0613
   *Description:* The content of the course was selected chapters from the book "Handbook of Pattern Recognition and Computer Vision," 3rd Edition, C. H. Chen and P. S. P. Wang, editors, World Scientific, 2005. The goal of the course was to widen the participants' knowledge in pattern recognition and computer vision. Examination was by presentation of one chapter and active attendence.
   *Comment:* 7 participants finished the course.

## 4.2 Dissertations

There were no dissertations at CBA in 2006.

# 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 Forest Sciences at SLU).

In this section, we list the 33 research projects that were active during 2006. 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 sixteen were completed since last year.

The list of projects is roughly grouped into image analysis theory; 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 cooperation partners outside CBA are.

As is obvious from the descriptions, most of the projects are carried out in close cooperation with researchers from other universities and from other research areas. In Section 5.2, we list the 28 international groups in 17 countries and 34 national groups with which we have had active cooperation in 2006.

## 5.1 Current research projects

**Theory: discrete geometry, volumes and fuzzy methods**

1. **Skeletonization in 3D discrete binary images**
   Robin Strand, Ingela Nyström, 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; David Brunner, Chemnitz University of Technology, Chemnitz, Germany
   *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. In general, the skeleton can not be both thin and fully reversible. We have been working on 3D skeletonization for the last decade.
   Topology preservation is guaranteed by removing only *simple points*. Usually, a condition based on the number of connected components in a small neighbourhood is considered to test whether a grid point is simple or not. Such a condition for grid points on the body-centered cubic (bcc) grid is presented and proven to be correct in the report *Simple points on the body-centered grid*, see 6.5.7. In the report, another condition for directional thinning is also proven to be correct. The condition is used to develop a directional thinning approach in *A high-performance parallel thinning approach using a non-cubic grid structure*, see 6.5.8. The resulting skeleton is a curve skeleton that is thin, but not reversible.

2. **Distance functions and distance transforms in discrete images**
   Robin Strand, Céline Fouard, Gunilla Borgefors, 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. The distance functions considered in this project (in contrast to Project 3) only depend on the positions of the grid points. During 2006, two kinds of *path-generated* distance functions are considered in this project. For

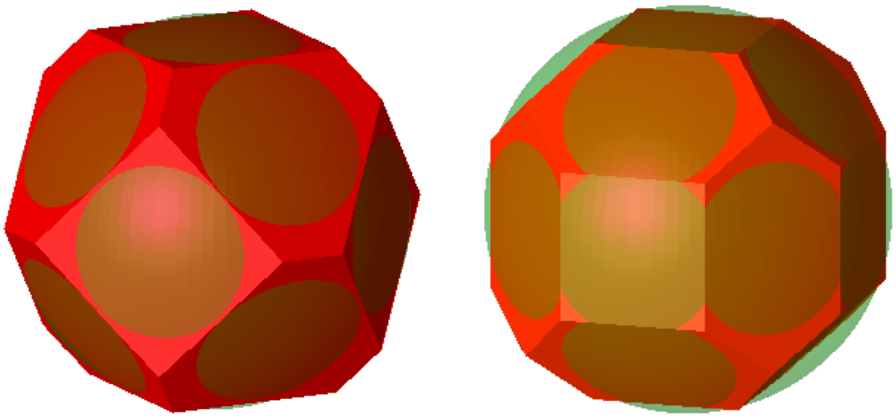


Figure 2: The asymptotic shape of balls when the optimal (the maximal absolute difference with a Euclidean ball is minimized) neighbourhood sequences are used for fcc (left) and bcc (right). Euclidean balls are shown to illustrate the error function that is used.).

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).

By combining weighted distances with distance based on neighbourhood sequences, a distance function with very low rotational dependency is obtained. Some theoretical results about such distance functions have been derived in two manuscript submitted for publication.

Weighted distance functions and distance transforms have been examined in a very general framework — modules and point-lattices, respectively. The paper describing these results has been accepted for publication in Pattern Recognition.

Distances based on neighbourhood sequences on the fcc and bcc grids, see Project 4, have also been examined. This research has resulted in a number of publications, see e.g. 6.3.9. The manuscripts include both results on the basic theory for such distance functions and "optimal" (minimizing the rotational dependency) neighbourhood sequences, see Figure 2.

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. In the DT obtained when using distances based on neighbourhood sequences, the distance values consitutes a layer-by-layer structure. The set of grid points having the same distance value constitutes a Jordan surface (or several Jordan surfaces). A Jordan surface separates the the set of grid points into two connected sets $A$ and $B$ such that $A$ is not connected with $B$. The DTs obtained when using distances based on neighbourhood sequences on the squre, cubic, bcc, and fcc grids are examined in *Generating distance maps with neighbourhood sequences*, 6.3.15.

3. **Comparison of gray weighted distance measures**
   Céline Fouard, Magnus Gedda
   *Funding:* SLU S Faculty; UU TN Faculty
   *Period:* 0601-
   *Abstract:* In several application projects we have discovered the benefit of computing distances weighted by the gray levels traversed, e.g., project 12. There are many ways of doing this, and in this project we have made a thorough comparison of the distances calculated with Gray Weighted Distance Transforms (GWDT) and the Weighted Distance Transforms On Curved Spaces (WDTOCS). A small example of shortest paths is found in Figure 3. The work was presented at Discrete Geometry for Computer Imagery (DGCI'06) and published in the proceedings from the conference. The next step is to do a through examination of the performance of the underlying algorithms in these calculations.

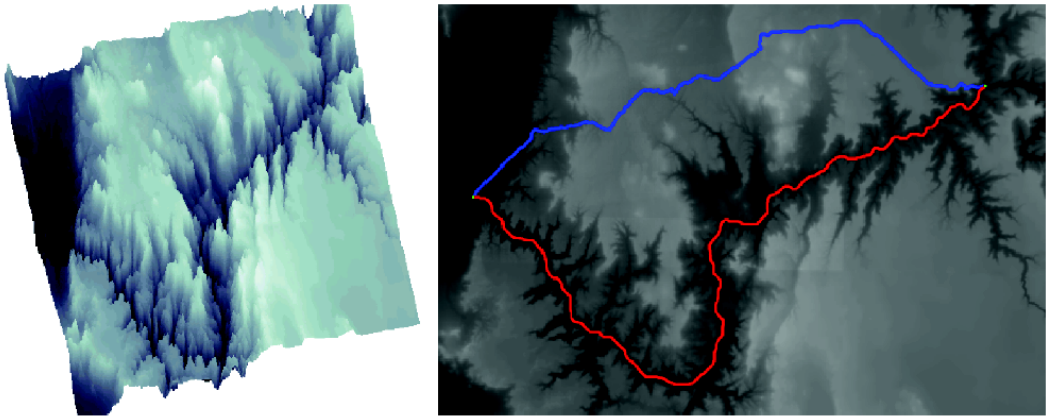


Figure 3: A height map of Grand Canyon, surface rendered (left) and with GWDT path (red) and WD-TOCS path (blue) overlaid (right).

4. **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; Peer Stelldinger, University of Hamburg, Germany; Benedek Nagy, Dept. of Computer Science, Faculty of Informatics, University of Debrecen, Debrecen, Hungary
   *Abstract:* The main goal of the project is to develop image analysis and processing methods for volume images digitized in non-standard 3D grids. 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. An image acquisition method, the *Direct Fourier method* has been developed for non-standard grids during 2006, see 6.3.14.
   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 fcc grid is a densest packing, meaning that the grid points are positioned in an optimally dense arrangement. The fcc and bcc grids are reciprocal, so the Fourier transform on an fcc grid results in a bcc grid. In some situations, the densest packing (fcc grid) is preferably in the frequency domain, resulting in a bcc grid in spatial domain. In some cases, the densest packing is prefered in the spatial domain.
   Some results about topology preserving digitization with the fcc and bcc grids were presented at IWCIA (see 6.3.13). The results show that especially the fcc grid is by far better than the cubic grid in this aspect. Other aspects of topology-preserving digitization on the fcc grid have also been examined, but are not yet published.

5. **Fuzzy shape analysis in 2D and 3D**
   Ingela Nyström, Joakim Lindblad, Gunilla Borgefors
   *Funding:* SLU S Faculty, UU TN Faculty
   *Period:* 0109–
   *Partners:* Nataša Sladoje (Matić), Faculty of Engineering, University of Novi Sad, Serbia;
   *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 and 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 a shape description can be achieved if the description is based on a fuzzy, instead of a crisp

shape representation, where the fuzzy membership of a point reflects the level to which that point belongs to the object.

During 2006, a manuscript on the representation and reconstruction of fuzzy disks by moments, containing derivation of theoretical error bounds for the accuracy of the estimation of moments of a continuous fuzzy disk from the moments of its digitization, as well as showing that, for a certain class of membership functions, there exists a one-to-one correspondence between the set of fuzzy disks and the set of their generalized moment representations, was accepted for publication in the Fuzzy Sets and Systems journal.

6. **Defuzzification of fuzzy segmented objects by feature invariance**
   Ingela Nyström, Joakim Lindblad, Stina Svensson
   *Funding:* SLU S Faculty, UU TN Faculty
   *Period:* 0301–
   *Partners:* Nataša Sladoje (Matić) and Tibor Lukić, Faculty of Engineering, University of Novi Sad, Serbia
   *Abstract:* This project concerns the development of a method for feature based defuzzification of spatial fuzzy sets. The developed method generates crisp shapes from fuzzy shapes by finding a crisp shape at a minimal distance to the fuzzy shape. We define the distance between two fuzzy sets as a distance between their feature-based representations in a chosen feature space. We have found it appropriate for defuzzification to incorporate both local and global features of the two sets. We have studied the use of membership values, gradient, area, perimeter, and centre of gravity in the distance measure. Several existing distance measures can be used to define the distance measure in the feature space. We have so far focused the research on Minkowski type distances measure.

   The defuzzification method was further developed during 2006. A method for generating the crisp discrete representation of a fuzzy set at an increased spatial resolution, compared to the resolution of the fuzzy set, was developed and presented at the IWCIA conference in June 2006. Additional refinement of the method was achieved by the use of a scale space approach, providing preservation of feature values over a range of scales in the defuzzification process. Initial results from such an approach, where area at a range of scales was used in the feature distance, were presented at the DGCI conference in October 2006. That presentation also included a practical implementation of the method for 3D data. An example of defuzzification of a 3D data set at increased resolution is presented in Figure 4.

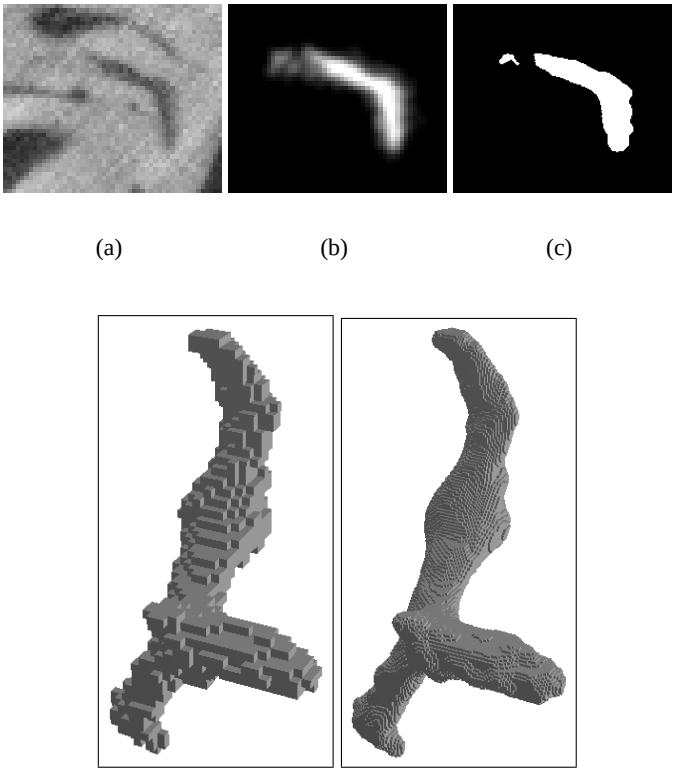
   Ongoing research regarding improvements of the optimization part of the method, as well as practical application of the defuzzification method to Cryo-ET data of proteins (see Project 12), was also undertaken during 2006.

7. **Decomposition of 3D objects**
   Stina Svensson, Magnus Gedda
   *Funding:* The Swedish Research Council (project 621-2005-5540); SLU S Faculty; UU TN Faculty
   *Period:* 9801–
   *Abstract:* Methods for decomposition of 3D discrete objects as well as grey-level representations of proteins (see Project 12) have earlier been developed at CBA. 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 fuzzy distance based hierarchical clustering of local maxima (see Project 3) with a region growing process to identify the parts of the fuzzy object. This approach shows promising results. An article describing the theoretical part of this work was accepted to Pattern Recognition Letters and available on-line during 2006.

8. **Hierarchical chamfer matching algorithm**
   Stina Svensson
   *Funding:* The Swedish Research Council (project 621-2005-5540); SLU S Faculty
   *Period:* 0601–
   *Partner:* Ida-Maria Sintorn, CSIRO Mathematical and Information Sciences, North Ryde (Sydney), Australia
   *Abstract:* Chamfer matching is a template matching method based on geometric image features and can be used for both 2D and 3D images. It finds good fits between the template and edges in a search image. A

generalized cost function between the edges in the search image and the template, a list of coordinate pairs corresponding to the searched pattern, is minimized. To guide the template to good positions, a distance transform (DT) is calculated from edges in the search image and the sum of the distance values hit by the superimposed template constitute the cost function. Translation, scaling, rotation, and perspective changes are for 2D images and translation, scaling, and rotation for 3D images. By embedding the chamfer matching in a resolution hierarchy (hierarchical chamfer matching algorithm, HCMA), the algorithm results in a fast, general and robust matching algorithm.

In this project, modifications of HCMA to even further improve its robustness are investigated. A first step is to use a distance weighted propagation of gradient magnitude (GM) as a cost image instead of the distance transform (DT) of a binarised edge image. The benefits are that no binarisation of the gradient magnitude image is needed, hence removing one step in the process and reducing the risk of loosing "true" match positions by a poor binarisation method. This approach, hierarchical chamfer matching based on propagation of gradient strengths (GM-HCMA), was presented at Discrete Geometry for Computer Imagery (DGCI'06) and published in the proceedings from the conference. GM-HCMA also applied in Project 12, showing good results.



(a) (b) (c)

(d) $d^{\Phi} = 0.02749$ (e) $d^{\Phi} = 0.01377$

Figure 4: Defuzzification of a bone region from a $\mu$CT volume image. Slice through the image volume (a). Slice through a fuzzy segmentation of the bone region in the image volume (b). Slice through a defuzzification, using meso-scale volume features of the fuzzy segmented object (c). 3D rendering of the $\alpha$-cut at smallest feature distance to the fuzzy object (d). 3D rendering of a high resolution defuzzification of the fuzzy segmented object (e). The values $d^{\Phi}$ below images (d) and (e) indicate the feature distance of the corresponding object to the original fuzzy image.

9. **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 was released during 2006.

## Analysis of microscopic biomedical images

10. **New objective quantitative analysis techniques for quantification of tissue regeneration around medical devices**
Gunilla Borgefors, Joakim Lindblad, Hamid Sarve
*Funding:* SLU, S Faculty, Swedish Research Council
*Period:* 0503–
*Partner:* Carina Johansson, Dept. of Clinical Medicine, Örebro University
*Abstract:* In order to evaluate how tissue reacts on implants, the interface between the implant and the tissue must be studied. Today, this procedure is done manually in a microscope.
The aim of this project is to develop automatized image analysis methods for analyzing images of the junction of tissue and implant. This method shall make the procedure more effective as well as giving an objective estimation.
The analysis involves segmentation of the images in different tissue-types and measurement of some relevant measures such as length, area and volume.
Before the analysis, methods that shall remove artifacts be applied. Differences in graylevels, color and possibly texture features will be used for the recognition. Known methods will be used to present the result. The interpretation of the values however, will not be done by the postgraduate student.
This project will result in a number of publications (at conferences and in technical and medical journals) about the new methods used as well as the resulting measurement.

11. **Analysis of skeletal muscle fibers in 3D images**
Patrick Karlsson, Ewert Bengtsson, Joakim Lindblad, Gunilla Borgefors
*Period:* 0603-
*Partners:* Anna-Stina Höglund, Jingxia Liu, Lars Larsson, Dept. of Neuroscience, UU
*Abstract:* The need for understanding of the three dimensional (3D) spatial arrangement of myonuclei in skeletal muscle fibers is great. A highly detailed 3D spatial description of the organization of myonuclei in healthy and diseased human muscle cells enables detailed understanding of the underlying mechanisms of muscle wasting associated with, e.g., neuromuscular disorders, and aging. The current poor understanding of the spatial arrangement of myonuclei is to be remedied by an interdisciplinary collaboration between the CBA and the Muscle Research Group (MRG) at UU. This project develops and evaluates methods for modeling and quantitative analysis of 3D distributions of myonuclei by utilizing the proficiency of modern confocal microscopic techniques to create true 3D volume images. Advanced computerized modeling of the elongated generalized cylinder structure of the imaged muscle cells is paramount in investigating the

myonuclear domain, i.e., each finite volume in which a myonucleus control the gene products. The complex topological conditions put on 3D models and measurement methods, compared to 2D equivalents, are a challenge in developing appropriate image analysis tools and algorithms. The project was presented with a poster presentation at “Medicinteknikdagarna 2006” in Uppsala.

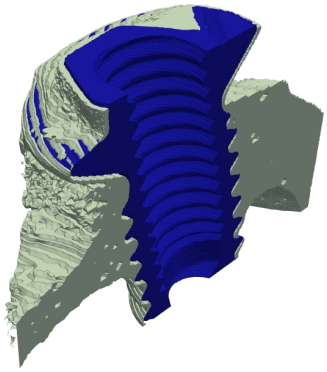


Figure 5: A 3D-rendering of a preliminary segmentation of the commercially pure titanium implant inserted in rabbit-tibia bone into implant (dark) and surrounding bone material (bright). The implant was imaged using SR$\mu$CT.

12. **Automated extraction of geometrical features of proteins from cryo electron tomographic data**
Stina Svensson, Magnus Gedda
*Funding:* The Swedish Research Council (project 621-2005-5540); SLU S Faculty; UU TN Faculty
*Period:* 0401-
*Partners:* Dept. of Cell and Molecular Biology (CMB), Karolinska Institute, Stockholm; Dipartimento di Energetica “S. Stecco” and Dipartimento di Fisica, Universitá di Firenze (UF), Florence, Italy; Laboratoire de Biophysique (LB), Statistique ITP/SB, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland, Medical Research Council Centre (MRCC), Cambridge, United Kingdom.
*Abstract:* State of the art imaging techniques makes it possible to study individual proteins and other macromolecules from a structural point of view. Descriptions with respect to geometry and shape facilitates studying protein dynamics. This type of study is essential to increase the understanding of their biological role. CMB has developed methods, using cryo electron tomography, for 3D imaging of individual proteins at a resolution of approximately 2 nm. Moreover, they have together with UF and LB developed methods for modelling protein dynamic based on the images. Fitting a model to each protein in the image has so far been done manually. For large-scale studies, computerized image analysis serves as an essential tool to automatically and objectively fit the protein model to image content. In this project, we develop methods to fill the gap between image and model and thereby make large-scale studies of the movement of proteins possible. We will develop methods for automatically extracting the geometrical features needed as input to the models. This will be done taking into account both grey-level information (which reflects the internal structure of the protein) and 3D shape information.

