Annual Report 2014

Centre for Image Analysis

Centrum för bildanalys

Cover: Illustrations from the seven PhD theses presented at Centre for Image Analysis (CBA) during 2014. Further information in Section 4.2.

Front, top left
Erik Wernersson — Selection of a wood fibre from a paper sheet for further characterisation.

Front, top right
Andreas Kårsnäs — Automatic detection of sub-cellular structures in breast tumour tissue for the quantification of sub-cellular protein expression levels.

Front, bottom left
Jimmy Azar — Multi-instance based feature descriptor of a tissue image: automatic extraction of lumen areas and profiling of surrounding regions by means of a progressively expanding set of neighborhood sampling rings.

Front, bottom right
Gustaf Kylberg — Examples of classes in the Kylberg Texture Dataset. The texture samples are intensity normalized to have the same mean and standard deviation.

Back, top
Lennart Svensson — The image series shows exploration of template matching results in an electron microscopy volume image. Left and center: two example registrations of a template IgG molecule. Right: visualization of the template to volume correlation for different rotations of the template.

Back, bottom left
Vladimir Ćurić — Adaptive morphological operators differentiate objects with respect to their contrast and not the size of the shape. Left: Input image. Right: Morphological erosion with salience-based adaptive structuring elements.

Back, bottom right
Patrik Malm — The biggest problem when analyzing Pap-smear specimen is to handle the many forms of debris that can be found across the specimen area. These obscure key structures and confuse analysis algorithms, leading to erroneous conclusions being drawn. Here, we illustrate four common types of debris found in Pap-smears. From top to bottom: Bacteria (small linear structures), leukocytes (dark circular objects), staining residues (dark flecks), and overlapping material.

Cover design:
Anton Axelsson

Edited by:
Gunilla Borgefors, Omer Ishaq, Filip Malmberg, Lena Nordström, Ingela Nyström, Sajith Kecheril Sadanandan, Ida-Maria Sintorn, Robin Strand

Centre for Image Analysis, Uppsala, Sweden

Contents

1 Introduction

The Centre for Image Analysis (CBA) conducts research and graduate education in computerised image analysis and perceptualisation. Our role is to develop theory in image processing as such, but also to develop better methods, algorithms and systems for various applications. We have found applications primarily in biomedicine and forestry. In addition to our own research, CBA contributes to image technology promotion and application in other research units and society.

1.1 General background

CBA was founded in 1988 and was until 2014 a collaboration between Uppsala University (UU) and the Swedish University of Agricultural Sciences (SLU). From an organizational point of view, CBA was an independent entity within our host universities until 2010.

At UU, we are hosted by the Disciplinary Domain of Science and Technology and today belong to one of five divisions within the Dept. of Information Technology (IT), the Division of Visual Information and Interaction (Vi2). At SLU, we belonged to the Dept. of Forest Genetics and Plant Physiology in Umeå until the end of 2014. The organizational matters are outlined in Section 2. The re-organizations have not prevented us from continuing and expanding our research.

A total of 42 people were working at the CBA in 2014: 20 PhD students, 20 researchers, one technical staff, and one administrator. Additionally, 13 Master students completed their thesis work with supervision from CBA. This does not mean, however, that we have had more than 50 full-time persons at CBA; many of us have split appointments, part time at CBA and part time elsewhere, adding up to approximately 30 full-time equivalents. Having world class scientists visiting CBA and CBA staff visiting their groups, for longer or shorter periods, is an important ingredient of our activities.

Most CBA staff undertake some undergraduate teaching. Previously this has been organised by other divisions, but with the organizational changes our division now handles undergraduate education. We are particularly pleased that Anders Hast qualified as Excellent Teacher at UU during 2014.

We conclude that the activities in 2014 were the highest in the history of CBA. It was a record with as many as seven (7!) PhD students who graduated during the year. In 2014, we published more than 45 internationally reviewed papers, which is among the highest numbers over the years. There are several reasons for this. The main reason is that so many of our PhD students were at the end of their studies, which is when they publish most. Another reason is that we have more researchers than before and are involved in more co-operation projects.

We had continued support from the Disciplinary Domain of Medicine and Pharmacy, the Science for Life Laboratory (SciLifeLab), and strategic resources within the Dept. of IT. The strong economy has led to recruitments of new PhD students and researchers during the year. A successful example of collaboration we have is with the Division of Radiology, where two of our staff members work part time in order to be close to radiology researchers and also have funding from there.

An outreach activity that was particularly important was the 22nd International Conference on Pattern Recognition (ICPR 2014) held in Stockholm in August with 1200 participants. See `http://www.icpr2014.org/`. A majority of the CBA staff was active in the arrangements. See Section 7.1.

Another outreach activity that may be mentioned is our participation in the annual national symposium organized by the Swedish Society for Automated Image Analysis (SSBA), which in March 2014 was held in Luleå. CBA accounted for more than a quarter of participants by 25 registrations. A proof as good as any that CBA is the largest image analysis group in Sweden.

Image processing is highly inter- and multi-disciplinary, with foundations in mathematics, statistics, physics, signal processing and computer science, and with applications 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 domain experts. Our collaborators are found locally as well as nationally and

internationally. For a complete list of our 46 national and 39 international collaborators, see Section 5.6.

We are very active in international and national societies and are pleased that our leaders are recognised in these societies. In fact, the past Head Ewert Bengtsson was elevated to IEEE Fellow at the end of 2014. It is worth mentioning that also the past Head Gunilla Borgefors is an IEEE Fellow (since 2008), which means that CBA now contributes with two out of a total of approximately 50 Swedish IEEE Fellows. The current Head Ingela Nyström has served as Secretary of the International Association of Pattern Recognition (IAPR) during 2010–2014 and was in August 2014 elected President of IAPR. Nationally, CBA currently has two board members in the Swedish Society for Automated Image Analysis (SSBA), Ida-Maria Sintorn and Anders Brun; Ida-Maria Sintorn has served as Treasurer of SSBA since 2009.

Both Ewert Bengtsson and Gunilla Borgefors are elected members of the Royal Society of Sciences in Uppsala and the Royal Swedish Academy of Engineering Sciences (IVA). Ingela Nyström is elected member of the Royal Society of Arts and Sciences of Uppsala. Nyström continues to coordinate the strategic research programme in the e-science field, eSSENCE. She was appointed member of the Council for Research Infrastructure (RFI) within the Swedish Research Council from January 1, 2014.

Gunilla Borgefors is Editor-in-Chief for the journal Pattern Recognition Letters and Cris Luengo is Area Editor for the same journal. Ewert Bengtsson is Associate Editor of Computer Methods and Programs in Biomedicine. Researchers at CBA also serve on several other journal editorial boards, scientific organization boards, conference committees, and PhD dissertation committees. In addition, we take an active part in reviewing grant applications and scientific papers submitted to conferences and journals.

In addition to the more common ways of spreading information about our activities and work, such as seminar series, publications, web-pages, etc., we have our "info-screen". Short trailers on our projects and activities are presented on an LCD monitor facing both entrances to our corridor at Polacksbacken, building 2, where many many students and colleagues from other groups pass on a daily basis.

This annual report is also available on the CBA webpage, see `http://www.cb.uu.se/annual_report/AR2014.pdf`

1.2 Summary of research

The objective of CBA is to carry out research and education in computerised image analysis and perceptualisation. We are pursuing this objective through a large number of research projects, ranging from fundamental mathematical methods development, to application-tailored development and testing, the latter mainly in biomedicine and forest industry. We are also developing new methods for perceptualisation, combining computer graphics, haptics, and image processing. Our research is organised in many projects of varying size, ranging in effort from a few person months to several person years. There is a lot of interaction between different researchers; generally, a person is involved in several different projects in different constellations with internal and external partners. In this context, the affiliation to UU or SLU of the particular researchers seldom has been of importance over the years.

On the theoretical side, most of our work is based on discrete mathematics with fundamental work on sampling grids, mathematical morphology, fuzzy methods, graph-based methods, skeletons, distance functions, and tessellations, in three and more dimensions.

Several projects deal with light microscopy, developing tools for modern quantitative biology and clinical cancer detection and grading. We are collaborating with local biologists and pathologists, research centers in the US and India, and a Danish company. We have close collaboration with the strategic research programmes SciLifeLab (and also eSSENCE) through which a research platform in quantitative microscopy is formed.

Another example of modality we work with is electron microscopy (EM). One application is focused on finding viruses in EM images. Since the texture of the virus particles is an important feature in identification of the different virus types, this project has also led to basic research on texture analysis.

New techniques are creating 3D images on microscopic scales. We have been analyzing EM tomography images of protein molecules for several years. Another technique is X-ray microtomography; we are developing methods to use such images to study the internal structure of paper, wood fibre composites as well as bone.

On a macroscopic scale, we are working with interactive segmentation of 3D CT and MR images by use of haptics. We have developed a segmentation toolbox, WISH, which is publicly available. Applications of this toolbox are, for example, facial surgery planning and measurements of CT wrist images.

Over the last several years, we have activities in perceptualisation under leadership of Guest Professor Ingrid Carlbom, with the goal of creating a commercial system for maxillo-cranio-facial surgery planning in which you can see, feel, and manipulate virtual 3D objects as if they were real. We have created a unique haptic system where virtual objects can be grabbed and manipulated. This project has obvious synergy with the Human-Computer Interaction research performed within the division.

See Section 5 for details on all our research projects.

An activity bridging research and education is the supervision of master thesis projects. This year, we completed 13 such projects. In Section 3.2, we present these theses.

1.3 How to contact CBA

CBA maintains a home-page (`http://www.cb.uu.se/`) both in English and in Swedish. The main structure contains links to a brief presentation, staff, vacant positions (if any), etc. It also contains information on courses, seminars (note that our Monday 14:15 seminar series is open to anyone interested), a layman introduction to image analysis, this annual report (as .html and .pdf versions), lists of all publications since CBA was created in 1988, and other material.

In addition, staff members have their own home-pages, which are linked from the CBA "Staff" page. On these, you can usually find detailed course and project information, etc.

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

Visiting address:	Lägerhyddsvägen 2 Polacksbacken, ITC, building 2, floor 1 Uppsala
Postal address:	Box 337 SE-751 05 Uppsala Sweden
Telephone:	+46 18 471 3460
E-mail:	`cb@cb.uu.se`

2 Organisation

From the start in 1988 until the end of 2010, CBA was an independent entity belonging equally to Uppsala University (UU) and Swedish University of Agricultural Sciences (SLU), administered through UU. After decisions by the host universities this was changed and from 2011 the UU part of CBA became a division within the Dept. of Information Technology. Within the Dept. of IT, there was a review of the division structure, so, in 2012, CBA and the previous Division for Human-Computer Interaction joined to become the Division for Visual Information and Interaction (Vi2). Ingela Nyström is head of Vi2 and also head of CBA. At SLU, the Dept. of Forest Genetics and Plant Physiology has been host department during the last years.

During 2011–2014, there was an agreement between the Vice Chancellors of the two universities, according to which CBA continues as a collaboration with joint activities administered by UU. The long term strategic planning of CBA is handled by a joint council with two representatives from each university. All personnel is employed at a department at one of the two universities, and everyday management of CBA is the responsibility of the head of the division of the Dept. of IT at UU to which CBA belongs.

The joint council *Centrumråd* held six committee meetings during 2014. The members appointed until December 31, 2014, were:

- Gunilla Borgefors, deputy chair, S-Faculty, SLU
- Elna-Marie Larsson, Faculty of Medicine, UU
- Cris Luengo, S-Faculty, SLU
- Ingela Nyström, chair, TN-Faculty, UU

In the Fall of 2014, the Vice-Chancellors signed an agreement of the termination of SLU's involvement in the longstanding CBA cooperation. From 2015, there will be no CBA staff belonging to SLU; Gunilla Borgefors is a full-time Guest Professor at Uppsala University since 2012 with funding from SLU, Cris Luengo has left his position at SLU for a permanent research position at the Dept. of IT, and the PhD students have completed their exams.

The many organizational changes in the past few years have of course affected us all, to varying degrees. However, as seen in this report, we have been able to keep up a high activity despite a turbulent period. Scientifically, we continue in our areas of strength:

- Theoretical image analysis, mainly based on discrete mathematics
- Quantitative microscopy
- Interactive biomedical image analysis
- Visualization and haptics

More specifically, we continue the development of the research area of hand-written text recognition of historical documents. Our collaboration with SciLifeLab continues and is further developed. At the same time, the PET/MRI equipment recently installed in Uppsala provides new research opportunities for us in the international front-line in collaboration with medical researchers. An opening, which is not a new direction for us but has been one of the CBA elements for many years, is the strategic initiatives in biomedical engineering being discussed within the Disciplinary Domain of Science and Technology, the Disciplinary Domain of Medicine and Pharmacy, and the Uppsala University Hospital.

CBA was founded in 1988 and is today Sweden's largest single unit for image analysis and has created a strong national and international position. This successful operation shows that center formations in

special cases are worth investing in for many years. 2014 was our last year in collaboration with SLU and was as such the most successful. We regret that the longstanding cooperation has ceased, but have high hopes for a continued future within UU, Sweden, and internationally.

2.1 Finances

After the re-organization, where CBA at UU now is part of the Division of Visual Information and Interaction (Vi2) at the Dept. of Information Technology, the CBA economy is not separate. In fact, Vi2 has been formed to become integrated in activities as well as organization. Hence, we report how this is financed as a whole. The total expenditure for Vi2 was 40.4 million SEK for 2014. To cover this, 42% came from UU, 6% from SLU, 36% from external sources, and 16% from undergraduate education.

The largest cost in our budget is personnel, which is 63% of the total cost. Over the years, the number of people working at CBA has varied considerably. During 2014, 42 people were working at CBA. Most of the personnel is employed by UU, the rest by SLU. Within the whole division Vi2, we counted more than 50 persons during the year (but not 50 full-time equivalents).

Even though CBA itself does not organise undergraduate education, Vi2 offers undergraduate education with several courses in Human-Computer Interaction themes. In addition, we have inherited the courses on Image Analysis, Computer Graphics, and Scientific Visualization previously organised by the Division of Scientific Computing and given by teachers from CBA. Most of us teach 10–20%, while some Senior Lecturers teach more. The economy in Table 1 below summarises the overall economy for Vi2 in 2014. This summary is based on joining the two accounts from UU and SLU (after clearing internal transactions between the universities). The numbers are rounded to the nearest 1000 SEK. The same numbers for income and costs are also given as pie charts in Figure 1. Who finances each project can be ascertained in Section 5, where all projects are listed. Project grants that have been received but not used are directly balanced to next year, and are thus not included in the income–cost tables.

Table 1: Vi2 income and costs for 2014 in kSEK.

Income		**Costs**	
UU	16799	Personnel	25081
SLU	2529	Equipment	99
UU undergraduate education	6476	Operating expenditure[4]	3175
Governmental grants[1]	8541	Rent	1880
Non-governmental grants[2]	1253	University overhead	9481
Contracts[3]	4800		
Financial netto	44		
Total income	**40442**	**Total cost**	**39716**

[1] The Swedish Research Council, Vinnova – Swedish Governmental Agency for Innovation Systems
[2] Research foundations, EU
[3] Internal invoices from UU and compensations
[4] Including travel and conferences

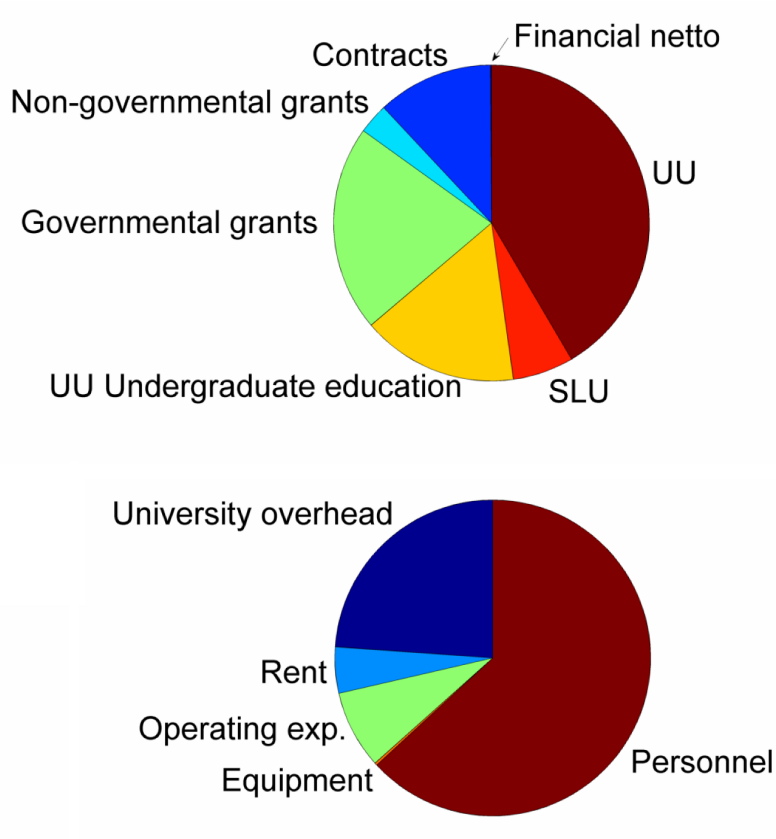


Figure 1: Vi2 income (top) and costs (below) for 2014.

2.2 Staff, CBA

Christophe Avenel, PhD, Post Doc., UU
Jimmy Azar, Graduate Student –141031, UU
Ewert Bengtsson, Professor, UU
Gunilla Borgefors, Professor, UU
Anders Brun, PhD, Researcher, UU
Ingrid Carlbom, Professor, UU
Vladimir Ćurić, Graduate Student –140831, UU
Olle Eriksson, PhD, Senior Lecturer, (part time) UU
Azadeh Fakhrzadeh, Graduate Student, SLU
Anders Hast, Docent and Excellent Teacher, Lecturer, UU
Omer Ishaq, Graduate Student, UU
Christer O. Kiselman, Guest Professor 140915–, UU
Gustaf Kylberg, Graduate Student –140331, UU
Andreas Kårsnäs, Industrial Graduate Student –140430, UU and Visiopharm, Hørsholm, Denmark
Elisabeth Linnér, Graduate Student, UU
Fei Liu, Graduate Student, University of Gävle
Cris Luengo, Docent, Researcher, SLU
Kristína Lidayová, Graduate Student, UU
Patrik Malm, Graduate Student –140228, UU
Filip Malmberg, PhD, Researcher, UU
Damian Matuszewski, Graduate Student 140804–, UU
Bo Nordin, PhD, Researcher/Senior Lecturer, (part time) UU
Lena Nordström, Administration
Fredrik Nysjö, Research Engineer, UU
Johan Nysjö, Graduate Student, UU
Ingela Nyström, Professor, Director, (part time) UU
Pontus Olsson, Graduate Student, UU
Alexandra Pacureanu, PhD, Post Doc –140131, UU
Kalyan Ram, Graduate Student, UU
Petter Ranefall, PhD, Bioinformatician, UU
Sajith Sadanandan Kecheril, Graduate Student, UU
Stefan Seipel, Professor, (part time) UU and University of Gävle
Bettina Selig, Graduate Student, SLU
Ida-Maria Sintorn, Docent, Assistant Professor, SLU –140131; Associate Senior Lecturer, UU –140201
Nataša Sladoje, PhD, Researcher 140901–, UU
Robin Strand, Docent, Researcher, UU
Lennart Svensson, Graduate Student –141231, SLU
Erik Wernersson, Graduate Student –141231, SLU
Fredrik Wahlberg, Graduate Student, UU
Tomas Wilkinson, Graduate Student, UU
Carolina Wählby, Docent, Senior Lecturer –140331, Professor 140401–, (part time) 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@it.uu.se`

Docent degrees from CBA

1. Lennart Thurfjell, 1999, UU
2. Ingela Nyström, 2002, UU
3. Lucia Ballerini, 2006, UU
4. Stina Svensson, 2007, SLU
5. Tomas Brandtberg, 2008, UU
6. Hans Frimmel, 2008, UU
7. Carolina Wählby, 2009, UU
8. Anders Hast, 2010, UU
9. Pasha Razifar, 2010, UU
10. Cris Luengo, 2011, SLU
11. Robin Strand, 2012, UU
12. Ida-Maria Sintorn, 2012, UU

CBA staff appointed Excellent Teachers

1. Anders Hast 2014, UU

3 Undergraduate education

Many students choose to do their Master Thesis at CBA, with someone from us as either supervisor or reviewer (or both). This year, 13 Master Thesis were completed (3.2.1–13), most of which were done together with other departments at UU or other universities or with industry. See Figure 2 for a bar graph showing the number of completed Master thesis projects at CBA during 2001–2014.

CBA is also involved in undergraduate courses. We organize courses in image analysis and visualization (3.1.1–7) and participate in various other courses. Course responsible teacher is written in bold.

Anders Hast was appointed "Excellent Teacher" by UU this year.

3.1 UU courses

1. **Computer Assisted Image Analysis I, 5hp**
   Anders Brun, Azadeh Fakhrzadeh, Kristína Lidayová, Cris Luengo, Robin Strand
   Period: 140120–0316

2. **Scientific Computing III, 5hp**
   Elisabeth Linnér
   Period: 140122–0318
   Comment: Given by Division of Sceintific Computing (TDB).

3. **Computer Graphics, 10hp**
   Anders Hast, Johan Nysjö, Pontus Olsson
   Period: 140324–0527

4. **Imperative and object oriented programming/methods, 20hp**
   Fredrik Wahlberg
   Period: 140903–150115

5. **Bioimaging and Cell Analysis, 7.5hp**
   Ida-Maria Sintorn, Robin Strand, Carolina Wählby
   Period: 140903–0929
   Comment: Given by Dept. of Immunology, Genetics and Pathology.

6. **Scientific Visualization, 5hp**
   Anders Hast, Johan Nysjö, **Stefan Seipel**
   Period: 140904–1024

7. **Computer Assisted Image Analysis I, 5hp**
   Ida-Maria Sintorn, Kristína Lidayová, Cris Luengo, Robin Strand, Tomas Wilkinson
   Period: 141027–1218

3.2 Master theses

1. **An Applied Model for Implementation of Innovative IT-Solutions for Telehealth into the Healthcare System**
   Student: Hannah Lundström, Tomas Berglund and Sara Lycke
   Supervisor: Per Matsson, Cenvigo AB, Uppsala, Anders Hast
   Reviewer: Göran Lindström, Dept. of Engineering Sciences, UU
   Publisher: UPTEC F 14019
   Abstract: Today, new technologies are introduced to the market every day, and constantly changing our way of living. Especially in the healthcare sector, the change process is approaching a point where doctors can benefit from the use of, for example, connected portable reading devices instead of paper-based medical record systems. The information and communication technology is promoting the evolution of a new pathway of care delivery, a paradigm shift that alters the fundamental relationship between a doctor and its

patient. The concept is defined as telehealth and formulates the provision of care at a distance and provides the possibility to treat patients in their home environment instead of at the hospital.

This master's thesis has been performed on the request of Cenvigo AB, a company active in the implementation of new IT-solutions into the healthcare and eldercare. Cenvigo AB are the owners of the Parkinson's Digital Assessment (PANDA) application. The application has been developed through research at Dalarna University and Uppsala University Hospital. This project will initiate the launch of PANDA and also create a model for implementation of innovative IT-solutions into the healthcare systems.

The model is founded in a theoretical framework and shaped with interviews related to the implementation of technology with a focus on telehealth applications. Interviews has been performed with healthcare professionals, technology developers and users to acquire a complete picture and opinions regarding the introduction of innovation in healthcare today. From the acquired information, a model is formulated as a stepwise and chronological linear process were identified key activities are included to promote a successful implementation process. The model is connected to the practice through the implementation of PANDA. In the process of implementing PANDA into the Swedish healthcare system, a collaboration with the innovation centre at Uppsala University Hospital as a healthcare organization stakeholder, has been initiated.

The model consists of five phases; Assessment, Dissemination, Adoption, Implementation and Continuation. The phases are seen as transitional steps in the innovation process, critical barriers to overcome towards a successfully implementation in a mainstream routine setting. Each phase includes a number of activities and to achieve progression in each phase, these activities must be performed in order to advance to the next phase. In the case of PANDA, the process of progression has passed assessment and are currently involved in activities related to the dissemination phase.

The purpose of the model is to be used both for existing and future applications in the segment of medicine technology sector. The structure of the model is designed to promote a co-design or a common value principle of development and practice regarding an innovation. By connecting actors from both technology and healthcare in close relationships the actual needs of healthcare professionals could more effectively be identified and developed into a solution, a result from the amplification of a two-way engagement. The outmost aim is to serve as a catalysing factor, complementing the implementation models of healthcare in Sweden today.

Through this study, a need for facilitating the implementation process of new technology into the healthcare systems has been identified. This model offers the necessary input that many technology companies lack. The recommendation to Cenvigo AB is to continue to develop the model during the last step in the process of launching PANDA, and parallel use this model as a business model mainly for technology start-ups and larger foreign companies that has not yet established pathways into the Swedish healthcare system.

2. **Realtime Virtual 3D Image of Kidney Using Pre-Operative CT Image for Geometry and Realtime US-Image for Tracking**
Student: Sebastian Ärleryd
Supervisor: Massimiliano Collarieti-Tosti, KTH, Stockholm
Reviewer: Anders Hast
Publisher: UPTEC F 14042
Abstract: In this thesis a method is presented to provide a 3D visualization of the human kidney and surrounding tissue during kidney surgery. The method takes advantage of the high detail of 3D X-Ray Computed Tomography (CT) and the high time resolution of Ultrasonography (US). By extracting the geometry from a single preoperative CT scan and animating the kidney by tracking its position in real time US images, a 3D visualization of the surgical volume can be created. The first part of the project consisted of building an imaging phantom as a simplified model of the human body around the kidney. It consists of three parts: the shell part representing surrounding tissue, the kidney part representing the kidney soft tissue and a kidney stone part embedded in the kidney part. The shell and soft tissue kidney parts was cast with a mixture of the synthetic polymer Polyvinyl Alchohol (PVA) and water. The kidney stone part was cast with epoxy glue. All three parts where designed to look like human tissue in CT and US images. The method is a pipeline of stages that starts with acquiring the CT image as a 3D matrix of intensity values. This matrix is then segmented, resulting in separate polygonal 3D models for the three phantom parts. A scan of the model is then performed using US, producing a sequence of US images. A computer program extracts easily recognizable image feature points from the images in the sequence. Knowing the spatial position and orientation of a new US image in which these features can be found again allows the position

of the kidney to be calculated. The presented method is realized as a proof of concept implementation of the pipeline. The implementation displays an interactive visualization where the kidney is positioned according to a user-selected US image scanned for image features. Using the proof of concept implementation as a guide, the accuracy of the proposed method is estimated to be bounded by the acquired image data. For high resolution CT and US images, the accuracy can be in the order of a few millimeters.

3. **Methods for Automatic Analysis of Glucose Uptake in Adipose Tissue Using Quantitative PET/MRI Data**
   Student: Jonathan Andersson
   Supervisor: Joel Kullberg, Dept. of Radiology, Oncology, and Radiation Sciences (ROS), Faculty of Medicine, UU
   Reviewer: Robin Strand
   Publisher: UPTEC F 14044
   Abstract: Brown adipose tissue (BAT) is the main tissue involved in non-shivering heat production. A greater understanding of BAT could possibly lead to new ways of prevention and treatment of obesity and type 2 diabetes. The increasing prevalence of these conditions and the problems they cause society and individuals make the study of the subject important.

   An ongoing study performed at the Turku University Hospital uses images acquired using PET/MRI with 18F-FDG as the tracer. Scans are performed on sedentary and athlete subjects during normal room temperature and during cold stimulation. Sedentary subjects then undergo scanning during cold stimulation again after a six weeks long exercise training intervention. This degree project used images from this study.

   The objective of this degree project was to examine methods to automatically and objectively quantify parameters relevant for activation of BAT in combined PET/MRI data. A secondary goal was to create images showing glucose uptake changes in subjects from images taken at different times.