The first step in this process is to identify significant parts of the protein. 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. During 2006, a method, theoretically described in Project 7 was presented at The International Conference on Pattern Recognition (ICPR) and published in the proceedings from the conference. The method was applied the Immunoglobulin G (IgG) antibody imaged by Cryo-ET. The IgG antibody consists of three parts, the Fc stem and the two Fab arms, and has a volume of 1500 voxels in the given sampling. The parts are approximately equal in size. In some cases, the connection (hinge) between a Fab and the Fc stem is not visible due to the resolution. Example are shown in Figure 6.

The next step is to extract relevant geometrical features. This work was, for the IgG antibody, initiated during 2006 in cooperation with UF and LB. The features of interest are the interdomain angles and the translation of the domains with respet to each others.

Moreover, we have recently started to investigate another protein, namely the Met tyrosine kinase receptor. This is done in cooperation with with MRCC, UF, and LB. The Met protein controls growth, invasion,

| | | | | |
|---|---|---|---|---|
| Fc stem | 426 | 679 | 472 | 533 |
| Fab arm | 422 | 451 | 791 | 743 |
| Fab arm | 592 | 511 | 579 | 336 |

Figure 6: Surface renderings of the IgG antibody with Fc stem shown in red and the two Fab arms in yellow and orange. The volume is given in number of voxels. In the rightmost case, the hinge region is not visible but the connection marked out (lengths are 23Å and 30Å).

and metastasis in cancer cells and activating Met mutations predispose to human cancer. It has a unique biological role and is therefore of interest to study. In its mature form, Met consists of an extracellular $\alpha$ chain and a longer $\beta$ chain. The $\alpha$ chain and the first part of the $\beta$ chain folds to a $\beta$ *propeller* structure. This $\beta$ propeller region is sufficient for the binding to its ligand, hepatocyte growth factor / scatter factor (HGF/SF). The remaining part of the $\beta$ chain is called *stalk*, due to its stalk-like structure. The stalk is, for the moment, understood to hold the $\beta$ propeller in correct orientation for the ligand binding. To get a better understanding of the biology behind, a quantitative study of the flexibility of the stalk for Met. During 2006, we have, using an approach similar to the above described, developed a method for identifying the $\beta$ propeller and the stalk. Furthermore, we have extracted a representation, a *stalk curve* suitable for extracting geometrical features regarding its flexibility. This work is described in a manuscript late 2006.

To find structures of interest in Cryo-ET data, a matching algorithm can be used. During 2006, an algorithm — Hierarchical chamfer matching based on propagation of gradient strengths (GM-HCMA) — was developed, see Project 8, and tested on Cryo-ET data of the IgG antibody. A template created from the Protein Data Bank was used. The results are illustrated in Figure 7. The work was presented at Discrete Geometry for Computer Imagery (DGCI'06) and published in the proceedings from the conference.

Figure 7: Results when using GM-HCMA to find IgG antibodies in Cryo-ET data. The figure shows the used template (top) and positions found by GM-HCMA (bottom), all corresponding to true IgGs except the rightmost (found object in yellow, template in blue).

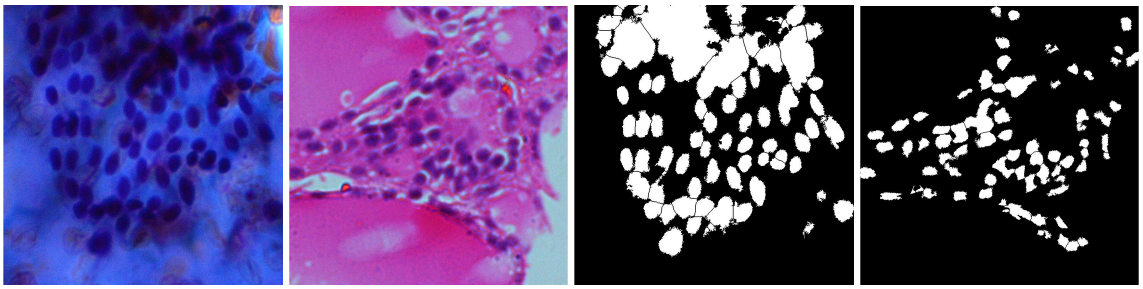


Figure 8: Segmentation result after applying seeded watershed segmentation method. The initial segmentation is based on the RGB color space.

13. **Segmentation and analysis methods for cytology**
    Amalka Pinidiyaarachchi, Carolina Wählby, Ewert Bengtsson
    *Funding:* SIDA
    *Period:* 0605–
    *Partner:* N. Rantatunga, Dept. of Pathology, University of Peradeniya, Sri Lanka
    *Abstract:* In many biomedical applications quantitative measurements of stained nuclei of both cytological and histological samples are used in aid of decision making by the expert. The digital images produced in such processes are in color and segmentation of specific regions of such images is an area that has been widely studied. A project is carried out in collaboration with the Dept. of Pathology, Faculty of Medicine, University of Peradeniya, Sri Lanka where thyroid smear samples are expected be analyzed. The image processing goal to be achieved is the development of successful color image segmentation methods. This involves tests in different color spaces, selection of a good segmentation method and dealing with heavily clustered cell nuclei segmentation. The biological goal in the study is to use the methods effectively in extracting various features of cell nuclei that can be used in expert decision making process. Figures 8 shows two sample images and the intermediate segmentation results after initial segmentation using color information followed by seeded watershed transform. Extensions of watersheds to color images where color gradient measures and statistical comparison with neighborhood are used are to be tested on the images in further studies.

14. **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, SIDA
    *Period:* 0305–
    *Partners:* Malin Jarvius, Chatarina Larsson, Mats Nilsson, Ola Söderberg, and Irene Weibrecht, 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.

15. **Image based measurements of single cell mtDNA mutation load and evaluation of cytplasm segmentation**
    Carolina Wählby, Amin Allalou
    *Period:* 0608–
    *Funding:* EU-Strep project ENLIGHT (ENhanced LIGase based Histochemical Techniques)
    *Partners:* Anton K. Raap, Frans M. van de Rijke, Roos Jahangir Tafrechi, Dept. of Molecular Cell Biology, Leiden University Medical Center, The Netherlands; Visiopharm, Hørsholm, Denmark
    *Abstract:* Cell cultures as well as cells in tissue always display a certain degree of variability, and measure-

ments based on cell averages will miss important information contained in a heterogeneous population. An automated method for image based measurements of mitochondiral DNA (mtDNA) mutations in individual cells has been implemented. The mitochondria are present in the cell's cytoplasm, and each cytoplasm has to be delineated. Three different methods for segmentation of cytoplasms were compared and it was shown that automated cytoplasmic delineation can be performed 30 times faster than manual delineation, with an accuracy as high as 87%. The final image based measurements of mitochondrial mutation load were also compared to, and showed high agreement with, measurements made using biochemical techniques. The development of image based single cell analysis will continue to be in focus in the ongoing ENLIGHT project. See also Figure 9.

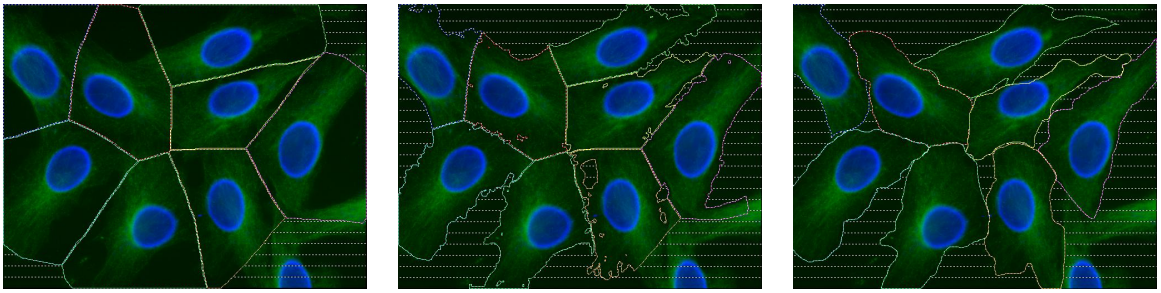


Figure 9: Result of cytoplasmic segmentation not making use of the cytoplasmic stain (left). Result when cytoplasmic stain is included (middle). Result from manual segmentation of the cytoplasm (right).

16. **Quantification and localization of colocalization**
    Milan Gavrilovic and Carolina Wählby
    *Period: 0611–*
    *Funding: EU-Strep project ENLIGHT*
    *Abstract:* In fluorescence microscopy, during acquisition of multiply labeled specimen, two or more of the emission signals can often be physically located in the same area or very near to one another in the final image due to their close proximity within the microscopic structure. This effect is known as colocalization. Since red and green wavelengths are usually selected, if spectral overlap occurs, these two wavelengths will appear as yellow emission. Existing methods for quantification and localization of colocalized pixels have been implemented and compared. At the same time work has been initiated on development of new methods based on spectral decomposition of reference spectra.

17. **Analysis of random array data**
    Carolina Wählby
    *Funding:* Uppsala BioX
    *Period:* 0501–
    *Abstract:* Nilsson *et al.* are developing new methodism 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. Blobs are 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 simultaneus identification of many different types of DNA fragments, transcripts, and proteins. The position of the reaction sites of a random blob array are random. In order to classify the blobs, they are first detected by a combination of filtering and morphological operations. Methods based on spectral decomposition are therafter used for blob classification.

## 3D analysis and visualization

18. **Improved interactive medical image analysis through haptic display methods**
Erik Vidholm, Ewert Bengtsson, Ingela Nyström, Stefan Seipel, Filip Malmberg
*Funding:* Swedish Research Council, UU TN Faculty
*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.
Our current applications are interactive liver segmentation from CT images, see Project 19, accelerating the computation of 3D gradient vector flow fields, see Project 22, and hardware assisted visualization of breast MR images, see Project 20. In additon to this, we are working on haptic interaction with 3D deformable surface meshes and 3D Live wire from a more theoretical point of view.

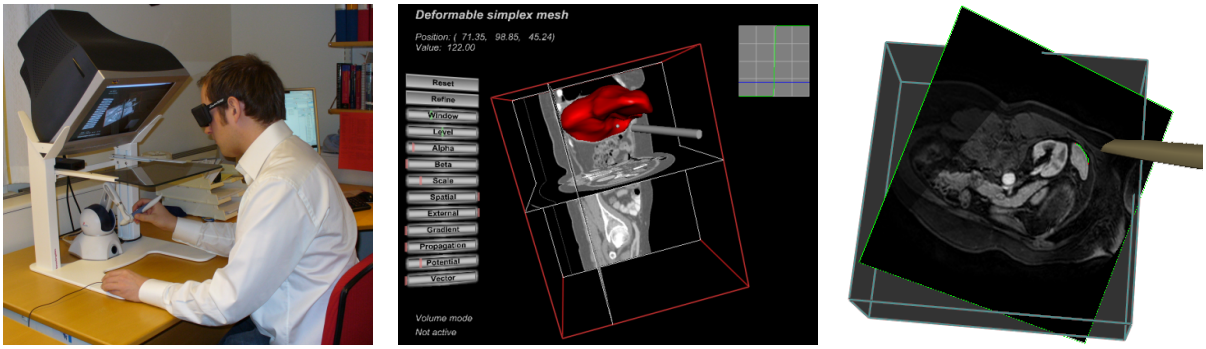



Figure 10: A user working with the haptic display (left). A screenshot from the deformable model application (middle). A screenshot from the 3D live-wire application (right).

19. **Interactive liver segmentation from CT images**
Erik Vidholm, Ingela Nyström, Ewert Bengtsson
*Funding:* Swedish Research Council, UU TN Faculty
*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 develop interactive methods for segmenting the liver from CT scans of patients with neuroendocrine tumors. Liver segmentation is of importance in hepatic surgery planning, where it is a first step in the process of finding vessels and tumours, and the classification of liver segments. Liver segmentation may also be useful for monitoring patients with liver metastases, where disease progress is correlated to enlargement of the liver.

We have used the fast marching algorithm, where haptics is used 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, i.e., the method has high precision. The

results from this project was presented at Medical Image Computing and Computer Assisted Intervention (MICCAI'06) in October. The next step is to verify the accuracy of the method.

20. **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 visualizing 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 visualization and evaluation. The project started during Bengtsson's sabbatical at the University of Queensland in 2004–2005 and continued as a joint project after his return to CBA. In September 2006, Erik Vidholm was visiting Andrew Mehnert at the department in Brisbane.

During 2006, we have developed a program where the 4D dataset is visualized with hardware accelerated maximum intensity projection (MIP) in the hue-saturation-value (HSV) colour space. The program also allows for drawing regions of interest.

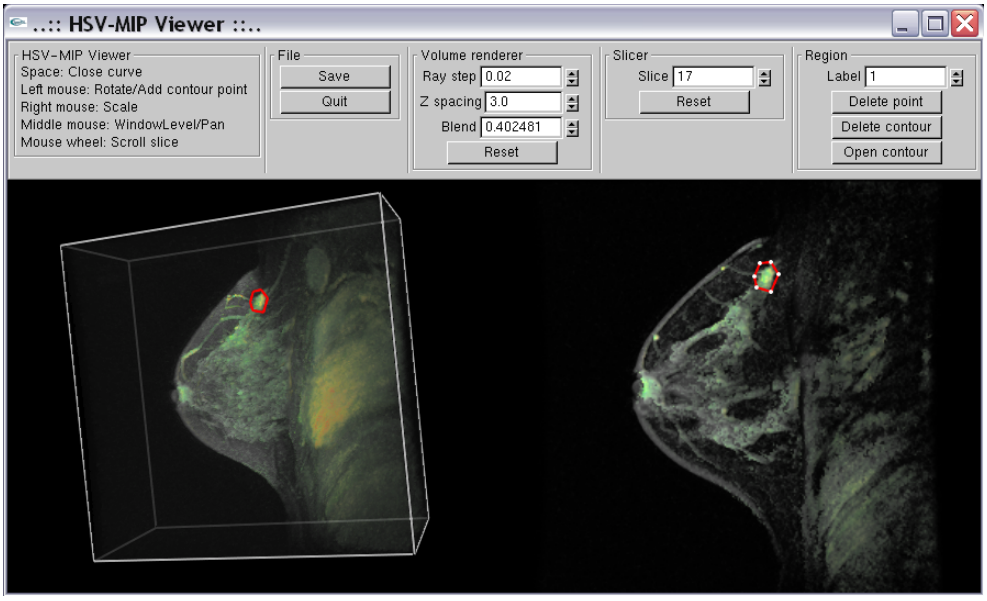



Figure 11: Screenshot from the visualization program. The uptake of MR contrast medium over time in each voxel of the breast volume images is converted to a colour coded MIP (left viewport), which can be rotated and explored dynamically giving a direct overview of points of interest, where there is a potential small malignant lesion. It is also possible to browse the slices of the color volume and to draw contours defining regions of interest (right viewport).

21. **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.

22. **Accelerating the computation of 3D gradient vector flow (GVF) fields**
Erik Vidholm, Ingela Nyström, Ewert Bengtsson
*Funding:* Swedish Research Council, UU TN Faculty
*Period:* 0508–
*Partner:* Per Sundqvist, Dept. of Information Technology, UU
*Abstract:* In our work on interactive 3D segmentation, see Project 18, we have developed 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 were presented at the International Conference on Pattern Recognition (ICPR'06) in August.

23. **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. Since then another book chapter and a few reviewed conference papers have been produced.

24. **Real-time rendering of ice**
Stefan Seipel
*Funding:* UU TN Faculty
*Period:* 0603–0608
*Comment:* Anders Nivfors (MSc student) is a cooperation partner.
*Abstract:* Ice is a common phenomenon in nature and occurs in our everyday surroundings in form of e.g. icicles and ice cubes. The rendering of ice is, however, a field of real-time computer graphics that has not been subject to exhaustive research. Realistic rendering of natural phenomena in real-time has always

been one of the most difficult tasks. As a result of this there are numerous papers describing techniques to implement fire, smoke, clouds, fog, water etc, but ice seems to be all ignored. In this project we identify the most eye catching characteristics of ice and what distinguishes ice from similar materials such as glass. The main focus of the project is to develop a method for rendering ice and its most important characteristics in real-time using the functionalities of the GPU on modern graphics cards. The methods developed are capable of filling a given convex geometry with air particles and bubbles as well as adding an arbitrary amount of cracks. They comprise the creation of a bumpy and irregular surface that reflects and refracts the environment. An improved image space technique for clipping a geometry using the Boolean difference of two geometries was developed, as well. It is applied to the cracks in order to clip them against the iceś geometry. Reflection and refraction effects on the ice were realized by using environment mapping. An improved method for two-sided refraction was developed that combines the normals of the front and back side of the ice object. See Figure 12.

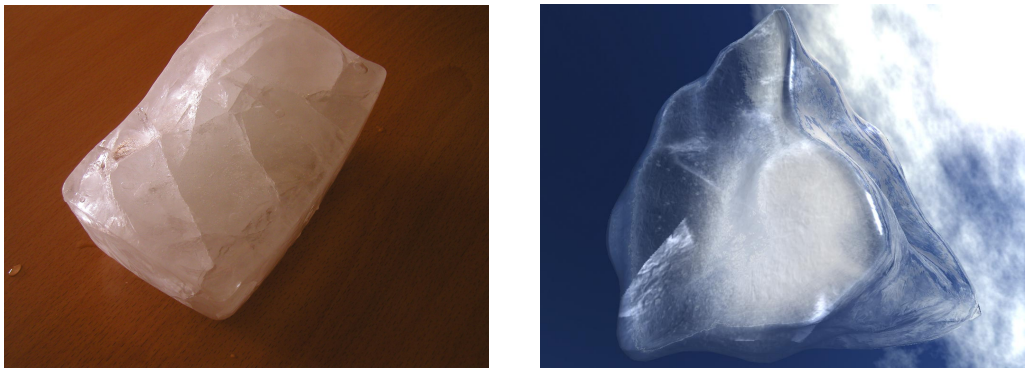


Figure 12: A real ice block frozen in a refrigerator (left). A synthetically rendered ice-cube (right).

25. **Visualization of multivariate 3D volume data**
Stefan Seipel
*Funding:* UU TN Faculty
*Period:* 0606–0612
*Comment:* Cezary Bloch (MSc student) is a cooperation partner.
*Abstract:* In this project we aimed at developing new methods to directly render multivariate volume data. When rendering 3D scalar fields (e.g. in medicine) on a 2D computer screen, the means for expressing various attributes in every voxel are usually limited to colors, only. Graphically more complex annotations or glyphs require a too large footprint on-screen and hamper perception of the spatial structure of the underlying data. In this project we looked at new methods direct visualization of more than one scalar value, excluding color manipulations. The general objective was to investigate if a secondary variable could be visualized by modulating the illumination functions in 3D rendering, or by using modulated textures to express the secondary attribute. As a result of this experimental project, we came up with a new method that utilizes 3D normal mapping. A 3D normal map is used in the 3D shading model of the volume renderer to create volumetric bumps. The appearance of bumps is modulated with respect to the values of the additional scalar attribute. See Figure 13.

26. **Collaborative 3D visualizations**
Stefan Seipel, Lars W. Pettersson
*Funding:* UU TN Faculty
*Period:* 0309–0612
*Partners:* Swedish Defense College; Dept. of Information Technology, UU; University College of Gävle
*Abstract:* In many important decision situations, more than only one stakeholder is concerned with the analysis and interpretation of the decisive data. Often, the data collected is very complex, it may be organized in several orthogonal dimensions or is ordered in multiple independent layers. Our technical means to efficiently visualize this complexity are limited to the two-dimensional grid of colored pixels on a computer screen. In this current project we investigate how we optimally can design visualizations that support more collaborating users who interact simultaneously with the same visualization in the same place. We

use a rather unique display technology (in collaboration with and at the Swedish Defense College - FHS) to present up to 8 individual pictures at the same display surface. It allows to selectively controlling, which picture(s) are seen by individual users. In this environment we study the effects of several features of advanced visualizations, which are dynamic observer conditions, stereoscopic cues, and layer separated visualizations. See Figure 14.

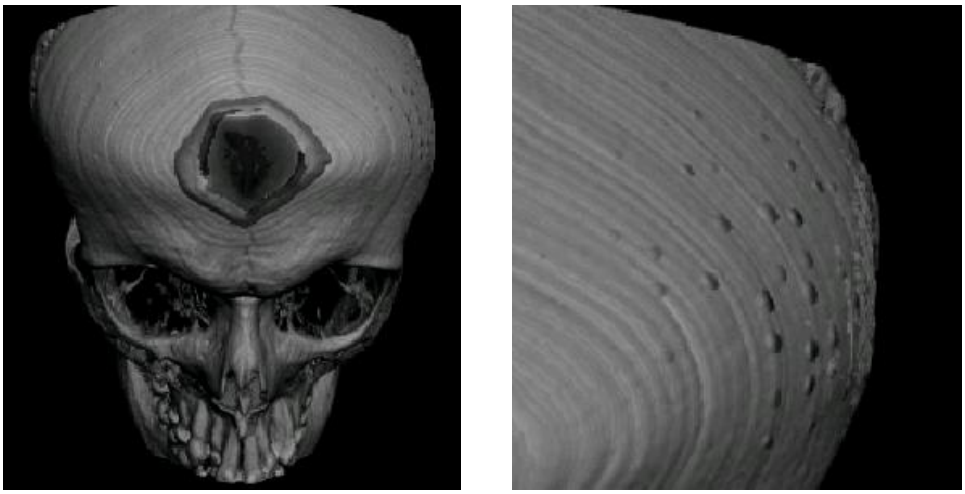


Figure 13: Direct volume rendering of a skull with volumetric bumps at the left forehead modulated by a secondary attribute in the dataset.

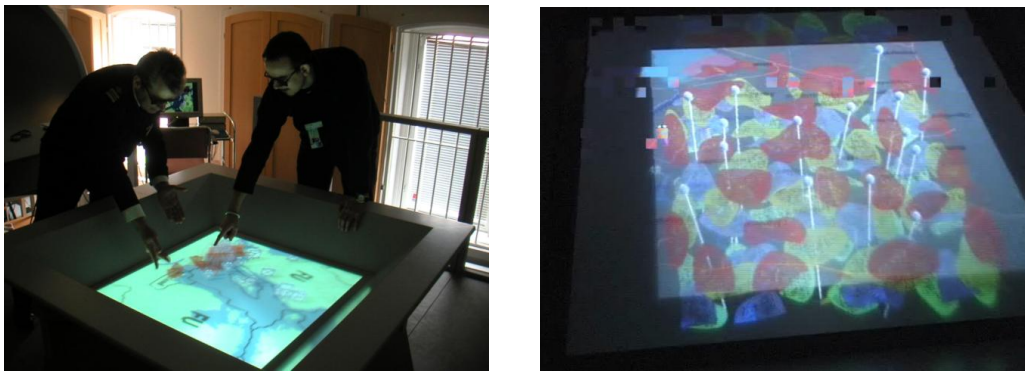


Figure 14: The AQUA display environment at FHS is our test bed (left). A layer-partitioned visualization in GIS applications (right).

## Forestry related applications

27. **Image analysis of the internal structure of paper and cellulose based composite materials in 3D images**
Maria Axelsson, Filip Malmberg, Stina Svensson, Joakim Lindblad, Gunilla Borgefors
*Funding:* SLU S Faculty
*Period:* 0406–
*Partners:* Norwegian Pulp and Paper Research Institute (PFI), Trondheim, Norway; STFI-Packforsk, Stockholm; KTH Solid Mechanics, Stockholm; StoraEnso, Falun
*Abstract:* The internal structure of paper is important to study since many material 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 performed in cross sectional two dimensional (2D) images and paper is a complex three dimen-

sional (3D) structure. Another application for wood-fibres that has recently gained a lot of interest is wood polymer composite materials. The properties of these materials do not only depend on the structure of the fibre network, but also on interaction between the fibres and the polymer matrix surrounding the fibres. Advances in imaging technology has made it possible to acquire 3D images of paper and wood polymer composite materials. In this project, image analysis methods for characterising the 3D material structure in such images are developed. The detailed knowledge of the material structure attainable with these methods is useful for improving material properties and for developing new materials.

An example slice from a binarised volume and a surface rendering of a sample of a composite material image with X-ray microtomography are shown in Figure 15.

The project objective is to achieve a complete segmentation of individual fibres and pores in volume images of the material. Given such a segmentation, any measurement of the internal structure is available. Measurements on individual fibres and the structural arrangement of fibres can then be related to macroscopical material properties. Other methods for measuring properties of the material, that do not require a complete segmentation of the samples, are also investigated.

In this project, different volume images of paper and composite materials are available for the studies. This includes one volume created from a series of 2D scanning electron microscopy (SEM) images at StoraEnso in Falun and X-ray microtomography volume images of paper and composite samples imaged at the European Radiation Synchrotron Facility (ESRF) in Grenoble, France. Furthermore, methods for creating other sample volume images are investigated.

During 2006, the project has resulted in a number of publications. A method for reducing ring artifacts in the volume images using orientation estimates and normalised convolution in the polar domain was presented at the DAGM conference in September 2006 and published in the Lecture Notes in Computer Science Series. See Figure 16 for an illustration of the method. At the Progress in Paper Physics Seminar three extended abstracts were presented. One abstract on 3D structure characterisation of newsprints, one on stress transfer and failure in pulp fibre reinforced composite materials and one on damage mechanisms in paper.

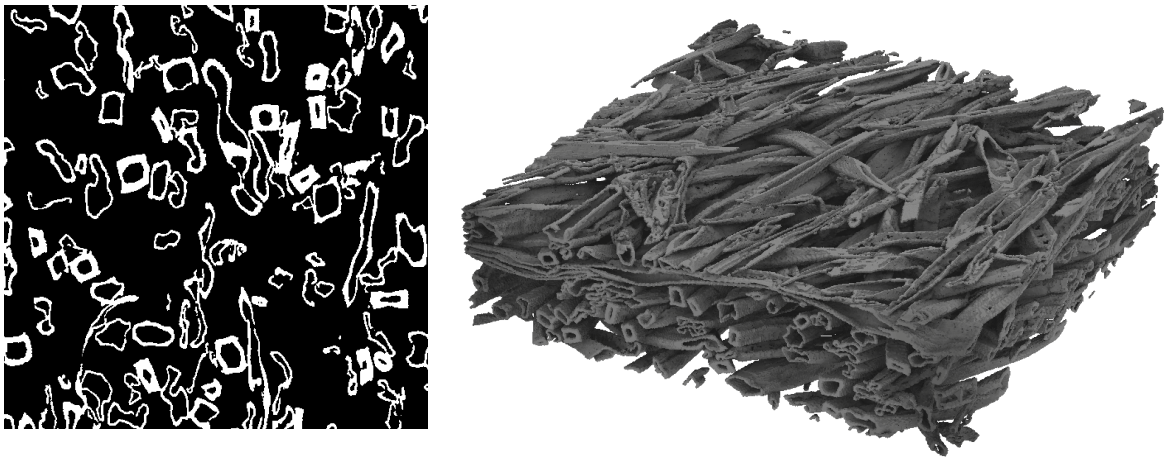


Figure 15: A slice from a binarised volume image of a composite material (left). A surface rendering of a sample of a composite material (right).

28. **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
    *Abstract:* Press felts are used in the manufacturing of paper to press water from the wet fibre 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 fibre web and the amount 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 that can be held in the interface pores between the press felt surface and the fibre web is estimated. Samples of press felts were compressed to different degrees against a glass plate and imaged in a Confocal Laser Scanning Microscope. A method for calculating the size of the interface pores by estimating the fibre web depression into the felt structure was developed. The method was published in Nordic Pulp and Paper Research Journal in 2006. And the method was also presented at SSBA 2006. For an example of 3D renderings of a press felt surface under load, see Figure 17.

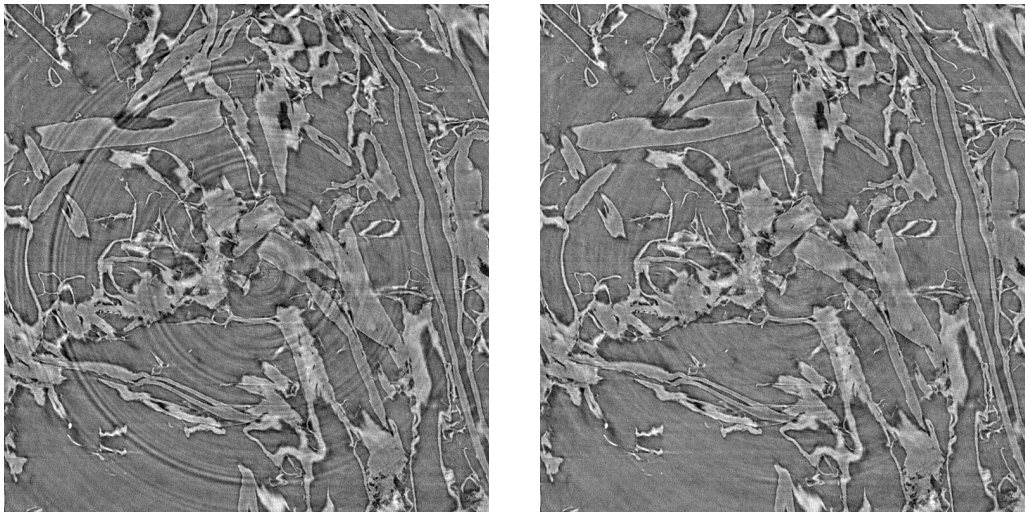


Figure 16: A slice from an X-ray microtomography image showing a ring artifact (left). Reduction of the ring artifact (right).

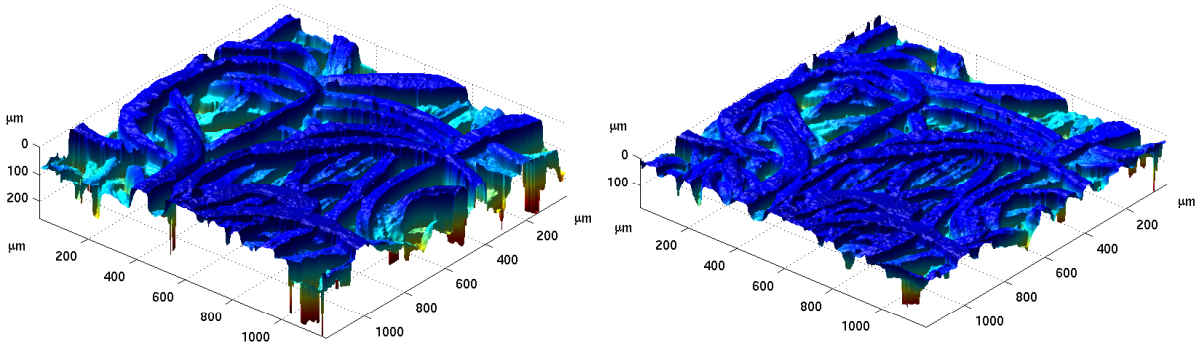



Figure 17: The surface of the press felt observed through a Confocal Laser Scanning Microscope. Load of 1 MPa (left). Load of 10 MPa (right).

29. **Log end feature extraction of untreated wood logs in saw mill environment**
Kristin Norell, Stina Svensson, 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:* The wood quality of a log can be analyzed to some extent by examining the log end. Such analysis is mostly performed manually at saw mills, where the log scaler has a couple of seconds to determine

features like the approximate annual ring density, presence of rot and precense of compression wood. By using an image analysis application instead, the analysis can be more robust. In this project methods to measure important properties of logs in saw mill environment using computerized image analysis is developed. Some interesting features are:

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

The images used are log end images of norway spruce and scots pine taken in a saw mill environment. The logs are sawn with a regular harvester or chain saw. Images used so far are picked to represent a large variety of features that can occur.
Pith position is found using filters to detect local orientation, Hough transform, and a final adjustment technique. Once the pith is found some other measurements will be easy, and others will be facilitated. Figure 18 shows two typical log end images. The result of the pith detection and the ground truth are marked with a white and a black +-sign, respectively. During 2006 the pith detection method has been presented at the Swedish Society for Automated Image Analysis Symposium and also submitted to a journal. Work has also been started on the detection of annual rings.

Figure 18: Typical log end images showing norway spruce. The result of the pith position detection is seen as a white +-sign and the ground truth as a black +-sign.

30. **Detection of rot in end faces of wood logs**
Kristin Norell, Stina Svensson
*Funding: SLU S Faculty*
*Period:* 0612–
*Partners:* Kim Dralle, Anders Björholm Dahl at Dralle A/S Cognitive Systems, Copenhagen, Denmark
*Abstract:* This project focuses on image analysis methods for identifying rot in log end faces. The purpose is to detect rot already while harvesting, or when the logs are in a stack waiting for transport. Logs are depicted using a standard color digital camera that can be mounted on a harvester or a vehicle. The goal is to find a robust method for detecting rot in timber suitable for practical use.

31. **Image analysis for quantitative estimation of seed vitality**
Joakim Lindblad, Gunilla Borgefors
*Funding:* The Swedish Farmers' Foundation for Agricultural Research (SLF)
*Period:* 0509–0603

*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 computer software for automatic segmentation and separation of individual plants as well as to measure relevant parameters, such as area and length, of the plants were developed. In early 2006, the software was delivered to SeedGard AB, where further testing and tuning of parameters followed.

## Remote sensing

32. **Nordkalotten Satellite Evaluation co-operation Network (NorSEN)**
Tommy Lindell
*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), Fredrik Bergholm
*Abstract:* Field measurements were performed on Lake Torneträsk, and near Abisko. From June 2004, spectrometer measurements were run by Fredrik Bergholm on the arctic vegetation around Abisko Naturvetenskapliga Station (ANS), and spectral measurements were performed by Tommy Lindell and Kai Sörensen on Lake Torneträsk. The field measurements have continued during the following years 2005 and 2006. Fredrik Bergholm has been measuring with spectrometers, among other things from the ski lift in Abisko. Tommy Lindell and Kai Sörensen has been taking water samples for analyses, made manual recording of spectral characteristics and have had a floating device on Torne Träsk for spectral measurements during the summer months. Tommy Lindell has collected and analysed satellite data from the lake. Kai Sörensen has been using ships on Hurigrutten for continuous sampling of spectral information and water quality variables. These field measurements have contributed to the data base for the Scandinavian NorSEN project, which formally started in 2005. The project deals with validation of satellite images in polar-near areas, and build-up of ground- based spectral sensors around ANS. Little scientific work has been done before on the use of satellite data in polar-near areas, with low sun angles and special atmospheric conditions. The project aims to find normalisation and correction measures of the satellite data for these areas.

33. **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.

## 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

*School of ITEE, University of Queensland, Brisbane*, Australia

*CSIRO Mathematical and Information Sciences, North Ryde (Sydney)*, Australia

*Dept. of Radiology, University Hospital Graz*, Austria

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

*Cognitive Systems, Copenhagen*, Denmark

*Visiopharm, Hørsholm*, Denmark

*Dept. of Physics, University of Jyväskylä*, Finland

*EPIDAURE project, INRIA, Sophia Antipolis*, France

*Chemnitz University of Technology, Chemnitz*, Germany

*Cognitive Systems Group, University of Hamburg*, Germany

*Institute for Computational Visualistics, University of Koblenz-Landau*, Germany

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

*Dept. of Energetic, University of Florence, Florence*, Italy

*National Research Council, Milan*, Italy

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

*Dept. of Molecular Cell Biology, Leiden University Medical Center*, The Netherlands

*Norwegian Institute for Water Research*, Norway

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

*Norwegian University of Science and Technology (NTNU), Trondheim*, Norway

*Faculty of Engineering, University of Novi Sad*, Serbia

*Research Group on Mathematical Linguistics, Rovira i Virgili University, Tarragona*, Spain

*University of Colombo School of Computing*, Sri Lanka

*University of Jaffna*, Sri Lanka

*University of Perodeniya*, Sri Lanka

*Laboratoire de Biophysique (LB), Statistique ITP/SB, Ecole Polytechnique Fédérale de Lausanne, Lausanne*, Switzerland

*Medical Research Council Centre (MRCC), Cambridge*, UK

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

*Dept. of Computer Science and Engineering, University of Washington, Seattle*, USA

**National**

*Abisko Scientific Research Station, Abisko*

*IMEGO AB, Göteborg*

*Sectra Imtec AB, Kista*

*SenseGraphics, Kista*

*AnalyCen Nordic AB, Lidköping*

*KFG AB, Sandviken*

*Barrera Kristiansen AB, Uppsala*

*Sensys Traffic, Uppsala*

*GE Health care, Uppsala/London*

*Imanet AB, Uppsala*

*Maxx Automation AB, Uppsala*

*SeedGard AB (prev. Acanova), Uppsala*

*StoraEnso Research, Falun*

*MRM Worldwide, Stockholm*

*Swedish Defense College, Stockholm*

*Swedish Pulp and Paper Research Institute (STFI), Stockholm*

*Swedish Timber Measurement Council (VMR), Sundsvall*

*Vattenfall Utveckling, Älvkarleby*

*Dept. of Clinical Medicine, Örebro University, Örebro*

*Dept. of Genetics and Pathology, UU*

*Dept. of Information Technology, UU*

*Dept. of Mathematics, UU*

*Dept. of Neuroscience, UU Hospital*

*Dept. of Oncology, Radiology, and Clinical Immunology, UU Hospital*

*Dept. of Physical & Analytical Chemistry, UU*

*Dept. of Psychology, UU*

*Dept. of Biometry and Engineering, SLU, Uppsala*

*Dept. of Wood Science (TRV), SLU, Uppsala*

*Dept. of Forest Products and Markets, SLU, Uppsala*

*Dept. of Mathematics, Natural Sciences, and Computing, University College of Gävle*

*Dept. of Cell and Molecular Biology (CMB), Karolinska Institute, Stockholm*

*KTH Solid Mechanics, Royal Institute of Technology, Stockholm*

*Dept. of Engineering, Physics and Mathematics, Mid-Sweden University, Sundsvall*

*Dept. of Computer Science, Umeå University, Umeå*

# 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 2006. We have authored one book chapter. We have published six journal articles and as many as 20 articles in refereed international conference proceedings. In addition, we published nine papers in non-refereed or abstract refereed conference proceedings and seven CBA reports. These numbers indicate yet another productive year for CBA.