   Parameters were quantified in adipose tissue directly without registration (image matching), and for neck scans also after registration. Results for the first three subjects who have completed the study are presented. Larger registration errors were encountered near moving organs and in regions with less information.

   The creation of images showing changes in glucose uptake seem to be working well for the neck scans, and somewhat well for other sub-volumes. These images can be useful for identification of BAT. Examples of these images are shown in the report.
   Comment: In cooperation with Turku University Hospital

4. **Cell Tracking in Microscopy Images Using a Rao-Blackwellized Particle Filter**
   Student: Sofia Lindmark
   Supervisor: Thomas Schön, Dept. of IT
   Reviewer: Carolina Wählby
   Publisher: UPTEC F 14048
   Abstract: Analysing migrating cells in microscopy time-lapse images has already helped the understanding of many biological processes and may be of importance in the development of new medical treatments. Today's biological experiments tend to produce a huge amount of dynamic image data and tracking the individual cells by hand has become a bottleneck for the further analysis work. A number of cell tracking methods have therefore been developed over the past decades, but still many of the techniques have a limited performance.

   The aim of this Master Project is to develop a particle filter algorithm that automatically detects and tracks a large number of individual cells in an image sequence. The solution is based on a Rao-Blackwellized particle filter for multiple object tracking. The report also covers a review of existing automatic cell tracking techniques, a review of well-known filter techniques for single target tracking and how these techniques have been developed to handle multiple target tracking. The designed algorithm has been tested on real microscopy image data of neutrophils with 400 to 500 cells in each frame. The designed algorithm works well in areas of the images where no cells touch and can in these situations also correct for some segmentation mistakes. In areas where cells touch, the algorithm works well if the segmentation is correct, but often makes mistakes when it is not. A target effectiveness of 77 percent and a track purity of 80 percent are then achieved.

5. **A Method for Detecting Resident Space Objects and Orbit Determination Based on Star Trackers and Image Analysis**
   Student: Karl Bengtsson Bernander
   Supervisor: Daniel Skaborn, ÅAC Microtec, Uppsala
   Reviewer: Cris Luengo
   Publisher: UPTEC F 14050
   Abstract: Satellites commonly use onboard digital cameras, called star trackers. A star tracker determines the satellite's attitude, i.e. its orientation in space, by comparing star positions with databases of star patterns. In this thesis, I investigate the possibility of extending the functionality of star trackers to also detect the presence of resident space objects (RSO) orbiting the earth. RSO consist of both active satellites and orbital debris, such as inactive satellites, spent rocket stages and particles of different sizes.
   I implement and compare nine detection algorithms based on image analysis. The input is two hundred synthetic images, consisting of a portion of the night sky with added random Gaussian and banding noise. RSO, visible as faint lines in random positions, are added to half of the images. The algorithms are evaluated with respect to sensitivity (the true positive rate) and specificity (the true negative rate). Also, a difficulty metric encompassing execution times and computational complexity is used.
   The Laplacian of Gaussian algorithm outperforms the rest, with a sensitivity of 0.99, a specificity of 1 and a low difficulty. It is further tested to determine how its performance changes when varying parameters such as line length and noise strength. For high sensitivity, there is a lower limit in how faint the line can appear. Finally, I show that it is possible to use the extracted information to roughly estimate the orbit of the RSO. This can be accomplished using the Gaussian angles-only method. Three angular measurements of the RSO positions are needed, in addition to the times and the positions of the observer satellite. A computer architecture capable of image processing is needed for an onboard implementation of the method.
6. **Pixel-Based Video Coding**
   Student: Johannes Olsson Sandgren
   Supervisor: Jonatan Samuelsson, Ericsson AB.
   Reviewer: Cris Luengo
   Publisher: UPTEC IT 14003
   Abstract: This paper studies the possibilities of extending the pixel-based compression algorithm LOCO-I, used by the lossless and near lossless image compression standard JPEG-LS, introduced by the Joint Photographic Experts Group (JPEG) in 1999, to video sequences and very low bit-rates. Bitrates below 1 bit per pixel are achieved through skipping signaling when the prediction of a pixels sufficiently good. The pixels to be skipped are implicitly detected by the decoder, minimizing the overhead. Different methods of quantization are tested, and the possibility of using vector quantization is investigated, by matching pixel sequences against a dynamically generated vector tree. Several different prediction schemes are evaluated, both linear and non-linear, with both static and adaptive weights. Maintaining the low computational complexity of LOCO-I has been a priority. The results are compared to different HEVC implementations with regards to compression speed and ratio.
7. **3D Rendering and Interaction in an Augmented Reality Mobile System**
   Student: Gabriel Tholsgård
   Supervisor: Aman Hamdan, BMW Group, Shanghai, China
   Reviewer: Anders Hast
   Publisher: UPTEC IT 14007
   Abstract: Augmented Reality (AR) is a concept that is getting more and more popular, and the number of applications using it is increasing. AR applications include several concepts such as image recognition and camera calibration, together known as tracking, and it also uses 2D and 3D graphics rendering. The most important and difficult part of AR applications is the tracking, where an object not only should be recognized in many different conditions, but it should also be determined how the object is viewed upon. This report describes how the task given by BMW Group in Shanghai was solved, which was to create an iPhone prototype AR application, that should be able to recognize objects inside of a car and be able to interact with them through the mobile phone. The report explains the implemented solution to this problem, what different recognition methods were tested and the different ways of creating the 3D graphics overlay that was evaluated. The AR application resulted in a functional AR application capable of recognizing the determined objects, draw their corresponding 3D representations and interact with them. However, the application was not complete as camera calibration was not used and a connection between the mobile phone andthe car was never established.

8. **Detection and Quantification of Small Changes in MRI Volumes**
   Student: Mariana Bustamante
   Supervisor: Robin Strand
   Reviewer: Anders Brun
   Publisher: UPTEC IT 14013
   Abstract: The focus of this research is to attempt to solve the problem of comparing two MRI brain volumes of the same subject taken at different times, and detect the location and size of the differences between them, especially when such differences are too small to be perceived with the naked eye.

   The research focuses on a combination of registration and morphometry techniques in order to create two different possible solutions: A voxel-based method and a tensor-based method. The first method uses Affine or B-Spline registration combined with voxel-by-voxel subtraction of the volumes; the second method uses Demons registration and analysis of the Jacobian determinants at each point of the deformation field obtained. The methods are implemented as modules for 3D Slicer, a software for medical image analysis and visualization.

   Both methods are tested on two types of experiments: Artificial experiments, in which made-up differences of distinct sizes are added to volumes of healthy subjects; and real experiments, in which MRIs of real patients are compared.

   The results obtained from the voxel-based method are very useful, since it was able to detect with almost complete accuracy all of the artificial differences and expected real differences during the experiments.

   The tensor-based method's results are not as accurate in location or size of the detected differences, and it usually includes more areas of differences where there seems to be none; even though it behaves adequately when the differences are large.

   Most of the results obtained are useful for the diagnostic of patients with non-severe trauma to the head; especially when using the voxel-based method. However, the results from both methods are just a suggestion of the size and location of injuries; and as a consequence, the procedure requires the presence of a medical practitioner.

9. **Adobe Flash Professional for iOS Game Development : A Feasible and Viable Alternative to Xcode?**
   Student: Leila Svantro
   Supervisor: Christopher Okhravi, Dept. of Informatics and Media, Faculty of Social Sciences, UU
   Reviewer: Anders Hast
   Publisher: UPTEC IT 14028
   Abstract: The smartphone operating system iOS is the second highest ranked after Android. The apps in App Store and Google Play combined consist of 70-80 % games, which are the primary entertainment applications. Many developers are learning game development or refreshing their skills to profit on this trend. The problem statements are: is it viable and feasible to use Adobe Flash Professional (AFP) for the iOS game development compared to Xcode and could AFP be used exclusively for iOS game development? Information on both IDEs has been analyzed. Furthermore, implementations and code comparisons have been made. The results and analysis shows differences regarding expenses while possibilities for developing the same kind of games essentially are equivalent. The conclusions are that AFP is a viable IDE for iOS game development in the aspect of possibilities. It is not feasible on a long-term basis when considering the expenses however it could be feasible on a short-term basis depending on the developer's requirements of extension and Mac OS for App Store publishing. AFP is not able to be used exclusively for the iOS game development if publishing to the App Store is a requirement however it is if publishing is restricted to single devices.

10. **An Interactive Interface for Multiple-Resolution Analysis of Large Images**
    Student: Nguyen-Anh-Thu Tran
    Supervisor: Petter Ranefall
    Reviewer: Carolina Wählby
    Publisher: UPTEC IT 14034
    Abstract: Digital image analysis has contributed greatly to medical sciences. Modern microscope slide scanning systems are capable of producing large images which can be more than one giga-pixel. It is useful for researchers to be able to view these images at multiple resolutions. For instance, to implement image-based sequencing of messenger ribonucleic acid (mRNA), high resolution images are required in detailed

analysis while those at low resolution offer better overall visualization. Taking that as the motivation, a map-viewer-like user interface with zooming and panning options has been developed to support detailed analysis in high resolution and at the same time be able to get a full overview in lower resolution. This thesis describes the context in which the interface is used as well as its design process.

11. **Moving Object Detection based on Background Modeling**
Student: Yuanqing Luo
Supervisor: Changqing Yin, Tongji University, Shanghai, China
Reviewer: Cris Luengo
Publisher: UPTEC IT 14046
Abstract: Aim at the moving objects detection, after studying several categories of background modeling methods, we design an improved Vibe algorithm based on image segmentation algorithm. Vibe algorithm builds background model via storing a sample set for each pixel. In order to detect moving objects, it uses several techniques such as fast initialization, random update and classification based on distance between pixel value and its sample set. In our improved algorithm, firstly we use histograms of multiple layers to extract moving objects in block-level in pre-process stage. Secondly we segment the blocks of moving objects via image segmentation algorithm. Then the algorithm constructs region-level information for the moving objects, designs the classification principles for regions and the modification mechanism among neighboring regions. In addition, to solve the problem that the original Vibe algorithm can easily introduce the ghost region into the background model, the improved algorithm designs and implements the fast ghost elimination algorithm. Compared with the tradition pixel-level background modeling methods, the improved method has better robustness and reliability against the factors like background disturbance, noise and existence of moving objects in the initial stage. Specifically, our algorithm improves the precision rate from 83.17% in the original Vibe algorithm to 95.35%, and recall rate from 81.48% to 90.25%.

Considering the affection of shadow to moving objects detection, this paper designs a shadow elimination algorithm based on Red Green and Illumination (RGI) color feature, which can be converted from RGB color space, and dynamic match threshold. The results of experiments demonstrate that the algorithm can effectively reduce the influence of shadow on the moving objects detection.

At last this paper makes a conclusion for the work of this thesis and discusses the future work.

12. **Usability Analysis of SmartPaint**
Student: Nadia Röning
Supervisor: Filip Malmberg
Reviewer: Mats Lind
Publisher: UPTEC IT 14051
Abstract: Image segmentation is the process of identifying and separating relevant objects and structures in an image. The purpose of segmentation is to simplify and/or change the representation of an image into something that is easier to analyze. SmartPaint is a software for semi-automatic segmentation of medical volume images, developed by Filip Malmberg. This thesis investigates whether SmartPaint is useful on several levels, such as usability, functionality and instructional effectiveness. The developer's ambition is that SmartPaint should be accessible to users without a background in computer science. Hence a formative usability study (Cooperative evaluation) was conducted, involving testing and interviewing participants. Given the result from the study and feedback from the participants, design proposals are given. Furthermore, ideas on how to expand the functionality, the instructional effectiveness and the learnability of SmartPaint are given.

13. **A Study of Digital In-Line Holographic Microscopy for Malaria Detection**
Student: Carl Christian Kirchmann, Elin Lundin and Jakob Andrén
Supervisor: Cris Luengo
Reviewer: Martin Sjödin, Dept. of Engineering Sciences, UU
Publisher: UPTEC TVE 14054
Abstract: The main purpose of the project was to create an initial lab set-up for a dig-ital in-line holographic microscope and a reconstruction algorithm. Different parameters including: light source, pin-hole size and distances pinhole-object and object-camera had to be optimized. The lab set-up is to be developed further by a master student at the University of Nairobi and then be used for malaria detection in blood samples. To acquire good enough resolution for malaria detection it has been found necessary to purchase a gray scale camera with smaller pixel size. Two dierent approaches, in this report called the on-sensor approach

and the object-magnication approach, were investigated. A reconstruction algorithm anda phase recovery algorithm was implemented as well as a super resolution algorithm to improve resolution of the holograms. The on-sensor approach proved easier and cheaper to use with approximately the same results as the object-magnication method. Necessary further research and development of experimental set-up was thoroughly discussed.

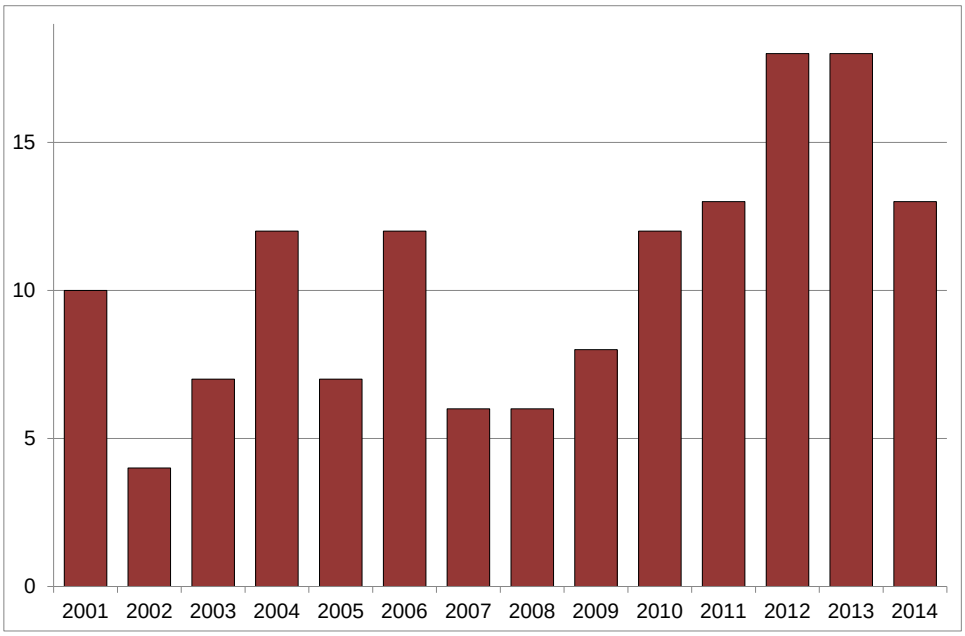


Figure 2: The number of Master thesis from CBA.

4 Graduate education

This year, we had a record number of seven dissertations at CBA. The most common theme is an aspect of medical image analysis, analysing images of proteins, viruses, cells, and tissue, but there are also theses analysing wood-fibre based materials and one on purely theoretical image analysis.

We give a number of PhD courses each year, both for our own students and for PhD students in subjects that use image analysis as a tool and need to know more about it. This year, there were three courses for external PhD students, two given at Karolinska Institutet, and three general courses for our own students. Course responsible teacher is written in bold in the list of courses in Section 4.1.

4.1 Graduate courses

1. **Research Methodology for Information Technology, 4hp**
   Examiner: **Gunilla Borgefors**
   Lecturer(s): Gunilla Borgefors, Ulrika Haak
   Period: 140424–0630
   Venue: The course was given at CBA.
   Description: The goal is to give general and useful knowledge about how to become a good and published researcher in information technology and/or various applications thereof. The first part consists of five traditional lectures on general themes. The second part is a series of seminars held by the participants, describing a relevant scientific conference or journal and making an oral and a written report.
   Comment: The written reports are collected in CBA Internal Report No. 53.

2. **Basic Image Analysis: Focused on Microscopy Applications, 3hp**
   Cris Luengo, **Ida-Maria Sintorn**, Carolina Wählby
   Period: 140917–1009
   Venue: The course was held at KI in Huddinge.
   Description: This postgraduate course in Basic Image Analysis was organized administered by the Regenerative Medicine Doctoral Program for PhD students at Karolinska Institutet and KTH.
   Comment: PhD level course: 9 lectures, 2 computer exercises (Fiji, CellProfiler), 1 week project on own data

3. **Scientific Data Presentation, 2hp**
   Gunilla Borgefors, **Cris Luengo**
   Period: 141008–1105
   Venue: The course was given at CBA.
   Description: The goal of the course is to give PhD students the ability to effectively present the data resulting from their experiments. The course covered different forms of graphs and tables for one and two-dimensional sampled data, categorical data, discrete values, etc.; certain aspects of human perception relevant to displaying data, including colour perception; the need to highlight the story in the data, refraining from displaying the non-essential things (without, of course, misrepresenting the data); and how to use drawing tools such as Illustrator or Inkscape to edit figures generated by Excel, MATLAB, or any other graphing tool.
   Comment: Funded by FUN, Faculty of Science and Technology

4. **Live Cell Imaging, 3hp**
   Ida-Maria Sintorn
   Venue: The course was held at KI in Huddinge.
   Period: 141013–1013
   Description: Basic principles of fluorescence microscopy and live cell imaging. Confocal Laser Scanning Microscopy Deconvolution fluorescence Microscopy Basic principles of advanced fluorescence techniques. Design and perform live cell imaging experiments. Data analysis and presentation.

5. **Scientific Visualization Workshop, 1hp**
   Anders Hast, Johan Nysjö, Pontus Olsson
   Period: 141127–1128
   Venue: The workshop was given at CBA.
   Description: A workshop for PhDs and other researchers arranged by SNIC-UPPMAX and SeSE.

6. **Classical & Modern Papers**
   PhD students at CBA, **Cris Luengo**
   Period: During the whole year
   Venue: The course was given at CBA.
   Description: Presentations and discussions of classical or modern papers in image processing.

4.2 Dissertations

1. *Date:* 20140207
   Image Analysis in Support of Computer-Assisted Cervical Cancer Screening
   Student: **Patrik Malm**
   Supervisor: Ewert Bengtsson
   Assistant Supervisors: Bo Nordin and Anders Brun
   Opponent: Calum MacAulay, British Columbia Cancer Research Center, Vancouver Canada
   Committee: Olli Yli-Harja, Tampere University of Technology, Finland; Ida-Maria Sintorn, CBA; Eva Forssell-Aronsson, Gothenburg University; Cleas Lundström, Linköping University; Hjalmar Brismar, Royal Institute of Technology
   Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-8828-4
   Abstract: Cervical cancer is a disease that annually claims the lives of over a quarter of a million women. A substantial number of these deaths could be prevented if population wide cancer screening, based on the Papanicolaou test, were globally available. The Papanicolaou test involves a visual review of cellular material obtained from the uterine cervix. While being relatively inexpensive from a material standpoint, the test requires highly trained cytology specialists to conduct the analysis. There is a great shortage of such specialists in developing countries, causing these to be grossly overrepresented in the mortality statistics. For the last 60 years, numerous attempts at constructing an automated system, able to perform the screening, have been made. Unfortunately, a cost-effective, automated system has yet to be produced.

   In this thesis, a set of methods, aimed to be used in the development of an automated screening system, are presented. These have been produced as part of an international cooperative effort to create a low-cost cervical cancer screening system. The contributions are linked to a number of key problems associated with the screening: Deciding which areas of a specimen that warrant analysis, delineating cervical cell nuclei, rejecting artefacts to make sure that only cells of diagnostic value are included when drawing conclusions regarding the final diagnosis of the specimen. Also, to facilitate efficient method development, two methods for creating synthetic images that mimic images acquired from specimen are described.

2. *Date:* 20140321
   Automatic Virus Identification using TEM – Image Segmentation and Texture Analysis
   Student: **Gustaf Kylberg**
   Supervisor: Ida-Maria Sintorn
   Assistant Supervisor: Gunilla Borgefors
   Opponent: Walter Kropatsch, Vienna University of Technology, Austria
   Committee: Stina Svensson, Ray Search Labs, Stockholm; Magnus Borga, Linköping University; Robin Strand, CBA; Abdenour Hadid, Oulo University, Finland; Kjell Hultenby, Karolinska Institute, Stockholm
   Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-8873-4
   Abstract: Viruses and their morphology have been detected and studied with electron microscopy (EM) since the end of the 1930s. The technique has been vital for the discovery of new viruses and in establishing the virus taxonomy. Today, electron microscopy is an important technique in clinical diagnostics. It both serves as a routine diagnostic technique as well as an essential tool for detecting infectious agents in new and unusual disease outbreaks.

   The technique does not depend on virus specific targets and can therefore detect any virus present in the sample. New or reemerging viruses can be detected in EM images while being unrecognizable by molecular methods.

   One problem with diagnostic EM is its high dependency on experts performing the analysis. Another problematic circumstance is that the EM facilities capable of handling the most dangerous pathogens are few, and decreasing in number.

   This thesis addresses these shortcomings with diagnostic EM by proposing image analysis methods mimicking the actions of an expert operating the microscope. The methods cover strategies for automatic image acquisition, segmentation of possible virus particles, as well as methods for extracting characteristic properties from the particles enabling virus identification.

   One discriminative property of viruses is their surface morphology or texture in the EM images. Describing texture in digital images is an important part of this thesis. Viruses show up in an arbitrary orientation in the TEM images, making rotation invariant texture description important. Rotation invariance and noise robustness are evaluated for several texture descriptors in the thesis. Three new texture datasets are introduced

to facilitate these evaluations. Invariant features and generalization performance in texture recognition are also addressed in a more general context.

The work presented in this thesis has been part of the project Panvirshield, aiming for an automatic diagnostic system for viral pathogens using EM. The work is also part of the miniTEM project where a new desktop low-voltage electron microscope is developed with the aspiration to become an easy to use system reaching high levels of automation for clinical tissue sections, viruses and other nano-sized particles.

3. *Date:* 20140411
Image Analysis Methods and Tools for Digital Histopathology Applications Relevant to Breast Cancer Diagnosis
Student: **Andreas Kårsnäs**
Supervisor: Robin Strand
Assistant Supervisors: Ewert Bengtsson and Carolina Wählby
Opponent: Anant Madabhushi, Case Western Reserve University, OH, US
Committee: Johan Lundin, Institute for Molecular Medicine Finland, Helsinki, Finland; Arne Östman, Karolinska Insitute, Stockholm; Andrew Mehnert, Chalmers Univ. of Technology; Irene Yu-Hua Gu, Chalmers Univ. of Technology; Anders Hast, CBA
Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-8889-5
Abstract: In 2012, more than 1.6 million new cases of breast cancer were diagnosed and about half a million women died of breast cancer. The incidence has increased in the developing world. The mortality, however, has decreased. This is thought to partly be the result of advances in diagnosis and treatment. Studying tissue samples from biopsies through a microscope is an important part of diagnosing breast cancer. Recent techniques include camera-equipped microscopes and whole slide scanning systems that allow for digital high-throughput scanning of tissue samples. The introduction of digital pathology has simplified parts of the analysis, but manual interpretation of tissue slides is still labor intensive and costly, and involves the risk for human errors and inconsistency. Digital image analysis has been proposed as an alternative approach that can assist the pathologist in making an accurate diagnosis by providing additional automatic, fast and reproducible analyses. This thesis addresses the automation of conventional analyses of tissue, stained for biomarkers specific for the diagnosis of breast cancer, with the purpose of complementing the role of the pathologist. In order to quantify biomarker expression, extraction and classification of sub-cellular structures are needed. This thesis presents a method that allows for robust and fast segmentation of cell nuclei meeting the need for methods that are accurate despite large biological variations and variations in staining. The method is inspired by sparse coding and is based on dictionaries of local image patches. It is implemented in a tool for quantifying biomarker expression of various sub-cellular structures in whole slide images. Also presented are two methods for classifying the sub-cellular localization of staining patterns, in an attempt to automate the validation of antibody specificity, an important task within the process of antibody generation. In addition, this thesis explores methods for evaluation of multimodal data. Algorithms for registering consecutive tissue sections stained for different biomarkers are evaluated, both in terms of registration accuracy and deformation of local structures. A novel region-growing segmentation method for multimodal data is also presented. In conclusion, this thesis presents computerized image analysis methods and tools of potential value for digital pathology applications.

4. *Date:* 140523
Distance Functions and Their Use in Adaptive Mathematical Morphology
Student: **Vladimir Ćurić**
Supervisor: Gunilla Borgefors
Assistant Supervisors: Cris Luengo, Nataša Sladoje
Opponent: Hugues Talbot, University Paris-Est - ESIEE, France
Committee: Christer Kiselman, UU; Gabriella Sanniti di Baja, Istituto di Cibernetica, Napoli, Italy; Alexander Medvedev, UU; Reiner Lenz, Linköping University; Anders Heyden, Lund University
Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-8923-6
Abstract: One of the main problems in image analysis is a comparison of different shapes in images. It is often desirable to determine the extent to which one shape differs from another. This is usually a difficult task because shapes vary in size, length, contrast, texture, orientation, etc. Shapes can be described using sets of points, crisp of fuzzy. Hence, distance functions between sets have been used for comparing different shapes.

Mathematical morphology is a non-linear theory related to the shape or morphology of features in the image, and morphological operators are defined by the interaction between an image and a small set called a structuring element. Although morphological operators have been extensively used to differentiate shapes by their size, it is not an easy task to differentiate shapes with respect to other features such as contrast or orientation. One approach for differentiation on these type of features is to use data-dependent structuring elements.

In this thesis, we investigate the usefulness of various distance functions for: (i) shape registration and recognition; and (ii) construction of adaptive structuring elements and functions.

We examine existing distance functions between sets, and propose a new one, called the Complement weighted sum of minimal distances, where the contribution of each point to the distance function is determined by the position of the point within the set. The usefulness of the new distance function is shown for different image registration and shape recognition problems. Furthermore, we extend the new distance function to fuzzy sets and show its applicability to classification of fuzzy objects.

We propose two different types of adaptive structuring elements from the salience map of the edge strength: (i) the shape of a structuring element is predefined, and its size is determined from the salience map; (ii) the shape and size of a structuring element are dependent on the salience map. Using this salience map, we also define adaptive structuring functions. We also present the applicability of adaptive mathematical morphology to image regularization. The connection between adaptive mathematical morphology and Lasry-Lions regularization of non-smooth functions provides an elegant tool for image regularization.

5. *Date:* 141020
Automated Tissue Image Analysis Using Pattern Recognition
Student: **Jimmy Azar**
Supervisor: Anders Hast
Assistant Supervisors: Ewert Bengtsson and Martin Simonsson
Opponent: Marco Loog, Pattern Recognition & Bioinformatics Group, Delft University of Technology, The Netherlands
Committee: Gunilla Borgefors, CBA; Thomas Schön, Dept. of Information Technology, UU; Mats Gustafsson, Dept. of Medical Sciences, UU; Arne Östman, Dept. of Oncology-Pathology, Karolinska Institutet; Fritz Albregtsen, Dept. of Informatics, University of Oslo
Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-9028-7
Abstract: Automated tissue image analysis aims to develop algorithms for a variety of histological applications. This has important implications in the diagnostic grading of cancer such as in breast and prostate tissue, as well as in the quantification of prognostic and predictive biomarkers that may help assess the risk of recurrence and the responsiveness of tumors to endocrine therapy. In this thesis, we use pattern recognition and image analysis techniques to solve several problems relating to histopathology and immunohistochemistry applications. In particular, we present a new method for the detection and localization of tissue microarray cores in an automated manner and compare it against conventional approaches. We also present an unsupervised method for color decomposition based on modeling the image formation process while taking into account acquisition noise. The method is unsupervised and is able to overcome the limitation of specifying absorption spectra for the stains that require separation. This is done by estimating reference colors through fitting a Gaussian mixture model trained using expectation-maximization. Another important factor in histopathology is the choice of stain, though it often goes unnoticed. Stain color combinations determine the extent of overlap between chromaticity clusters in color space, and this intrinsic overlap sets a main limitation on the performance of classification methods, regardless of their nature or complexity. In this thesis, we present a framework for optimizing the selection of histological stains in a manner that is aligned with the final objective of automation, rather than visual analysis. Immunohistochemistry can facilitate the quantification of biomarkers such as estrogen, progesterone, and the human epidermal growth factor 2 receptors, in addition to Ki-67 proteins that are associated with cell growth and proliferation. As an application, we propose a method for the identification of paired antibodies based on correlating probability maps of immunostaining patterns across adjacent tissue sections. Finally, we present a new feature descriptor for characterizing glandular structure and tissue architecture, which form an important component of Gleason and tubule-based Elston grading. The method is based on defining shape-preserving, neighborhood annuli around lumen regions and gathering quantitative and spatial data concerning the various tissue-types.