## 6.1 Book chapters

1. **Kedjekod – ett sätt att beskriva former i digitala bilder**
   *Authors:* Borgefors, G.
   *Editors:* Berglund, D.
   *Publisher:* Liber, Stockholm
   *Comment:* pp. 38–42 in "Problemlösning är #1"

## 6.2 Journal articles

1. **Estimation of the pore volume at the interface between paper web and press felt**
   *Authors:* Axelsson, M.; Östlund, C.(1); Vomhoff, H.(1); Svensson, S.
   (1) STFI Packforsk, Stockholm
   *Journal:* Nordic Pulp and Paper Research Journal 21(3), 2006
   *Abstract:* A method for determining the water content at the interface between a press felt and a paper web has been developed. The water content was obtained by subtracting the estimated volume of the indented fibre web from the measured felt surface porosity of the press felt. The felt surface porosity was calculated from a topography map that was imaged with a Confocal Laser Scanning Microscope (CLSM) method. Here, the press felt was compressed against a smooth surface using a stress in the range of 0 to 10 MPa. Artefacts in the CLSM images were reduced using an image analysis method. The indentation of paper webs into the measured felt surface pores at different applied pressures was estimated using another image analysis method, simulating a rolling ball, with different radii of curvature for the different pressures and grammages, rolling over the felt surface. The ball radii were determined for a low and a high grammage web using the STFI-Packforsk Dewatering model.

   The method was evaluated in a case study with four press felts that had batt fibre diameters in a range between 22 and 78 $\mu m$. The indentation was calculated for webs with a low (15 $g/m^2$) and a high grammage (105 $g/m^2$), respectively. The evaluation showed that a considerable amount of porespace is available at the interface between the web and the felt. In most cases, the volume of the water-filled pores accounted for approximately 50% of the total surface porosity of the felt. Assuming a complete water saturation of the web/felt interface, approximately 10 $g/m^2$ of water for the finest felt surface up to 40 $g/m^2$ for the coarsest felt surface, could be located at the interface between the press felt and the paper web at a load of 10 MPa. This implies that a considerable amount of water is available for separation rewetting.

2. **Two preprocessing techniques based on grey level and geometric thickness to improve segmentation results**
   *Author:* Eriksson, M.
   *Journal:* Pattern Recognition Letters 27(3):160–166, 2006
   *Abstract:* Two different techniques of performing preprocessing of an image to improve segmentation results are presented. The methods use the grey level thickness of the objects, in order to find the resulting image, by varying the size of a neighbourhood depending on the sum of the included grey levels. The first method, RW, uses the random walk of a particle, defined in the neighbourhood of the position of the particle. The resulting image holds the number of times the particle visits a pixel. Instead of randomization to find the number of visits, the second method, IP, scans the image iteratively and calculates the expected value of the same number. Three different kinds of real world applications are demonstrated to get better segmentation results with the preprocessing techniques included than without.

3. **Surface glyphs for efficient visualization of multivariate data**
   *Authors:* Forsell, C.(1); Seipel, S.; Lind, M.(1)
   (1) Dept. of Information Science, UU
   *Journal:* Information Visualization 5(2):112–124, 2006
   *Abstract:* We present a first effort to evaluate the possible utility of a new type of surface glyphs intended for visualizations of multivariate spatial data. The glyphs 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; 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. A large number of possible 3D glyphs for the visualization of spatial data can be constructed using such properties. One group of such glyphs is based on the local sign of surface curvature. We investigated this group in two visualization experiments. The results show that available sources of 3D structural information were sufficient for our subjects to make fast and accurate judgments. Some implications for visualization are also discussed.

4. **Volume-wise application of principal component analysis on masked dynamic PET data in sinogram domain**
   *Author:* Razifar, P.; Axelsson, J.(1); Schneider, H.(1); Långström, B.(1); Bengtsson, E; Bergström, M.(1)
   (1) Uppsala Imanet
   *Journal:* IEEE Transactions on Nuclear Science 53(5):2759–2768, 2006
   *Abstract:* Most of the methods used for analyzing PET data are applied in the spatial domain (image domain), in which reconstructed images contain all different types of effects and errors caused by the reconstruction algorithm such as correlation in-between pixels, correlations in-between frames, and streak-artifacts. In this paper, we have investigated a new, pixel wise, noise prenormalization method used for transformation of input data followed by volume-wise application of principal component analysis (PCA) on masked dynamic PET data in the sinogram domain. We are aiming to improve the performance of PCA and to provide images with improved quality and signal extraction. We compare the performance of PCA and the image quality obtained with the new method with previously published approaches. The results show improvement of performance of PCA with respect to image quality, signal extraction, precision, and visualization.

5. **A new application of pre-normalized principal component analysis for improvement of image quality and clinical diagnosis in human brain PET studies–clinical brain studies using [11C]-GR205171, [11C]-L-deuterium-deprenyl, [11C]-5-Hydroxy-L-Tryptophan, [11C]-L-DOPA and Pittsburgh Compound-B.**
   *Author:* Razifar, P.; Axelsson, J.(1); Schneider, H.(1); Långström, B.(1); Bengtsson, E; Bergström, M.(1)
   (1) Uppsala Imanet
   *Journal:* Neuroimage 33(2):588–598, 2006
   *Abstract:* Principal component analysis (PCA) is one of the most applied multivariate image analysis tool on dynamic Positron Emission Tomography (PET). Independent of used reconstruction methodologies, PET images contain correlation in-between pixels, correlations in-between frame and errors caused by the reconstruction algorithm including different corrections, which can affect the performance of the PCA. In this study, we have investigated a new approach of application of PCA on pre-normalized, dynamic human PET images. A range of different tracers have been used for this purpose to explore the performance of the new method as a way to improve detection and visualization of significant changes in tracer kinetics

and to enhance the discrimination between pathological and healthy regions in the brain. We compare the new results with the results obtained using other methods. Images generated using the new approach contain more detailed anatomical information with higher quality, precision and visualization, compared with images generated using other methods.

6. **Parameterizations of digital surfaces homeomorphic to a sphere using discrete harmonic functions**
   *Author:* Weistrand, O.
   *Journal:* Pattern Recognition Letters 27(16):1934–1941, 2006
   *Abstract:* We discuss how to map simply connected digital surfaces to the unit sphere using discrete harmonic functions. This technique is well known for constructing parametrizations of surfaces onto simpler domains. A common problem is the creation of dense clusters of vertices, which leads to numerical instability of methods operating on this mapping. By an explicit calculation, we quantify the cluster density for a simple model example. This example shows that distances between mapped vertices can decrease exponentially in regions on the sphere. By numerical examples, we show that severe clustering often occurs for natural objects. A computationally inexpensive algorithm, based on a bijective transformation of the unit sphere, is suggested for post-processing of clusters. Experiments indicate that this algorithm often improves the mapping such that convergence of a non-linear optimization program is achieved. The program aims at optimizing the parameterization, making it useful for global shape analysis. Examples of approximations in terms of spherical harmonics functions are presented.

## 6.3 Refereed conference proceedings

1. **Reduction of ring artifacts in high resolution x-ray microtomography images**
   *Authors:* Axelsson, M.; Svensson, S.; Borgefors, G.
   *Conference:* The 28th DAGM (The German Association for Pattern Recognition) Symposium. LNCS vol. 4174 pp. 61–70
   *Editors:* Franke, K.; Mueller R.; Nickolay B; Schaefer R.
   *Abstract:* Ring artifacts can occur in reconstructed images from X-ray microtomography as full or partial circles centred on the rotation axis. In this paper, a 2D method is proposed that reduces these ring artifacts in the reconstructed images. The method consists of two main parts. First, the artifacts are localised in the image using local orientation estimation of the image structures and filtering to find ring patterns in the orientation information. Second, the map of the located artifacts is used to calculate a correction image using normalised convolution. The method is evaluated on 2D images from volume data of paper fibre imaged at the European Synchrotron Radiation Facility (ESRF) with high resolution X-ray microtomography. The results show that the proposed method reduces the artifacts and restores the pixel values for all types of partial and complete ring artifacts where the signal is not completely saturated.

2. **An objective comparison between gray weighted distance transforms and weighted distance transforms on curved spaces**
   *Authors:* Fouard, C.; Gedda, M.
   *Conference:* 13th International Conference on Discrete Geometry for Computer Imagery (DGCI'06). LNCS vol. 4245, pp. 259–270
   *Editor:* Kuba, A.; Nyúl, L.; Palágyi, K.
   *Abstract:* In this paper, we compare two different definitions of distance transform for gray level images: the Gray Weighted Distance Transform (GWDT), and the Weighted Distance Transform On Curved Space (WDTOCS). We show through theoretical and experimental comparisons the differences, the strengths and the weaknesses of these two distances.

3. **Fuzzy distance based hierarchical clustering calculated using the A* algorithm**
   *Authors:* Gedda, M.; Svensson, S.
   *Conference:* 11th International Workshop on Combinatorial Image Analysis (IWCIA'06). LNCS vol. 4040, pp. 101–115
   *Editor:* Reulke, R.; Eckhardt, U.; Flach, B.; Knauer, U.; Polthier, K.
   *Abstract:* We present a method for calculating fuzzy distances between pairs of points in an image using the A* algorithm and, furthermore, apply this method for fuzzy distance based hierarchical clustering. The method is general and can be of use in numerous applications. In our case we intend to use the clustering in an algorithm for delineation of objects corresponding to parts of proteins in 3D images. The image is defined

as a fuzzy object and represented as a graph, enabling a path finding approach for distance calculations. The fuzzy distance between two adjacent points is used as edge weight and a heuristic is defined for fuzzy sets. A* is applied to the calculation of fuzzy distance between pair of points and hierarchical clustering is used to group the points. The normalised Hubert's statistic is used as validity index to determine the number of clusters. The method is tested on three 2D images; two synthetic images and one fuzzy distance transformed microscopy image of stem cells. All experiments show promising initial results.

4. **Incremental spherical interpolation with quadratically varying angle**
   *Authors:* Hast, A.; Barrera, T.(1); Bengtsson, E.
   (1) Barrera-Kristiansen AB
   *Conference:* SIGRAD'06, the annual SIGRAD conference, Skövde
   *Abstract:* Spherical linear interpolation has got a number of important applications in computer graphics. We show how spherical interpolation can be performed efficiently even for the case when the angle vary quadratically over the interval. The computation will be fast since the implementation does not need to evaluate any trigonometric functions in the inner loop. Furthermore, no renormalization is necessary and therefore it is a true spherical interpolation. This type of interpolation, with non equal angle steps, should be useful for animation with accelerating or decelerating movements, or perhaps even in other types of applications.

5. **Possibilities in using skin texture based image registration for movement analysis**
   *Authors:* Holmberg, B.(1); Nordin, B.; Bengtsson, E.; Lanshammar, H.(1)
   (1) Dept. of Infomation Technology, UU
   *Conference:* Ninth International Symposium On the 3D Analysis of Human Movement.
   *Abstract:* The focus of this investigation is if image registration can be achieved between different images of skin on the lower legs of humans.
   The purpose of the registration is to retrieve information of the movements in the image. Initially this movement is in 2D but further studies will focus more on stereo possibilities and 3D analysis.
   The 2D image registration shows good promise when using high quality image data of skin and when using low quality image data of more pronounced texture. Further investigations will show if skin based registration can also be used on images of typical video quality.

6. **Feature based defuzzification at increased spatial resolution**
   *Authors:* Lindblad, J; Sladoje, N.
   *Conference:* 11th International Workshop on Combinatorial Image Analysis (IWCIA'06). LNCS vol. 4040, pp. 131–143
   *Editor:* Reulke, R.; Eckhardt, U.; Flach, B.; Knauer, U.; Polthier, K.
   *Abstract:* Defuzzification of fuzzy spatial sets by feature distance minimization, recently proposed as an alternative to crisp segmentation, is studied further. Fully utilizing information available in a fuzzy (discrete) representation of a continuous shape, we present an improved defuzzification method, such that the crisp discrete representation of a fuzzy set is generated at an increased spatial resolution, compared to the resolution of the fuzzy set. The correspondence between a fuzzy and a crisp set is established through a distance between their representations based on selected features, where the different resolutions of the images to compare are taken into account. The performance of the method is tested on both synthetic and real images.

7. **Feature based defuzzification in $\mathbb{Z}^2$ and $\mathbb{Z}^3$ using a scale space approach**
   *Authors:* Lindblad, J; Sladoje, N.; Lukic, T.(1)
   (1) Faculty of Engineering, University if Novi Sad, Novi Sad, Serbia
   *Conference:* 13th International Conference on Discrete Geometry for Computer Imagery (DGCI'06). LNCS vol. 4245, pp. 379–390
   *Editor:* Kuba, A.; Nyúl, L.; Palágyi, K.
   *Abstract:* A defuzzification method based on feature distance minimization is further improved by incorporating into the distance function feature values measured on object representations at different scales. It is noticed that such an approach can improve defuzzification results by better preserving the properties of a fuzzy set; area preservation at scales in-between local (pixel-size) and global (the whole object) provides that characteristics of the fuzzy object are more appropriately exhibited in the defuzzification. For the purpose of comparing sets of different resolution, we propose a feature vector representation of a (fuzzy and crisp) set, utilizing a resolution pyramid. The distance measure is accordingly adjusted. The defuzzification method is extended to the 3D case. Illustrative examples are given.

8. **A 3D live-wire segmentation method for volume images using haptic interaction**
*Authors:* Malmberg, F.; Vidholm, E.; Nyström, I.
*Conference:* 13th International Conference on Discrete Geometry for Computer Imagery (DGCI'06). LNCS vol. 4245, pp. 663–673
*Editor:* Kuba, A.; Nyúl, L.; Palágyi, K.
*Abstract:* Designing interactive segmentation methods for digital volume images is difficult, mainly because efficient 3D interaction is much harder to achieve than interaction with 2D images. To overcome this issue, we use a system that combines stereo graphics and haptics to facilitate efficient 3D interaction. We propose a new method, based on the 2D live-wire method, for segmenting volume images. Our method consists of two parts: an interface for drawing 3D live-wire curves onto the boundary of an object in a volume image, and an algorithm for connecting two such curves to create a discrete surface.

9. **Approximating Euclidean distance using distances based on neighbourhood sequences in non-standard three-dimensional grids**
*Authors:* Nagy, B.(1); Strand, R.
(1) Dept. of Computer Science, Faculty of Informatics, University of Debrecen, PO Box 12, 4010, Debrecen, Hungary and Research Group on Mathematical Linguistics, Rovira i Virgili University, Tarragona, Spain
*Conference:* 11th International Workshop on Combinatorial Image Analysis (IWCIA'06). LNCS vol. 4040, pp. 89–100
*Editor:* Reulke, R.; Eckhardt, U.; Flach, B.; Knauer, U.; Polthier, K.
*Abstract:* In image processing, it is often of great importance to have small rotational dependency for distance functions. We present an optimization for distances based on neighbourhood sequences for the face-centered cubic (fcc) and body-centered cubic (bcc) grids. In the optimization, several error functions are used measuring different geometrical properties of the balls obtained when using these distances.

10. **Effects of layer partitioning in collaborative 3D visualizations**
*Authors:* Pettersson, L.W.; Kjellin, A.(1); Lind, M.(1); Seipel, S.
(1) Dept. of Information Science, UU
*Conference:* The 2nd International Symposium on Visual Computing (ISVC'06). LNCS vol. 4291 pp. 180–190
*Editor:* Bebis, G.; Boyle, R.; Parvin, B.; Koracin, D.; Remagnino, P.; Nefian, A.; Meenakshisundaram, G.; Pascucci, V.; Zara, J.; Molineros, J.; Thiesel, H. Malzbender, T.
*Abstract:* Display technologies that support multiple independent views of the same co-located 3D visualization volume make new forms of collaboration possible. In this field of research, until now most efforts have focused on technical solutions and their applications. The main contribution of this paper is the results from a study comparing integral and partitioned 3D content in a head coupled stereoscopic environment through independent views of a shared 3D visualization.
In our study we used a geospatial task that was solved by ten pairs of collaborating individuals (dyads). We measured task performance by time and error rate for the dyads in two main conditions: a) an integral visualization that presented a map in the display surface and four layers at different depths below the display surface to each of the observers, and b) a partitioned visualization, where two mutually exclusive subsets of the layers were presented to each of the observers together with the map in the display surface.
The results from the study showed significant differences in regard to performance times between the two conditions. Task performance was significantly better in the condition with layer partitioning. Partitioned visualizations can thus, at least in some cases, improve performance in tasks requiring collaboration between users.

11. **Enhanced visualizations of thermographic data in process industry**
*Authors:* Seipel, S.; Forsberg, A.(1); Wesslén, D.(1)
(1) Dept. of Mathematics and Computer Science, University of Gävle, Gävle
*Editor:* Proceedings of Eurographics/IEEE-VGTC Symposium on Visualization, pp. 307–314
*Abstract:* In this paper, we describe an improved method for visualization of thermographic data in the paper and pulp process industry. We present an application that allows process operators to freely choose how absolute temperatures and time varying changes of thermographic scans should be mapped to colors and/or 3D shapes. Of the possible combinations, we selected two different forms of 3D visualizations and an existing conventional 2D map visualization. We then evaluated these visualization forms with regard to

their effectiveness in experimental field studies. The field tests were carried out to measure the operators' performance in early detection of insulation damages on lime kilns. The results we obtained from the study show that the two new forms of 3D visualization lead to a reduction of the detection times by about two-thirds and one-third, respectively, when compared to the conventional 2D map representation. Since lime kiln monitoring is based on the rather generic method of continuous thermographic imaging, we suggest that these results also hold for the control and surveillance of other processes.

12. **Efficient rendering of multiple refractions and reflections in natural objects**
*Authors:*Seipel, S.; Nivfors, A.
*Conference:* SIGRAD'06, the annual SIGRAD conference, Skövde. Linköping University Electronic Press, pp. 1–6
*Editor:* Gustavsson, H.
*Abstract:* In this paper we present a multi-pass rendering approach for approximating the effects of multiple refractions and specularreflections in transparent or semitransparent materials. These optical effects are typically found in natural materials like ice butalso in glass artworks. The rendering technique proposed in thispaper is intended to perform at real-time frame rates and aim atachieving naturally looking effects rather than simulating physically correct interaction between light and matter. Part of our method is an improved image space technique for clipping ageometry using the Boolean difference of two geometries in order to create internal surfaces of reflection inside transparent objects.It employs a number of generic cracks surface geometries which are clipped against the geometry to be rendered. Reflection and refraction effects on the ice are implemented by using environment mapping. Two-sided refraction is accomplished bycombining the normal vectors of the front and back side of the ice object. Our method renders icy objects with convincing visual appearance in real-time on state-of-the-art graphics hardware.

13. **Topology preserving digitization with FCC and BCC grids**
*Authors:* Stelldinger, P.(1); Strand, R.
(1) Cognitive Systems Group, University of Hamburg, Hamburg, Germany
*Conference:* 11th International Workshop on Combinatorial Image Analysis (IWCIA'06). LNCS vol. 4040, pp. 226–240
*Editor:* Reulke, R.; Eckhardt, U.; Flach, B.; Knauer, U.; Polthier, K.
*Abstract:* In digitizing 3D objects one wants as much as possible object properties to be preserved in its digital reconstruction. One of the most fundamental properties is topology. Only recently a sampling theorem for cubic grids could be proved which guarantees topology preservation [1]. The drawback of this theorem is that it requires more complicated reconstruction methods than the direct representation with voxels. In this paper we show that face centered cubic (fcc) and body centered cubic (bcc) grids can be used as an alternative. The fcc and bcc voxel representations can directly be used for a topologically correct reconstruction. Moreover this is possible with coarser grid resolutions than in the case of a cubic grid. The new sampling theorems for fcc and bcc grids also give absolute bounds for the geometric error.

14. **Using the hexagonal grid for three-dimensional images: direct Fourier method reconstruction and weighted distance transform**
*Authors:* Strand, R.
*Conference:* 18th International Conference on Pattern Recognition (ICPR'06). Proceedings vol. 2, pp. 1169-1172
*Abstract:* An image reconstruction technique for computed tomography (CT) images, the direct Fourier method, is shown to apply to non-standard grids. In CT, the 3D image is obtained by reconstructing 2D slices separately. We propose to use the Hexagonal grid for the 2D slices, resulting in 3D images on non-standard grids. Low-level image processing is also considered for these grids – optimal weights to be used for computing the weighted distance transform are calculated.