6. *Date:* 20141124

Image Analysis and Interactive Visualization Techniques for Electron Microscopy Tomograms

Student: **Lennart Svensson**

Supervisor: Ida-Maria Sintorn

Assistant Supervisors: Ingela Nyström, Gunilla Borgefors

Opponent: Willy Wriggers, Associate Professor, Weill Conell Medical College & Researcher, D.E. Shaw Research New York, US

Committee: Hans Hebert, Karolinska Institutet, Stockholm; Nataša Sladoje, University of Novi Sad, Serbia; Stefan Seipel, CBA

Publisher: Acta Universitatis Agriculturae Sueciae, ISBN: 978-91-576-8136-2

Abstract: Images are an important data source in modern science and engineering. A continued challenge is to perform measurements on and extract useful information from the image data, i.e., to perform image analysis. Additionally, the image analysis results need to be visualized for best comprehension and to enable correct assessments. In this thesis, research is presented about digital image analysis and three-dimensional (3-D) visualization techniques for use with transmission electron microscopy (TEM) image data and in particular electron tomography, which provides 3-D reconstructions of the nano-structures. The electron tomograms are difficult to interpret because of, e.g., low signal-to-noise ratio, artefacts that stem from sample preparation and insufficient reconstruction information. Analysis is often performed by visual inspection or by registration, i.e., fitting, of molecular models to the image data. Setting up a visualization can however be tedious, and there may be large intra- and inter-user variation in how visualization parameters are set. Therefore, one topic studied in this thesis concerns automatic setup of the transfer function used in direct volume rendering of these tomograms. Results indicate that histogram and gradient based measures are useful in producing automatic and coherent visualizations. Furthermore, research has been conducted concerning registration of templates built using molecular models. Explorative visualization techniques are presented that can provide means of visualizing and navigating model parameter spaces. This gives a new type of visualization feedback to the biologist interpretating the TEM data. The introduced probabilistic template has an improved coverage of the molecular flexibility, by incorporating several conformations into a static model. Evaluation by cross-validation shows that the probabilistic template gives a higher correlation response than using a Protein Databank (PDB) devised model. The software ProViz (for Protein Visualization) is also introduced, where selected developed techniques have been incorporated and are demonstrated in practice.

7. *Date:* 20141205
Characterisation of Wood-Fibre–Based Materials Using Image Analysis
Student: **Erik Wernersson**
Supervisor: Gunilla Borgefors
Assistant Supervisors: Cris Luengo and Anders Brun
Opponent: Michal Kozubek, Masaryk University, Brno, Czech Republic
Committee: Gunnar Sparr, Lund Institute of Technology/Lund University; Björn Kruse, Linköping University, Örjan Smedby, Linköping University
Publisher: Acta Universitatis Agriculturae Sueciae, ISBN: 978-91-576-8146-1
Abstract: Wood fibres are the main constituent of paper and are also used to alter properties of plastics in wood-fibre–based composite materials. The manufacturing of these materials involves numerous parameters that determine the quality of the products. The link between the manufacturing parameters and the final products can often be found in properties of the microstructure, which calls for advanced characterisation methods of the materials. Computerised image analysis is the discipline of using computers to automatically extract information from digital images. Computerised image analysis can be used to create automated methods suitable for the analysis of large data volumes. Inherently these methods give reproducible results and are not biased by individual analysts. In this thesis, three-dimensional X-ray computed tomography (CT) at micrometre resolution is used to image paper and composites. Image analysis methods are developed to characterise properties of individual fibres, properties of fibre–fibre bonds, and properties of the whole fibre networks based on these CT images. The main contributions of this thesis is the development of new automated image-analysis methods for characterisation of wood-fibre–based materials. This include the areas of fibre–fibre contacts and the free–fibre lengths. A method for reduction of phase contrast in mixed mode CT images is presented. This method retrieves absorption from images with both absorption and phase contrast. Curvature calculations in volumetric images are discussed and a new method is proposed that is suitable for three-dimensional images of materials with wood fibres, where the surfaces of the objects are close together.

5 Research

Our research activities are conducted in a large number of projects, both very application oriented and very theoretical, both large and small, both long-running and short-lived. Our largest application field is, since a long time, biomedicine, both analysis of microscopic images of everything from proteins to tissue samples and analysis of whole organs or the whole body. There are also other applications, especially the analysis of old, handwritten documents and forest industry applications. As this is the last year SLU will be involved in CBA, the latter will naturally end in their present form, but some may continue in new constellations. The tools we use are general image analysis tools, graphical tools for visualisation and haptic tools. In addition to developing or inventing the tools we need for our applications, we also do theoretical research in discrete geometry and mathematical morphology, both in two and three dimensions.

In Section 5.6 we have collected all our research partners, international and national, with whom we had active co-operation in the form of either a joint project or a joint publication, during the year.

5.1 Analysis of microscopic biomedical images

1. **Identification of Highly Pathogenic Viruses in Transmission Electron Microscopy Images**
   Gustaf Kylberg, Ida-Maria Sintorn, Ewert Bengtsson, Gunilla Borgefors
   Partners: Vironova AB; Delong Instruments, Brno, Czech Republic; Ali Mirazimi, Kjell-Olof Höglund, Centre for Microbiological Preparedness; Swedish Institute for Infectious Disease Control (SMI)
   Funding: 2008–2011 Swedish Civil Contingencies Agency (MSB), Swedish Defense Materiel Administration (FMV), Swedish Agency for Innovative Systems (VINNOVA). 2011–2013 Eurostar project
   Period: 0801–
   Abstract: This project aims at automating the virus identification process in high resolution TEM images. This, in combination with Project 2 to create a rapid, objective, and user independent virus diagnostic system. The identification task consists of method development for segmenting virus particles with different shapes and sizes and extracting descriptive features of both shape and texture to enable the classification into virus species. Texture features such as variants of Local Binary Patterns and Regional Moments (filter banks constructed from orthogonal moments), are being evaluated on virus textures as well as other texture datasets to get a deeper understanding of the discriminant power of the features under different conditions. A paper comparing, combining and evaluating the discriminating power of local texture descriptors for virus classification was presented at the 22nd International Conference on Pattern Recognition (ICPR) in Stockholm in August and Gustaf Kylberg defended his PhD thesis closely linked to this project in March 2014.

2. **The MiniTEM Project - Development of a Desk-top TEM with Automated Image Acquisition**
   Gustaf Kylberg, Ida-Maria Sintorn, Ewert Bengtsson, Gunilla Borgefors
   Partners: Vironova AB; Delong Instruments, Brno, Czech Republic
   Funding: Eurostar project
   Period: 1107–
   Abstract: Transmission electron microscopy (TEM) is an important clinical diagnostic

and material analysis tool. Transmission electron microscopes are expensive, complex, sensitive and bulky machines, often housed in specially built rooms to avoid vibrations affecting the imaging process. They are to a very large extent manually operated, meaning that an expert in electron microscopy and preferably also in the application at hand needs to perform the analysis at the microscope, an often very time consuming task.

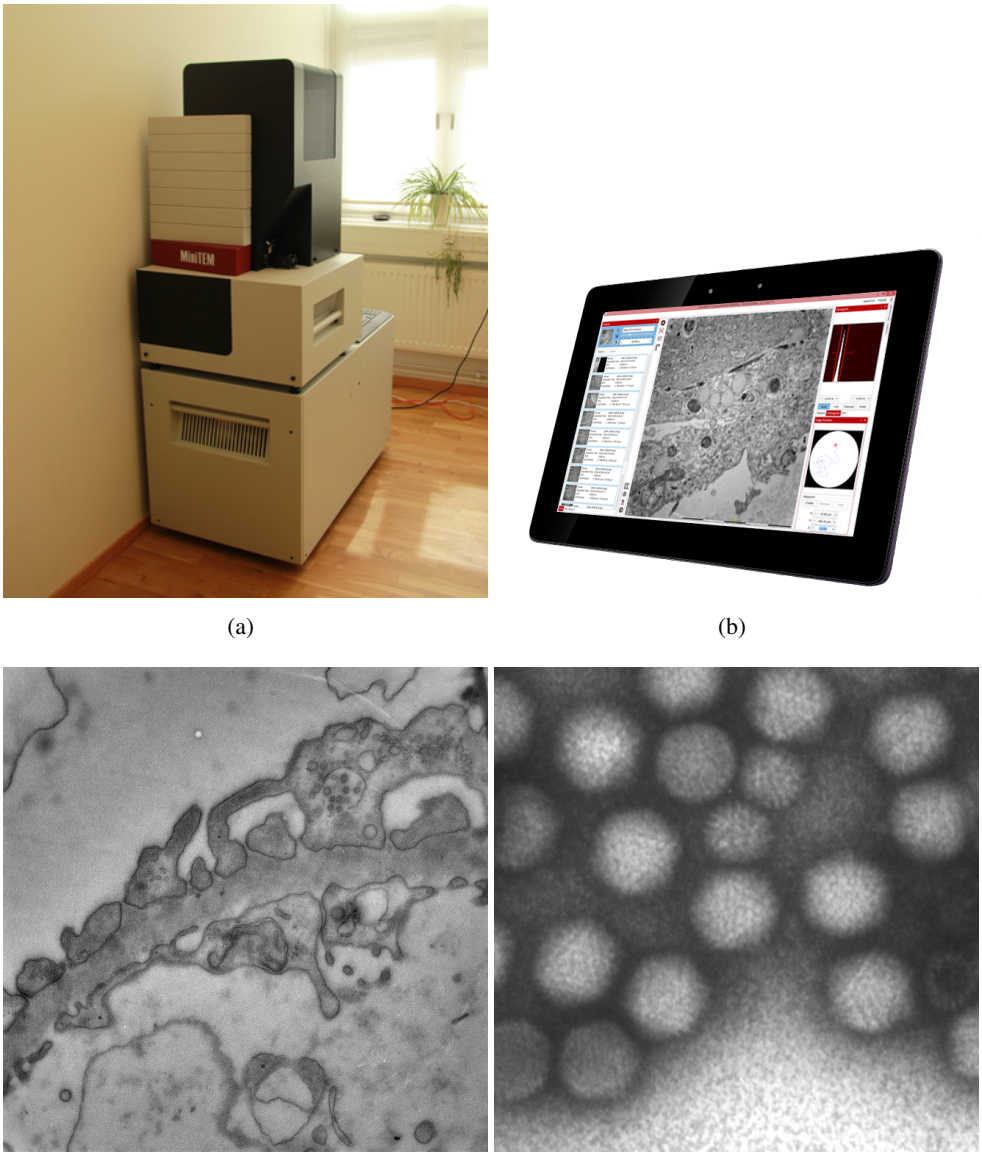
This project aimed at developing the MiniTEM, a desk-top low voltage TEM designed for imaging biological samples, with a high degree of automation regarding instrument alignment, image acquisition and analysis. The goal was a small, cheap, robust, and easy to use system that requires no more training than any simple lab equipment, and can be hosted in any office or lab (even mobile).

Automating the image acquisition process is key for reducing the manual input and making the imaging and analysis more objective. Within the project different strategies for automating the image acquisition were developed and investigated. The first was acquisition of images at random positions on the grid. The second was to search for a specific structure/object and only acquire (store) the images containing the structure/object of interest. The third was similar to the second approach but embedded in a multi-scale approach with the goal to make the acquisition more efficient.

The MiniTEM was launched and displayed at the International Microscopy Congress in Prague in September. One instrument was at the conference site and a second piece, physically in Stockholm, was operated remotely from Prague. Abstracts and posters about the project, the developled image analysis methods, and actual instrument, have been presented at various international and national conferences and meetings throughout the year. Gustaf Kylberg successfully defended his PhD thesis early 2014, which was closely linked to this project. The MiniTEM, its GUI and two example images showing a mixture of typical clinical application areas are shown in Figure 3.

3. **Detection and Localization of Florescent Signals in STORM Data Using Compressed Sensing**
   Omer Ishaq, Alexandra Pacureanu, Carolina Wählby
   Partners: Johan Elf, Gustaf Ullman, Fredrik Persson, Dept. of Cell & Molecular Biology, UU
   Funding: SciLifeLab Uppsala, eSSENCE, VR junior researcher grant to CW
   Period: 1211–
   Abstract: Stochastic optical reconstruction microscopy (STORM) is a super-resolution microscopy image acquisition technique for single-molecule localization. Like other stochastic super-resolution microscopy techniques it incorporates a trade-off between spatial- and temporal-resolution. Recently, a compressed-sensing (CS) based variant of STORM, called FasterSTORM, has been developed which substantially increases the temporal sampling of a stack of STORM image frames. This improvement is realized by increasing the density of activated fluorophores in each frame, followed by a subsequent CS-based retrieval of single-molecule positions even with overlapping fluorescent signals. However, the CS-based retrieval/decoding step is time consuming and can take as much as three hours for each image frame. We have accelerated the FasterSTORM method through parallel processing on multi-core processors. Additionally, we have tested and tried a number of L1-solvers for CS-based recovery of molecule positions. We are in the process of comparing the performance of the FasterSTORM against a wavelet-based approach to localize fluorescent signals in time-lapse images of bacterial cells.

In 2014, a paper comparing convex and greedy solvers and evaluating the sensitivity of the FasterSTORM to estimation bias of the point spread function (PSF) was accepted for oral presentation at the 22nd International Conference on Pattern Recognition (ICPR 2014).



(a) (b)

(c) (d)

Figure 3: The MiniTEM instruments, its GUI and images of a filtering membrane in a kidney section and a mixture of Adeno and Rota viruses.

4. ***In Situ* Sequencing of mRNA**
   Carolina Wählby, Alexandra Pacureanu, Petter Ranefall
   Partners: Mats Nilsson, Rongqin Ke, Marco Mignardi, Thomas Hauling, Xiaoyan Qian, SciLifeLab Stockholm/Stockholm University
   Funding: SciLifeLab Uppsala; TN-faculty, UU
   Period: 1109–
   Abstract: Profiling of gene expression is prerequisite for understanding the function of cells, organs and organisms, in health and disease. The sequencing techniques currently

in use rely on homogenization of the samples. Therefore, the obtained information represents either the average expression profile of the tissue sample or expression profiles of isolated single cells. Our collaborators have developed a new molecular method, enabling *in situ* sequencing of mRNA, so that protein expression can be observed directly in cultured cells or tissue samples. We have developed image analysis tools for automated analysis of sequencing data, mapping, and visualization of gene expression patterns (Figure 4). We presented the work as part of a Special Session on Advances in Computer-Aided Histopathology at the IEEE International Symposium on Biomedical Imaging (ISBI 2014) in Beijing. The project was also presented at the 1st annual conference for the Society of Biomolecular Imaging and Informatics SBI2, at the JB Martin Conference Center at Harvard Medical School, Boston, MA, USA, where Carolina Wählby was honored with the SBI2 'President's innovation award' for her presentation on 'Combining image-based *in situ* RNA screening with quantitative analysis of cell and tissue morphology'.

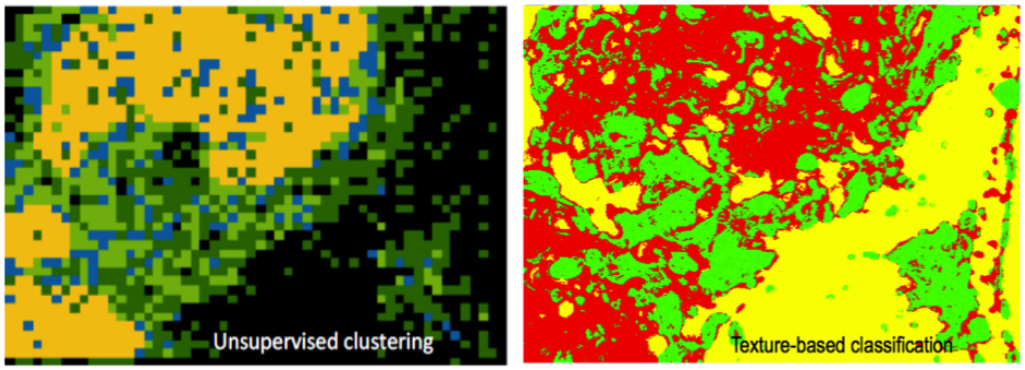


Figure 4: Coupling gene expression to cell and tissue morphology. The gene expression map was divided into patches of 100×100 pixels, and patches were clustered by k-means clustering (100 random seeds). The resulting spatial patterns (left) correlate with independent texture-based classification (right) of an H&E staining of the same tissue sample.

5. **Evaluation of the Effect of Compaction Oligonucleotides on the Strength and Integrity of Florescent Signals**
   Omer Ishaq, Petter Ranefall, Carolina Wählby
   Partners: Carl-Magnus Clausson, Linda Andersson, Ola Söderberg, Dept. of Immunology, Genetics and Pathology, UU
   Funding: SciLife Lab Uppsala
   Period: 1310–
   Abstract: Rolling circle amplification (RCA) performs nucleic acid replication for rapid synthesis of multiple concatenated copies of circular DNA. These molecules can be visually observed through the use of florescent markers. Moreover, the introduction of a compaction oligonucleotide during RCA results in brighter and more compact signals. The project aims to evaluate the effect of compaction oligonucleotides on the strength and integrity of florescent signals. A manuscript has been submitted for journal publication.

6. **SciLifeLab Cancer Stem Cell Program**
   Damian Matuszewski, Carolina Wählby, Ida-Maria Sintorn
   Partners: Sven Nelander, Karin Forsberg-Nilsson, Irina Alafuzoff, Ulf Landegren, Anna Segerman, Tobias Sjöblom, Lene Urborn and Bengt Westermark, Dept. of Immunology, Genetics and Pathology and SciLifeLab, UU, Bo Lundgren, the Karolinska Institute and

SciLifeLab, Stockholm, Rebecka Jörnsten, Chalmers, Gothenburg, and Göran Hesselager, UU Hospital, Uppsala
Funding: AstraZeneca-Science for Life Laboratory Joint Research Program
Period: 1303–
Abstract: The SciLifeLab Cancer Stem Cell Program is a cross-platform initiative to characterize cancer stem cells (CSCs). Previously, the development of drugs targeting the CSC population in solid tumors has been curbed by the lack of valid cell model systems, and the complex genetic heterogeneity across tumors, factors that make it hard to assess new targets or predict drug responses in the individual patient. To solve these problems, our aim is to develop a biobank of highly characterized CSC cultures as a valid model of cancer heterogeneity. We will combine mathematical and experimental approaches, including image-based high-throughput cell screening, to define the spectrum of therapeutically relevant regulatory differences between patients. This will help elucidate mechanisms of action and enable accurate targeting of disease subgroups. During 2013-2014, patient data was collected, and a number of primary cell lines were established. Cultured cells were exposed to a different treatments and doses (more than 2500 different treatments per cell line), and imaged by fluorescence as well as bright-field microscopy, and current focus is on extracting meaningful morphological descriptors from the image data (Figure 5). Developed tools are also applied in a cell cycle analysis project realized together with Jordi Carreras Puigvert, the Karolinska Institute and SciLifeLab, Stockholm.

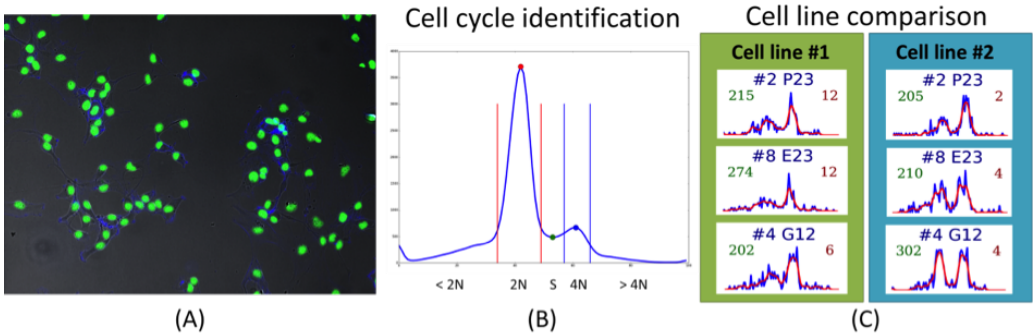


Figure 5: (A) Sample cancer stem cells image. (B) and (C) present histograms of one of the automatically extracted features DNA content per cell. (B) The different phases of the cell cycle can be identified based on the DNA content in negative control cells, by assuming that cells spend the majority of their time with either two ($2N$ phase) or four ($4N$ phase) copies of the DNA. Cells from different cell lines respond in a slightly different way to the same drug treatments. (C) DNA histograms for treatments that arrest part of the cell population in the $4N$ phase.

7. **Endothelial Cell Segmentation of the Cornea of Human Eyes**
Bettina Selig, Cris Luengo
Partners: Bernd Rieger, Quantitative Imaging Group, Delft University of Technology, The Netherlands; Koen Vermeer, The Rotterdam Eye Hospital, The Netherlands
Funding: S-faculty, SLU
Period: 1103–1412
Abstract: The corneal endothelium plays a key role in maintaining the transparency of the cornea.Because the cells in the endothelium do not regenerate, the cell density decreases with age; this reduces its ability to maintain the processes needed to keep the

cornea transparent. Thus, being able to measure this density in patients is very important. The endothelium can be imaged by specular microscopy or by confocal scanners, and measurements can be obtained manually, automatically with manual corrections, or fully automatically with current software (e.g., Nidek's NAVIS). Unfortunately, the results of the automatic methods are often useless, especially at low cell densities. Together with the Rotterdam Eye Hospital, we have developed a fully automatic method to segment individual cells in the corneal endothelium. The result of the method can be used to determine the cell density, but also other parameters of interest, like pleomorphism (cell shape) and polymegathism (cell size variation). Our segmentation method produces a segmentation that matches a manual segmentation reasonably well, for a wide range of cell densities and image qualities. These results have been submitted for publication during 2014.

8. **CerviScan**
   Ewert Bengtsson, Patrik Malm, Bo Nordin
   Partners: Rajesh Kumar, Centre for Development of Advanced Computing (CDAC), Thiruvananthapuram, Kerala, India; K. Sujathan, Regional Cancer Centre, Thiruvananthapuram, Kerala, India; Andrew Mehnert, Chalmers
   Funding: Swedish Governmental Agency for Innovation Systems (VINNOVA); Swedish Research Council; SIDA
   Period: 0801–
   Abstract: Cervical cancer is a disease that annually kills over a quarter of a million women world-wide. This number could be substantially reduced if women were regularly screened for signs of cancer precursors using the well-established Pap-test. If detected early, these precursors can be treated with a very high rate of success. A problem with the Pap-test is that it requires highly trained cytotechnologists to perform the time consuming visual analysis of the specimen. For over 50 years attempts to automate this process have been made but still no cost effective systems are available.

   The CerviScan project is an initiative from the Indian government, managed by the research institute CDAC in cooperation with the Regional Cancer Centre (RCC) in Kerala and CBA in Sweden, aimed at creating a low cost, automated screening system. The system will reduce the number of cytotechnologists needed for population screening by identifying and removing specimen that are clearly normal. A prototype system has been created and used to screen over 1000 specimen. Initial classification results are promising but screening times are still about 10 times longer than what is realistic in a real screening setting. Plans for the next phase of the project, focusing on dedicated hardware, are awaiting the result of a funding application in India.

   A sub project on developing improved ways of describing the nuclear chromatin patterns based on new image analysis methods has been spun off and is describe as Project 17. The project has resulted in several recent publications. Patrik Malm defended his PhD thesis closely linked to this project in February 2014.

9. **Automated Tissue Image Analysis using Pattern Recognition**
   Jimmy Azar, Anders Hast, Ewert Bengtsson
   Funding: TN-faculty, UU
   Period: 1001–1410
   Abstract: The research was initially part of a VR supported project for grading of prostate cancer. The final part of the research which took place during 2014 extended this to more general ways of describing the architecture of histological tissues.

Immunohistochemistry can facilitate the quantification of biomarkers such as estrogen, progesterone, and the human epidermal growth factor 2 receptors, in addition to Ki-67 proteins that are associated with cell growth and proliferation. We developed a method for the identification of paired antibodies based on correlating probability maps of immunostaining patterns across adjacent tissue sections. Samples from the Human Protein Atlas project were used to test the method.

We also developed a new feature descriptor for characterizing glandular structure and tissue architecture, which form an important component of Gleason and tubule-based Elston grading. The method is based on defining shape-preserving, neighborhood annuli around lumen regions.

These two studies were accepted as journal papers. Jimmy Azar defended his PhD thesis closely linked to this project in October 2014.

10. **Segmentation and Tracking of E.coli Bacteria in Bright-Field Microscopy Images**
Sajith Kecheril Sadanandan, Carolina Wählby
Partners: Johan Elf, David Fange, Alexis Boucharin, Dept. of Cell & Molecular Biology, UU; Klas E. G. Magnusson, Joakim Jaldén, ACCESS Linnaeus Centre, KTH.
Funding: SciLifeLab Uppsala, eSSENCE, VR junior researcher grant to CW
Period: 1210–
Abstract: Live cell experiments pave way to understand the complex biological functions of living organisms. Most live cell experiments require monitoring of cells under different conditions over several generations. The biological experiments display wide variations even when performed under similar conditions, and therefore need to include large population studied over several generations to provide statistically verifiable conclusions. Time-lapse images of such experiments usually generate large quantities of data, which become extremely difficult for human observers to evaluate. Thus, automated systems are helpful to analysis of such data and provide valuable inference from the experiment. In this work we segment and track E. coli bacteria cells over time. We developed a novel segmentation method, which is fast and robust in delineating bacterial cells in phase contrast microscopy images. The preliminary results (Figure 6) were presented as poster at the International Bioimage Informatics 2014 conference in Leuven, Belgium.

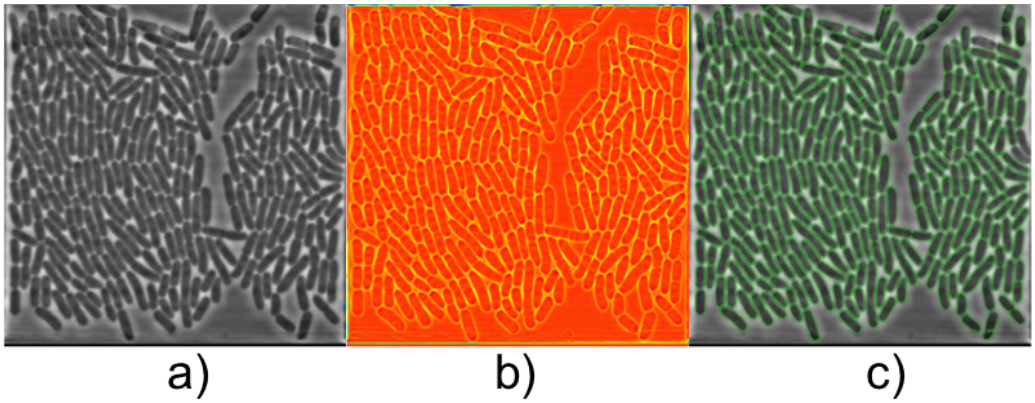


Figure 6: a) Input phase contrast image of E. coli bacteria, b) contrast enhanced image and c) segmentation result overlaid on the input image.

11. **Modelling Diffusion on Cell Surfaces**
Ida-Maria Sintorn, Robin Strand
Partners: Ingela Parmryd, Dept. of Medical Cell Biology, UU; Jeremy Adler, Dept. of Immunology, Genetics and Pathology, UU
Funding: TN-faculty, UU; S-faculty, SLU; VINNMER programme, Swedish Governmental Agency for Innovation Systems
Period: 1101–
Abstract: A cell surface is a highly irregular and rough. The surface topography is however usually ignored in current models of the plasma membrane, which are based on 2D observations of diffusion that really occurs in 3D. In this project, we model diffusion on non-flat surfaces to explain biological processes occurring on the cell surface.

12. **Analysis of Male Reproductive Tract Morphology in Reproductive Toxicology**
Azadeh Fakhrzadeh, Cris Luengo, Gunilla Borgefors
Partners: Ellinor Spörndly-Nees, Lena Holm, Dept. of Anatomy, Physiology and Biochemistry, SLU
Funding: SLU (KoN)
Period: 1009–
Abstract: Reproductive toxicology is the study of chemicals and their effects on the reproductive system of humans and animals. In reproductive toxicology, there is a strong need to detect structural differences in organs that often have both a complex microscopic structure and function. This problem is further complicated because standard techniques are based on the examination of two-dimensional sections of a three-dimensional structure. The aim of this project is to develop methods to objectively describe microscopic structures of male reproductive organs and to test these in reproductive toxicology research. The project is comparative and includes studies of organs from rooster and mink. We are developing automatic and interactive methods to analyse the relevant structures in the histology images of testis.

    Generating sperm in seminiferous tubules is a cyclic process, during which various generations of germ cells in the epithelial layer undergo a series of developmental steps. This cycle is typically subdivided into 12 different stages. We are developing a texture-based classification method to determine each tubule's stage. We are able to distinguish consistently stages if they are grouped into five classes (Figure 7).

13. **Combating Breast Cancer by Digital Pathology**
Andreas Kårsnäs, Robin Strand, Carolina Wählby, Ewert Bengtsson
Partners: Visiopharm, Hørsholm, Denmark; Clinical Pathology Division, Vejle Hospital, Vejle, Denmark
Funding: NordForsk Private Public Partnership PhD Programme and Visiopharm
Period: 0909–1412
Abstract: The results of analyses of tissue biopsies by pathologists are crucial for breast cancer patients. In particular, the precision of a patient's prognosis, and the ability to predict the consequences of various treatment opportunities before actually exposing the cancer patient, depend on the detection and quantification of biomarkers in tissue sections by microscopy. Experience from the last decade has revealed that manual detection and quantification of biomarkers by microscopy of tissue biopsies is highly dependent on the competencies and stamina of the individual pathologist. The aim of the present PhD project is to develop software-based algorithms that can facilitate the workflow and ensure

objective and more precise results of the quantitative microscopy procedures in breast cancer.

Andreas Kårsnäs defended his PhD thesis closely linked to this project in April 2014. A manuscript describing a new method for registering histological images of consecutive sections with different staining by using locally rigid transforms is currently under review and a journal article presenting a histopathological tool for sub-cellular quantification was accepted for publication in the journal *Computer methods in Biomechanics and Biomedical Engineering: Imaging & Visualization*, in 2014

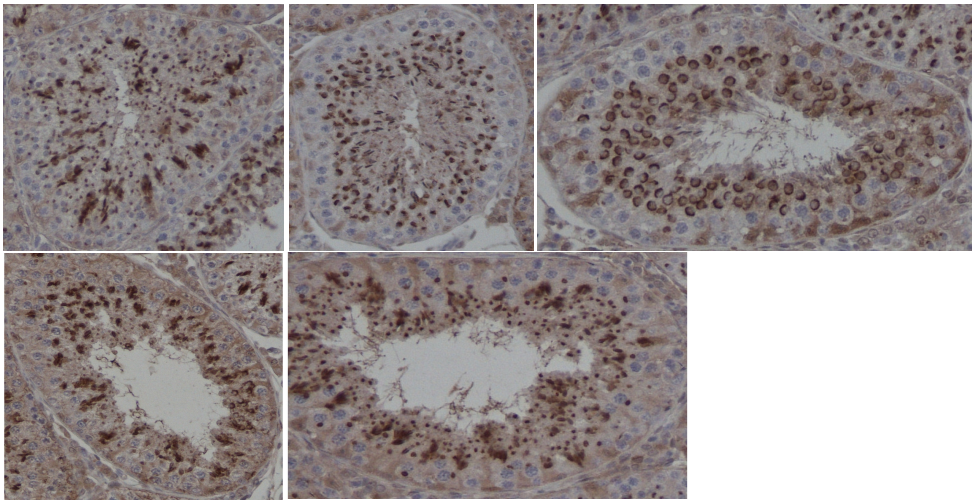


Figure 7: Cross sections of seminiferous tubules representative for the five classes we can distinguish consistently. Differences are mostly in the shape of the nuclei (stained in brown).

14. **Automatic, Quantitative Malignancy Grading of Prostate Cancer using Image Analysis**
Ingrid Carlbom, Christophe Avenel
Partners: Christer Busch, Dept. of Surgical Sciences, and Anna Tolf, Dept. of Genetics and Pathology, University Hospital
Funding: The Swedish Research Council; Hagstrandska fonden.
Period: 1001–
Abstract: Online Prostate Tissue Grading Tool: Using our OpenSeaDragon-based image selection tool we built an image database of 650 small images from whole mount sections, where each image has one dominant pattern that represents a malignancy grade, precancerous tissue, or benign tissue. With our online grading tool, fourteen internationally prominent pathologists from seven countries are in the process of grading these images according to the Gleason system (Figure 8).

With 50% of the images graded, we see similar grade variations as seen in other studies; for example, in 43% of the cases more than three pathologists disagree. But unlike other studies on intra- and interobserver grading variation, which are based on entire biopsies or whole mounts, each image in our study contains only one dominant pattern, allowing us to identify patterns that cause the discrepancies. Our goal is to establish a consensus for these patterns, thereby promoting international grading standardization.

Automatic segmentation of prostate glands and nuclei: Using the stromal density map from the color decomposition of Sirius-hematoxylin-stained tissue, we extract the glandu-

lar structures using morphological operations combined with standard image processing operations. With the glandular units as masks, we then extract the epithelium and the lumen from the epithelial density maps. Qualitative analysis of over 5000 glands indicates that the segmentation results in highly accurate representations of the glandular shape, including the epithelium and the lumen (Figure 9a).

Earlier we developed an algorithm to find the epithelial nuclei locations and approximate shapes in the epithelial density maps. We have augmented the algorithm to find a more precise shape of the nuclei using a deformable circular model (Figure 9b).

Consensus-Based Training Dataset: Using the automatically segmented glandular units, we label each gland based on the Gleason Grade produced by one pathologist. This labelling is on a finer scale than the Gleason grades; for example, grade 4 will be separated into fine caliber 4 and cribriform 4. Other grades are also divided to capture differences within the grade. To date we have labelled more than 5000 glands with one pathologist, giving us a dataset for continued development of our automatic grading algorithm. The labels will be updated when we reach a consensus grade with our international panel of experts.

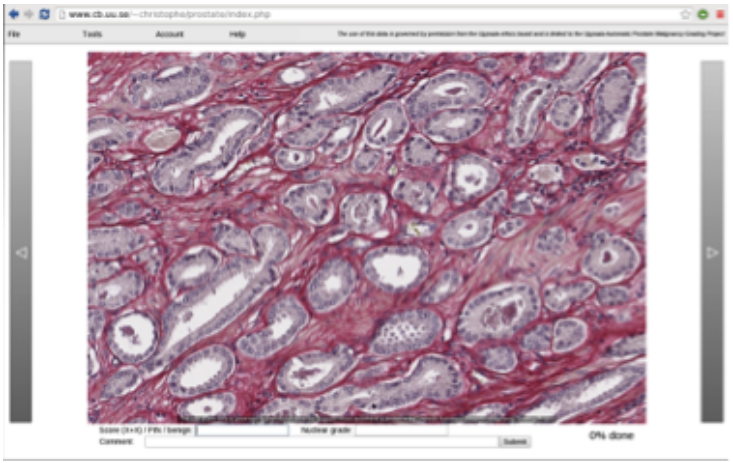
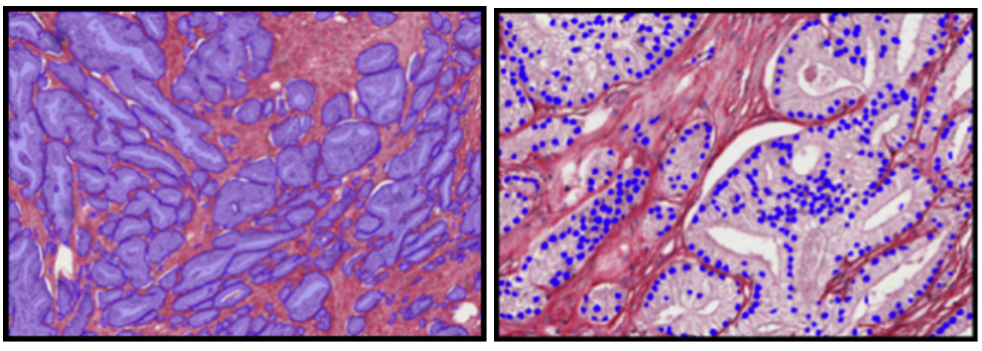


Figure 8: The user gives a Gleason Score below the image or indicates PIN or benign as the primary pattern



(a) (b)

Figure 9: (a) Segmented glands; (b) Segmented epithelial nuclei

15. **Quantification of Zebrafish Lipid Droplets**
Petter Ranefall, Carolina Wählby
Partners: Marcel den Hoed, Manoj Bandaru, Erik Ingelsson, Dept. of Medical Sciences and SciLifeLab, UU
Funding: SciLifeLab Uppsala
Period: 1308–
Abstract: The aim of this project is to identify novel targets for the therapeutic intervention of coronary artery disease. This is done by following-up results from genome-wide association studies in epidemiological studies using a zebrafish model system. Using image analysis we try to identify and characterize causal genes within loci that have so far been identified as associated with coronary heart disease by (high-throughput) screening of atherogenic processes in wildtype and mutant zebrafish, both before and after feeding on a control diet or a diet high in cholesterol. Using confocal microscopy we can image fat accumulation in the zebrafish. Our results confirm that zebrafish larvae represent a promising model system for early-stage atherosclerosis. An abstract has been submitted.

16. **Tools for Analysis and Visualization of Giga-Pixel Sized Slide-Scanner Images.**
Petter Ranefall, Alexandra Pacureanu, Carolina Wählby, Thu Tran
Partners: Mats Nilsson, Thomas Hauling, Marco Mignardi, Jessica Svedlund, Elin Lundin, Xiaoyan Qian, Dept. of Biochemistry and Biophysics and SciLifeLab, Stockholm University.
Funding: SciLifeLab
Period: 1308–
Abstract: The aim is to create a tool for full resolution image analysis of large images, e.g. slide scanner data, with the possibility of visual examination and interaction at multiple resolutions. The tool is built on a free and open-source framework for visual examination at multiple resolutions with the option to toggle results on or off, such as segmentation masks, classification results, and tissue morphology measurements, using a map view with seamless zooming and panning capabilities, allowing for fast navigation between a full-tissue view and high-resolution sub-cellular observations. The aim is to also have an interface that enables visual/manual selection of regions of interest, target discovery, and understanding of novel spatial relationships within the tissue environment. A bachelor thesis project with the aim of designing the user interface was carried out by the student Thu Tran. This user interface has then been extended with full functionality into a system that we call 'TissueMaps', which is now being evaluated at Mats Nilsson's lab. During 2014 'TissueMaps' has also been presented/demonstrated at some different conferences: BioImage Informatics in Leuven, Belgium, eSSENCE in Umeå, SSBA in Luleå, and the Nordic Symposium on Digital Pathology in Linköping.

17. **Advanced Methods for Reliable and Cost Efficient Image Processing in Life Sciences**
Nataša Sladoje, Ewert Bengtsson, Ida-Maria Sintorn
Partners: Joakim Lindblad, Faculty of Technical Sciences, University of Novi Sad, Serbia
Funding: Swedish Governmental Agency for Innovation Systems (VINNOVA); UU TN-faculty
Period: 1308–
Abstract: Within this project we aim at advancing the state-of-the-art methods of digital image processing and analysis, so that some of the societally important and highly challenging and relevant research task in life sciences can be successfully addressed. Our goal

is to increase reliability and efficiency, as well as robustness against variations in preparation quality, of computer assisted image analysis in two particular research tracks, related to two applications: (1) Chromatin distribution analysis for cervical cancer diagnostics, and (2) virus detection and recognition in TEM images.

Advances in cyto-patological research combined with the desire for as early as possible cancer detection, have put focus on the analysis of very subtle changes in the chromatin structure of cell nuclei. The application related to recognition and classification of viruses is focused on development of efficient methods adjusted to less expensive equipment, by that increasing applicability and usefulness of the results for a wider community. Efficient utilization of available images data to characterize barely resolved structures, is crucial in both cases. The intention is to use results from resent theoretical work within the framework of discrete mathematics, where knowledge from the field of fuzzy sets is combined with explicit usage of intensity and shape information in images. This theoretical framework provides methods which enable preservation and efficient usage of information, aggregate information of different types, improve robustness of the developed methods and increase precision of the analysis results. Based on conducted studies, the developed framework has shown high potential in applications where efficient utilization of information is of importance and where reliability of the analysis results and their timely delivery are both required.

5.2 3D analysis and visualization

18. **Haptics and its Applications to Medicine**
Ingrid Carlbom, Pontus Olsson, Fredrik Nysjö
Partners: Stefan Johansson (Division of Microsystems Technology, UU and Teknovest AB); Jan-Michaél Hirsch, Dept. of Surgical Sciences, Oral & Maxillofacial Surgery, UU and Consultant at Dept. of Plastic- and Maxillofacial Surgery, UU Hospital; Andreas Thor, Dept. of Surgical Sciences, Oral & Maxillofacial Surgery, UU Hospital; Andres Rodriguez Lorenzo, Dept. of Surgical Sciences, Plastic Surgery, UU Hospital; PiezoMotors AB.
Funding: Dept. of Surgical Sciences, Oral & Maxillofacial Surgery, UU Hospital; Thuréus Stiftelsen
Period: 1301–
Abstract: This year we augmented the Uppsala Haptics-Assisted Surgery Planning (HASP) system with virtual reconstruction of head and neck defects by fibula osteocutaneous free flaps (FOFF), including bone, vessels, and soft-tissue of the FOFF in the defect reconstruction. With the HASP stereo graphics and haptic feedback, using patient-specific CT-angio data, the surgeons can plan bone resection, fibula design, recipient vessels selection, pedicle and perforator location selection, and skin-paddle configuration.

Two surgeons tested HASP on four cases they had previously operated: three with composite mandibular defects and one with a composite cervical spine defect (Figure 10). During the planning session, it became apparent that some problems encountered during the actual surgery could have been avoided. In one case, the fibula reconstruction was incomplete since the fibula had to be reversed and thus did not reach the temporal fossa. In another case, the fibula had to be rotated 180 degrees to correct the plate and screw placement in relation to the perforator. In the spinal case, difficulty in finding the optimal fibula shape and position required extra ischemia time. The surgeons found HASP to be an efficient planning tool for FOFF reconstructions. The testing of alternative reconstructions to arrive at an optimal FOFF solution preoperatively potentially improves patient healing, function and aesthetics, and reduces operating room time.

19. **ProViz – Interactive Visualization of 3D Protein Images**
Lennart Svensson, Ida-Maria Sintorn, Ingela Nyström, Fredrik Nysjö, Johan Nysjö, Anders Brun, Gunilla Borgefors
Partners: Dept. of Cell and Molecular Biology, Karolinska Institute; SenseGraphics AB
Funding: The Visualization Program by Knowledge Foundation; Vaardal Foundation; Foundation for Strategic Research; VINNOVA; Invest in Sweden Agency; SLU, faculty funding
Period: 0807–1412
Abstract: Electron tomography is the only microscopy technique that allows 3-D imaging of biological samples at nano-meter resolution. It thus enables studies of both the dynamics of proteins and individual macromolecular structures in tissue. However, the electron tomography images have a low signal-to-noise ratio, which makes image analysis methods an important tool in interpreting the images. The ProViz project aims at developing visualization and analysis methods in this area.

The project focus 2014 has been on finalizing and testing the methods and software as well as preparing the manuscript describing and demonstrating the ProViz software. Lennart Svensson defended his PhD thesis very closely linked to this project.

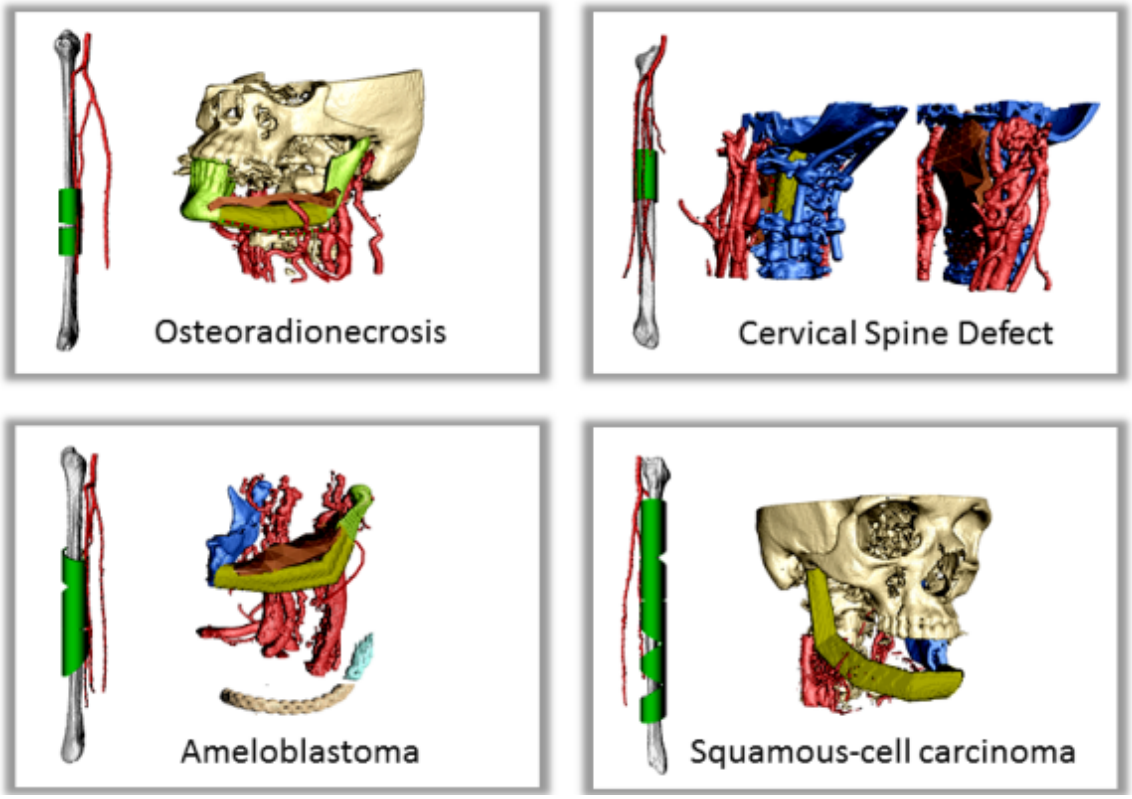


Figure 10: The resulting plans for the four cases. The whole fibula with osteotomy positions and orientations are shown in relation to surrounding vessels to the left of each case.

20. **Analysis and Processing of Three-Dimensional Magnetic Resonance Images on Optimal Lattices**
Elisabeth Linnér, Robin Strand
Funding: TN-faculty, UU
Period: 1005–
Abstract: Three-dimensional images are widely used in, for example, health care. With optimal sampling lattices, the amount of data can be reduced by 20-30% without affecting the image quality, lowering the demands on the hardware used to store and process the images, and reducing processing time.

In this project, methods for image acquisition, analysis and visualization using optimal sampling lattices are studied and developed, with special focus on medical applications. The intention is that this project will lead to faster and better processing of images with less demands on data storage capacity. One of the goals of the project is to release open source software for producing, processing, analyzing and visualizing volume images sampled on BCC and FCC lattices, so as to make them readily available for potential users to explore on their own. During 2014, the focus has been on distance transforms. Two reviewed conference papers exploring a graph-based implementation of the anti-aliased Euclidean distance transform have been published, and the work on the open source software is progressing.

21. **Registration of Medical Volume Images**
Robin Strand, Filip Malmberg
Partner: Joel Kullberg, Håkan Ahlström, Dept. of Radiology, Oncology and Radiation Science, UU
Funding: Faculty of Medicine, UU
Period: 1208–
Abstract: In this project, we mainly process magnetic resonance tomography (MR) images. MR images are very useful in clinical use and in medical research, e.g., for analyzing the composition of the human body. At the division of Radiology, UU, a huge amount of MR data, including whole body MR images is acquired for research on the connection between the composition of the human body and disease.

To compare volume images voxel by voxel, we develop image registration methods. For example, large scale analysis is enabled by image registration methods that utilizes, for example, segmented tissue (e.g., Project 22) and anatomical landmarks. Based on this idea, we have developed Imiomics (imaging omics) – an image analysis concept, including image registration, that allows statistical and holistic analysis of whole-body image data (Figure 11). The Imiomics concept is holistic in three respects: (i) The whole body is analyzed, (ii) All collected image data is used in the analysis and (iii) It allows integration of all other collected non-imaging patient information in the analysis.

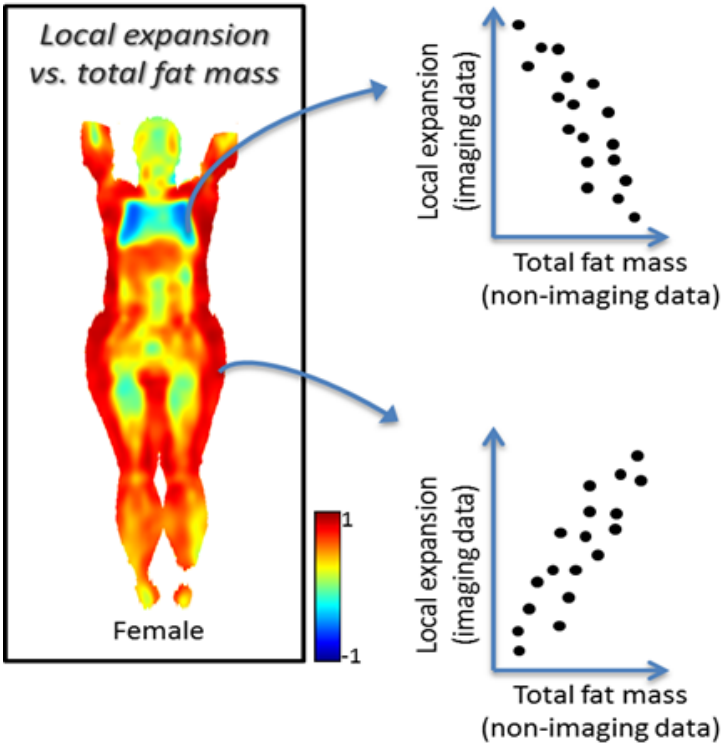


Figure 11: An illustration of a correlation map obtained by Imiomics. In this example, point-wise correlations between local tissue volume and body fat mass (measured by bioelectrical impedance analysis, BIA).

22. **Interactive Segmentation and Analysis of Medical Images**
Filip Malmberg, Robin Strand, Ingela Nyström, Ewert Bengtsson
Partners: Joel Kullberg, Håkan Ahlström, Dept. of Radiology, Oncology and Radiation Science, UU
Funding: TN-faculty, UU
Period: 1106–
Abstract: Three-dimensional imaging technique such as computed tomography (CT) and magnetic resonance imaging (MRI) are now routinely used in medicine. This has lead to an ever increasing flow of high-resolution, high-dimensional, image data that needs to be qualitatively and quantitatively analyzed. Typically, this analysis requires accurate segmentation of the image.

At CBA, we have been developing powerful new methods for interactive image segmentation. In this project, We seek to employ these methods for segmentation of medical images, in collaboration with the Dept. of Radiology, Oncology and Radiation Science (ROS) at the UU Hospital.

During 2014, we published an article describing *Smartpaint*, a tool for interactive segmentation of volume images. The SmartPaint software is publicly available and can be downloaded from `http://www.cb.uu.se/~filip/SmartPaint/`. To date, this software has been downloaded more than 500 times.

23. **Orbit Segmentation for Cranio-Maxillofacial Surgery Planning**
Johan Nysjö, Ida-Maria Sintorn, Ingela Nyström, Filip Malmberg
Partners: Jan Michael Hirsch, Andreas Thor, Johanna Nilsson, Dept. of Surgical Sciences, UU Hospital; Roman Khonsari, Pitie Salpetriere Hospital, Paris, France; Jonathan Britto, Great Ormond Street Hospital, London, UK
Funding: TN-faculty, UU
Period: 0912–
Abstract: An important component in cranio-maxillofacial (CMF) surgery planning is to be able to accurately measure the extent of certain anatomical structures. The shape and volume of the orbits (eye sockets) are of particular interest. These properties can be measured in CT images of the skull, but this requires accurate segmentation of the orbits. Today, segmentation is usually performed by manual tracing of the orbit in a large number of slices of the CT image. This task is very time-consuming, and sensitive to operator errors. Semi-automatic segmentation methods could reduce the required operator time substantially. In this project, we are developing a prototype of a semi-automatic system for segmenting the orbit in CT images. The segmentation system is based on WISH, a software package for interactive visualization and segmentation that has been developed at CBA since 2003. WISH has been released under an open-source license and is available for download at `http://www.cb.uu.se/research/haptics`.

Our main focus during 2014 has been to continue our collaboration with surgeons from the Craniofacial Centre at Great Ormond Street Hospital, London, UK, in a project that aims to analyse the size and shape of the orbits in a large set of pre- and post-operative CT images of patients with congenital disorders. Our semi-automatic segmentation system has been used to rapidly segment the orbits in these datasets, and we have extended the system with automatic registration-based techniques for performing size and shape analysis of the segmented orbits. Abstracts about the ongoing work have been presented at medical conferences. We completed the size and shape analysis experiments for the study during the autumn and have now started to summarize the results in manuscripts.

24. **Precise 3D Angle Measurements in CT Wrist Images**
Johan Nysjö, Filip Malmberg, Ingela Nyström, Ida-Maria Sintorn
Partners: Albert Christersson, Sune Larsson, Dept. of Orthopedics, UU Hospital
Funding: TN-faculty, UU
Period: 1111–
Abstract: To be able to decide the correct treatment of a fracture, orthopedic surgeons need to assess the details about the fracture. One of the most important factors is the fracture displacement, particularly the angulation of the fracture. The wrist is the most common location for fractures in the human being. When a fracture is located close to a joint, for example, in the wrist, the angulation of the joint line in relation to the long axis of the long bone needs to be measured. Since the surface of the joint line in the wrist is highly irregular, and since it is difficult to take X-rays of the wrist in exactly the same projections from time to time, conventional X-ray is not an optimal method for this purpose. In most clinical cases, conventional 2D angle measurements in X-ray images are satisfactory for making correct decisions about treatment, but when comparing two different methods of treatment, for instance, two different operation techniques, the accuracy and precision of the angle measurements need to be higher.

In this project, we are developing a system for performing precise 3D angle measurements in computed tomography (CT) images of the wrist. Our proposed system is semi-automatic; the user is required to guide the system by indicating the approximate position and orientation of various parts of the radius bone. This information is subsequently used as input to an automatic algorithm that makes precise angle measurements. We have developed a RANSAC-based method for estimating the long axis of the radius bone and a registration-based method (Figure 12) for measuring the orientation of the joint surface of the radius. Preliminary evaluations have shown that these two methods together enable relative measurements of the dorsal angle in the wrist with sub-millimeter precision. During 2014, we performed a more extensive case study (involving 40 CT scan sequences of fractures wrists) to further evaluate the performance of our 3D angle measurement method and compare it with the conventional 2D X-ray measurement method. A manuscript about this study is under preparation.