15. **Generating distance maps with neighbourhood sequences**
*Authors:* Strand, R.; Nagy, B.(1); Fouard, C.; Borgefors, G.
(1) Dept. of Computer Science, Faculty of Informatics, University of Debrecen, Debrecen, Hungary; Research Group on Mathematical Linguistics, Rovira i Virgili University, Tarragona, Spain
*Conference:* 13th International Conference on Discrete Geometry for Computer Imagery (DGCI'06). LNCS vol. 4245, pp. 295–307
*Editor:* Kuba, A.; Nyúl, L.; Palágyi, K.
*Abstract:* A sequential algorithm for computing the distance map using distances based on neighbourhood

sequences (of any length) in the 2D square grid; and 3D cubic, face-centered cubic, and body-centered cubic grids is presented. Conditions for the algorithm to produce correct results are derived using a path-based approach. Previous sequential algorithms for this task have been based on algorithms that compute the digital Euclidean distance transform. It is shown that the latter approach is not well-suited for distances based on neighbourhood sequences.

16. **Using a fuzzy framework for delineation and decomposition of immunoglobulin G in cryo electron tomographic images**
    *Authors:* Svensson, S.; Gedda, M.; Fanelli, D.(1); Skoglund, U.(1); Öfverstedt, L.-G.(1); Sandin, S.(2)
    (1) Dept. of Cell and Molecular Biology, Karolinska Institute, Stockholm
    (2) Division of Structural Studies, MRC Laboratory of Molecular Biology, Cambridge, UK
    *Conference:* 18th International Conference on Pattern Recognition (ICPR'06). Proceedings vol. 4, pp. 687–690
    *Abstract:* In structural studies of proteins, the first task is to identify the different parts of the protein. We present a robust method using a fuzzy framework for delineating a protein and to identify its parts. The method is used in a study of the immunoglobulin G antibody, individually imaged using cryo electron tomography, with satisfactory results.

17. **Hierarchical chamfer matching based on propagation of gradient strengths**
    *Authors:* Svensson, S.; Sintorn, I.-M.(1)
    (1) CSIRO Mathematical and Information Sciences Australia
    *Conference:* 13th International Conference on Discrete Geometry for Computer Imagery (DGCI'06). LNCS vol. 4245, pp. 308–319
    *Editor:* Kuba, A.; Nyúl, L.; Palágyi, K.
    *Abstract:* A modification of the hierarchical chamfer matching algorithm (HCMA) with the effect that no binarisation of the edge information is performed is investigated. HCMA is a template matching algorithm used in many applications. A distance transform (DT) from binarised edges in the search image is used to guide the template to good positions. Local minima of a function using the distance values hit by the template correspond to potential matches. We propose to use distance weighted propagation of gradient magnitude information as a cost image instead of a DT from the edges. By this we keep as much information as possible until later in the matching process and, hence, do not risk to discard good matches in the edge detection and binarisation process.

18. **Fast and robust semi-automatic liver segmentation with haptic interaction**
    *Authors:* Vidholm, E.; Nilsson, S.(1); Nyström, I.
    (1) Dept. of Oncology, Radiology, and Clinical Immunology, UU Hospital
    *Conference:* Medical Image Computing and Computer-Assisted Intervention (MICCAI'06), LNCS vol. 4191 pp. 774–781
    *Editors:* Larsen, R.; Nielsen, M.; Sporring, J.
    *Abstract:* We present a method for semi-automatic segmentation of the liver from CT scans. True 3D interaction with haptic feedback is used to facilitate initialization, i.e., seeding of a fast marching algorithm. Four users initialized 52 datasets and the mean interaction time was 40 seconds. The segmentation accuracy was verified by a radiologist. Volume measurements and segmentation precision show that the method has a high reproducibility.

19. **Accelerating the computation of 3D gradient vector flow fields**
    *Authors:* Vidholm, E.; Sundqvist, P.(1); Nyström, I.
    (1) Dept. of Infomation Technology, UU
    *Conference:* 18th International Conference on Pattern Recognition (ICPR'06). Proceedings vol. 3, pp. 677–680
    *Abstract:* In 3D segmentation, a deformable model can be efficiently guided by a gradient vector flow (GVF) field. The computation of a GVF field consists mainly of solving a huge discretized system of elliptic partial differential equations. These discrete equations have several properties that can be utilized to accelerate the process of finding an approximate solution. Here, stationary iterative methods, preconditioned conjugate gradient methods, and multigrid methods are considered in order to compute the GVF field at computational times acceptable for interactive 3D segmentation.

20. **Finding cells, finding molecules, finding patterns**
*Authors:* Wählby, C.; Karlsson, P.; Henriksson, S.(1); Larsson, C.(1); Nilsson, M.(1); Bengtsson, E.
(1) Dept. of Genetics and Pathology, UU
*Conference:* Advances in Data Mining: Workshop on Mass-Data Analysis of Images and Signals in Medicine, Biotechnology and Chemistry, MDA'06, Leipzig, Germany. LNAI vol. 4065, pp 15–24
*Abstract:* Many modern molecular labeling techniques result in bright point signals. Signals from molecules that are detected directly inside a cell can be captured by fluorescence microscopy. Signals representing different types of molecules may be randomly distributed in the cells or show systematic patterns indicating that the corresponding molecules have specific, non-random localizations and functions in the cell. Assessing this information requires high speed robust image segmentation followed by signal detection, and finally pattern analysis. We present and discuss this type of methods and show an example of how the distribution of different variants of mitochondrial DNA can be analyzed.

## 6.4 Non-refereed conferences and workshops

1. **Detailed quantification of the 3D structure of newsprints in X-ray synchrotron radiation microtomography images**
*Author:* Axelsson, M.; Chinga, G.(1); Svensson, S.; Nygård, P.(1); Malmberg, F.; Solheim, O.(1); Lindblad, J.; Borgefors, G.
(1) Paper and Fiber Research Institute (PFI), Trondheim, Norway
*Conference:* Progress in Paper Physics Seminar, Oxford, Ohio, 2006

2. **Volume estimation of the interface pores between paper web and press felt**
*Authors:* Axelsson, M.; Östlund, C.(1); Vomhoff, H.(1); Svensson, S.
(1) STFI-Packforsk, Stockholm
*Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA'06, pp. 49–52)
*Editors:* Georgsson, F.; Börlin, N.
*Publisher:* Umeå University

3. **Stress transfer and failure in pulpfibre reinforced composites: Effects of microstructure characterized by Xray microtomography**
*Author:* Bogren, K.(1,2); Gamstedt, K.(1,2); Berthold, F.(2); Lindström, M.(2); Nygård, P.(3); Malmberg, F.; Lindblad, J.; Axelsson, M.; Svensson, S.; Borgefors, G.
(1) KTH Solid Mechanics, Royal Institute of Technology, Stockholm
(2) STFI-Packforsk, Box 5604, Stockholm
(3) Paper and Fiber Research Institute (PFI), Trondheim, Norway
*Conference:* 2006 Progress in Paper Physics: A seminar

4. **Weighted distance expression in modules**
*Authors:* Fouard, C.; Strand, R.
*Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA'06), pp. 9–12
*Editors:* Georgsson, F.; Börlin, N.
*Publisher:* Umeå University

5. **Separation of blob-like structures using fuzzy distance based hierarchical clustering**
*Authors:* Gedda, M.; Svensson, S.
*Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA'06), pp. 73–76
*Editors:* Georgsson, F.; Börlin, N.
*Publisher:* Umeå University

6. **Live-wire based interactive segmentation of volume images using haptics**
*Authors:* Malmberg, F.; Vidholm, E.; Nyström, I.
*Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA'06), pp. 57–60
*Editors:* Georgsson, F.; Börlin, N.
*Publisher:* Umeå University

7. **Finding the pith in rough cross-sections of logs in saw mill environments**
   *Authors:* Norell, K.
   *Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA'06), pp. 129–132
   *Editors:* Georgsson, F.; Börlin, N.
   *Publisher:* Umeå University

8. **Damage mechanisms in paper**
   *Authors:* Nygård, P.(1); Gradin, P(2).; Gregersen, Ø(3); Lindblad, J.; Axelsson, M.; Svensson, S.; Malmberg, F.; Borgefors, G.
   (1) Paper and Fiber Research Institute (PFI), Trondheim, Norway
   (2) Mid-Sweden University, FSCN, Dept. of Engineering, Physics and Mathematics, Sundsvall
   (3) Norwegian University of Science and Technology (NTNU), Trondheim, Norway
   *Conference:* 2006 Progress in Paper Physics: A seminar

9. **A sequential algorithm for computing the distance transform using distances based on neighbourhood sequences in $\mathbb{Z}^3$**
   *Authors:* Strand, R.; Fouard, C.
   *Conference:* Swedish Society for Automated Image Analysis Symposium (SSBA'06), pp. 1–4
   *Editors:* Georgsson, F.; Börlin, N.
   *Publisher:* Umeå University

## 6.5 Other publications

See also Section 3.2 for Master theses finished during 2006.

1. **CBA annual report 2005**
   *Editors:* Bengtsson, E.; Norell, K.; Nyström, I.; Strand, R.; Wadelius, L.
   *Publisher:* Centre for Image Analysis, 84 pages

2. **Finding the pith in untreated cross-sections of logs in saw mill environments using computerized image analysis**
   *Author:* Norell, K.
   *Publisher:* CBA Internal report no. 37, 12 pages.

3. **Weighted distance transforms generalized to modules and their computation on point lattices**
   *Author:* Fouard, C.; Strand, R.
   *Publisher:* CBA Internal report no. 38, 37 pages.

4. **Some properties for distances based on neighbourhood sequences in the face-centered cubic grid and the body-centered cubic grid**
   *Author:* Strand, R.; Benedek, N.
   *Publisher:* CBA Internal report no. 39, 15 pages.

5. **Visualization in 3D medical imaging**
   *Author:* Somaskandan, S.
   *Publisher:* CBA Internal report no. 40, 25 pages.

6. **An overview of image analysis in paper science**
   *Author:* Axelsson, M.
   *Publisher:* CBA Internal report no. 41, 35 pages.

7. **Simple points on the body-centered cubic grid**
   *Author:* Strand, R.; Brunner, D.
   *Publisher:* CBA Internal report no. 42, 10 pages.

8. **A high-performance parallel thinning approach using a non-cubic grid structure**
   *Author:* Brunner, D.; Strand, R.
   *Publisher:* Technical report, Faculty of Computer Science, Chemnitz University of Technology, Germany.

# 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 2006. 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 once again CBA personnel received an important award: Hamed Hamid Muhammed was apponted the Benzelius award from the Royal Society of Sciences for his PhD thesis entitled *Hyperspectral image generation, processing and analysis*.

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 24 seminars outside CBA, most in the Uppsala area, but also in Serbia. We had twelve invited seminars at CBA, from USA, Italy, Sri Lanka, France, Germany, and Sweden. In addition, we held 29 seminars in our "Monday seminar series", of which 13 were Master Thesis presentations. We gave two special invited talks, six oral and seven poster presentations at international fully reviewed conferences, and eight other oral conference presentations. We had four long term visitors from abroad, i.e., from France, USA, Germany, and Serbia. 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 36 international and 41 national "committees" of the most varying types in which we have served.

## 7.1 Awards

1. **Hamed Hamid Muhammed**
   *Award:* Benzelius award from the Royal Society of Sciences

## 7.2 Organised conferences and workshops

1. **UPPMAX kickoff**
   *Organisers:* Ingela Nyström (through UPPMAX)
   *Address:* Uppsala Learning Lab and Centre for Image Analysis
   *Date:* 060927–28
   *Comment:* A 2-day kickoff was organized. The first day, UPPMAX board and staff met at ULL. The second day, UPPMAX staff worked together at CBA.

2. **ENLIGHT image analysis training course**
   *Organisers:* Niels Foged and Lars Pedresen, Visiopharm, Carolina Wählby, CBA
   *Address:* Nordsjaellands Conference Center, Denmark
   *Date:* 061025–27
   *Comment:* The course/conference had two goals: (1) to give a general introduction to image based cell

analysis and to introduce the Visiopharm image analysis software (VIS) to relevant representatives of organisations that plan to install and use this software in their contribution to the ENLIGHT project, (2) to clarify individual needs and qualifications for image analysis at each ENLIGHT organisation. Carolina Wählby was responsible for the lectures on image analysis. Amin Allalou and Carolina Wählby arrived on 061022 to present new functionality added to VIS and plan the course. Ewert Bengtsson was also present during the course.

## 7.3 Seminars held outside CBA

1. **Ewert Bengtsson**
   *Date:* 060207
   *Address:* Genzell lecture hall, UU Hospital
   *Title:* Introduction to image analysis.
   *Comment:* A seminar at the workshop "CRU Postgraduate research school in Reproductive Biology: Introduction to image analysis".

2. **Stina Svensson**
   *Date:* 060207
   *Address:* Genzel lecture hall, UU Hospital
   *Title:* Computerized image analysis as an essential tool for studying protein dynamics from cryo electron tomographic data.
   *Comment:* A seminar at the workshop "CRU Postgraduate research school in Reproductive Biology: Introduction to image analysis".

3. **Stina Svensson**
   *Date:* 060221
   *Address:* Dept. of Bioenergy, SLU
   *Title:* Datoriserad bildanalys med inriktning på naturresurser och miljö
   *Comment:* Guest lecture on the course Geografiska Informationssystem (GIS).

4. **Ingela Nyström**
   *Date:* 060221
   *Address:* Dept. of Computer Science, Umeå University
   *Title:* Discrete geometry in digital images.

5. **Gunilla Borgefors**
   *Date:* 060303
   *Address:* Dept. of Mathematics, UU
   *Title:* The discrete potato peeling problem.
   *Comment:* This was a part of a seminar series at the Dept. of Mathematics.

6. **Ingela Nyström**
   *Date:* 060310
   *Address:* The Collegium for Development Studies, UU
   *Title:* PhD supervision in biomedical image analysis at CBA.
   *Comment:* Presenting our Lankesian involvement at the workshop arranged for SPIDER.

7. **Maria Axelsson**
   *Date:* 060313
   *Address:* Dept. of Wood Science, SLU
   *Title:* Image analysis of 3D images of paper fibre.
   *Comment:* Presentation during the course "Förädling av skogsråvara — från skog till slutprodukt".

8. **Kristin Norell**
   *Date:* 060313
   *Address:* Dept. of Wood Science, SLU
   *Title:* Log end analysis in a saw mill environment, using computerized image analysis.
   *Comment:* Presentation during the course "Förädling av skogsråvara — från skog till slutprodukt".

9. **Gunilla Borgefors**
   *Date:* 060321
   *Address:* S-faculty, SLU, Umeå
   *Title:* Presentation of CBA and its activities.
   *Comment:* Seminar on the second day of the “Annual meeting of S-faculty, SLU” which is a two-day event.

10. **Stina Svensson**
    *Date:* 060504
    *Address:* Halmstad University
    *Title:* Computerised image analysis as an essential tool for studying protein dynamics from cryo electron tomographic data.
    *Comment:* A seminar for ”The National Research School in Genomics and Bioinformatics” which takes place four times per year.

11. **Ewert Bengtsson**
    *Date:* 060518
    *Address:* QD-Systems, Uppsala
    *Title:* Visualization in medicine
    *Comment:* Invited presentation in at the seminar on “ICT & Life Science: E-Health” to an audience of local business people in the IT and Life Science sector.

12. **Ewert Bengtsson**
    *Date:* 060612
    *Address:* Rudbeck Lab, UU
    *Title:* Introduction to biomedical image analysis
    *Comment:* One hour lecture on a summer school on introduction for biomedical Phd students.

13. **Kristin Norell**
    *Date:* 060612
    *Address:* Gamla Teatern, Östersund
    *Title:* Analysing log ends — pith detection
    *Comment:* Seminar during a meeting with the development groups at The Swedish Timber Measurement Council. Hosted by Lars Björklund.

14. **Stina Svensson**
    *Date:* 060808
    *Address:* Science research school, Karlskoga
    *Title:* Undersök världen med hjälp av digitala bilder
    *Comment:* Lecture for upper secondary school pupils from all over the country. The research school is organised every summer by PhD students from Swedish universities.

15. **Kristin Norell**
    *Date:* 060831
    *Address:* Sigtunahöjden hotel and conference centre, Sigtuna
    *Title:* Image analysis for log end quality control.
    *Comment:* A seminar held during a meeting with The Swedish Timber Measurement Council.

16. **Carolina Wählby**
    *Date:* 060905
    *Address:* Dept. of Medical Engineering, Karolinska Institutet, Stockholm
    *Title:* Image analysis — an overview
    *Comment:* The seminar was hosted by Lars Gösta Hellström and was given as part of a course in medical imaging techniques.

17. **Carolina Wählby**
    *Date:* 060928–29
    *Address:* Wik's Castle, Uppsala
    *Title:* Gating in 16 dimensions, or how to classify blobs on random arrays.
    *Comment:* A seminar at the Molecular Medicine group conference (Landegren and Nilsson group). The conference was an internal group meeting where current projects as well as future ideas were presented and discussed.

18. **Joakim Lindblad**
    *Date:* 061031
    *Address:* Centre of Mathematics and Statistics, Faculty of Engineering, University of Novi Sad, Serbia
    *Title:* Image analysis for automatic segmentation of cytoplasms and classification of Rac1 activation.

19. **Carolina Wählby**
    *Date:* 061109
    *Address:* Dept. of Genetics and Pathology, Rudbeck Lab, UU
    *Title:* Using VIS for single cell analysis.
    *Comment:* The seminar was given as part of the ENLIGHT Practical course on Proximity Ligation in situ, organized by Anders Alderborn and Mats Gullberg.

20. **Carolina Wählby**
    *Date:* 061110
    *Address:* Molecular Medicine Group, Dept. of Genetics and Pathology, Rudbeck Lab, UU
    *Title:* The Visiopharm software and database.
    *Comment:* The seminar was given as part of a weekly seminar series at the Landegren-Nilsson group.

21. **Carolina Wählby**
    *Date:* 061205
    *Address:* Dept. of Engineering Science, Materials Science Programme, UU
    *Title:* Bildbehandling och bildanalys: bakgrund, principer och exempel från ytavbildning och mikroskopi.
    *Comment:* The seminar was hosted by Fredrik Nikolajeff, and was given as part of a course in methods for surface imaging.

22. **Ewert Bengtsson**
    *Date:* 061206
    *Address:* Uppsala Learning Lab, UU
    *Title:* Uppsala university and the Bologna process.
    *Comment:* The importance of IT support for the Bologna process and UU strategies for this.

23. **Carolina Wählby**
    *Date:* 061213
    *Address:* Dept. of Information Technology, UU
    *Title:* Spectral decomposition in fluorescence microscopy.
    *Comment:* The seminar was hosted by Per Lötstedt and was part of a weekly seminar series at the Dept. of Information Technology.

24. **Ewert Bengtsson**
    *Date:* 061214
    *Address:* Dept. of Information Technology, UU
    *Title:* Medical imaging and medical image analysis.
    *Comment:* A lecture as part of the course Medical Engineering.

## 7.4 Seminars at CBA with invited guest lecturers

1. **Steven L. Tanimoto**
    *Address:* Dept. of Computer Science and Engineering, University of Washington, Seattle, USA
    *Date:* 060227
    *Title:* Transparent software methodologies for image processing.