25. **Skeleton-Based Vascular Segmentation at Interactive Speed**
Kristína Lidayová, Hans Frimmel, Ewert Bengtsson
Partners: Örjan Smedby, Chunliang Wang, Center for Medical Image Science and Visualization (CMIV), Linköping University
Funding: VR grant to Örjan Smedby
Period: 1207–
Abstract: Precise segmentation of vascular structures is crucial for studying the effect of stenoses on arterial blood flow. The goal of this project is to develop and evaluate vascular segmentation, which will be fast enough to permit interactive clinical use. The first part is the extraction of the centerline tree (skeleton) from the gray-scale CT image. Later this skeleton is used as a seed region. The method should offer sub-voxel accuracy.

During 2013, we improved the software for fast vessel centerline tree extraction. The method has been tested on several CT data and the results look promissing. Generally main vessel centerlines are detected, but an improvement needs to be done in order to remove some false positive centerlines.

In year 2014, we improved the software to its final stage. It works on the original Com-

puted Tomography Angiography (CTA) image as the input and produces a node-link representation of the vascular structures for the lower limbs. The method (Figure 13) works in two passes: first pass extracts the skeleton of large arteries, and second pass focus on extracting small arteries. Each pass contains three major steps: (1) sets proper intensity ranges for different anatomy structures based on Gaussian curve fitting to the image histogram; (2) apply different filters to detect voxels that are part of arteries, where filters are designed based on intensity and size analysis of ellipse shape on 2-D planes; (3) connect nodes to obtain a centerline tree for the entire vasculature. The method has been tested on 25 CTA scans of the lower limbs (Figure 14) and achieved an average of 96% overlap rate with ground truth. The average computational time is 121 sec/scan.

A paper summarizing this work was written and was sent to a Special issue of Pattern Recognition Letters on skeletonization and its applications. At the current stage the paper is under major revision. The work was pressented at SSBA conference and Medicinteknikdagarna.

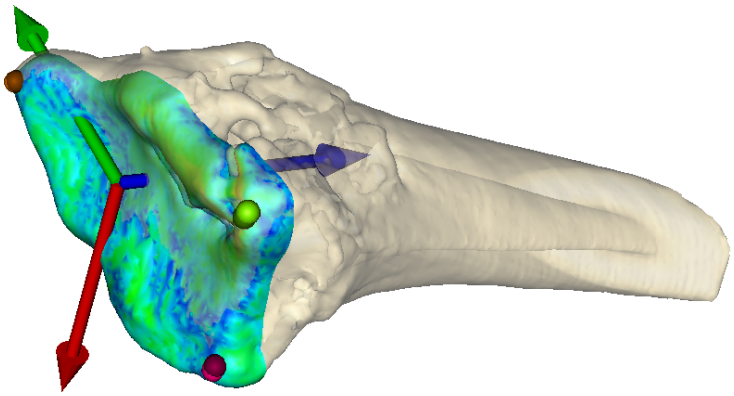


Figure 12: Registration-based method for estimating the joint surface orientation in a fractured radius bone in the wrist. A template model of the joint surface is fitted to the target radius bone through landmark-guided surface registration, so that a local reference coordinate system of the template can be used to represent the joint surface orientation. The distance between the template and the joint surface is color-coded during the semi-automatic registration process.

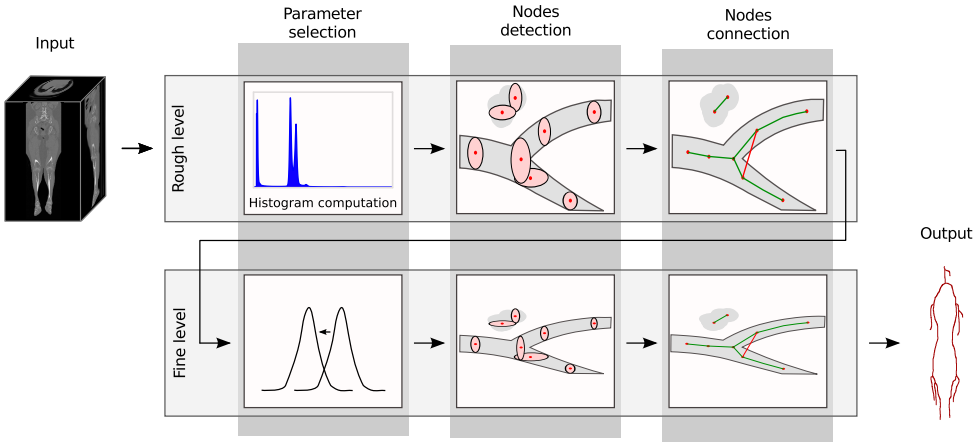


Figure 13: Flow chart of the proposed method

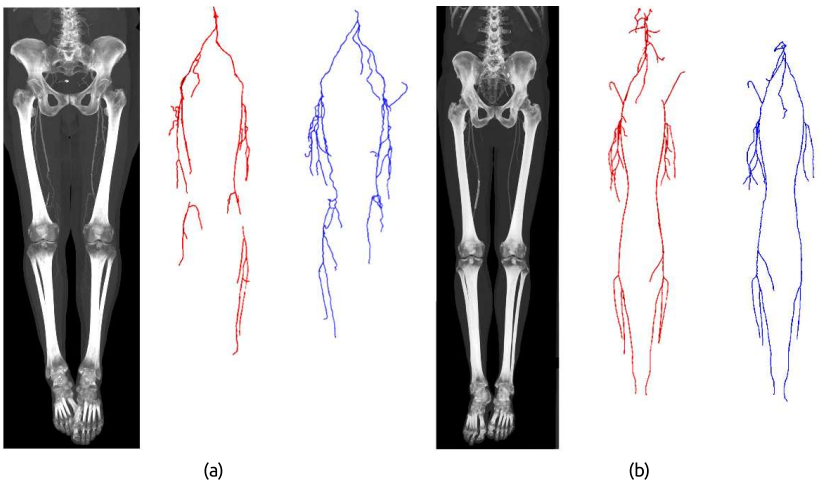


Figure 14: Maximum intensity projection, resulting skeleton in red colour and reference skeleton in blue colour are shown for two cases from a clinical routine, (a) contains an occluded segment in the femoral artery, (b) contains an arterial stent.

26. **Ubiquitous Visualization in the Built Environment**
Stefan Seipel, Fei Liu
Partner: Dept. of Industrial Development, IT and Land Management, University of Gävle
Funding: University of Gävle; TN-faculty, UU
Period: 1108–
Abstract: This project deals with mobile visualization and augmented reality (AR) in indoor and outdoor environments. Several key problems for robust mobile visualization are addressed such as spatial tracking and calibration; image based 2D and 3D registration and efficient graphical representations in mobile user interfaces.

During 2014, two major lines of work have been carried out: Registration of thermal infrared and visible facade images for augmented reality-based building inspection. Here, the problem of multi-modal image registration is addressed through identification of high-level (quadrilateral) features which model the shapes of commonly present facade elements, such as windows (Figure 15). These features are generated by grouping edge line segments with the help of image perspective information, namely, vanishing points. Our method adopts a forward selection algorithm for selecting feature correspondences needed to estimate the transformation model (Figure 16). During the formation of the feature correspondence set, the correctness of selected feature correspondences at each step is verified through the quality of the resulting registration, which is based on the ratio of areas between the transformed features and the reference features. Part of this work has been published in the Journal of Image and Graphics. Other results of this work are currently prepared for publication.

Another activity in the project has been the development of a video-see through augmented reality system along with an experimental study on positioning accuracy in indoor augmented reality. In this work, a marker-based augmented reality application has been developed which displays construction elements (pipes) hidden inside walls as virtual models that are visually overlaid in real time upon video images of the real wall (Figure 17 (left)). Using this application, we conducted a user experiment to find out how precise the localization of hidden structures in walls could be performed by the use of a video-see

through augmented reality guidance system. Another objective was to investigate different factors that are influential on positioning accuracy, such as e.g. visual parallax and method for targeting (Figure 17 (right)). Experiment results have been gathered and as of now they are analyzed and prepared for publication.

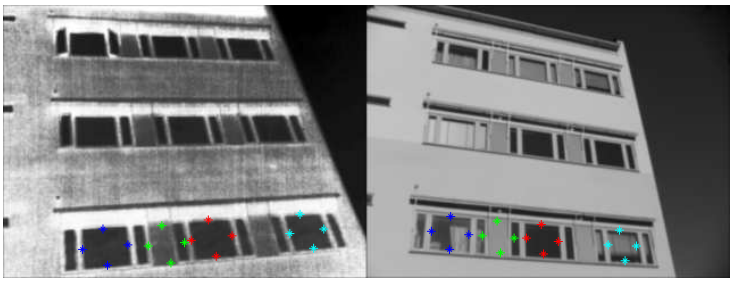


Figure 15: Selected control points for registration. Within an image, control points with the same color means they are from the same quadrilateral feature while across the images, the same color indicates correspondence.

Figure 16: Registration result showing the fusion of thermal infrared and visible images by alpha blending.

Figure 17: The augmented reality application running on the tablet (left). Experimental setup (right).

5.3 Forestry related applications

27. **Diffraction Artifact Reduction in µCT Imaging**
Erik Wernersson, Cris Luengo, Anders Brun, Gunilla Borgefors
Partners: Jan Van den Bulcke, Dept. of Forest and Water Management, Ghent University, Belgium; Matthieu Boone, Dept. of Physics and Astronomy, Ghent University, Belgium
Funding: S-faculty, SLU
Period: 1009–1412
Abstract: When imaging wood based materials, diffraction causes artefacts especially around sharp edges. While sometimes useful, and the only measurable properties of the imaged objects, they might as well be a nuisance which hinders proper analysis of the absorption coefficient. In this project, different ways to reduce such artefacts are investigated, especially in already reconstructed images. Compare to previous approaches, this is much faster and does not require that the original projection images are stored.

    This year we presented a paper at SSBA that showed how to tune the parameters of the method that we published in the Journal of the Optical Society of America A (2013). Erik Wernersson defended his PhD thesis closely related to this project in December 2014.

28. **Image Analysis of the Internal Structure of Paper and Wood Fibre Based Composite Materials in 3D images**
Erik Wernersson, Anders Brun, Cris Luengo, Gunilla Borgefors
Partners: Gary Chinga, Norwegian Pulp and Fibre Research Institute, Trondheim, Norway; Catherine Östlund, Innventia, Stockholm; Thomas Joffre, Dept. of Engineering Sciences, Applied Mechanics, UU; Arttu Miettinen, Dept. of Physics, University of Jyväskylä (UJ), Finland; Joakim Lindblad, University of Novi Sad, Serbia; Svetlana Borodulina, Dept. of Solid Mechanics and BiMaC Innovation Center, KTH
Funding: S-faculty, SLU; WoodWisdom-Net
Period: 0406–1412
Abstract: The internal structure of paper is important because many of its 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 affects paper quality is not fully understood, since most structure analysis of paper has been performed in cross-sectional, two-dimensional (2D) images whereas paper is a complex, three-dimensional (3D) structure. Another application for wood fibres that has recently gained 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 the interaction between the fibres and the polymer matrix surrounding the fibres.

    Advances in imaging technology have 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.

    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 desired measurement of the internal structure is available. A sample segmentation result is shown in Figure 18. Measurements on individual fibres and the structural arrangement of fibres can then be related to macroscopic material properties.

In this project, different volume images of paper and composite materials are available: one volume created from a series of 2D scanning electron microscopy (SEM) images at StoraEnso, Falun; and X-ray microtomography volume images of paper and composite samples imaged at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, at the Paul Scherrer Institut (PSI) in Villigen, Switzerland and also from tabletop scanners at University of Jyväskylä, Finland, at Applied Mechanics, Uppsala University, and at Innventia, Stockholm.

This year we published papers in the Nordic Pulp & Paper Research Journal, Cellulose, and the Mechanics of Materials. Erik Wernersson defended his PhD thesis closely related to this project in December 2014.

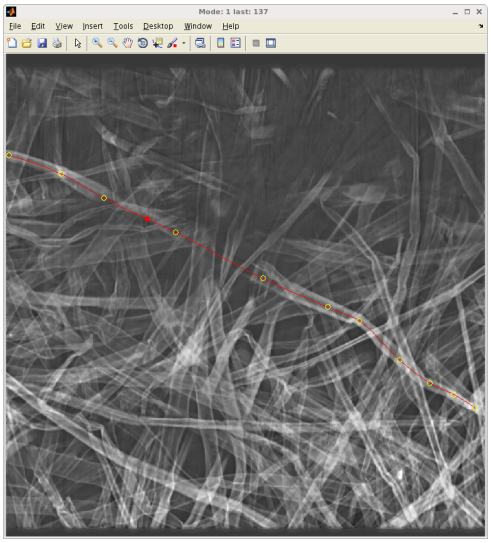


Figure 18: Through an interactive tool, users can quickly select and trace fibres within a 3D image of a paper sheet. Here, a 2D projection parallel to the sheet is shown. [Taken from our paper in Nordic Pulp and Paper Research Journal 29(3) 2014, and also used as cover image for that issue.]

29. **Ring Width and Density Profiling with Helical CT**
Erik Wernersson, Cris Luengo, Anders Brun, Gunilla Borgefors
Partners: Jan Van den Bulcke, Dept. of Forest and Water Management, Ghent University, Belgium
Funding: S-faculty, SLU
Period: 1201–1412
Abstract: Dendrochronology relies on accurate measurements of annual ring widths. The most common method is to use a flatbed scanner to acquire high resolution images of polished wood surfaces. In this project we investigate potential gains using a helical X-ray device which produces volume images. Direct advantages include non destructive and simplified sample preparation procedures as well as compensation for the orientation of the inner structure which can not be seen with ordinary flatbed scans. It is also possible to find density profiles using the same images.

One article was published in Dendrochronologia. Erik Wernersson defended his PhD thesis closely related to this project in December 2014.

30. **Light Scattering in Paper**
Erik Wernersson, Cris Luengo
Partners: Tomas Linder and Torbjörn Löfqvist, Luleå University of Technology, Luleå
Funding: S-faculty, SLU
Period: 1212–1412
Abstract: Fibre orientation is an important structural property in paper and other fibrous materials. In this study we explore the relation between light scattering and in-plane fibre orientation in paper sheets. Light diffusion from a focused light source is simulated using a Monte Carlo technique where parameters describing the paper micro-structure were determined from 3D x-ray computed tomography images. Measurements and simulations on both spatially resolved reflectance and transmittance light scattering patterns show an elliptical shape where the main axis is aligned towards the fibre orientation.

Good qualitative agreement was found at low intensities and the results indicate that fibre orientation in thin fibre-based materials can be determined using spatially resolved reflectance or transmittance. Published in Optics Express. Erik Wernersson defended his PhD thesis closely related to this project in December 2014.

31. **Large-scale quantification of gene expression in Arabidopsis**
Azadeh Fakhrzadeh, Cris Luengo
Partners: Urs Fischer, Hardy Hall, Umeå Plant Science Centre, SLU
Funding: S-faculty, SLU
Period: 1402–
Abstract: Arabidopsis is the most important plant model organism. For animal model organisms such as Drosophila melanogaster (fruitfly), C. elegans (roundworm) and Danio rerio (zebrafish), efforts have been made to map gene expression on a per-cell or sub-cell resolution. In this project, we develop tools to create the first such map for a plant species. We prepare thin sections of the root, hypocotyl and stem of the plant at various stages between sprouting and maturity. These sections are fluorescently stained such that the cell walls can be visualized in the confocal microscope. Each section also receives a FISH (fluorescent in situ hybridization) stain for a particular protein. Sections are then imaged at a magnification that allows most of the section to fit in the field of view. This yields several thousand cells in each image. Next, we use a fully automatic segmentation and quantification pipeline that allows measurement of relative amount and quality of the stained protein in each subcellular area (wall and lumen are separated, and each divided into four regions: inner, outer and two lateral). Cells are automatically classified into the various cell types, which allows statistics of expression over each of the cell types, for example. We currently have imaged several thousand sections, from both wildtype and mutant samples, stained for hundreds of different genes (Figure 19).

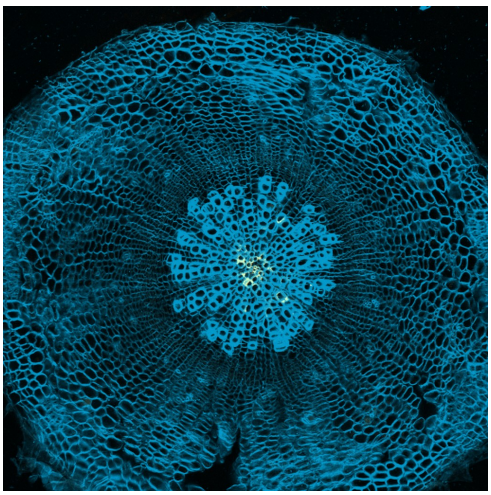


Figure 19: Cross section of the hypocotyl of a 21-day old Arabidopsis, stained for cell walls (blue) and a protein of interest (green).

5.4 Other applications

32. **Writer Identification and Dating**
Fredrik Wahlberg, Anders Brun
Partners: Lasse Mårtensson, Dept. of Business and Economics Studies, Högskolan i Gävle
Funding: UU; Swedish Research Council
Period: 1401–
Abstract: The problem of identifying the writer of some handwritten text is of great interest in both forensic and historical research. Sadly the magical CSI machine for identifying a scribal hand does not exist. Using image analysis, statistical models of how a scribe used the quill pen on a parchment can be collected. These measurements are treated as a statistical distribution over writing practices. We using this information to identify single writers and perform style based dating of historical manuscripts.

33. **Optical Character Recognition of Handwritten Texts**
Anders Brun, Ewert Bengtsson, Fredrik Wahlberg, Tomas Wilkinson, Kalyan Ram
Partners: Lasse Mårtensson, Dept. of Business and Economics Studies, Högskolan i Gävle; Mats Dahllöf, Dept. of Linguistics and Philology, UU; Alicia Fornés, Universitat Autònoma de Barcelona, Italy
Funding: Faculty of Languages and Humanities, UU; Swedish Research Council
Period: 1008–
Abstract: Optical character recognition (OCR) is still, after nearly 100 years of research, an active area of research. Currently, one of the frontiers is the recognition of handwritten text (HTR), in particular from historical documents. This year, we had a two month visit by guest researcher Alicia Fornés from Universitat Autònoma de Barcelona. We submitted several grant applications and continued a collaboration with the Swedish Museum of Natural History. Promising results during the year include a novel visualization technique, image based word clouds (Figure 20), large scale analysis of medieval letters, better techniques for document binarization and cluster analysis of letter shapes (Figure 21).

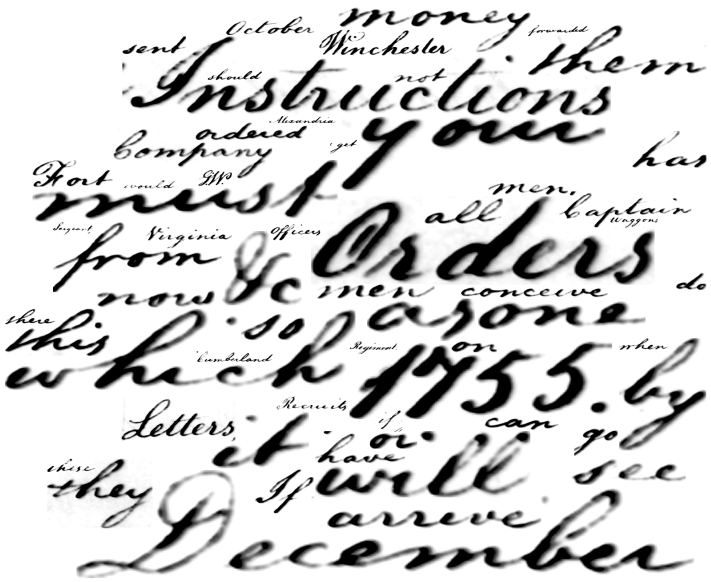


Figure 20: An image-based word cloud generated from a scanned collection of a 18th century letters written by George Washington. The cloud approximately contains the most frequently occuring images of words in the collection.

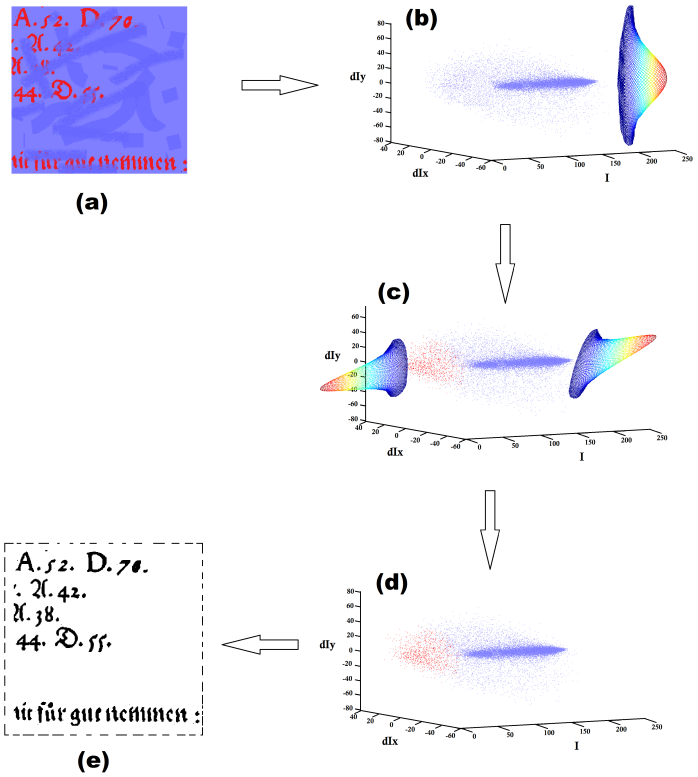


Figure 21: Hierarchical Mean Shift clustering based binarization procedure is outlined here with input as shown in (a) and output as indicated in (e) through separation of foreground and background clusters in a three dimentional space of intensity, x-derivative, y-derivative at each pixel as shown in (b)-(d).

34. **GeoMemories**
Anders Hast
Partners: Andrea Marchetti, Salvatore Minutoli, Alessandro Prosperi, Alessandro Lugari, Maurizio Tesconi, Beatrice Rapisarda, Matteo Abrate, Clara Bacciu, Davide Gazzé, Sergio Bianchi, Istituto di Informatica e Telematica (IIT), Pisa, Italy
Abstract: The GeoMemories project is aimed at making publicly available, through web access, heritage preserved in the archives of Aerofototeca Nazionale in Rome, which contains photographs covering the Italian territory from the end of 1800 till modern days. The web application is based on google earth but oriented towards the management of the temporal variable, so that geospatial changes can be monitored over time. The historical aerial photos need to be digitized, illumination corrected, orthorectified, georeferenced and finally stitched together. Anders Hast spent one year (2011) at IIT, CNR in Pisa Italy as an ERCIM fellow working with image processing and computer vision aspects in the project. Since returning to UU he is a research associate at IIT, CNR and continues working with the project and focus has been on how to improve the algorithms needed and several papers have been published. Recently the challenges and advantages of stereo visualisation of the historical archive has been investigated.

35. **Image Analysis for Landscape Analysis**
Anders Brun
Partners: Bo Malmberg, Michael Nielsen, Dept. of Human Geography, Stockholm University; Anders Wästfelt, Dept. of Economics, SLU
Funding: UU/SU
Period: 0901–
Abstract: This project is a collaboration with researchers at SU and SLU. It aims to derive information about the landscape (rural and city) from satellite images. The project focuses on using texture analysis of images, rather than only pixelwise spectral analysis, to segment the image into different meaningful regions. One journal manuscript was published during 2014 and the collaboration with the GLEAN project at the Dept. of Political Science at Stockholm University has continued.

36. **Recognition and Image Analysis for Natural History Collections**
Anders Brun, Tomas Wilkinson
Partners: Stefan Daume, Swedish Museum of Natural History; Alicia Fornés, Universitat Autònoma de Barcelona, Italy
Funding: UU/SU
Period: 1401–
Abstract: In this project we investigate ways to automatically interpret text labels, which are often handwritten, in large natural history collections. Examples of such collections include for instance herbarium sheets and collections of insects. It is estimated that we have around 33 million collected specimen in Sweden alone. Some of these have been digitized, in particular herbarium sheets, but the process is very labor intense. Addring automatic recognition of text, would speed up this process considerably and make the digitized data more useful for further data mining. During 2015, we were co-applicants for one large infrastructure grant proposal and Anders Brun gave an invited speech at the Swedish Natural History Museum Digitization Symposium.

37. **Tracking Honey Bees and their Interactions**
Cris Luengo
Partners: Olle Terenius, Ingemar Fries, Joachim Rodrigues de Miranda, Eva Forsgren, Barbara Locke, Dept. of Ecology, SLU; Fredrik Liljeros, Dept. of Sociology, Stockholm University
Funding: Åke Wiberg Foundation; S-faculty, SLU
Period: 1003–
Abstract: In this project, we are creating a system in which we can observe a portion of a bee hive (containing about one thousand individuals, each tagged with a unique identifier on its back) over days or weeks. Bees will be free to enter and exit the hive, and the environment will be set up to be as natural as possible for the bees. The purpose is to observe the natural behaviour of the bees, and record the type and duration of interaction between individuals. During 2014, we applied for funding to continue this work.

5.5 General theory and tools

38. **The Stochastic Watershed**
Bettina Selig, Cris Luengo, Ida-Maria Sintorn, Filip Malmberg, Robin Strand
Funding: S-faculty, SLU
Period: 1102–
Abstract: The stochastic watershed is a method recently presented that builds on the classical seeded watershed algorithm. It creates a probability density function for edges in the image by repeated applications of the seeded watershed with random seeds. Previously, we developed a perturbation-based approach to improve the properties of the algorithm: by adding noise to the input image at every application of the seeded watershed, we were able to avoid larger regions being split.

During 2014, we published an efficient, deterministic algorithm that computes the result that one would obtain after an infinite number of repetitions of the seeded watershed (Pattern Recognition Letters), as well as an efficient algorithm to convert this tree-based result back to all edges in the image's graph.

We also submitted a paper that describes a method to combine the perturbation-based approach with the deterministic algorithm. This combined method is much faster than the original perturbation-based method, and improves on its results slightly.

39. **Adaptive Mathematical Morphology**
Vladimir Ćurić, Cris Luengo, Gunilla Borgefors
Partners: Anders Landström, Matthew Thurley, Luleå University of Technology, Luleå; Sébastien Lefèvre, University of South Brittany, Vannes, France; Jesús Angulo, Santiago Velasco-Forero, Centre for Mathematical Morphology, MINES ParisTech, Fontainebleau, France
Funding: Graduate School in Mathematics and Computing (FMB)
Period: 1101–
Abstract: The construction of adaptive structuring elements that adjust their shape and size to the local structures in the image has recently been a popular topic in mathematical morphology. Despite that several methods for the construction of spatially adaptive structuring elements have been proposed, it is still an open problem, both from a theoretical and implementation point of view. We have proposed the salience adaptive structuring

elements, which modify their shape and size according to the saliency of nearby edges in the image, as well as structuring element with a predefined shape that only changes size based on the saliency of nearby edges.

This year, we published an overview paper on adaptive mathematical morphology, in which we compared a few of the most important methods for constructing adaptive structuring elements, as well as theoretical advances on how to properly define morphological operators. Currently, we are working towards defining more complex morphological operators using adaptive structuring elements, such as an adaptive hit-or-miss transform. Vladimir Ćurić defended his PhD thesis closely linked to this project in May 2014.

40. **Digital Distance Functions and Distance Transforms**
Robin Strand, Gunilla Borgefors
Partner: Benedek Nagy, Dept. of Computer Science, Faculty of Informatics, University of Debrecen, Hungary; Nicols Normand, IRCCyN, University of Nantes, France
Funding: TN-faculty, UU; S-faculty, SLU
Period: 9309–
Abstract: The distance between any two grid points in a grid is defined by a distance function. In this project, weighted distances have been considered for many years. A generalization of the weighted distances is obtained by using both weights and a *neighborhood sequence* to define the distance function. The neighborhood sequence allows the size of the neighborhood to vary along the paths.

In 2014, the work was focused on weight sequence distance functions, where weighted neighborhood sequences of infinte length are allowed.

41. **The Minimum Barrier Distance**
Robin Strand, Filip Malmberg, Elisabeth Linnér
Partners: Punam K. Saha, Dept. of Electrical and Computer Engineering and the Dept. of Radiology, University of Iowa, IA, USA; Krzysztof C. Ciesielski, Dept. of Mathematics, West Virginia University, Morgantown, WV, USA; Dept. of Radiology, MIPG, University of Pennsylvania, PA, USA
Funding: TN-faculty, UU
Period: 1103–
Abstract: In this project, we introduce a distance function on a fuzzy subset that gives the minimum barrier that has to be passed to go from one point to another. Theoretical properties as well as efficient computational solutions for minimum barrier distance have been developed. An initial application of minimum barrier distance in image segmentation is presented. The experiments show that the minimum barrier distance is robust to noise and blur, and also seed point position, since it captures the total change in membership values across an interface instead of gradient as a measure of slope that is sensitive to noise and blur.

During 2014, a paper describing an efficient method for exact calculation of minimum barrier distance transforms was published in Computer Vision and Image Understanding. Another paper, published in the proceedings of the international conference on Discrete Geometry for Computer Imagery, investigated the stability of the minimum barrier distance with respect to seed point position.

42. **Set Distances and their Application in Image Analysis**
Vladimir Ćurić, Gunilla Borgefors, Nataša Sladoje
Partner: Joakim Lindblad, Faculty of Technical Sciences, University of Novi Sad, Serbia
Funding: Graduate School in Mathematics and Computing (FMB); TN-faculty, UU
Period: 0908–1406
Abstract: We have, in 2014, concluded our study related to methods for measuring distances between sets, summarizing the results in two journal publications and in Vladimir's PhD thesis, successfully defended in May 2014. To measure how similar sets are can be useful for solving various image analysis related problems, such as registration, image retrieval and segmentation evaluation.

During the project, we have evaluated existing and developed new set distances which are useful in image registration related problems. A new set distance between crisp sets of points is presented and evaluated w.r.t. utiliziation in rigid body registration of binary images, as well as for multi-modal 2D–3D registration of 2D histological sections of bone implant with corresponding 3D synchrotron radiation micro computed tomography (SRμCT) bone implant volumes. This work is published in the Pattern Analysis and Applications journal.

We extended our study to fuzzy objects and proposed four novel point-to-set distances defined for fuzzy or gray-level image data, two based on integration of alpha cuts and two based on the fuzzy distance transform. We further used these point-to-set distances to define distances between fuzzy sets. Theoretical study and performance evaluation of the proposed distances con- firm their excellent behaviour in template matching and object classification. New distance measures enable inclusion of both spatial and intensity information, which makes them applicable to texture matching problems as well. The results of this study are published in IEEE Transactions on Image Processing. Vladimir defended his PhD thesis closely linked to this project in 2014.

43. **Direct Curvature Calculation of Surfaces in 3D Volumes**
Erik Wernersson, Cris Luengo, Anders Brun, Gunilla Borgefors
Funding: S-faculty, SLU
Period: 1009–1412
Abstract: Curvature is known to be a useful local descriptor of 2D surfaces, embedded in 3D space. Not only for parametric surfaces but also estimated from objects in digital images with applications ranging from visualisation to segmentation. Within this project, we have studied curvature calculated from the structure tensor, in contrast to the most common methods which derive curvature directly from image differentials. Using the structure tensor, we were able to use non-standard derivative operators to determine curvature. We also used non-linear smoothing to create the structure tensor. These two modifications together allow for a more precise estimate of curvature in places where the curvature changes quickly, or where two surfaces of different curvature are close together. We also correctly determine the sign of the curvature, which allows us to distinguish concave and convex surfaces. This distinction is useful for example to differentiate the inner and outer surface of a wood fibre. Erik defended his PhD thesis closely linked to this project in December of 2014.

44. **Image Enhancement based on Energy Minimization**
Nataša Sladoje
Partners: Joakim Lindblad, Buda Bajić, Faculty of Engineering, University of Novi Sad, Serbia
Funding: Swedish Governmental Agency for Innovation Systems (VINNOVA); TN-faculty, UU
Period: 1409–
Abstract: A common approach to solve the very important but severely ill-posed problem of image deconvolution, is to formulate it in a form of an energy minimization problem. Typically, some regularization is applied, utilizing available a priori knowledge. Total variation regularization is among most popular approaches, due to its generally good performance.
Within this project we are exploring different ways to improve the results of energy minimization based image deconvolution. During 2014 we have studied utilization of different *potential functions* in restoration of images degraded by both noise and blur. We have tested performance of seven known potentials, convex as well as non-convex, utilizing empirically determined optimal parameter settings for each of them. We have performed optimization by a flexible and efficient SPG method. Our study confirm that some appropriately chosen potentials provide a straightforward way to increase quality of the restored images.
We have presented the results of our study at the International Conference on Image Analysis and Recognition (ICIAR 2014), held in Algarve, Portugal. The proceedings of the conference is printed in the Lecture Notes in Computer Science series.

45. **Coverage Model and its Application to High Precision Medical Image Processing**
Nataša Sladoje
Partners: Joakim Lindblad, Faculty of Technical Sciences, University of Novi Sad, Serbia; Attila Tanács and Zoltan Kato, Dept. of Image Processing and Computer Graphics, University of Szeged, Hungary
Funding: TN-faculty, UU
Period: 1409–
Abstract: The coverage model, that we have been developing for several years now, provides a framework for representing continuous objects present in digital images as spatial fuzzy subsets. Assigned membership values indicate to what extent image elements are covered by the imaged objects. During last years, we have shown, both theoretically, and in applications, that the model can be used to improve information extraction from digital images and to reduce problems originating from limited spatial resolution.
During 2014, we have finalized our study on a unified framework to recover linear geometric correspondences between binary objects in n-dimensions. The solution of the registration problem is obtained by solving polynomial systems of equations that are based on geometric moments of the template and observation, with no need for additional correspondences.
To further improve the performance of this fast and efficient registration method, we have proposed to use coverage information to compensate for possibly insufficient spatial resolution and to reach the desired precision of moments estimates. The work is published in the Pattern Recognition journal, where the advantages of this approach are clearly demonstrated, in particular in terms of increased percentage of registration results in the highest scoring group. An illustration of the proposed methods is demonstrated on real X-ray images of hip replacement implants and 3D CT volumes of the pelvic area (Figure 22).

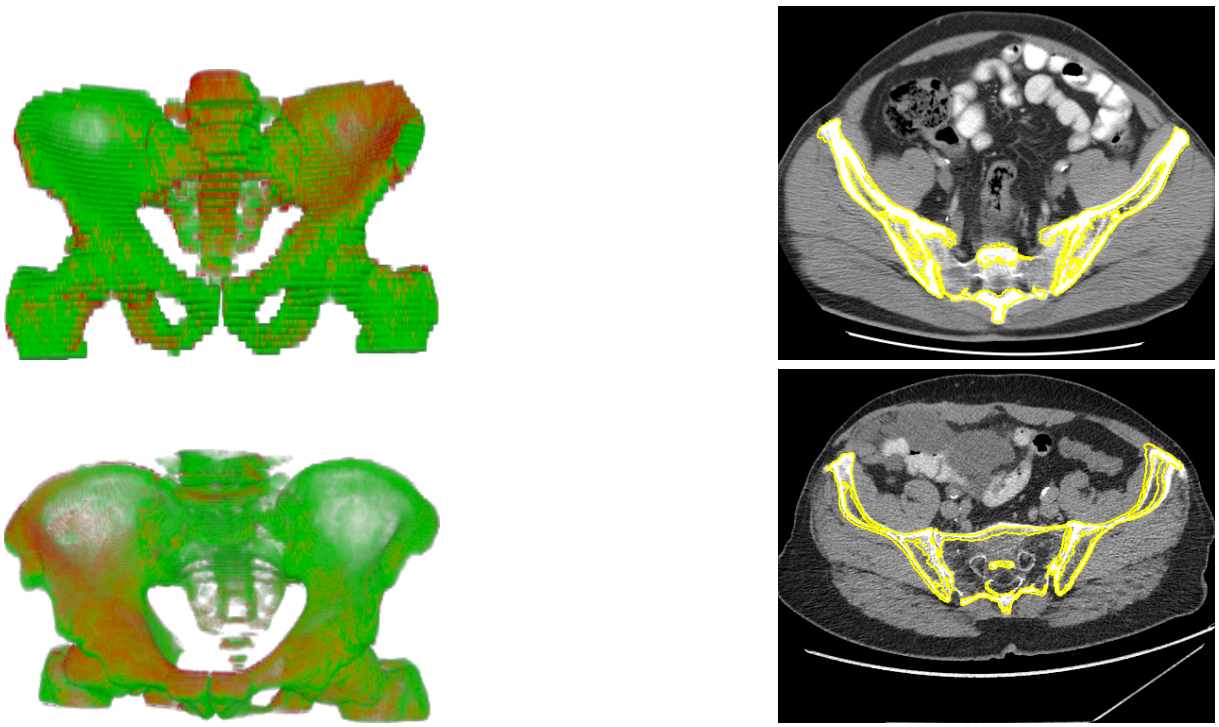


Figure 22: Registration of pelvic CT data: superimposed registered 3D bone models (left column), and bone contours of the registered template (yellow) overlaid on a CT slice of the observations (right column).

46. **Digital Hyperplanes**
Christer Kiselman
Partner: Adama Koné, Université de Bamako
Funding: International Science Programme; Université de Bamako; Kingdom of Sweden
Period: 1011-
Abstract: Digital planes in all dimensions are studied, which means that digital straightness is in focus. The general goal is to generalize to any dimension the results of Kiselman's 2011 paper in Mathematika (Figure 23).

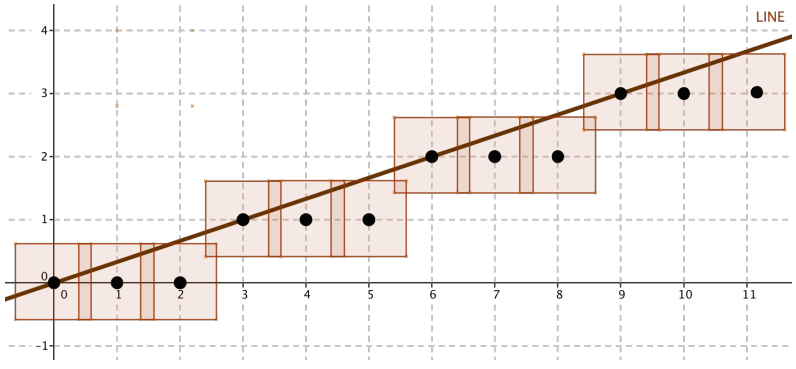


Figure 23: The figure shows how a Euclidean straight line can, or cannot, be covered by dilations of one of its discretizations, in this case the discretization defined by the floor function. The structuring element of the dilations is a rectangle. The project concerns analogous results in higher dimensions.

47. **Convexity of Marginal Functions in the Discrete Case**
Christer Kiselman
Partner: Shiva Samieinia, KTH
Funding: Stockholm University; KTH; Kingdom of Sweden
Period: 1011-
Abstract: We define, using difference operators, classes of functions defined on the set of points with integer coordinates which are preserved under the formation of marginal functions. The duality between classes of functions with certain convexity properties and families of second-order difference operators plays an important role and is explained using notions from mathematical morphology. A manuscript was submitted in 2014. Some problems remain to be solved (Figure 24).

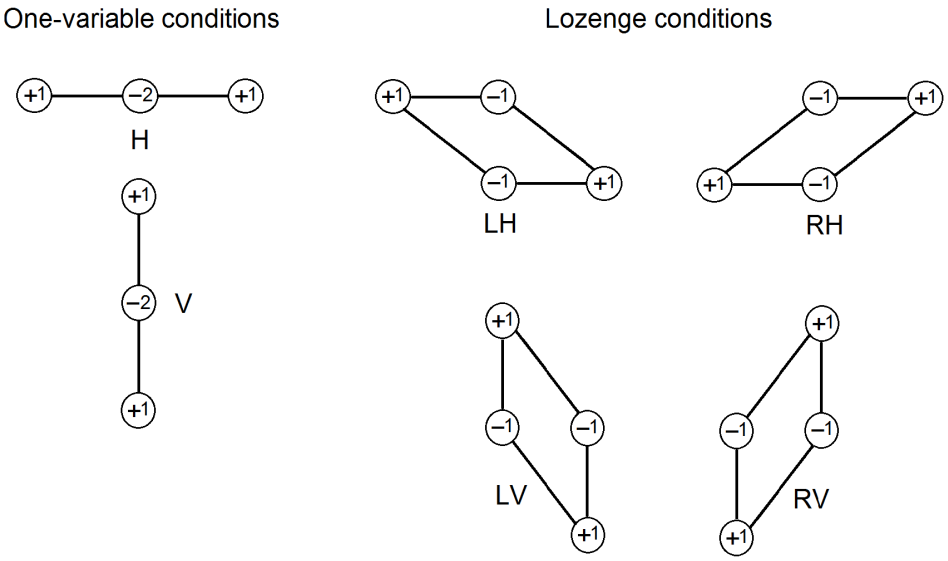


Figure 24: The marginal function of a convex function of real variables is easily seen to be convex, but in the discrete case, nothing is obvious. For a function of two integer variables, six conditions involving second-order difference operators are sufficient for its marginal function to be convex extensible. The figure shows the weights in these difference operators.

48. **Euclid's Straight Lines**
Christer Kiselman
Funding: Kingdom of Sweden
Period: 0701-
Abstract: The project is both linguistic and mathematical. We raise two questions on Euclid's Elements: How to explain that Propositions 16 and 27 in his first book do not follow, strictly speaking, from his postulates (or are perhaps meaningless)? and: What are the mathematical consequences of the meanings of the term eutheia, which we today often prefer to consider as different?

The answer to the first question is that orientability is a tacit assumption. The answer to the second is rather a discussion on efforts to avoid actual infinity, and having to (in some sense or another) construct equivalence classes of segments to achieve uniqueness. An article will appear in Normat.

49. **Discrete Convolution Equations**
Christer Kiselman
Funding: Kingdom of Sweden
Period: 1201-
Abstract: We study solvability of convolution equations for functions with discrete support in $\mathbf{R}^n$, a special case being functions with support in the integer points. The more general case is of interest for several grids in Euclidean space, like the body-centred and face-centered tesselations of three-space, as well as for the non-periodic grids that appear in the study of quasicrystals. The theorem of existence of fundamental solutions by de Boor, Höllig & Riemenschneider is generalized to general discrete supports, using only elementary methods. We also study the asymptotic growth of sequences and arrays using the Fenchel transformation. Estimates using the Fourier transformation will be studied later.

50. **DIPimage and DIPlib**
Cris Luengo
Partners: Bernd Rieger, Lucas van Vliet, Quantitative Imaging Group, Delft University of Technology, The Netherlands; Michael van Ginkel, Unilever Research and Development, Colworth House, Bedford, UK
Funding: S-faculty, SLU
Period: 0807–1412
Abstract: DIPimage is a MATLAB toolbox for scientific image analysis, useful for both teaching and research (`http://www.diplib.org`). It has been in active development since 1999, when it was created at Delft University of Technology. In 2008, when Cris Luengo moved to Uppsala, CBA was added to the project as a main development site. DIPlib, created in 1995, is a C library containing many hundreds of image analysis routines. DIPlib is the core of the DIPimage toolbox, and both projects are developed in parallel. Because DIPlib provides efficient algorithms, MATLAB is useful for image analysis beyond the prototyping stage. Together, MATLAB and DIPimage form a powerful tool for working with scalar and vector images in any number of dimensions.

Versions 2.6 and 2.7 were released in 2014. Version 2.6 added the option to do arithmetic operations without changing the data type of the image, useful when working with very large images. We also fixed a major bug that appeared due to some undocumented internal change in MATLAB, which caused the output images of certain functions to be copied

unnecessarily. Version 2.7 added the possibility to record macros (as MATLAB M-files), added a few new functions, and fixed many bugs. In particular, we had to make many changes for compatibility with MATLAB's new graphic system.

51. **UPPMAX Cluster Computing**
Petter Ranefall, Ida-Maria Sintorn, Carolina Wählby
Partners: Hans Karlsson, Elias Rudberg, Ola Spjuth, UPPMAX
Funding: SciLife Lab Uppsala; eSSENCE; Dept. of IT, UU
Period: 1110-
Abstract: Life science applications generate a huge amount of image data that has to be stored and analysed in an efficient way. This project is focused on providing easy access to high-performance computers and large-scale storage. In collaboration with Uppsala Multidisciplinary Center for Advanced Computational Science (UPPMAX) image analysis software are being installed and maintained on the cluster. Database solutions with easy web access to image data are also being developed and maintained. This project has also provided workshops and seminars to help life science researchers to get started and use the resources. Several new large-scale image analysis projects using the computer cluster were initiated in 2014.

5.6 Cooperation partners

International

Flanders Heritage Agency, Brussels, Belgium

Dept. of Forest and Water Management, Ghent University, Belgium

Dept. of Physics and Astronomy, Ghent University, Belgium

Delong Instruments, Brno, Czech Republic

Clinical Pathology Division, Vejle hospital, Vejle, Denmark

Visiopharm, Hørsholm, Denmark

Dept. of Physics, University of Jyväskylä (UJ), Finland

CREATIS, Université de Lyon, France

IRCCyN, University of Nantes, France

University of South Brittany, Vannes, France

Pitie Salpetriere Hospital, France

European Synchrotron Radiation Facility, Grenoble, France

École Nationale Supérieure des Mines de Saint-Étienne, France

Centre for Mathematical Morphology, Ecole des Mines de Paris - MINES ParisTech, Fontainebleau, France

Bavarian Forest National Park, Germany

Julius Wolff Institute, Berlin-Brandenburg School for Regenerative Therapies, Charité-Universitätsmedizin Berlin, Germany

Dept. of Computer Science, University of Debrecen, Hungary

Dept. of Image Processing and Computer Graphics, University of Szeged, Hungary

Centre for Development of Advanced Computing, Thiruvananthapuram, India

Regional Cancer Centre, Thiruvananthapuram, India

Istituto di Informatica e Telematica (IIT), Pisa, Italy

Dept. of Computer Engineering, Inje University, Gyeongnam, Republic of Korea

Dept. of Pathology, Yonsei University, Seoul, Republic of Korea

Dept. of Anatomy, Gachon University, Incheon, Republic of Korea

Université de Bamako, Mali

Eye Hospital Rotterdam, The Netherlands

Quantitative Imaging Group, Delft University of Technology, The Netherlands

Norwegian Pulp and Paper Research Institute, Trondheim, Norway

Faculty of Technical Sciences, University of Novi Sad, Serbia

Unilever Research and Development, Colworth House, Bedford, UK

University College London, UK

Great Ormond Street Hospital, UK

Broad Institute of Harvard and MIT, USA

Massachusetts General Hospital, Boston, MA, USA

Dept. of Electrical and Computer Engineering, University of Iowa, IA, USA

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

School of Medicine, Vanderbilt University, Nashville, TN, USA

Dept. of Mathematics, West Virginia University, Morgantown, WV, USA

Dept. of Biology, University of Virginia, Charlottesville, VA, USA

National

Dept. of Engineering Sciences, Applied Mechanics, UU

Dept. of Engineering Sciences, UU

Dept. of Immunology, Genetics and Pathology, UU

Dept. of Linguistics and Philology, UU

Dept. of Medical Cell Biology, UU

Dept. of Medical Sciences, UU

Dept. of Cell and Molecular Biology, UU

Dept. of Plastic- and Maxillofacial Surgery, UU Hospital

Dept. of Orthopedics, UU Hospital

Dept. of Radiology, Oncology and Radiation Science, UU

Dept. of Scandinavian Languages, UU

Dept. of Surgical Sciences, Oral and Maxillofacial Surgery, UU

Dept. of Surgical Sciences, Plastic Surgery, UU

Dept. of Surgical Sciences, UU

SciLifeLab, Stockholm

SciLifeLab, UU

Division of Microsystems Technology, UU

Dept. of Anatomy, Physiology and Biochemistry, SLU

Dept. of Ecology, SLU

Dept. of Economics, SLU

SenseGraphics AB, Kista

Center for Medical Image Science and Visualization (CMIV), Linköping University

Dept. of Computer Science, Electrical and Space Engineering, Luleå University of Technology

Division of Fluid and Experimental Mechanics, Luleå University of Technology

Centre for Microbiological Preparedness; Swedish Institute for Infectious Disease Control (SMI), Solna

Dept. of Human Geography, Stockholm University

Dept. of Sociology, Stockholm University

Dept. of Biochemistry and Biophysics and SciLifeLab, Stockholm University

Stockholm University

Division of Fibre Technology, School of Chemical Science and Engineering, KTH, Stockholm

Dept. of Solid Mechanics and BiMaC Innovation Center, KTH, Stockholm

The Wallenberg Wood Science Centre, School of Chemical Science and Engineering, KTH, Stockholm

The Royal Institute of Technology, KTH, Stockholm

Dept. of Cell and Molecular Biology, Karolinska Institute, Stockholm

Karolinska Institute, Stockholm

Swedish Museum of Natural History, Stockholm

Department of Industrial Development, IT and Land Management, University of Gävle

University of Gävle

Dept. of Signals and Systems, Chalmers University of Technology, Göteborg

Innventia, Stockholm

Vironova AB, Stockholm

PiezoMotors AB, Uppsala

Technovest AB

Umeå Plant Science Centre, Umeå University.

UPPMAX, UU

Uppsala University Hospital

6 Publications

Publishing in international conference proceedings and journal with high visibility is perhaps our most important aim. This year, we published 46 fully reviewed papers, 26 in journals and 20 in proceedings. Note that in our field, conference proceedings often rank higher than journals in impact factor, as measured by Google Scholar. As we were part of the organisation of ICPR 2014 (see Section 7.1) and this prestigious conference took place in Stockholm it is natural that we had seven papers there. The rest of the conference papers were spread on ten different conferences. For the journal papers, three were published in Pattern Recognition Letters and three in Computational and Mathematical Methods in Medicine, while the other 20 papers each found its home in a unique journal. This wide spread of publication places have become typical with us, as we apply our methods on a very wide field of tasks and have co-operation partners from many different areas. We also had 13 papers in partly or non-reviewed meetings, where the principal one is the Swedish Society for Automated Image Analysis (SSBA) annual Symposium.

We are of course also frequent reviewers of the work of other scientists, both for journals and conferences. The latter is somewhat visible in Section 7.8, as participation in programme committees, but not all conference reviewing is visible there and the reviewing of journals not at all. This is in the nature of blind reviewing and hard to document.

Authors affiliated with CBA are in bold.

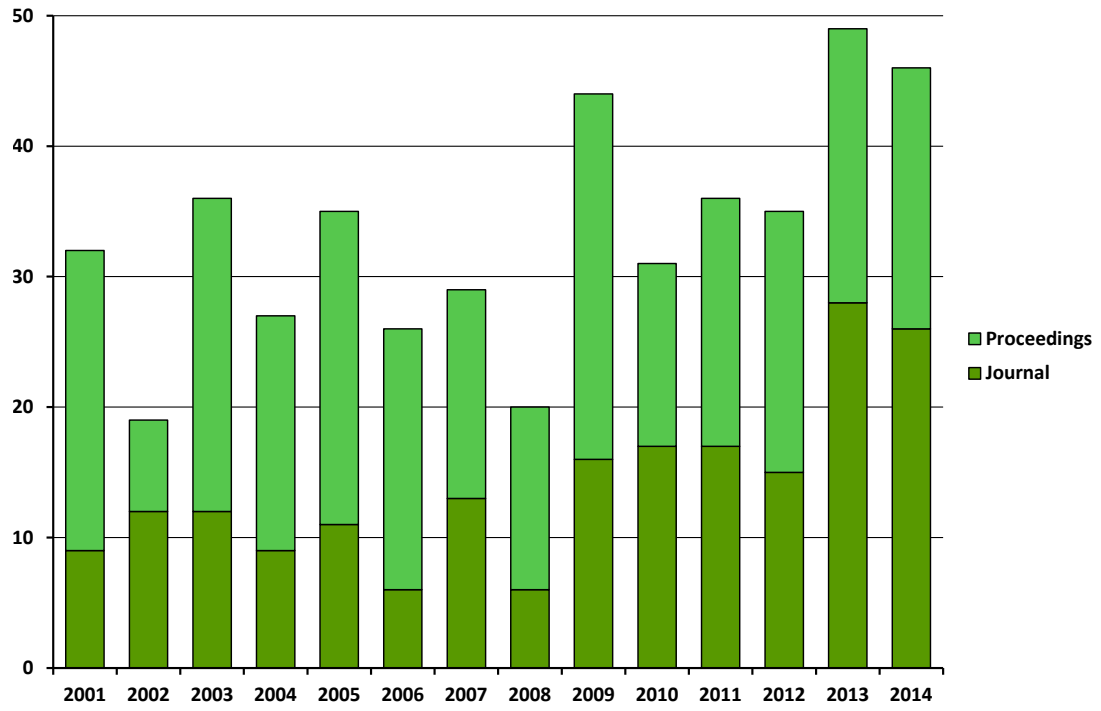


Figure 25: The number of publications from CBA 2001-2014.

6.1 Book chapters

1. **Kiel rekoni rektojn kaj strekojn inter ĉiuj kurboj kaj aliaj bildoj sur la komputila ekrano?**
   Author: **Christer O. Kiselman**
   Book: Internacia Simpozio "Apliko de Esperanto en la profesia agado". Prelegaro, Vol. II, pp 72-92
   Editors: Bojidar Leonov, BG Karlovo
   Publisher: Akademio Internacia de la Sciencoj, AIS-Bulgario, San Marino

2. **Solving Geospatial Tasks in 2D and 3D Visualizations of Maps**
   Author: **Stefan Seipel**
   Book: Information Visualisation: Techniques, Usability and Evaluation, pages 222-271
   Publisher: Cambridge Scholars Publishing

6.2 Special Journal Issues

1. **Pattern Recognition Letters 47:1–182, 2014**
   Special issue on Advances in Mathematical Morphology
   Editor: **Cris L. Luengo Hendriks**

6.3 Journal articles

1. **Image Segmentation and Identification of Paired Antibodies in Breast Tissue**
   Authors: **Jimmy C. Azar, Martin Simonsson, Ewert Bengtsson, Anders Hast**
   Journal: Computational & Mathematical Methods in Medicine, Vol. 2014, Article ID 647273, 11 pages
   Abstract: Comparing staining patterns of paired antibodies designed towards a specific protein but toward different epitopes of the protein provides quality control over the binding and the antibodies' ability to identify the target protein correctly and exclusively. We present a method for automated quantification of immunostaining patterns for antibodies in breast tissue using the Human Protein Atlas database. In such tissue, dark brown dye 3,3'-diaminobenzidine is used as an antibody-specific stain whereas the blue dye hematoxylin is used as a counterstain. The proposed method is based on clustering and relative scaling of features following principal component analysis. Our method is able (1) to accurately segment and identify staining patterns and quantify the amount of staining and (2) to detect paired antibodies by correlating the segmentation results among different cases. Moreover, the method is simple, operating in a low-dimensional feature space, and computationally efficient which makes it suitable for high-throughput processing of tissue microarrays.