2. **Duccio Fanelli**
   *Address:* Dept. of Cell and Molecular Biology, Karolinska Institutet, Stockholm and Dept. of Energetic, University of Florence, Florence, Italy
   *Date:* 060406
   *Title:* Large-scale dynamics of antibodies from tomographic data.

3. **Fredrik Georgsson**
   *Address:* Dept. of Computer Science, Umeå University
   *Date:* 060426
   *Title:* Mammography — A complete analysis.

4. **Prasad Wimalaratne, Nihal Kodikara**
   *Address:* University of Colombo School of Computing, Sri Lanka
   *Date:* 060502
   *Title:* Computer graphics research at University of Colombo School of Computing, Sri Lanka.

5. **Steven L. Tanimoto**
   *Address:* Dept. of Computer Science and Engineering, University of Washington, Seattle, USA
   *Date:* 060509
   *Title:* A tour of PixelMath2006.

6. **Lucia Ballerini**
   *Date:* 060510
   *Topic:* Docent Lecture for Lucia Ballerini.

7. **Céline Fouard**
   *Address:* EPIDAURE project, INRIA, Sophia Antipolis, France
   *Date:* 060529
   *Title:* Which gray-level distance to choose?

8. **Eva Pärt-Enander**
   *Address:* Uppsala Learning Lab, UU
   *Date:* 060828
   *Title:* Marratech, Ping-Pong etc.

9. **Matthias Biedermann**
   *Address:* Institute for Computational Visualistics, University of Koblenz-Landau, Germany
   *Date:* 060911
   *Title:* Introduction to my work at CBA

10. **Jayaram K. Udupa**
    *Address:* Medical Image Processing Group, Dept. of Radiology, University of Pennsylvania, Philadelphia, USA
    *Date:* 061009
    *Title:* Synergistic hybrid image segmentation: Combining model-based and image-based strategies.

11. **Matthias Biedermann**
    *Address:* Institute for Computational Visualistics, University of Koblenz-Landau, Germany
    *Date:* 061120
    *Title:* Liver segmentation goes GPU - results from my work at CBA.

12. **Tony Barrera**
    *Address:* Barrera–Kristiansen AB, Uppsala
    *Date:* 061211
    *Title:* Setting constraints on general Hermite curves and surfaces.

## 7.5 Seminars at CBA

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

1. **Björn Nilsson**
   *Date:* 060109
   *Title:* Non-contact quality measurements of open die forging.
   *Comment:* Master thesis presentation.

2. **Amalka Pinidiyaarachchi**
   *Date:* 060116
   *Title:* Using ITK/VTK in Matlab.

3. **Magnus Gedda**
   *Date:* 060123
   *Title:* Effective point-to-point fuzzy distance calculations using the A* algorithm.

4. **Kristin Norell**
   *Date:* 060130
   *Title:* Finding the pith in untreated cross-sections of logs in saw mill environments.

5. **Maria Axelsson**
   *Date:* 060206
   *Title:* Estimation of the pore volume at the interface between paper web and press felt.

6. **Johan Östrand**
   *Date:* 060220
   *Title:* An optical character recognition method for an automatic number plate recognition application applied to Swedish number plates.
   *Comment:* Master thesis presentation.

7. **Jesper Renck**
   *Date:* 060228
   *Title:* Automatisk kameraövervakning av spillfåran för att öka allmänhetens säkerhet
   *Comment:* Master thesis presentation.

8. **Ewert Bengtsson**
   *Date:* 060306
   *Title:* Spectral camera design options.

9. **Per Uddholm**
   *Date:* 060313
   *Title:* Estimation of fibre orientation using steerable filters.
   *Comment:* Master thesis presentation.

10. **Stina Svensson**
    *Date:* 060320
    *Title:* A decomposition scheme for 3D fuzzy objects & studying protein dynamics from cryo electron tomographic data.

11. **Gunilla Borgefors**
    *Date:* 060403
    *Title:* Fossiles from image analysis in the 1980s.

12. **Ingela Nyström, Maria Axelsson, Magnus Gedda, Filip Malmberg, Kristin Norell, Stina Svensson and Erik Vidholm.**
    *Date:* 060404
    *Topic:* Three-dimensional images show what is inside
    *Comment:* CBA took part in the Research day — “Forskningens dag” where students from the Faculty of Science and Technology, UU were invited. About 20 students visited CBA. Nyström was host.

13. **Petter Holmberg**
    *Date:* 060410
    *Title:* Contour extraction and modelling of horses using background subtraction and active shape models.
    *Comment:* Master thesis presentation.

14. **Suthakar Somaskandan**
    *Date:* 060424
    *Title:* Visualization in 3D medical imaging.

15. **Magnus Gedda**
    *Date:* 060508
    *Title:* Using LaTeX Beamer for creating presentations.

16. **Erik Vidholm**
    *Date:* 060515
    *Title:* Accelerating the computation of gradient vector flow fields.

17. **Joakim Lindblad**
    *Date:* 060522
    *Title:* Defuzzification of fuzzy spatial sets by feature distance minimization.

18. **Mikael Lönnberg**
    *Date:* 060607
    *Title:* Skanner som detektionsinstrument
    *Comment:* Master thesis presentation.

19. **Carl-Johan Otterheim**
    *Date:* 060609
    *Title:* Image segmentation for Alcro colouring program/Becker's Painter
    *Comment:* Master thesis presentation.

20. **Olena Tankyevych**
    *Date:* 060612
    *Title:* Automated abdominal tissue segmentation of multicontrast magnetic resonance images.
    *Comment:* Master thesis presentation.

21. **Patrick Karlsson**
    *Date:* 060619
    *Title:* Finding cells, finding molecules, finding patterns.

22. **Jonas Jämtberg**
    *Date:* 060904
    *Title:* Image analysis of current collectors.
    *Comment:* Master thesis presentation.

23. **Yao Wang**
    *Date:* 060918
    *Title:* Improved segmentation and classification of seeds.
    *Comment:* Master thesis presentation.

24. **Åsa Berglund**
    *Date:* 060925
    *Title:* The impact of NEQ on detectability of microcalcifications in mammography.
    *Comment:* Master thesis presentation.

25. **Erik Melin**
    *Date:* 061023
    *Title:* The joint operator.

26. **Ewert Bengtsson**
    *Date:* 061030
    *Title:* An update on modern imaging systems in medicine.

27. **Kristin Norell**
    *Date:* 061106
    *Title:* Detection of direction and symmetries in 2D images.

28. **Filip Malmberg**
    *Date:* 061113
    *Title:* Stress transfer and failure in pulp-fibre reinforced composites.

29. **Anders Berggren**
    *Date:* 061204
    *Title:* Image analysis methods for measuring the outer layer in the secondary cell wall of wood cells.
    *Comment:* Master thesis presentation.

30. **Daniel Fransson**
    *Date:* 061218
    *Title:* Noise reduction of X-ray microtomography images of paper using anisotropic filtering methods.
    *Comment:* Master thesis presentation.

## 7.6 Conference participation

### 7.6.1 Special invited speakers

1. *Conference:* Image analysis day at SMILE
   **Ewert Bengtsson**
   *Date:* 060913
   *Address:* Novum, Karolinska University Hospital, Stockholm
   *Title:* Introduction to image analysis for medical applications at the Centre for Image Analysis, Uppsala.

2. *Conference:* Medical Image Science - Uniting the Research Lab and the Clinical Routine
   **Ewert Bengtsson**
   *Date:* 061006
   *Address:* CMIV Linköping University Hospital
   *Title:* 3D Medical Images - Macro, Micro and Nano.

### 7.6.2 Oral presentations - refereed conferences

1. *Conference:* International Workshop on Combinatorial Image Analysis 2006 (IWCIA'06)
   **Magnus Gedda**
   *Date:* 060619–21
   *Address:* Humboldt-Universität, Berlin, Germany
   *Title:* Fuzzy distance based hierarchical clustering calculated using the A* algorithm.

2. *Conference:* International Workshop on Combinatorial Image Analysis 2006 (IWCIA'06)
   **Joakim Lindblad**
   *Date:* 060619–21
   *Address:* Humboldt-Universität, Berlin, Germany
   *Title:* Feature based defuzzification at increased spatial resolution.

3. *Conference:* International Workshop on Combinatorial Image Analysis 2006 (IWCIA'06)
   **Robin Strand**
   *Date:* 060619–21
   *Address:* Humboldt-Universität, Berlin, Germany
   *Title:* Approximating Euclidean distance using distances based on neighbourhood sequences in non-standard three-dimensional grids.

4. *Conference:* 18th International Conference on Pattern Recognition 2006 (ICPR'06)
   **Robin Strand**
   *Date:* 060820–24
   *Address:* Hong Kong, China
   *Title:* Using the hexagonal grid for three-dimensional images: Direct Fourier method reconstruction and weighted distance transform.

5. *Conference:* 13th International Conference on Discrete Geometry for Computer Imagery 2006 (DGCI'06)
   **Filip Malmberg**
   *Date:* 061025–27
   *Address:* Szeged, Hungary
   *Title:* A 3D live-wire segmentation method for volume images using haptic interaction.

6. *Conference:* 13th International Conference on Discrete Geometry for Computer Imagery 2006 (DGCI'06)
   **Robin Strand**
   *Date:* 061025–27
   *Address:* Szeged, Hungary
   *Title:* Generating Distance Maps with Neighbourhood Sequences.

### 7.6.3 Poster presentations - refereed conferences

1. *Conference:* 18th International Conference on Pattern Recognition 2006 (ICPR'06)
   **Magnus Gedda**
   *Date:* 060820–24
   *Address:* Hong Kong, China
   *Title:* Using a fuzzy framework for delineation and decomposition of immunoglobulin G in cryo electron tomographic images.

2. *Conference:* 18th International Conference on Pattern Recognition 2006 (ICPR'06)
   **Ingela Nyström, Erik Vidholm**
   *Date:* 060820–24
   *Address:* Hong Kong, China
   *Title:* Accelerating the computation of 3D gradient vector flow fields.
   *Comment:* In addition, Nyström was Swedish representative at the IAPR governing board meeting.

3. *Conference:* 18th International Conference on Pattern Recognition 2006 (ICPR'06)
   **Stina Svensson**
   *Date:* 060820–24
   *Address:* Hong Kong, China
   *Title:* Using a fuzzy framework for delineation and decomposition of immunoglobulin G in cryo electron tomographic images.
   *Comment:* Representative of TC18 - Discrete Geometry at IAPR TC meeting (21 August). Session chair for one session in the Systems, Robotics and Applications track.

4. *Conference:* 28th Annual Symposium of the German Association for Pattern Recognition 2006 (DAGM'06)
   **Maria Axelsson**
   *Date:* 060912–14
   *Address:* Berlin, Germany
   *Title:* Reduction of ring artifacts in high resolution X-ray microtomography images.

5. *Conference:* Medical Image Computing and Computer Assisted Intervention 2006 (MICCAI'06)
   **Erik Vidholm, Ingela Nyström**
   *Date:* 061001–06
   *Address:* Copenhagen, Denmark
   *Title:* Fast and robust semi-automatic liver segmentation with haptic interaction.

6. *Conference:* 8th International Information Technology Conference 2006 (IITC'06)
   **Amalka Pinidiyaarachchi**
   *Date:* 061012–13
   *Address:* University of Colombo School of Computing, Colombo, Sri Lanka.
   *Title:* Feasibility of using digital image processing in the assessment of cytology smears.

7. *Conference:* 13th International Conference on Discrete Geometry for Computer Imagery 2006 (DGCI'06)
   **Stina Svensson**
   *Date:* 061025–27
   *Address:* Szeged, Hungary
   *Title:* Hierarchical chamfer matching based on propagation of gradient strengths.
   *Comment:* Attended the steering committee meeting in place of Gunilla Borgefors.

### 7.6.4 Oral presentations

1. *Conference:* Swedish Society for Automated Image Analysis Symposium 2006 (SSBA'06)
   **Maria Axelsson**
   *Date:* 060316–17
   *Address:* Dept. of Computing Science, Umeå University
   *Title:* Volume estimation of the interface pores between paper web and press felt.

2. *Conference:* Swedish Society for Automated Image Analysis Symposium 2006 (SSBA'06)
   **Magnus Gedda**
   *Date:* 060316–17
   *Address:* Dept. of Computing Science, Umeå University
   *Title:* Separation of blob-like structures using fuzzy distance based hierarchical clustering.

3. *Conference:* Swedish Society for Automated Image Analysis Symposium 2006 (SSBA'06)
   **Filip Malmberg**
   *Date:* 060316–17
   *Address:* Dept. of Computing Science, Umeå University
   *Title:* Live-wire based interactive segmentation of volume images using haptics.

4. *Conference:* Swedish Society for Automated Image Analysis Symposium 2006 (SSBA'06)
   **Kristin Norell**
   *Date:* 060316–17
   *Address:* Dept. of Computing Science, Umeå University
   *Title:* Finding the pith in rough cross-sections of logs in saw mill environments.

5. *Conference:* Swedish Society for Automated Image Analysis Symposium 2006 (SSBA'06)
   **Robin Strand**
   *Date:* 060316–17
   *Address:* Dept. of Computing Science, Umeå University
   *Title:* A sequential algorithm for computing the distance transform using distances based on neighbourhood sequences in $\mathbb{Z}^3$.

6. **Carolina Wählby**
   *Date:* 060823
   *Address:* Krusenberg Herrgård, Uppsala
   *Title:* WP2: Image Analysis
   *Comment:* A kick-off conference for the three year ENLIGHT (ENhanced LIGase-based Histochemical Techniques) project, financed by EU. The second work package of the project, WP2, involves CBA as well as the Danish company Visiopharm. The task of WP2 is development of image analysis tools for automated, rapid and reliable quantification of in situ assay signals. Ewert Bengtsson and Amin Allalou attended the conference.

7. *Conference:* 2006 Progress in Paper Physics
   **Maria Axelsson**
   *Date:* 061001–05
   *Address:* Miami University, Oxford, Ohio, USA
   *Title:* Detailed quantification of the 3D structure of newsprints in X-ray synchrotron radiation microtomography images.

8. *Conference:* UU deans meeting
   **Ewert Bengtsson**
   *Date:* 061130–1201
   *Address:* Krusenberg conference centre
   *Title:* IT at UU - current situation and strategies.

### 7.6.5 Poster presentations

1. *Conference:* The 1st International Workshop on Approaches to Single-Cell Analysis
   **Carolina Wählby**
   *Date:* 060621–22
   *Address:* UU main building
   *Title:* Digital image analysis for single-cell approaches.

### 7.6.6 Attendee

1. *Conference:* International Conferences in Central Europe on Computer Graphics, Visualization and Computer Vision 2006 (WSCG'06)
   **Ewert Bengtsson**
   *Date:* 060130–0202
   *Address:* Univ West Bohemia, Plzen, Czech Republic
   *Comment:* Participated and acted as session chair.

2. *Conference:* PhD student day, Swedish Society for Automated Image Analysis Symposium 2006
   **Maria Axelsson, Magnus Gedda, Patrick Karlsson, Filip Malmberg, Kristin Norell, Suthakar Somaskandan, Erik Vidholm**
   *Date:* 060315
   *Address:* Dept. of Computing Science, Umeå University

3. *Conference:* Swedish Society for Automated Image Analysis Symposium 2006 (SSBA'06)
   **Ewert Bengtsson, Gunilla Borgefors, Joakim Lindblad, Ingela Nyström, Suthakar Somaskandan, Stina Svensson, Erik Vidholm**
   *Date:* 060315–17
   *Address:* Dept. of Computing Science, Umeå University
   *Comment:* Nyström hosted the SSBA 30 year anniversary cocktail party and was chair of the SSBA Annual Meeting. Borgefors participated in the jubilee meeting of former SSBA Presidents.

4. *Conference:* The Kiselmanfest: An International Symposium in Complex Analysis and Digital Geometry
   **Ewert Bengtsson, Gunilla Borgefors, Ingela Nyström**
   *Date:* 060515–18
   *Address:* MIC Aula, UU
   *Comment:* In honor of Professor Christer O. Kiselman on the occasion of his retirement. Borgefors was session chair and member of the organizing committee.

5. *Conference:* Wood Ultrastructure Research Centre (WURC) Annual Internal Seminar
   **Stina Svensson, Anders Berggren (master thesis student)**
   *Date:* 060518
   *Address:* Sigtunahöjden hotel and conference centre, Sigtuna, Sweden

6. *Conference:* Bio-X Programme Conference
   **Carolina Wählby**
   *Date:* 060523
   *Address:* Grand Hotel, Lund
   *Comment:* An informal conference arranged by the Swedish Foundation for Strategic Research (SSF) to communicate progress in the Foundation's Bio-X Framework Grants programme that started in spring 2005. The goal of this programme is to promote bold research that not only represents excellent science but via effects at a "systems" level also may provide a basis for future activities of potentially high economic and societal value.

7. *Conference:* CEF 10 years
   **Ewert Bengtsson**
   *Date:* 060615
   *Address:* Eklundshof, Uppsala
   *Comment:* Centre for entrepreneurmanship (CEF) and corporate development at UU celebrated its first 10 years with a conference.

8. *Conference:* The 6th SACR meeting - The Cytoskeleton, Regulation and Disease
   **Patrick Karlsson**
   *Date:* 060616–17
   *Address:* Gimo Herrgård
   *Comment:* The Swedish association for Cytoskeletal research.

9. *Conference:* International Workshop on Combinatorial Image Analysis 2006 (IWCIA'06)
   **Gunilla Borgefors**
   *Date:* 060618–21
   *Address:* Adlershof, Berlin, Germany
   *Comment:* Borgefors was session chair.

10. *Conference:* 2006 Progress in Paper Physics
    **Filip Malmberg**
    *Date:* 061001–05
    *Address:* Miami University, Oxford, Ohio, USA

11. *Conference:* Medical Image Computing and Computer Assisted Intervention 2006 (MICCAI'06)
    **Ewert Bengtsson**
    *Date:* 061002–1005
    *Address:* Copenhagen, Denmark

12. *Conference:* Swedish Medical Engineering Conference 2006, Medicinteknikdagarna
    **Patrick Karlsson, Hamid Sarve**
    *Date:* 061003–04
    *Address:* UU main building

13. *Conference:* Medical Image Science - Uniting the Research Lab and the Clinical Routine
    **Ingela Nyström**
    *Date:* 061006
    *Address:* CMIV, Linköping University

14. *Conference:* Jämställt - myter och verklighet.
    **Kristin Norell, Maria Axelsson**
    *Date:* 061018–19
    *Adress:* Centre for Gender Research, UU
    *Comment:* A national equality conference for universities.

15. *Conference:* SNIC Interaction 2006
    **Ingela Nyström**
    *Date:* 061120–21
    *Address:* LUNARC, Lund University
    *Comment:* Representing UPPMAX.

16. *Conference:* 13th International Conference on Discrete Geometry for Computer Imagery 2006 (DGCI'06)
    **Joakim Lindblad**
    *Date:* 061025–27
    *Address:* Szeged, Hungary
    *Comment:* Lindblad was co-author of the paper "Feature based defuzzification in $\mathbb{Z}^2$ and $\mathbb{Z}^3$ using a scale space approach". Oral presentation by T. Lukić.

17. *Conference:* GIS at Uppsala University
    **Ewert Bengtsson**
    *Date:* 061115
    *Address:* Ekonomikum, Uppsala
    *Comment:* Bengtsson acted as chair of this half day conference.