2. **Screening for Cervical Cancer Using Automated Analysis of PAP-Smears**
   Authors: **Ewert Bengtsson, Patrik Malm**
   Journal: Computational and Mathematical Methods in Medicine, Vol. 2014, Article ID 842037, 12 pages
   Abstract: Cervical cancer is one of the most deadly and common forms of cancer among women if no action is taken to prevent it, yet it is preventable through a simple screening test, the so-called PAP-smear. This is the most effective cancer prevention measure developed so far. But the visual examination of the smears is time consuming and expensive and there have been numerous attempts at automating the analysis ever since the test was introduced more than 60 years ago. The first commercial systems for automated analysis of the cell samples appeared around the turn of the millennium but they have had limited impact on the screening costs. In this paper we examine the key issues that need to be addressed when an automated analysis system is developed and discuss how these challenges have been met over the years. The lessons learned may be useful in the efforts to create a cost-effective screening system that could make affordable screening for cervical cancer available for all women globally, thus preventing most of the quarter million annual unnecessary deaths still caused by this disease.

3. **3D Tree-Ring Analysis Using Helical X-Ray Tomography**
   Authors: Jan van den Bulcke(1), **Erik L.G. Wernersson**, Manuel Dierick(2), Denis Van Loo(2), Bert Masschael(2), Loes Brabant(2), Matthieu N. Boone(2), Luc Van Hoorebeke(2), Kristof Haneca(3), **Anders Brun, Cris L. Luengo Hendriks**, Joris Van Acker(1)
   (1) UGCT Ghent University, Dept. of Forest and Water Management, Laboratory of Wood Technology, Ghent, Belgium
   (2) UGCT Ghent University, Dept. of Physics and Astronomy, Ghent, Belgium
   (3) Flanders Heritage Agency, Brussels, Belgium
   Journal: Dendrochronologia, Vol. 32, nr 1, pages 39-46
   Abstract: The current state-of-the-art of tree-ring analysis and densitometry is still mainly limited to two dimensions and mostly requires proper treatment of the surface of the samples. In this paper we elaborate on the potential of helical X-ray computed tomography for 3D tree-ring analysis. Microdensitometrical profiles are obtained by processing of the reconstructed volumes. Correction of the structure direction, taking into account the angle of growth rings and grain, results in very accurate microdensity and precise ring width measurements. Both a manual as well as an automated methodology is proposed here, of which the MATLAB (c) code is available. Examples are given for pine (Pinus sylvestris L), oak (Quercus robur L) and teak (Tectona grandis L.). In all, the methodologies applied here on the 3D volumes are useful for growth related studies, enabling a fast and non-destructive analysis.

4. **Efficient Algorithm for Finding the Exact Minimum Barrier Distance**
   Authors: Krzysztof Chris Ciesielskia(1,2), **Robin Strand(3), Filip Malmberg(3)**, Punam K. Saha(4)
   (1) Dept. of Mathematics, West Virginia University, Morgantown, WV, USA
   (2) Dept. of Radiology, MIPG, University of Pennsylvania, Philadelphia, PA, USA
   (3) Dept. of Radiology, Oncology and Radiation Science, UU
   (4) Dept. of Electrical and Computer Engineering and Dept. of Radiology, The University of Iowa, Iowa City, USA
   Journal: Computer Vision and Image Understanding, Vol. 123, pages 53-64
   Abstract: The minimum barrier distance, MBD, introduced recently in [1], is a pseudo-metric defined on a compact subset D of the Euclidean space $R \sup n$ and whose values depend on a fixed map (an image) f from D into R. The MBD is defined as the minimal value of the barrier strength of a path between the points, which constitutes the length of the smallest interval containing all values of f along the path.

   In this paper we present a polynomial time algorithm, that provably calculates the exact values of MBD for the digital images. We compare this new algorithm, theoretically and experimentally, with the algorithm presented in [1], which computes the approximate values of the MBD. Moreover, we notice that every generalized distance function can be naturally translated to an image segmentation algorithm. The algorithms that fall under such category include: Relative Fuzzy Connectedness, and those associated with the minimum barrier, fuzzy distance, and geodesic distance functions. In particular, we compare experimentally these four algorithms on the 2D and 3D natural and medical images with known ground truth and at varying level of noise, blur, and inhomogeneity.

5. **Adaptive Mathematical Morphology: A Survey of the Field**
   Authors: **Vladimir Ćurić**, Anders Landström(1), Matthew J. Thurley(1), **Cris L. Luengo Hendriks**
   (1) Dept. of Computer Science, Electrical and Space Engineering, Luleå University of Technology, Sweden
   Journal: Pattern Recognition Letters, Vol. 47, pages 18-28
   Abstract: We present an up-to-date survey on the topic of adaptive mathematical morphology. A broad review of research performed within the field is provided, as well as an in-depth summary of the theoretical advances within the field. Adaptivity can come in many different ways, based on different attributes, measures, and parameters. Similarities and differences between a few selected methods for adaptive structuring elements are considered, providing perspective on the consequences of different types of adaptivity. We also provide a brief analysis of perspectives and trends within the field, discussing possible directions for future studies.

6. **A New Set Distance and Its Application to Shape Registration**
   Authors: **Vladimir Ćurić**, Joakim Lindblad(1), Nataša Sladoje(1), **Hamid Sarve, Gunilla Borgefors**
   (1) Faculty of Technical Sciences, University of Novi Sad, Serbia.
   Journal: Pattern Analysis and Applications, Vol. 17, nr 1, pages 141-152
   Abstract: We propose a new distance measure, called Complement weighted sum of minimal distances, between finite sets in Zn and evaluate its usefulness for shape registration and matching. In this set distance the contribution of each point of each set is weighted according to its distance to the complement of the set. In this way, outliers and noise contribute less to the new similarity measure. We evaluate the performance of the new set distance for registration of shapes in binary images and compare it to a number of often used set distances found in the literature. The most extensive evaluation uses a set of synthetic 2D images. We also show three examples of real problems: registering a set of 2D images extracted from synchrotron radiation micro-computed tomography (SR μ CT) volumes depicting bone implants; the difficult multimodal registration task of finding the exact location of a 2D slice of a bone implant, as imaged by a light microscope, within a 3D SR μ CT volume of the same implant; and finally recognition of handwritten characters. The evaluation shows that our new set distance performs well for all tasks and outperforms the other observed distance measures in most cases. It is therefore useful in many image registration and shape comparison tasks.

7. **Canine Body Composition Quantification Using 3 Tesla Fat Water MRI**
   Authors: Aliya Gifford(1,2), Joel Kullberg(3), Johan Berglund(3), **Filip Malmberg**, Katie C. Coate(4), Phillip E. Williams(4), Alan D. Cherrington(4), Malcolm J. Avison(1,2,5,6), E. Brian Welch(1,2,6)
   (1) Vanderbilt University Institute of Imaging Science, Vanderbilt University School of Medicine, Nashville, Tennessee, USA
   (2) Chemical and Physical Biology Program, Vanderbilt University School of Medicine, Nashville, Tennessee, USA
   (3) Dept. of Radiology, UU, Uppsala, Sweden
   (4) Dept. of Molecular Physiology and Biophysics, Vanderbilt University School of Medicine, Nashville, Tennessee, USA
   (5) Dept. of Pharmacology, Vanderbilt University School of Medicine, Nashville, Tennessee, USA
   (6) Dept. of Radiology & Radiological Sciences, Vanderbilt University School of Medicine, Nashville, Tennessee, USA
   Journal: Journal of Magnetic Resonance Imaging, Vol. 39, Issue 2, pages 485-491
   Abstract: Purpose: To test the hypothesis that a whole-body fat-water MRI (FWMRI) protocol acquired at 3 Tesla combined with semi-automated image analysis techniques enables precise volume and mass quantification of adipose, lean, and bone tissue depots that agree with static scale mass and scale mass changes in the context of a longitudinal study of large-breed dogs placed on an obesogenic high-fat, high-fructose diet.

   Materials and Methods: Six healthy adult male dogs were scanned twice, at weeks 0 (baseline) and 4, of the dietary regiment. FWMRI-derived volumes of adipose tissue (total, visceral, and subcutaneous), lean tissue, and cortical bone were quantified using a semi-automated approach. Volumes were converted to masses using published tissue densities.

   Results: FWMRI-derived total mass corresponds with scale mass with a concordance correlation coefficient of 0.931 (95% confidence interval = [0.813, 0.975]), and slope and intercept values of 1.12 and -2.23 kg, respectively. Visceral, subcutaneous and total adipose tissue masses increased significantly from weeks 0 to 4, while neither cortical bone nor lean tissue masses changed significantly. This is evidenced by a mean percent change of 70.2% for visceral, 67.0% for subcutaneous, and 67.1% for total adipose tissue.

   Conclusion: FWMRI can precisely quantify and map body composition with respect to adipose, lean, and bone tissue depots. The described approach provides a valuable tool to examine the role of distinct tissue depots in an established animal model of human metabolic disease

8. **Simple Filter Design for First and Second Order Derivatives by a Double Filtering Approach**
   Author: **Anders Hast**
   Journal: Pattern Recognition Letters, Vol. 42, pages 65-71
   Abstract: Spline filters are usually implemented in two steps, where in the first step the basis coefficients are computed by deconvolving the sampled function with a factorized filter and the second step reconstructs the sampled function. It will be shown how separable spline filters using different splines can be constructed with fixed kernels, requiring no inverse filtering. Especially, it is discussed how first and second order derivatives can be computed correctly using cubic or trigonometric splines by a double filtering approach giving filters of length 7.

9. **How to Promote Student Creativity and Learning Using Tutorials in Teaching Graphics and Visualisation**
   Author: **Anders Hast**
   Journal: Journal for Geometry and Graphics, Vol. 18, nr 2, pages 237-245
   Abstract: Course assignments play an important role in the learning process. However, they can be constructed in such a way that they prohibit creativity, rather than promoting it. Therefore it was investigated how programming assignments are set up that students encounter in computer science education and which approach could help the students in problem solving and whether these would help or prohibit them to be creative or not. Especially, an online tutorial about visualisation using VTK and Python was used as an example in different courses on visualisation. It was also examined how students in the computer graphics courses that did not have access to such tutorial answered questions about assignments.

10. **Improved Illumination Correction That Preserves Medium Sized Objects**
Authors: **Anders Hast**, Andrea Marchetti(1)
(1) Consiglio Nazionale delle Ricerche, Institute of Informatics and Telematics, Pisa, Italy
Journal: Machine Graphics & Vision, Vol. 23, nr 1/2, pages 3-20
Abstract: Illumination correction is a method used for removing the influence of light coming from the environment and of other distorting factors in the image capturing process. An algorithm based on the luminance mapping is proposed that can be used to remove low frequency variations in the intensity, and to increase the contrast in low contrast areas when necessary. Moreover, the algorithm can be employed to preserve the intensity of medium-sized objects with different intensity or colour than their surroundings, which otherwise would tend to be washed out. Furthermore, examples are given showing how the method can be used for both greyscale images and colour photos.

11. **Effects of Defects on the Tensile Strength of Short-Fibre Composite Materials**
Authors: Thomas Joffre(1), Arttu Miettinen(2), **Erik L.G. Wernersson**, Per Isaksson(1), E. Kristofer Gamstedt(1)
(1) Ångström Laboratory, Dept. of Engineering Sciences, UU
(2) Dept. of Physics, University of Jyväskylä, Jyväskylä, Finland
Journal: Mechanics of Materials, Vol. 75, pages 125-134
Abstract: Heterogeneous materials tend to fail at the weakest cross-section, where the presence of microstructural heterogeneities or defects controls the tensile strength. Short-fibre composites are an example of heterogeneous materials, where unwanted fibre agglomerates are likely to initiate tensile failure. In this study, the dimensions and orientation of fibre agglomerates have been analysed from three-dimensional images obtained by X-ray microtomography. The geometry of the specific agglomerate responsible for failure initiation has been identified and correlated with the strength. At the plane of fracture, a defect in the form of a large fibre agglomerate was almost inevitably found. These new experimental findings highlight a problem of some existing strength criteria, which are principally based on a rule of mixture of the strengths of constituent phases, and not on the weakest link. Only a weak correlation was found between stress concentration induced by the critical agglomerate and the strength. A strong correlation was however found between the stress intensity and the strength, which underlines the importance of the size of largest defects in formulation of improved failure criteria for short-fibre composites. The increased use of three-dimensional imaging will facilitate the quantification of dimensions of the critical flaws.

12. **Automated Analysis of Dynamic Behavior of Single Cells in Picoliter Droplets**
Authors: Mohammad Ali Khorshidi(1), Prem Kumar Periyannan Rajeswari(1), **Carolina Wählby(2,3)**, Håkan N. Jönsson(1), Helene Andersson Svahn(1)
(1) Division of Proteomics and Nanobiotechnology, Science for Life Laboratory, KTH Royal Institute of Technology, Stockholm, Sweden
(2) Science for Life Laboratory, UU
(3) Broad Institute of Harvard and MIT, Cambridge, USA
Journal: Lab on a Chip, Vol. 14, pages 931-937
Abstract: We present a droplet-based microfluidic platform to automatically track and characterize the behavior of single cells over time. This high-throughput assay allows encapsulation of single cells in microdroplets and traps intact droplets in arrays of miniature wells on a PDMS-glass chip. Automated time-lapse fluorescence imaging and image analysis of the incubated droplets on the chip allows the determination of the viability of individual cells over time. In order to automatically track the droplets containing cells, we developed a simple method based on circular Hough transform to identify droplets in images and quantify the number of live and dead cells in each droplet. Here, we studied the viability of several hundred single isolated HEK293T cells over time and demonstrated a high survival rate of the encapsulated cells for up to 11 hours. The presented platform has a wide range of potential applications for single cell analysis, e.g. monitoring heterogeneity of drug action over time and rapidly assessing the transient behavior of single cells under various conditions and treatments in vitro.

13. **3D Texture Analysis in Renal Cell Carcinoma Tissue Image Grading**
Authors: Tae-Yun Kim(1), Nam-Hoon Cho(2), Goo-Bo Jeong(3), **Ewert Bengtsson**, Heung-Kook Choi(1)
(1) Dept. of Computer Engineering, Inje University, Gyeongnam, Republic of Korea
(2) Dept. of Pathology, Yonsei University, Seoul, Republic of Korea
(3) Dept. of Anatomy, Gachon University, Incheon, Republic of Korea
Journal: Computational and Mathematical Methods in Medicine, Vol. 2014, Article ID 536217, 12 pages
Abstract: One of the most significant processes in cancer cell and tissue image analysis is the efficient extraction of features for grading purposes. This research applied two types of three-dimensional texture analysis methods to the extraction of feature values from renal cell carcinoma tissue images, and then evaluated the validity of the methods statistically through grade classification. First, we used a confocal laser scanning microscope to obtain image slices of four grades of renal cell carcinoma, which were then reconstructed into 3D volumes. Next, we extracted quantitative values using a 3D gray level cooccurrence matrix (GLCM) and a 3D wavelet based on two types of basis functions. To evaluate their validity, we predefined 6 different statistical classifiers and applied these to the extracted feature sets. In the grade classification results, 3D Haar wavelet texture features combined with principal component analysis showed the best discrimination results. Classification using 3D wavelet texture features was significantly better than 3D GLCM, suggesting that the former has potential for use in a computer-based grading system.

14. **Priors for X-Ray in-Line Phase Tomography of Heterogeneous Objects**
Authors: Max Langer(1,2), Peter Cloetens(2), Bernhard Hesse(1,2,3), Heikki Suhonen(2),
Alexandra Pacureanu(4), Kay Raum(3), Françoise Peyrin(1,2)
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(2) European Synchrotron Radiation Facility, Grenoble, France
(3) Julius Wolff Institute, Berlin-Brandenburg School for Regenerative Therapies, Charité-Universitätsmedizin Berlin, Germany
(4) Science for Life Laboratory, UU
Journal: Philosophical Transactions. Series A: Mathematical, physical, and engineering science, Vol. 372, nr 2010, 20130129, pages 1-9
Abstract: We present a new prior for phase retrieval from X-ray Fresnel diffraction patterns. Fresnel diffraction patterns are achieved by letting a highly coherent X-ray beam propagate in free space after interaction with an object. Previously, either homogeneous or multi-material object assumptions have been used. The advantage of the homogeneous object assumption is that the prior can be introduced in the Radon domain. Heterogeneous object priors, on the other hand, have to be applied in the object domain. Here, we let the relationship between attenuation and refractive index vary as a function of the measured attenuation index. The method is evaluated using images acquired at beamline ID19 (ESRF, Grenoble, France) of a phantom where the prior is calculated by linear interpolation and of a healing bone obtained from a rat osteotomy model. It is shown that the ratio between attenuation and refractive index in bone for different levels of mineralization follows a power law. Reconstruction was performed using the mixed approach but is compatible with other, more advanced models. We achieve more precise reconstructions than previously reported in literature. We believe that the proposed method will find application in biomedical imaging problems where the object is strongly heterogeneous, such as bone healing and biomaterials engineering.

15. **Light Scattering in Fibrous Media with Different Degrees of in-Plane Fiber Alignment**
Authors: Tomas Linder(1), Torbjörn Löfqvist(1), **Erik L. G. Wernersson**, Per Gren(2)
(1) EISLAB, Dept. of Computer Science, Electrical and Space Engineering, Luleå University of Technology, Luleå, Sweden
(2) Division of Fluid and Experimental Mechanics, Luleå University of Technology, Luleå, Sweden
Journal: Optics Express, Vol. 22, Issue 14, pages 16829-16840
Abstract: Fiber orientation is an important structural property in paper and other fibrous materials. In this study we explore the relation between light scattering and in-plane fiber orientation in paper sheets. Light diffusion from a focused light source is simulated using a Monte Carlo technique where parameters describing the paper micro-structure were determined from 3D x-ray computed tomography images. Measurements and simulations on both spatially resolved reflectance and transmittance light scattering patterns show an elliptical shape where the main axis is aligned towards the fiber orientation. Good qualitative agreement was found at low intensities and the results indicate that fiber orientation in thin fiber-based materials can be determined using spatially resolved reflectance or transmittance.

16. **Evaluation of Prostate Segmentation Algorithms for MRI: The PROMISE12 Challenge**
Authors: Geert Litjens(1), Robert Toth(2), Wendy van de Ven(1), Caroline Hoeks(1), Sjoerd Kerkstra(1), Bram van Ginneken(1), Graham Vincent(3), Gwenael Guillard(3), Neil Birbeck(4), Jindang Zhang(4), **Robin Strand, Filip Malmberg**, Yangming Ou(5), Christos Davatzikos(5), Matthias Kirschner(6), Florian Jung(6), Jing Yuan(7), Wu Qiu(7), Qinquan Gao(8), Philip Eddie Edwards(8), Bianca Maan(9), Ferdinand van der Heijden(9), Sumya Ghose(10,11,12), Jhimli Mitra(10,11,12), Jason Dowling(10), Dean Barratt(13), Henkjan Huisman(1), Anant Madabhushi(2)
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(8) Imperial College London, England, United Kingdom
(9) University of Twente, The Netherlands
(10) Commonwealth Scientific and Industrial Research Organisation, Australia
(11) Université de Bourgogne, France
(12) Universitat de Girona, Spain
(13) University College London, England, United Kingdom
Journal: Medical Image Analysis, Vol. 18, nr 2, pages 359-373
Abstract: Prostate MRI image segmentation has been an area of intense research due to the increased use of MRI as a modality for the clinical workup of prostate cancer. Segmentation is useful for various tasks, e.g. to accurately localize prostate boundaries for radiotherapy or to initialize multi-modal registration algorithms. In the past, it has been difficult for research groups to evaluate prostate segmentation algorithms on multi-center, multi-vendor and multi-protocol data. Especially because we are dealing with MR images, image appearance, resolution and the presence of artifacts are affected by differences in scanners and/or protocols, which in turn can have a large influence on algorithm accuracy. The Prostate MR Image Segmentation (PROMISE12) challenge was setup to allow a fair and meaningful comparison of segmentation methods on the basis of performance and robustness. In this work we will discuss the initial results of the online PROMISE12 challenge, and the results obtained in the live challenge workshop hosted by the MICCAI2012 conference. In the challenge, 100 prostate MR cases from 4 different centers were included, with differences in scanner manufacturer, field strength and protocol. A total of 11 teams from academic research groups and industry participated. Algorithms showed a wide variety in methods and implementation, including active appearance models, atlas registration and level sets. Evaluation was performed using boundary and volume based metrics which were combined into a single score relating the metrics to human expert performance. The winners of the challenge where the algorithms by teams Imorphics and ScrAutoProstate, with scores of 85.72 and 84.29 overall. Both algorithms where significantly better than all other algorithms in the challenge (Math Eq) and had an efficient implementation with a run time of 8 min and 3 s per case respectively. Overall, active appearance model based approaches seemed to outperform other approaches like multi-atlas registration, both on accuracy and computation time. Although average algorithm performance was good to excellent and the Imorphics algorithm outperformed the second observer on average, we showed that algorithm combination might lead to further improvement, indicating that optimal performance for prostate segmentation is not yet obtained. All results are available online at http://promise12.grand-challenge.org/.

17. **Detection of Façade Regions in Street View Images from Split-and-Merge of Perspective Patches**
Authors: **Fei Liu, Stefan Seipel**
Journal: Journal of Image and Graphics, Vol. 2, nr 1, pages 8-14
Abstract: Identification of building façades from digital images is one of the central problems in mobile augmented reality (MAR) applications in the built environment. Directly analyzing the whole image can increase the difficulty of façade identification due to the presence of image portions which are not façade. This paper presents an automatic approach to façade region detection given a single street view image as a pre-processing step to subsequent steps of façade identification. We devise a coarse façade region detection method based on the observation that façades are image regions with repetitive patterns containing a large amount of vertical and horizontal line segments. Firstly, scan lines are constructed from vanishing points

and center points of image line segments. Hue profiles along these lines are then analyzed and used to decompose the image into rectilinear patches with similar repetitive patterns. Finally, patches are merged into larger coherent regions and the main building façade region is chosen based on the occurrence of horizontal and vertical line segments within each of the merged regions. A validation of our method showed that on average façade regions are detected in conformity with manually segmented images as ground truth.

18. **An Efficient Algorithm for Exact Evaluation of Stochastic Watersheds**
Authors: **Filip Malmberg, Cris L. Luengo Hendriks**
Journal: Pattern Recognition Letters, Vol. 47, pages 80-84
Abstract: The stochastic watershed is a method for unsupervised image segmentation proposed by Angulo and Jeulin (2007). The method first computes a probability density function (PDF), assigning to each piece of contour in the image the probability to appear as a segmentation boundary in seeded watershed segmentation with randomly selected seeds. Contours that appear with high probability are assumed to be more important. This PDF is then post-processed to obtain a final segmentation. The main computational hurdle with the stochastic watershed method is the calculation of the PDF. In the original publication by Angulo and Jeulin, the PDF was estimated by Monte Carlo simulation, i.e., repeatedly selecting random markers and performing seeded watershed segmentation. Meyer and Stawiaski (2010) showed that the PDF can be calculated exactly, without performing any Monte Carlo simulations, but do not provide any implementation details. In a naive implementation, the computational cost of their method is too high to make it useful in practice. Here, we extend the work of Meyer and Stawiaski by presenting an efficient (quasi-linear) algorithm for exact computation of the PDF. We demonstrate that in practice, the proposed method is faster than any previously reported method by more than two orders of magnitude. The algorithm is formulated for general undirected graphs, and thus trivially generalizes to images with any number of dimensions.

19. **New Insights into the Mechanisms behind the Strengthening of Lignocellulosic Fibrous Networks with Polyamines**
Authors: Andrew Marais(1,5), Mikael S. Magnusson(2,5), Thomas Joffre(3), **Erik L. G. Wernersson**, Lars Wågberg(1,4,5)
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Journal: Cellulose 21, pages 3941-3950
Abstract: Polyelectrolytes have been used extensively in the papermaking industry for various purposes. Although recent studies have shown that polyamines can be efficient dry-strength additives, the mechanism governing the strength enhancement of paper materials following the adsorption of polyamines onto pulp fibres is still not well understood. In this study, the effect of the adsorption of polyallylamine hydrochloride (PAH) onto the surface of unbleached kraft pulp fibres was investigated on both the fibre and the network scale. Isolated fibre crosses were mechanically tested to evaluate the impact of the chemical additive on the interfibre joint strength on the microscopic scale and the effect was compared with that previously observed on the paper sheet scale. X-ray microtomography was used to understand structural changes in the fibrous network following the adsorption of a polyamine such as PAH. Using image analysis methods, it was possible to determine the number of interfibre contacts (or joints) per unit length of fibre as well as the average interfibre joint contact area. The results showed that the median interfibre joint strength increased by 18 $\%$ upon adsorption of PAH. This can be achieved both by a larger molecular contact area in the contact zones and by a stronger molecular adhesion. The addition of the polymer also increased the number of efficient interfibre contacts per sheet volume. This combination of effects is the reason why polyamines such as PAH can increase the dry tensile strength of paper materials.

20. **Automatic Mapping of Standing Dead Trees after an Insect Outbreak Using the Window Independent Context Segmentation Method**
Authors: Michael Nielsen(1), Marco Heurich(2), Bo Malmberg(1), **Anders Brun**
(1) Stockholm University
(2) Bavarian Forest National Park
Journal: Journal of Forestry, Vol. 112, nr 6, pages 564-571
Abstract: Since the 1980s, there has been an increase in the spruce bark beetle population in the Bavarian Forest National Park in southeastern Germany. There is a need for accurate and time-effective methods for monitoring the outbreak, because manual interpretation of image data is time-consuming and expensive. In this article, the window independent context segmentation method is used to map deadwood areas. The aim is to evaluate the method's ability to monitor deadwood areas on a yearly basis. Two-color infrared scenes with a spatial resolution of 40 x 40 cm from 2001 and 2008 were used for the study. The method was found to be effective with an overall accuracy of 88% for the 2001 scene and 90% for the 2008 scene.

21. **A Streaming Distance Transform Algorithm for Neighborhood-Sequence Distances**
Authors: Nicolas Normand(1), **Robin Strand**, Pierre Evenou(1), Aurore Arlicot(1)
(1) LUNAM Université, Université de Nantes, IRCCyN UMR CNRS 6597, France
Journal: Image Processing On Line, Vol. 4, pages 196-203
Abstract: We describe an algorithm that computes a "translated" 2D Neighborhood-Sequence Distance Transform (DT) using a look up table approach. It requires a single raster scan of the input image and produces one line of output for every line of input. The neighborhood sequence is specified either by providing one period of some integer periodic sequence or by providing the rate of appearance of neighborhoods. The full algorithm optionally derives the regular (centered) DT from the "translated" DT, providing the result image on the fly, with a minimal delay, before the input image is fully processed. Its efficiency can benefit all applications that use neighborhood-sequence distances, particularly when pipelined processing architectures are involved, or when the size of objects in the source image is limited.

22. **Spotting Words in Medieval Manuscripts**
Authors: **Fredrik Wahlberg**, Mats Dahllöf(1), Lasse Mårtensson(2), **Anders Brun**
(1) Dept. of Linguistics and Philology, UU
(2) University of Gävle, Sweden
Journal: Studia Neophilologica, Vol. 86, pages 171-186
Abstract: This article discusses the technology of handwritten text recognition (HTR) as a tool for the analysis of historical handwritten documents. We give a broad overview of this field of research, but the focus is on the use of a method called word spotting' for finding words directly and automatically in scanned images of manuscript pages. We illustrate and evaluate this method by applying it to a medieval manuscript. Word spotting uses digital image analysis to represent stretches of writing as sequences of numerical features. These are intended to capture the linguistically significant aspects of the visual shape of the writing. Two potential words can then be compared mathematically and their degree of similarity assigned a value. Our version of this method gives a false positive rate of about 30%, when the true positive rate is close to 100%, for an application where we search for very frequent short words in a 16th-Century Old Swedish cursiva recentior manuscript. Word spotting would be of use e.g. to researchers who want to explore the content of manuscripts when editions or other transcriptions are unavailable.