18. *Conference:* Skogskonferens 226: Skogen - mot oljeberoendet och för klimatmålen
    **Stina Svensson, Joakim Lindblad**
    *Date:* 061128–29
    *Address:* Ultuna, Uppsala

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

1. **Cèline Fouard**
   *Address:* EPIDAURE project, INRIA, Sophia Antipolis, France
   *Host:* Gunilla Borgefors
   *Date:* 060101–0801
   *Topic:* Weighted distance transforms and fuzzy sets. See Projects 2 and 3.

2. **Steven L. Tanimoto**
   *Address:* Dept. of Computer Science and Engineering, University of Washington, Seattle, USA
   *Hosts:* Gunilla Borgefors, Ewert Bengtsson
   *Date:* 060222–0512
   *Topic:* Image analysis as a tool for mathematics understanding.

3. **Matthias Biedermann**
   *Address:* Institute for Computational Visualistics, University of Koblenz-Landau, Germany
   *Host:* Ingela Nyström
   *Date:* 060828–1130
   *Topic:* Joint project on how to pursue image processing on the GPU.

4. **Nataša Sladoje**
   *Address:* Centre of Mathematics and Statistics, Faculty of Engineering, University of Novi Sad, Serbia
   *Host:* Gunilla Borgefors
   *Date:* 061001–1014
   *Topic:* Planning the course "Fuzzy sets and fuzzy techniques" and continued cooperation on Project 6.

## 7.8 Visits to other research groups (for at least 2 weeks)

1. **Joakim Lindblad**
   *Host:* Erich Sorantin
   *Address:* Dept. of Radiology, University Hospital Graz, Austria
   *Date:* 060424–0505
   *Topic:* Research visit
   *Comments:* Visit together with Nataša Sladoje for exchange of knowledge and ideas.

## 7.9 Short visits to other research groups and meetings outside CBA

**Note: Meetings occassioned by permanent appointments are listed in section 7.11**

1. **Most personell at CBA**
   *Host:* Uppsala Imanet, "PET-centrum"
   *Address:* Uppsala Imanet, Uppsala Science Park
   *Date:* 060110
   *Topic:* The "Lucia-visit" of CBA.

2. **Ewert Bengtsson**
   *Address:* Vetenskapsrådet, The Swedish Research Council conference room, Stockholm
   *Date:* 060117
   *Topic:* Hearing with evaluation committee for medical engineering.

3. **Gunilla Borgefors**
   *Host:* Jürgen Goebbels, Dieter Scharnweber
   *Address:* Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung m.b.H. (BESSY), Adlershof, Berlin, Germany
   *Date:* 060126–27
   *Topic:* Investigating the possibility of using micro-CT images from BESSY to quantify bone implant healing
   *Comments:* Travelled with Carina Johansson, Örebro University.

4. **Ewert Bengtsson**
   *Date:* 060217
   *Address:* The Swedish Society of Physicians, Stockholm
   *Title:* Witness seminar about the history of IT in biomedicine in Sweden
   *Comment:* People involved in the early development of IT for biomedical applications were invited to testify for a group collecting material for the project "History of IT in Sweden".

5. **Ingela Nyström**
   *Hosts:* Fredrik Georgsson, Christina Olsén
   *Address:* Dept. of Computer Science, Umeå University
   *Date:* 060221
   *Topic:* Planning of SSBA Symposium.

6. **Joakim Lindblad**
   *Host:* Gustaf Forsberg
   *Address:* SeedGard AB, Uppsala
   *Date:* 060222
   *Topic:* Seed vitality
   *Comments:* Concluding meeting for the seed vitality project.

7. **Ewert Bengtsson**
   *Host:* Inger Kristoffersson
   *Address:* City Hall, Uppsala
   *Date:* 060223
   *Topic:* Planning of a delegation to Nanying, China from Uppsala to discuss cooperation in the IT- and biotech areas. About 10 persons attending.

8. **Ewert Bengtsson**
   *Host:* Inger Kristoffersson
   *Address:* The Office of Foreign Relations, City of Nanying, China
   *Date:* 060301–0308
   *Topic:* Delegation to Nanying
   *Comments:* Representing UU on this delegation trip, meeting many researchers and companies interested in collaboration. A delegation of 12 persons from Uppsala.

9. **Stina Svensson, Magnus Gedda**
   *Hosts:* Ulf Skoglund, Lars-Göran Öfverstedt
   *Address:* Dept. of Cell and Molecular Biology, Karolinska Institutet, Stockholm
   *Date:* 060302
   *Topic:* Discussions and information on collaboration project.

10. **Stina Svensson, Anders Berggren**
    *Host:* Jonas Brändström
    *Address:* Dept. of Wood Science, SLU
    *Date:* 060303
    *Topic:* Follow up meeting for master thesis work (Anders Berggren).

11. **Stina Svensson**
    *Host:* Duccio Fanelli, Sara Sandin, Ulf Skoglund
    *Address:* Dept. of Cell and Molecular Biology, Karolinska Institutet, Stockholm
    *Dates:* 060304 and 060403
    *Topic:* Discussion on the common project: automated extraction of geometrical features of proteins from cryo electron tomographic data.

12. **Ewert Bengtsson**
    *Address:* Gimo Herrgård
    *Date:* 060307
    *Topic:* Meeting of the deans of UU. All of UU leadership was present. Bengtsson present on behalf of Virtual IT-faculty.

13. **Ewert Bengtsson**
    *Host:* Mats Fredriksson
    *Address:* Biomedical Centre Uppsala
    *Date:* 060320
    *Topic:* Planning the response from the Faculty of Science and Technology to the proposed Uppsala Brain Centre.

14. **Ewert Bengtsson**
    *Host:* Jan-Otto Carlsson
    *Address:* Office of the Dean
    *Date:* 060327
    *Topic:* Discussion about possibility of transferring Geoinformatics to CBA and of creating a visualisation lab.

15. **Ewert Bengtsson**
    *Address:* Eklundshof, Uppsala
    *Date:* 060329
    *Topic:* Science and its cultures
    *Comment:* A seminar summing the results from the 6 year project “Science and technology in school” for which Bengtsson has participated in the board meetings.

16. **Kristin Norell, Hamid Sarve, Erik Vidholm**
    *Address:* Centre for Gender Research, UU
    *Date:* 060404
    *Topic:* Varför är det manligt att programmera?
    *Comment:* Seminar by Inger Boivie attended by the CBA equality group through Vidholm and Norell.

17. **Kristin Norell**
    *Host:* Ari Karjula
    *Address:* Heby Sawmill, Heby
    *Date:* 060406
    *Topic:* Collecting images at Heby saw mill together with Lars Björklund (VMR).

18. **Ewert Bengtsson**
    *Host:* Doris Dongsheng Yang, Director of International Cooperation
    *Address:* Jiading Campus, Shanghai, China
    *Date:* 060407
    *Topic:* Visit to Tongji University, Shanghai, China
    *Comments:* Discussing the experiences from the exchange of students between UU IT-department and Tongji Univ.

19. **Erik Vidholm**
    *Host:* Daniel Evestedt, Mark Dixon, Tommy Forsell, Johan Beskow
    *Address:* SenseGraphics, Kista, Sweden
    *Topic:* Discussion about haptics programming and volume visualization. Karljohan Lundin, Norrköping Visualization and Interaction Studio, Linköping University, also attended the meetings. (2 meetings during the year.)

20. **Ewert Bengtsson**
    *Host:* Inger Kristoffersson
    *Address:* City Hall, Uppsala
    *Date:* 060426
    *Topic:* Follow up meeting on the delegation trip to Nanying.

21. **Gunilla Borgefors**
    *Host:* Phil Salmon
    *Address:* SkyScan, Aartselaar (Antwerpen), Belgium
    *Date:* 060426–28
    *Topic:* Investigating the possibilities of using microtomography images from SkyScan for evaluating bone implants (and paper structure).
    *Comments:* Carina Johansson, Örebro University, also participated.

22. **Ewert Bengtsson**
    *Host:* Christer Busch
    *Address:* Dept. of Genetics and Pathology, Rudbeck Lab, UU
    *Date:* 060428
    *Topic:* Discussion about possible renewed cooperation on histopathology image analysis. Petter Ranefall, AstraZeneca Research and Development, Mölndal, also attended.

23. **Ewert Bengtsson**
    *Address:* Stockholm City Hall
    *Date:* 060511
    *Topic:* Bengtsson attended the Stockholm Challenge Award Price Ceremony.

24. **Ewert Bengtsson**
    *Address:* The office of the vice chancellor
    *Date:* 060512
    *Topic:* Information about the possibilities of a new research position on brain image analysis at UU with Bo Sundqvist, Håkan Ahlström, Ulf Petterson and Mats Fredrikson also attended.

25. **Ewert Bengtsson**
    *Address:* The Castle Gardens, Uppsala
    *Date:* 060512
    *Topic:* Informal discussion with Anders Hallberg about future IT strategy for UU.

26. **Ewert Bengtsson and Carolina Wählby**
    *Host:* Michael Grunkin and Niels Foged
    *Address:* Visiopharm, Copenhagen, Denmark
    *Date:* 060529
    *Topic:* Discussions on cooperation
    *Comments:* The meeting was the first exchange of ideas for the recently granted EU ENLIGHT project.

27. **Ewert Bengtsson**
*Address:* Ångström Laboratory
*Date:* 060531
*Topic:* Fuel cell and membrane design
*Comments:* Bengtsson helped arrange this informal seminar with Sergei Lvov, Penn State University, State College, Pennsylvania, USA, and people working on the same topic as this visitor.

28. **Stina Svensson**
*Host:* Duccio Fanelli
*Address:* Dept. of Cell and Molecular Biology, Karolinska Institutet, Stockholm
*Date:* 060606
*Topic:* Discussions and information on collaboration project.

29. **Maria Axelsson, Filip Malmberg, Joakim Lindblad and Stina Svensson**
*Host:* Jussi Timonen and Tuomas Turpeinen
*Address:* Dept. of Physics, University of Jyväskylä, Finland
*Date:* 060609–10
*Topic:* Research visit
*Comments:* Visit to the group working with paper and fibrous material at Dept. of Physics in Jyväskylä, Finland in order to establish a possible collaboration.

30. **Erik Vidholm**
*Host:* Gunnar Jansson
*Address:* Dept. of Psychology, UU
*Date:* 060615
*Topic:* Discussion about haptics and perception. Ulrika Dreifaldt, Interaction Design Center, University of Limerick, Ireland, also attended.

31. **Ingela Nyström**
*Host:* Gabor Szekely
*Address:* Dept. of Information Technology and Electrical Engineering, ETH Zürich, Switzerland
*Date:* 060620–21
*Topic:* Study visit of the Computer Vision Laboratory.
*Comments:* Many projects were presented on medical image analysis, haptic visualization, and augmented reality.

32. **Stina Svensson, Joakim Lindblad, Gunilla Borgefors**
*Host:* Geoffrey Daniel, Stig Bardage
*Address:* Dept. of Wood Science (TRV), SLU
*Date:* 060809
*Topic:* Future joint research.
*Comments:* General discussion of possible future cooperation.

33. **Joakim Lindblad**
*Host:* Jonas Sahlsten
*Address:* Dept. of Population Biology and Conservation Biology, UU
*Date:* 060818
*Topic:* Research visit
*Comments:* Discussion regarding methods to describe and analyse shapes of bird habitats.

34. **Ewert Bengtsson**
*Address:* Uppsala Learning Lab, UU
*Date:* 060829
*Topic:* Meeting about the need of a portal for employees of UU.

35. **Ewert Bengtsson**
*Address:* Uppsala Science Park
*Date:* 060830
*Topic:* Meeting for “peer-coaching” within the Vinnova key actors program to promote exploitation of university research results.

36. **Erik Vidholm**
*Host:* Andrew Mehnert
*Address:* University of Queensland, ITEE, Brisbane, Australia
*Date:* 060906–14
*Topic:* Work on dynamic MR sequences of breast.

37. **Stina Svensson and Magnus Gedda**
*Host:* Ulf Skoglund
*Address:* Dept. of Cell and Molecular Biology, Karolinska Institutet, Stockholm
*Date:* 060907
*Topic:* Project updating and future plans.

38. **Stina Svensson**
*Address:* SLU, Umeå (by phone)
*Date:* 060913
*Topic:* Contact persons for postgraduate studies, SLU.

39. **Ingela Nyström**
*Host:* Eva Pärt-Enander
*Address:* Uppsala Learning Lab, UU
*Date:* 060921
*Topic:* Available IT techniques at ULL.

40. **Kristin Norell, Stina Svensson**
*Host:* Kim Dralle
*Address:* Dralle A/S Cognitive Systems, Copenhagen, Denmark
*Date:* 060926
*Topic:* Meeting about the joint project on detecting rot in log end images.
*Comments:* Also present was Anders Dahl and others from Dralle.

41. **Amin Allalou**
*Hosts:* Anton K. Raap and Frans van de Rijke
*Address:* Dept. of Molecular Cell Biology, Leiden University Medical Center, Leiden, The Netherlands
*Date:* 061004–06
*Topic:* Discussions on image based single cell analysis.
*Comments:* The visit was part of the ENLIGHT project to exchange ideas and define the needs for an image based single cell analysis system based on new functionality developed at CBA and integrated with the Visiopharm VIS platform.

42. **Kristin Norell**
*Address:* SLU
*Date:* 061005
*Topic:* Könsroller i arbetslivet - Om kvinnligt och manligt i ledarrollen.
*Comment:* A seminar by Bodil Wennberg, Emotional Intelligence AB. This was a part of a seminar series for PhD students at SLU about leadership.

43. **Stina Svensson**
*Host:* Duccio Fanelli
*Address:* Dept. of Energetic, University of Florence, Florence, Italy
*Date:* 061016–20
*Topic:* Joint work.

44. **Carolina Wählby**
*Host:* David Mitchell and Ida-Maria Sintorn
*Address:* CSIRO Mathematical and Information Sciences, Australia
*Date:* 061018
*Topic:* Discussions on future cooperations

45. **Joakim Lindblad**
*Host:* Nataša Sladoje, Silvia Ghilezan
*Address:* Centre of Mathematics and Statistics, Faculty of Engineering, University of Novi Sad, Serbia
*Date:* 061029–1101
*Topic:* Research visit
*Comments:* Joint research project and invited speaker at the Seminar of Mathematics and Statistics.

46. **Hamid Sarve, Joakim Lindblad, Carina Johansson**
*Host:* Felix Beckmann
*Address:* Deutsches Electronen-Syncrotron, Hamburg, Germany
*Date:* 061031–1103
*Topic:* SR$\mu$CT-scanning
*Comments:* Beamtime at Deutsches Electronen- Syncrotron in Hamburg for three days.

47. **Erik Vidholm, Ingela Nyström**
*Host:* Sven Nilsson
*Address:* Dept. of Radiology, UU Hospital
*Date:* 061031
*Topic:* Discussion about liver segmentation.

48. **Ewert Bengtsson, Erik Vidholm**
*Host:* Anders Magnusson
*Address:* Dept. of Radiology, UU Hospital
*Date:* 061107
*Topic:* Discussion about a possible joint project and application on 3D modelling of breasts based on CT for reconstructive surgery after cancer operations.

49. **Ewert Bengtsson**
*Date:* 061121
*Address:* UU main building
*Topic:* The pedagogial education and experience of PhD students.
*Comment:* A half day meeting about university policy to ensure that PhD students get proper pedagogical training.

50. **Ewert Bengtsson**
*Host:* Johanna Lundmark, UU
*Address:* Uppsala Science Park
*Date:* 061123
*Topic:* UU reference group for the Swedish Science Net project.

51. **Hamid Sarve**
*Host:* Carina Johansson
*Address:* Sahlgrenska University Hospital, Göteborg
*Date:* 061124
*Topic:* Discussions on the bone implant project.
*Comments:* Discussed some issues with Carina Johansson and paid visit to their laboratory.

52. **Ewert Bengtsson**
*Host:* Jan Hirsch
*Address:* UU Hospital
*Date:* 061129
*Topic:* Meeting with three surgeons about possible cooperation on 3D modelling in head surgery.

53. **Carolina Wählby**
*Host:* Björn Eriksson, Ann-Catrin Svensson, Peter Karlberg and Mats Gullberg
*Address:* Olink AB, Uppsala
*Date:* 061206
*Topic:* Simple software for image based PLA-analysis.
*Comments:* Olink AB makes kits for proximity-ligation assays (PLA). Software tools are needed for efficient readout of the signals from the PLA. Ideas for such software were discussed, and a first Matlab-based version was created by CW and installed at Olink 061214.

54. **Kristin Norell**
*Host:* Björn Hannrup
*Address:* Skogforsk, Uppsala
*Date:* 061211
*Topic:* Meeting together with Lars Björklund (VMR) and Christina Lundgren (VMR) about methods on measuring timber.

55. **Ewert Bengtsson**
*Host:* Anders Hallberg
*Address:* Uppsala Castle and the Ångström Laboratory
*Date:* 061213
*Topic:* Bengtsson attended a lecture by the Nobel Laureates in Physics and lunch in their honour at the Uppsala Castle.

## 7.10 Other visitors

1. **Britt Östlund**
*Address:* Vetenskapsrådet, The Swedish Research Council
*Host:* Ewert Bengtsson
*Date:* 060103
*Topic:* The future coordination of IT at UU.

2. **Örjan Nordhage**
*Address:* Dept. of Nuclear and Partical Physics, UU
*Host:* Ingela Nyström
*Date:* 060112
*Topic:* Measurements of pellets in a radiation beam.

3. **Hans Ekwall**
*Address:* Dept. of Reproduction, SLU
*Host:* Ewert Bengtsson
*Date:* 060122
*Topic:* Possible cooperation on electron microscopy image analysis.

4. **Ingrid Carlbom**
*Address:* USA
*Host:* Ewert Bengtsson
*Date:* 060123
*Topic:* Possible cooperation on image analysis in histopathology.

5. **Lennart Thurfjell(1), Gunnar Jansson(2)**
*Adress:* (1) GE Healthcare, Uppsala, (2) Dept. of Psychology, UU
*Host:* Erik Vidholm, Ewert Bengtsson, Ingela Nyström, Stefan Seipel
*Topic:* 3 meetings with the reference group of the haptics project during the year.

6. **Jonas Brändström**
*Adress:* Dept. of Wood Science, SLU
*Host:* Stina Svensson, Anders Berggren
*Date:* 060330
*Topic:* Follow up meeting for master thesis work (Anders Berggren).

7. **Ingrid Carlbom**
   *Address:* Multimedia Research Laboratory, Lucent Technologies Bell Laboratories, USA
   *Host:* Ewert Bengtsson
   *Date:* 060123
   *Topic:* Image analysis research cooperation.

8. **Gustaf Forsberg**
   *Address:* SeedGard AB, Ultuna, Uppsala
   *Host:* Joakim Lindblad
   *Date:* 060202
   *Topic:* Seed vitality
   *Comments:* Planning and demonstration meeting for the seed vitality project.

9. **Anna-Stina Höglund**
   *Address:* Dept. of Neuroscience, UU
   *Host:* Gunilla Borgefors
   *Date:* 060203
   *Topic:* Visualizing 3D confocal microscopy data depicting muscle fibres
   *Comments:* This contact led to a joint VR application.

10. **Sven Nilsson**
    *Address:* Dept. of Radiology and Clinical Immunology, UU Hospital
    *Host:* Erik Vidholm, Ingela Nyström
    *Topic:* Discussion about liver segmentation. At least 4 meetings during the year.

11. **Carina Johansson**
    *Address:* Dept. of Clinical Medicine, Örebro University
    *Host:* Hamid Sarve, Gunilla Borgefors
    *Topic:* Meeting about the bone implant project. (3 meetings during the year.)

12. **Toshiaki Ikom**
    *Address:* Canon Inc, Japan
    *Host:* Ewert Bengtsson
    *Date:* 060306
    *Number of visitors:* 4
    *Topic:* Possible future cooperation
    *Comments:* A high level delegation visiting a few selected groups and the vice-chancellor at UU.

13. **Duccio Fanelli**
    *Address:* Dept. of Cell and Molecular Biology, Karolinska Institutet, Stockholm and Dept. of Energetic, University of Florence, Florence, Italy
    *Host:* Stina Svensson, Magnus Gedda
    *Date:* 060406
    *Topic:* Discussion on automated extraction of geometrical features of proteins from cryo electron tomographic data.

14. **Fredrik Georgsson**
    *Address:* Dept. of Computing Science, Umeå University
    *Host:* Patrick Karlsson, Magnus Gedda, Ingela Nyström
    *Date:* 060426
    *Topic:* Mammography as digital image analysis.
    *Comments:* Guest lecture at the Computerised Image Analysis course.

15. **Nahid Kodikara, Prasad Wimalaratne**
    *Address:* University of Colombo, Sri Lanka
    *Host:* Ewert Bengtsson, Ingela Nyström
    *Date:* 060427–0509
    *Topic:* Collaboration in relation to PhD student Suthakar Somaskandan
    *Comments:* Several meetings and seminars took place during the visit.

16. **David Gee, Gerhard Bax**
    *Address:* Dept. of Earth Sciences, UU
    *Host:* Ewert Bengtsson
    *Date:* 060516
    *Topic:* Discussion about cooperation in Geoinformatics at UU

17. **Ylva Jannok-Nutti**
    *Address:* Dept. of Educational Sciences, Luleå University
    *Host:* Gunilla Borgefors
    *Date:* 060518–19
    *Topic:* Mathematical patterns in Sami handicrafts
    *Comments:* Jannok-Nutti's advisor Lars-Erik Persson also particpated.

18. **Holland Cheng**
    *Address:* UC Davis, University of California, USA
    *Hosts:* Ewert Bengtsson, Joakim Lindblad, Stina Svensson
    *Date:* 060531
    *Topic:* Discussion about possible cooperation on volume image analysis of EMT images of virus particles
    *Comments:* We have filed a joint application to the American Human Frontiers Program.

19. **Lars Roepstorff**
    *Address:* Dept. of Equine studies, SLU, Uppsala
    *Host:* Gunilla Borgefors, Joakim Lindblad, Petter Holmberg
    *Date:* 060607
    *Topic:* Master Thesis
    *Comments:* The meeting was marked the finish of Holmberg's Master Thesis and also discussed possible future cooperation.

20. **Ulrika Dreifaldt**
    *Address:* Interaction Design Center, University of Limerick, Ireland
    *Host:* Erik Vidholm
    *Date:* 060615
    *Topic:* Discussion about haptics in medical applications.

21. **Kristoffer Gamstedt, Karin Bogren**
    *Address:* STFI-Packforsk, KTH Solid Mechanics, Stockholm
    *Host:* Filip Malmberg, Joakim Lindblad, Stina Svensson
    *Date:* 060615
    *Topic:* Discussion of the project "Stress transfer and failure in pulp-fibre reinforced composites".

22. **Örjan Nordhage**
    *Address:* Dept. of Nuclear and Partical Physics, UU
    *Host:* Ingela Nyström, Bo Nordin
    *Date:* 060619
    *Topic:* Visualization of hydrogen micro-spheres (pellets) being internal target for ion-beam experiments.

23. **Mats-Ola Ottosson**
    *Address:* UU
    *Host:* Ewert Bengtsson
    *Date:* 060706
    *Topic:* About the future organisation to coordinate and strategically plan IT at UU.

24. **Mats Gullberg(1), Ann-Catrin Andersson(1), Anders Alderborn(2)**
    *Address:* (1) Olink AB, Uppsala, (2) Dept. of Genetics and Pathology, the Rudbeck Lab, UU
    *Host:* Carolina Wählby, Amin Allalou
    *Date:* 060822
    *Number of visitors:* 3
    *Topic:* Demonstrations of possibilities of image based single cell analys
    *Comments:* The meeting was intended to give a preview of issues to be brought up during the ENLIGHT kick-off later in August.

25. **SSBA Board**
*Address:* Umeå, Linköping, Göteborg, Malmö, Lund
*Host:* Ingela Nyström
*Date:* 060831
*Number of visitors:* 7
*Topic:* SSBA Board Meeting.

26. **Kim Dralle**
*Address:* Dralle A/S Cognitive Systems, Copenhagen, Denmark
*Host:* Kristin Norell, Stina Svensson, Joakim Lindblad
*Date:* 060906
*Topic:* Meeting with new contact Kim Dralle about a possible cooperation.

27. **Italo Masiello**
*Address:* Centre for Cognition, Understanding, and Learning, Karolinska Institutet, Stockholm
*Host:* Ewert Bengtsson, Ingela Nyström
*Date:* 060907
*Topic:* Abdominal Open Surgery Simulator.
*Comments:* Discussions on a joint project and application.

28. **Per Nygård(1), Karin Bogren(2)**
*Adress:* (1) Paper and Fiber Research Institute, Trondheim, Norway, (2) STFI-Packforsk, KTH Solid Mechanics, Stockholm
*Host:* Joakim Lindblad, Stina Svensson, Maria Axelsson, Filip Malmberg
*Date:* 060918
*Topic:* 3D characterisation of fibrous material.

29. **Jayaram K. Udupa**
*Address:* Medical Image Processing Group, Dept. of Radiology, University of Pennsylvania, Philadelphia, USA
*Host:* Ingela Nyström
*Date:* 061009
*Topic:* Discussions on various projects of common interest, in particular the haptics project.

30. **Anthony Meader**
*Address:* E-Health Research Centre, Brisbane, Australia
*Host:* Ewert Bengtsson
*Date:* 061010
*Topic:* Possible cooperation on medical image analysis and E-health.

31. **Peter Meurer**
*Address:* Edutools, Uppsala
*Host:* Ewert Bengtsson
*Date:* 061011
*Topic:* Possible cooperation on applications of face detection and segmentation.

32. **Lisa Sennerby Fosse and Torbjörn Fagerström**
*Hosts:* Ewert Bengtsson and Gunilla Borgefors
*Date:* 061025
*Topic:* General presentation of CBA.
*Comment:* Sennerby Fosse is vice-chancellor of SLU and Fagerström is pro vice-chancellor of SLU.

33. **Mats Nilsson**
*Address:* Dept. of Pharmaceutical Biosciences, UU
*Host:* Ewert Bengtsson, Joakim Lindblad, Stina Svensson
*Date:* 061107
*Topic:* Discussion on a possible master thesis work suggested by Mats Nilsson, on measuring heart beat frequency in mouse and rat embryo cultures.

34. **Anders Hallberg**
*Host:* Ingela Nyström, Ewert Bengtsson
*Date:* 061109
*Number of visitors:* 4
*Topic:* The role of UPPMAX for Uppsala University and vice versa
*Comments:* Hallberg is Vice-Chancellor of UU. Bo Thidé, Börje Johansson, and Sverker Holmgren were part in the presentation, that also included a visit to the super-computer Ra.

35. **Anders Tegeman**
*Address:* Hantverkargatan 36, Hofors
*Host:* Ewert Bengtsson
*Date:* 061113
*Topic:* Scientific discussion
*Comments:* Discussion about possibilities of image analysis of small objects in blood.

36. **Ewert Bengtsson**
*Date:* 20061127
*Address:* CBA new premises
*Title:* CBA 18 years + moving in party
*Comment:* Celebrating coming of age (18 years) and inaugurating our new premises. About 70 guests. a brief presentation about our research by Bengtsson.

37. **Per Nygård(1), Kristoffer Gamstedt(2)**
*Adress:* (1) Paper and Fiber Research Institute, Trondheim, Norway, (2) STFI-Packforsk and KTH Solid Mechanics, Stockholm
*Hosts:* Joakim Lindblad, Stina Svensson
*Topic:* 2 phone meetings in November and December with discussion on joint application.

38. **Karin Bogren, Kristoffer Gamstedt**
*Address:* STFI-Packforsk and KTH Solid Mechanics, Stockholm
*Hosts:* Joakim Lindblad, Filip Malmberg
*Date:* 061208
*Topic:* Project meeting, Stress transfer and failure in pulp-fibre reinforced composites.

39. **Petter Ranefall**
*Address:* AstraZeneca Research and Development, Mölndal
*Host:* Ewert Bengtsson, Ingela Nyström, Erik Vidholm
*Date:* 061211
*Topic:* Interactive image analysis.
*Comments:* Talked to our former CBA colleague about his current work at Astra and about possible cooperation.

40. **Lars-Erik Larsson**
*Address:* Royal Academy of Engineering Sciences, IVA
*Host:* Ewert Bengtsson
*Date:* 061213
*Topic:* Introducing Ewert Bengtsson and wishing him welcome to IVA Section VII
*Comments:* Lars-Erik is chair of IVA VII to which Ewert has been elected.

41. **Peter Trollsås and Anders Sundström**
*Address:* Parameter AB, Stockholm
*Host:* Jonas Jarvius, Dept. Genetics & Pathology, Rudbeck Lab, UU, Carolina Wählby
*Date:* 061219
*Number of visitors:* 2
*Topic:* Demonstration of line-scanners and real-time image analysis.
*Comments:* A fast line-scanner together with real-time image analysis is needed for flow-system based analysis of fluorescent signals produced using highly specific single-molecule detection probes developed at Rudbeck lab and Olink AB.

## 7.11 Committees

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

**Ewert Bengtsson**
International:

- 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) 2004–
  *Comment:* Member since 1974.
- Member of ”The International Society for Optical Engineering”, (SPIE)
- Member of “Eurographics”, the European Association for Computer Graphics
- Programme Committee of WSCG’06
  *Comment:* International conference series in Computer Graphics and Image Analysis held in Plzen, Czech Rèpublic in February each year
- Programme Committee of Track III: Signal, Speech and Image Processing of ICPR’06
  *Comment:* International Conference on Pattern Recognition, Hong Kong, China.
- Programme Committee of NORSIG’06.
  *Comment:* Nordic Signal Processing Conference in Reykjavik, Iceland, June 2006.
- Programme Committee of the Workshop on Mass-Data Analysis of Images and Signals, July 2006
- Expert evaluator for application for EURYI - European Young Investigators Award.
- Expert evaluator for applications to Swedish Research Links, for the Swedish Science Council, August 2006
- Expert evaluator of project proposals for the European Community 6th Framework Human Frontier Science Programme Organization.
- PhD thesis examiner and dissertation opponent for Antti Niemistö, Tampere University of Technology, 061124
  *Comment:* Title: Quantitative image analysis methods for applications in biomedical microscopy.

National:

- Member of the Royal Society of Sciences in Uppsala (Kungliga Vetenskaps societeten), 199809–
  *Comment:* Elected member of this, the oldest scientific society in Sweden. (4 meetings.)
- Chair of the Virtual Faculty of Information Technology, UU, 199807–
  *Comment:* The faculty is responsible for coordinating all aspects of the information technology field at UU. The faculty board has about 15 members. 4 meetings and additionally 5 preparatory and follow up meetings.
- Advisor to the Rector on Information Technology at UU, 199802–
  *Comment:* One of seven advisors appointed to lead the strategic planning of UU and give advice to the Rector. (5 meetings.)
- Member of “Rektorsrådet” the Rector’s advisory council, 199802–
  *Comment:* (5 meetings.)
- Chair of the WWW management board of UU, 200001–
  *Comment:* (5 meetings.)

- Chair of the board of the UPI, the Unit for Development of Teaching and Interactive Learning of UU, 200407–
  *Comment:* (9 meetings and additionally 4 internal planning meetings.)
- Project leader for a National IT User Centre, NITA, 200008–
  *Comment:* Established a Swedish national IT user centre funded by Vinnova and UU and in cooperation with industry. During 2006 several informal meetings concerning future financing and cooperation plans took place. (6 meetings.)
- Member of the reference group of the Unit for Development of Pedagogy and Interactive Learning of Uppsala University formed 200301.
  *Comment:* (2 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. (8 meetings.)
- 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:* (7 meetings.)
- Member of the Uppsala Chamber of Commerce IT board, representing UU. 200006–
  *Comment:* Working with various activities to promote cooperation researchers - companies. (6 meetings.)
- Member of the IT-cluster group, 200108–
  *Comment:* A group under the chairmanship of Uppsala municipality with the task of promoting the IT business activity in Uppsala by making the present competence and activity known to the local, national and international community. All kinds of organisations are represented on the committee. Bengtsson represents UU. (6 meetings.)
- SUUS IT group, 050301
  *Comment:* Representing UU on the group for cooperation between universities in the Stockholm region in the IT field. (3 meetings)
- Board of EHealth Centre at UU, 050817–
  *Comment:* Member of the board of this Centre representing the faculty of Science and Technology. (6 meetings)
- IT in university learning, 051007–060215
  *Comment:* Chair of this committee charged with the task of proposing how the work to develop and support the use of IT in UU undergraduate education should be coordinated between the faculty and the central levels. (3 meetings)
- Member of the scientific board of Hillevi Fries Research Scholarship Foundation.
  *Comment:* A Swedish foundation that accepts applications and gives out research grants for urology research. The board has three members. (2 meetings.)
- Member of the Royal Swedish Academy of Engineering Sciences, Section VII: Basic and Interdisciplinary Engineering Sciences. 0610–
- On the committee to elect a new pro-vice-chancellor for Uppsala University. *Comment:* (2 meetings.)
- On the steering committee for the project “rational web publishing” at UU. *Comment’:* (1 meeting.)
- PhD Dissertation Committee for Heide Stollberg, Biomedical & X-ray Physics, KTH, Stockholm, 061020
  *Comment:* Title: Compact soft X-ray microscopy: Image processing and instrumentation.

**Gunilla Borgefors**
International:

- Fellow of the International Association for Pattern Recognition (IAPR), 1998–
- Senior member of the Institute of Electrical and Electronics Engineers, Inc. (IEEE), 1998–
- Member of the Advisory Committee of the International Association for Pattern Recognition (IAPR), 2006–
- Area editor of Pattern Recognition Letters, 2004–
  *Comment:* On the editorial Board since 1998. Published by Elsevier.
- Editorial Board member of Image Processing and Communications, 1994–
  *Comment:* Published by the Institute of Telecommunications, Bydgoszcz, Poland.
- Editorial Board member of 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, 2003–
- Steering committee for Discrete Geometry for Computer Imagery (DGCI) conferences, 2000–
- Programme Committee for International Workshop on Combinatorial Image Analysis 2006 (IWCIA'06), Berlin, Germany, June 2006
- Programme Committee for the 18th International Conference on Pattern Recognition (ICPR), Hong Kong, China, August 2006
- Steering Committee for the 13th International Conference on Discrete Geometry for Computer Imagery (DGCI), Szeged, Hungary, October 2006
- Opponent of Leena Ikonen for the degree of Doctor of Science, Dept. of Information Technology, Lappeenranta University of Technology, Lappeenranta , Finland, 20060615
  *Comment:* Title: Distance Transforms on Gray-Level Surfaces

National:

- Royal Society of Sciences in Uppsala (Kungliga Vetenskaps-societeten), Member No. 19, 200009–
  *Comment:* Elected member of this, the oldest scientific society in Sweden (founded 1710).
- Member of Swedish Parliamentarians and Scientists, 1987–
  *Comment:* Members are elected. Only one scientist per field admitted.
- Permanent member of 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. (1 meeting.)
- Nomination Committee, Swedish Society for Automated Image Analysis (SSBA)
- Organizing committee for The Kiselmanfest: An International Symposium in Complex Analysis and Digital Geometry, 20060101–20060518
  *Comment:* The symposium was organized in honor of Professor Christer O. Kiselman on the occasion of his retirement.
- The Prize and Reward committee of the Faculty of Forestry, SLU, 20060101
  *Comment:* (1 meeting.)
- Electorial board for Swedish Research Council, 200606–200611
  *Comment:* (Three one-day meetings.)
- Language committee of the Factulty of Science and Technology, Uppsala University, 20061001–20081231
  *Comment:* The main task of this committee is to encourage the use of good written and spoken Swedish at the faculty, especially regarding under-graduate education. (3 meetings.)

- Dissertation committee of Kidane Asrat, Dept. of Mathematics, UU, 20060120
  *Comment:* Title: Analysis of Algorithms for Combinatorial Auctions and Related Problems

**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), 2002–
- 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.
- Programme Committee for the 13th International Conference on Discrete Geometry for Computer Imagery (DGCI 2006), Szeged, Hungary, 20060101–20061031
  *Comment:* Proceedings LNCS 4245
- Programme Committee for International Workshop on Combinatorial Image Analysis 2006 (IWCIA 2006), Berlin, Germany, 20060101–20060621
  *Comment:* Proceedings LNCS 4040
- Programme Committee Track III for the 18th International Conference on Pattern Recognition (ICPR 2006), Hong Kong, China, 20060101–20060831
- Preliminary examiner of PhD thesis for Leena Ikonen, Lappeenranta University of Technology, Finland, 20060111–20060406
  *Comment:* Title: Distance Transforms on Gray-level Surfaces
- Opponent for Christoph Spuhler, Dept. of Information Technology and Electrical Engineering, ETH Zürich, Switzerland, 20060621
  *Comment:* Title: Interactive Centerline Finding in Complex Tubular Structures

National:

- Board member of Swedish Society for Automated Image Analysis (SSBA), 2000–
  *Comment:* President 2002–2006
- Member of the Recruitment Board, Dept. of Information Technology, UU, 2005–
- Licentiate Opponent for Johanna Pettersson, Dept. of Biomedical Engineering, Linköping University, 20060420
  *Comment:* Title: Automatic Generation of Patient Specific Models for Hip Surgery Simulation
- Licentiate Opponent for Joel Kullberg, Dept. of Oncology, Radiology and Clinical Immunology, UU, 20060602
  *Comment:* Title: Imaging based whole-body lipid analysis
- Licentiate Opponent for Magnus Eriksson, Dept. of Neuronic Engineering, KTH, 20060609
  *Comment:* Title: Haptic and Visual Simulation of a Material Cutting Process

**Stefan Seipel**
National:

- Vice-chair of the SIGRAD organisation (Svenska föreningen för grafisk databehandling) 2004–
  *Comment:* Programme Committee member for SIGRAD'06 - Computer Games (SIGRAD'06)
- External reviewer of applicants for Research Associate positions in Visualization at University of Linköping, 0606

- Dissertation Committee for Thomas Porathe, Mälardalens University, 060522
  *Comment:* Title: 3-D Nautical Charts and Safe Navigation
- Dissertation Committee for the Doctoral Dissertation of Patrick Ljung, Linköping University, 061006
  *Comment:* Title: Efficient methods for direct volume rendering of large data sets

**Stina Svensson**
International:

- IAPR-TC18 discrete geometry, 20061117
  *Comment:* Vice chair (one of two) for technical committee no. 18 of IAPR.

National:

- PhD Dissertation Committee for Anders Ericsson, Centre for Mathematical Sciences, Lund Institute of Technology, Lund University, 20060922
  *Comment:* Title: Automatic Shape Modelling with Applications in Medical Imaging

**Robin Strand**
International:

- Programme Committee for the 11th International Workshop on Combinatorial Image Analysis (IWCIA 2006), 20060101–20060621