23. **Characterisations of Fibre Networks in Paper Using Micro Computed Tomography Images**
Authors: **Erik L. G. Wernersson**, Svetlana Borodulina(1), Artem Kulachenko(1), **Gunilla Borgefors**
(1) Dept. of Solid Mechanics, KTH Royal Institute of Technology, Stockholm, Sweden
Journal: Nordic Pulp and Paper Research Magazine, Vol. 29, No. 3, pages 468-475
Abstract: Although several methods exist for characterisation of the morphology of wood fibres, the application of these procedures for the analysis of paper microstructure has been limited due to their complexity or shortcomings. Here, a methodology for microstructure characterisation of individual fibres, as well as paper, is presented which is based on three dimensional computed tomography images of paper at micrometer resolution. The first step of the method consists of a graphical user interface (GUI), designed to minimize the amount of manual labour. To manually identify a fibre from a 2 x 2 mm^2 paper sheet takes about one minute with this GUI. Then several algorithms are available to analyse the image data automatically guided by the user input. With this approach it is possible to measure several characteristic properties without complete segmentation of the individual fibres. The methodology includes a method to calculate the contact

areas between fibres even in extreme cases of severely deformed fibres, which are naturally present in paper. Among the measurable properties are also estimators for the free fibre lengths and fibre wall thickness.
Comment: Journal front page illustration

24. **High- and Low-Throughput Scoring of Fat Mass and Body Fat Distribution in C. Elegans**
Authors: **Carolina Wählby(1,2)**, Annie Lee Conery(3), Mark-Anthony Bray(2), Lee Kamentsky(2), Jonah Larkins-Ford(3), Katherine L. Sokolnicki(2), Matthew Veneskey(2), Kerry Michaels(4), Anne E. Carpenter(2), Eyleen J. O'Rourke(4)
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(4) Dept. of Biology, University of Virginia, Charlottesville, VA, USA
Journal: Methods, Vol. 68, Issue 3, pages 492-499
Abstract: Fat accumulation is a complex phenotype affected by factors such as neuroendocrine signaling, feeding, activity, and reproductive output. Accordingly, the most informative screens for genes and compounds affecting fat accumulation would be those carried out in whole living animals. Caenorhabditis elegans is a well-established and effective model organism, especially for biological processes that involve organ systems and multicellular interactions, such as metabolism. Every cell in the transparent body of C. elegans is visible under a light microscope. Consequently, an accessible and reliable method to visualize worm lipid-droplet fat depots would make C. elegans the only metazoan in which genes affecting not only fat mass but also body fat distribution could be assessed at a genome-wide scale.

Here we present a radical improvement in oil red O worm staining together with high-throughput image-based phenotyping. The three-step sample preparation method is robust, formaldehyde-free, and inexpensive, and requires only 15 min of hands-on time to process a 96-well plate. Together with our free and user-friendly automated image analysis package, this method enables C. elegans sample preparation and phenotype scoring at a scale that is compatible with genome-wide screens. Thus we present a feasible approach to small-scale phenotyping and large-scale screening for genetic and/or chemical perturbations that lead to alterations in fat quantity and distribution in whole animals.

25. **Bone Canalicular Network Segmentation in 3D Nano-CT Images through Geodesic Voting and Image Tessellation**
Authors: Maria A Zuluaga(1,2,3), Maciej Orkisz(2), Pei Dong(2,3), **Alexandra Pacureanu(4)**, Pierre-Jean Gouttenoire(2,3), Françoise Peyrin(2,3)
(1) Centre for Medical Image Computing, University College London, UK
(2) CREATIS, Université de Lyon, France
(3) European Synchrotron Radiation Facility, Grenoble, France
(4) Science for Life Laboratory, UU
Journal: Physics in Medicine and Biology, Vol. 59, No. 9, pages 2155-2171
Abstract: Recent studies emphasized the role of the bone lacuno-canalicular network (LCN) in the understanding of bone diseases such as osteoporosis. However, suitable methods to investigate this structure are lacking. The aim of this paper is to introduce a methodology to segment the LCN from three-dimensional (3D) synchrotron radiation nano-CT images. Segmentation of such structures is challenging due to several factors such as limited contrast and signal-to-noise ratio, partial volume effects and huge number of data that needs to be processed, which restrains user interaction. We use an approach based on minimum-cost paths and geodesic voting, for which we propose a fully automatic initialization scheme based on a tessellation of the image domain. The centroids of pre-segmented lacunæ are used as Voronoi-tessellation seeds and as start-points of a fast-marching front propagation, whereas the end-points are distributed in the vicinity of each Voronoi-region boundary. This initialization scheme was devised to cope with complex biological structures involving cells interconnected by multiple thread-like, branching processes, while the seminal geodesic-voting method only copes with tree-like structures. Our method has been assessed quantitatively on phantom data and qualitatively on real datasets, demonstrating its feasibility. To the best of our knowledge, presented 3D renderings of lacunæ interconnected by their canaliculi were achieved for the first time.

26. **Evaluation of the Automatic methods for Building Extraction**
Authors: Julia Åhlén(1), **Stefan Seipel, Fei Liu**
(1) Dept. of Industrial Development, IT and Land Management, University of Gävle, Sweden
Journal: International Journal of Computers and Communications, Vol. 8, pages 171-176
Abstract: Recognition of buildings is not a trivial task, yet highly demanded in many applications including augmented reality for mobile phones. Recognition rate can be increased significantly if building façade extraction will take place prior to the recognition process. It is also a challenging task since each building can be viewed from different angles or under different lighting conditions. Natural situation outdoor is when buildings are occluded by trees, street signs and other objects. This interferes for successful building façade recognition. In this paper we evaluate the knowledge based approach to automatically segment out the whole building façade or major parts of the façade. This automatic building detection algorithm is then evaluated against other segmentation methods such as SIFT and vanishing point approach. This work contains two main steps: segmentation of building façades region using two different approaches and evaluation of the methods using database of reference features. Building recognition model (BRM) includes evaluation step that uses Chamfer metrics. BMR is then compared to vanishing points segmentation. In the evaluation mode, comparison of these two different segmentation methods is done using the data from ZuBuD. Reference matching is also done using Scale Invariant Feature Transform. The results show that the recognition rate is satisfactory for the BMR model and there is no need to extract the whole building façade for the successful recognition.

6.4 Refereed conference proceedings

Authors affiliated with CBA are in bold.

1. **Document Binarization Using Topological Clustering Guided Laplacian Energy Segmentation**
   Authors: **Kalyan Ram Ayyalasomayajula, Anders Brun**
   In Proceedings: International Conference on Frontiers in Handwriting Recognition (ICFHR)
   Abstract: The current approach for text binarization proposes a clustering algorithm as a preprocessing stage to an energy-based segmentation method. It uses a clustering algorithm to obtain a coarse estimate of the background (BG) and foreground (FG) pixels. These estimates are used as a prior for the source and sink points of a graph cut implementation,which is used to efficiently find the minimum energy solution of an objective function to separate the BG and FG. The binary image thus obtained is used to refine the edge map that guides the graph cut algorithm. A final binary image is obtained by once again performing the graph cut guided by the refined edges on a Laplacian of the image.

2. **An evaluation of potential functions for regularized image deblurring**
   Authors: Buda Bajić(1), Joakim Lindblad(1), **Nataša Sladoje**
   (1) Faculty of Technical Sciences, University of Novi Sad, Serbia
   In Proceedings: International Conference on Image Analysis and Recognition (ICIAR), Vilamoura, Portugal, Lecture Notes in Computer Science 8814, pages, 150-158
   Abstract: We explore utilization of seven different potential functions in restoration of images degraded by both noise and blur. Spectral Projected Gradient method confirms its excellent performance in terms of speed and flexibility for optimization of complex energy functions. Results obtained on images affected by different levels of Gaussian noise and different sizes of the Point Spread Functions, are presented. The Huber potential function demonstrates outstanding performance.

3. **Quantitative and Automated Microscopy - Where Do We Stand after 80 Years of Research?**
   Author: **Ewert Bengtsson**
   In Proceedings: IEEE 11th International Symposium on Biomedical Imaging (ISBI), pages 274-277
   Abstract: Visual information is essential in medicine; almost all cancer is diagnosed through visual examination of tissue samples. But while the human visual system is excellent at recognizing patterns it is poor at providing reproducible quantitative data. Many tasks also require inspection of many thousands of images. Computerized image analysis has been developed ever since the first computers became available to provide quantitative data and to automate tedious tasks. Still the impact on routine pathology is limited. In this paper the historical development of the field is briefly outlined and the reasons for the limited impact so far are analyzed and some predictions are made about the future.

4. **Picro-Sirius-HTX Stain for Blind Color Decomposition of Histopathological Prostate Tissue**
   Authors: **Ingrid Carlbom, Christophe Avenel**, Christer Busch(1)
   (1) Dept. of Immunology Genetics and Pathology, UU
   In Proceedings: IEEE 11th International Symposium on Biomedical Imaging (ISBI), pages 282-285
   Abstract: Gleason grading is the most widely used system for determining the severity of prostate cancer. The Gleason grade is determined visually under a microscope from prostate tissue that is most often stained with Hematoxylin-Eosin (H& E). In an earlier study we demonstrated that this stain is not ideal for machine learning applications, but that other stains, such as Sirius-hematoxylin (Sir-Htx), may perform better. In this paper we illustrate the advantages of this stain over H&E for blind color decomposition. When compared to ground truth defined by an experienced pathologist, the relative root-mean-square errors of the color decomposition mixing matrices for Sir-Htx are better than those for H&E by a factor of two, and the Pearson correlation coefficients of the density maps resulting from the decomposition of Sir-Htx-stained tissue gives a 99% correlation with the ground truth. Qualitative examples of the density maps confirm the quantitative findings and illustrate that the density maps will allow accurate segmentation of morphological features that determine the Gleason grade.

5. **Pixel Classification Using General Adaptive Neighborhood-Based Features**
   Authors: Víctor González-Castro(1), Johan Debayle(1), **Vladimir Ćurić**
   (1) École Nationale Supérieure des Mines de Saint-Étienne, France
   In Proceedings: 22nd International Conference on Pattern Recognition (ICPR), pages 3750-3755
   Abstract: This paper introduces a new descriptor for characterizing and classifying the pixels of texture images by means of General Adaptive Neighborhoods (GANs). The GAN of a pixel is a spatial region

surrounding it and fitting its local image structure. The features describing each pixel are then regionbased and intensity-based measurements of its corresponding GAN. In addition, these features are combined with the graylevel values of adaptive mathematical morphology operators using GANs as structuring elements. The classification of each pixel of images belonging to five different textures of the VisTex database has been carried out to test the performance of this descriptor. For the sake of comparison, other adaptive neighborhoods introduced in the literature have also been used to extract these features from: the Morphological Amoebas (MA), adaptive geodesic neighborhoods (AGN) and salience adaptive structuring elements (SASE). Experimental results show that the GAN-based method outperforms the others for the performed classification task, achieving an overall accuracy of 97.25% in the five-way classifications, and area under curve values close to 1 in all the five one class vs. all classes" binary classification problems.

6. **Robust and Invariant Phase Based Local Feature Matching**
   Author: **Anders Hast**
   In Proceedings: 22nd International Conference on Pattern Recognition (ICPR), pages 809-814
   Abstract: Any feature matching algorithm needs to be robust, producing few false positives but also needs to be invariant to changes in rotation, illumination and scale. Several improvements are proposed to a previously published Phase Correlation based algorithm, which operates on local disc areas, using the Log Polar Transform to sample the disc neighborhood and the FFT to obtain the phase. It will be shown that the matching can be done in the frequency domain directly, using the Chi-squared distance, instead of computing the cross power spectrum. Moreover, it will be shown how combining these methods yields an algorithm that sorts out a majority of the false positives. The need for a peak to sub lobe ratio computation in order to cope with sub pixel accuracy will be discussed as well as how the FFT of the periodic component can enhance the matching. The result is a robust local feature matcher that is able to cope with rotational, illumination and scale differences to a certain degree.

7. **Towards Automatic Stereo Pair Extraction for 3D Visualisation of Historical Aerial Photographs**
   Author: **Anders Hast**
   In Proceedings: International Conference on 3D Imaging (IC3D), 8 pages
   Abstract: An efficient and almost automatic method for stereo pair extraction of aerial photos is proposed. There are several challenging problems that needs to be taken into consideration when creating stereo pairs from historical aerial photos. These problems are discussed and solutions are proposed in order to obtain an almost automatic procedure with as little input as possible needed from the user. The result is a rectified and illumination corrected stereo pair. It will be discussed why viewing aerial photos in stereo is important since the depth cue gives more information than single photos do.

8. **Invariant Interest Point Detection Based on Variations of the Spinor Tensor**
   Authors: **Anders Hast**, Andrea Marchetti(1)
   (1) Consiglio Nazionale delle Ricerche, Institute of Informatics and Telematics, Pisa, Italy
   In Proceedings: 22nd International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision (WSCG), Communication papers proceedings, pages 49-56
   Abstract: Image features are obtained by using some kind of interest point detector, which often is based on a symmetric matrix such as the structure tensor or the Hessian matrix. These features need to be invariant to rotation and to some degree also to scaling in order to be useful for feature matching in applications such as image registration. Recently, the spinor tensor has been proposed for edge detection. It was investigated herein how it also can be used for feature matching and it will be proven that some simplifications, leading to variations of the response function based on the tensor, will improve its characteristics. The result is a set of different approaches that will be compared to the well known methods using the Hessian and the structure tensor. Most importantly the invariance when it comes to rotation and scaling will be compared.

9. **An Evaluation of the Faster STORM Method for Super-resolution Microscopy**
   Authors: **Omer Ishaq(1)**, Johan Elf(1,2), **Carolina Wählby(1,3)**
   (1) Science for Life Laboratory, SciLifeLab, UU
   (2) Dept. of Cell and Molecular Biology, UU
   (3) Imaging Platform, Broad Institute of Harvard and MIT, Cambridge, MA, USA
   In Proceedings: 22nd International Conference on Pattern Recognition, Stockholm, Sweden, pages 4435-4440
   Abstract: Development of new stochastic super-resolution methods together with fluorescence microscopy

imaging enables visualization of biological processes at increasing spatial and temporal resolution. Quantitative evaluation of such imaging experiments call for computational analysis methods that localize the signals with high precision and recall. Furthermore, it is desirable that the methods are fast and possible to parallelize so that the ever increasing amounts of collected data can be handled in an efficient way. We here in address signal detection in super-resolution microscopy by approaches based on compressed sensing. We describe how a previously published approach can be parallelized, reducing processing time at least four times. We also evaluate the effect of a greedy optimization approach on signal recovery at high noise and molecule density. Furthermore, our evaluation reveals how previously published compressed sensing algorithms have a performance that degrades to that of a random signal detector at high molecule density. Finally, we show the approximation of the imaging system's point spread function affects recall and precision of signal detection, illustrating the importance of parameter optimization. We evaluate the methods on synthetic data with varying signal to noise ratio and increasing molecular density, and visualize performance on real super-resolution microscopy data from a time-lapse sequence of living cells.

10. **Geovisualization of Uncertainty in Simulated Flood Maps**
Authors: Nancy Joy Lim(1), **Stefan Seipel**
(1) University of Gävle, Sweden
In Proceedings: IADIS conference in Computer Graphics, Visualization, Computer Vision and Image Processing (CGCVIP), pages 206-214
Abstract: The paper presents a three-dimensional (3D) geovisualisation model of uncertainties in simulated flood maps that can help communicate uncertain information in the data being used. An entropy-based measure was employed for uncertainty quantification. In developing the model, Visualisation Toolkit (VTK) was utilised. Different data derived from earlier simulation study and other maps were represented in the model. Cartographic principles were considered in the map design. A Graphical User Interface (GUI), which was developed in Tkinter, was also created to further support exploratory data analysis. The resulting model allowed visual identification of uncertain areas, as well as displaying spatial relationship between the entropy and the slope values. This geovisualisation has still to be tested to assess its effectiveness as a communication tool. However, this type of uncertainty visualisation in flood mapping is an initial step that can lead to its adoption in decision-making when presented comprehensively to its users. Thus, further improvement and development is still suggested for this kind of information presentation.

11. **Optimizing Optics and Imaging for Pattern Recognition Based Screening Tasks**
Authors: Joakim Lindblad(1), **Nataša Sladoje(1), Patrik Malm, Ewert Bengtsson**, Ramin Moshavegh(2), Andrew Mehnert(2)
(1) Faculty of Technical Sciences, University of Novi Sad, Serbia
(2) Dept. of Signals and Systems, Chalmers University of Technology, Gothenburg, Sweden
In Proceedings: 22nd International Conference on Pattern Recognition (ICPR), Stockholm, Sweden, pages 3333-3338
Abstract: We present a method for simulating lower quality images starting from higher quality ones, based on acquired image pairs from different optical setups. The method does not require estimates of point (or line) spread functions of the system, but utilizes the relative transfer function derived from images of real specimen of interest in the observed application. Thanks to the use of a larger number of real specimen, excellent stability and robustness of the method is achieved. The intended use is exploring the influence of image quality on features and classification accuracy in pattern recognition based screening tasks. Visual evaluation of the obtained images strongly confirms usefulness of the method. The approach is quantitatively evaluated by observing stability of feature values, proven useful for PAP-smear classification, between synthetic and real images from seven different microscope setups. The evaluation shows that features from the synthetically generated lower resolution images are as similar to features from real images at that resolution, as features from two different images of the same specimen, taken at the same low resolution, are to each other.

12. **Anti-Aliased Euclidean Distance Transform on 3D Sampling Lattices**
Authors: **Elisabeth Linnér, Robin Strand**
In Proceedings: 18th IAPR International Conference on Discrete Geometry for Computer Imagery (DGCI), Siena, Italy, Lecture Notes in Computer Science 8668, pages 88-98
Abstract: The Euclidean distance transform (EDT) is used in many essential operations in image processing, such as basic morphology, level sets, registration and path finding. The anti-aliased Euclidean distance

transform (AAEDT), previously presented for two-dimensional images, uses the gray-level information in, for example, area sampled images to calculate distances with sub-pixel precision. Here, we extend the studies of AAEDT to three dimensions, and to the Body-Centered Cubic (BCC) and Face-Centered Cubic (FCC) lattices, which are, in many respects, considered the optimal three-dimensional sampling lattices. We compare different ways of converting gray-level information to distance values, and find that the lesser directional dependencies of optimal sampling lattices lead to better approximations of the true Euclidean distance.

13. **A Graph-Based Implementation of the Anti-Aliased Euclidean Distance Transform**
Authors: **Elisabeth Linnér, Robin Strand**
In Proceedings: 22nd International Conference on Pattern Recognition (ICPR), Stockholm, Sweden, pages 1025-1030
Abstract: With this paper, we present an algorithm for the anti-aliased Euclidean distance transform, based on wave front propagation, that can easily be extended to images of arbitrary dimensionality and sampling lattices. We investigate the behavior and weaknesses of the algorithm, applied to synthetic two-dimensional area-sampled images, and suggest an enhancement to the original method, with complexity proportional to the number of edge elements, that may reduce the amount and relative magnitude of the errors in the transformed image by as much as a factor of 10.

14. **Exact Evaluation of Stochastic Watersheds : From Trees to General Graphs**
Authors: **Filip Malmberg, Bettina Selig, Cris L. Luengo Hendriks**
In Proceedings: 18th IAPR International Conference on Discrete Geometry for Computer Imagery (DGCI), Siena, Italy, Lecture Notes in Computer Science 8668, pages 309-319
Abstract: The stochastic watershed is a method for identifying salient contours in an image, with applications to image segmentation. The method computes a probability density function (PDF), assigning to each piece of contour in the image the probability to appear as a segmentation boundary in seeded watershed segmentation with randomly selected seedpoints. Contours that appear with high probability are assumed to be more important. This paper concerns an efficient method for computing the stochastic watershed PDF exactly, without performing any actual seeded watershed computations. A method for exact evaluation of stochastic watersheds was proposed by Meyer and Stawiaski (2010). Their method does not operate directly on the image, but on a compact tree representation where each edge in the tree corresponds to a watershed partition of the image elements. The output of the exact evaluation algorithm is thus a PDF defined over the edges of the tree. While the compact tree representation is useful in its own right, it is in many cases desirable to convert the results from this abstract representation back to the image, e.g, for further processing. Here, we present an efficient linear time algorithm for performing this conversion.

15. **A Structural Texture Approach for Characterising Malignancy Associated Changes in Pap Smears Based on Mean-Shift and the Watershed Transform**
Authors: Andrew Mehnert(1), Ramin Moshavegh(1), K. Sujathan(1), **Patrik Malm, Ewert Bengtsson**
(1) Dept. of Signals and Systems, Chalmers University of Technology, Gothenburg, Sweden
In Proceedings: 22nd International Conference on Pattern Recognition (ICPR), Stockholm, Sweden pages 1189-1193
Abstract: This paper presents a novel structural approach to quantitatively characterising nuclear chromatin texture in light microscope images of Pap smears. The approach is based on segmenting the chromatin into blob-like primitives and characterising their properties and arrangement. The segmentation approach makes use of multiple focal planes. It comprises two basic steps: (i) mean-shift filtering in the feature space formed by concatenating pixel spatial coordinates and intensity values centred around the best all-in-focus plane, and (ii) hierarchical marker-based watershed segmentation. The paper also presents an empirical evaluation of the approach based on the classification of 43 routine clinical Pap smears. Two variants of the approach were compared to a reference approach (employing extended depth-of-field rather than mean-shift) in a feature selection/classification experiment, involving 138 segmentation-based features, for discriminating normal and abnormal slides. The results demonstrate improved performance over the reference approach. The results of a second feature selection/classification experiment, including additional classes of features from the literature, show that a combination of the proposed structural and conventional features yields a classification performance of 0.919 ± 0.015 (AUC $\pm$ Std. Dev.). Overall the results demonstrate the efficacy of the proposed structural approach and confirm that it is indeed possible to detect malignancy associated changes (MACs) in conventional Papanicolaou stain.

16. **Virus Recognition Based on Local Texture**
Authors: **Ida-Maria Sintorn(1), Gustaf Kylberg**
(1) Vironova AB, Stockholm, Sweden
In Proceedings: 22nd International Conference on Pattern Recognition (ICPR), Stockholm Sweden, pages 3227-3232
Abstract: To detect and identify viruses in electron microscopy images is crucial in certain clinical emergency situations. It is currently a highly manual task, requiring an expert sitting at the microscope to perform the analysis visually. Here we focus on and investigate one aspect towards automating the virus diagnostic task, namely recognizing the virus type based on their texture once possible virus objects have been segmented. We show that by using only local texture descriptors we achieve a classification rate of almost 89% on texture patches from 15 different virus types and a debris (false object) class. We compare and combine 5 different types of local texture descriptors and show that by combining the different types a lower classification error is achieved. We use a Random Forest Classifier and compare two approaches for feature selection.

17. **The Minimum Barrier Distance - Stability to Seed Point Position**
Authors: **Robin Strand, Filip Malmberg**, Punam Saha(1), **Elisabeth Linnér**
(1) University of Iowa, USA
In Proceedings: 18th IAPR International Conference on Discrete Geometry for Computer Imagery (DGCI), Siena, Italy, Lecture Notes in Computer Science, vol 8668, pages 111-121
Abstract: Distance and path-cost functions have been used for image segmentation at various forms, e.g., region growing or live-wire boundary tracing using interactive user input. Different approaches are associated with different fundamental advantages as well as difficulties. In this paper, we investigate the stability of segmentation with respect to perturbations in seed point position for a recently introduced pseudo-distance method referred to as the minimum barrier distance. Conditions are sought for which segmentation results are invariant with respect to the position of seed points and a proof of their correctness is presented. A notion of $\hat{I}'$-interface is introduced defining the object-background interface at various gradations and its relation to stability of segmentation is examined. Finally, experimental results are presented examining different aspects of stability of segmentation results to seed point position.

18. **Scribal Attribution using a Novel 3-D Quill-Curvature Feature Histogram**
Authors: **Fredrik Wahlberg, Anders Brun**, Lasse Mårtensson(1)
(1)University of Gävle, Sweden
In Proceedings: International Conference on Frontiers in Handwriting Recognition (ICFHR),Crete, Greece
Abstract: In this paper, we propose a novel pipeline for automated scribal attribution based on the Quill feature: 1) We compensate the Quill feature histogram for pen changes and page warping. 2) We add curvature as a third dimension in the feature histogram, to better separate characteristics like loops and lines. 3) We also investigate the use of several dissimilarity measures between the feature histograms. 4) We propose and evaluate semi-supervised learning for classification, to reduce the need of labeled samples.Our evaluation is performed on 1104 pages from a 15th century Swedish manuscript. It was chosen because it represents a significant part of Swedish manuscripts of said period.Our results show that only a few percent of the material need labelling for average precisions above 95%. Our novel curvature and registration extensions, together with semi-supervised learning, outperformed the current Quill feature.

19. **Knowledge Based Single Building Extraction and Recognition**
Authors: Julia Åhlén(1), **Stefan Seipel**
(1) Dept. of Industrial Development, IT and Land Management, University of Gävle, Sweden
In Proceedings: WSEAS International Conference on Computer Engineering and Applications, pages 29-35
Abstract: Building façade extraction is the primary step in the recognition process in outdoor scenes. It is also a challenging task since each building can be viewed from different angles or under different lighting conditions. In outdoor imagery, regions, such as sky, trees, pavement cause interference for a successful building façade recognition.In this paper we propose a knowledge based approach to automatically segment out the whole façade or major parts of the façade from outdoor scene. The found building regions are then subjected to recognition process. The system is composed of two modules: segmentation of building façades region module and façade recognition module.In the façade segmentation module, color processing and objects position coordinates are used. In the façade recognition module, Chamfer metrics are applied.

In real time recognition scenario, the image with a building is first analyzed in order to extract the façade region, which is then compared to a database with feature descriptors in order to find a match. The results show that the recognition rate is dependent on a precision of building extraction part, which in turn, depends on a homogeneity of colors of façades.

20. **Time-Space Visualisation of Amur River Channel Changes Due to Flooding Disaster**
Authors: Julia Åhlén(1), **Stefan Seipel**
(1) Dept. of Industrial Development, IT and Land Management, University of Gävle, Sweden
In Proceedings: International Multidisciplinary Scientific GeoScience Conference (SGEM)
Abstract: The analysis of flooding levels is a highly complex temporal and spatial assessment task that involves estimation of distances between references in geographical space as well as estimations of instances along the time-line that coincide with given spatial locations. This work has an aim to interactively explore changes of Amur River boundaries caused by the severe flooding in September 2013. In our analysis of river bank changes we use satellite imagery (Landsat 7) to extract parts belonging to Amur River. We use imagery from that covers time interval July 2003 until February 2014. Image data is pre-processed using low level image processing techniques prior to visualization. Pre-processing has a purpose to extract information about the boundaries of the river, and to transform it into a vectorized format, suitable as inputs subsequent visualization. We develop visualization tools to explore the spatial and temporal relationship in the change of river banks. In particular the visualization shall allow for exploring specific geographic locations and their proximity to the river/floods at arbitrary times. We propose a time space visualization that emanates from edge detection, morphological operations and boundary statistics on Landsat 2D imagery in order to extract the borders of Amur River. For the visualization we use the time-spacecube metaphor. It is based on a 3D rectilinear context, where the 2D geographical coordinate system is extended with a time-axis pointing along the 3rd Cartesian axis. Such visualization facilitates analysis of the channel shape of Amur River and thus enabling for a conclusion regarding the defined problem. As a result we demonstrate our time-space visualization for river Amur and using some amount of geographical point data as a reference we suggest an adequate method of interpolation or imputation that can be employed to estimate value at a given location and time.

6.5 Non-refereed conferences and workshops

Authors affiliated with CBA are in bold.

1. **How to Promote Student Creativity and Learning using Tutorials in Teaching Graphics and Visualisation**
   Author: Anders Hast
   In Proceedings: 16th International Conference on Geometry and Graphics (ICGG), Innsbruck University Press, pages 626-633

2. **An Interactive Tool for Deformable Registration of Volume Images**
   Authors: **Filip Malmberg, Robin Strand**, Richard Nordenskjöld(1), Joel Kullberg(1)
   (1) Dept. of Radiology, UU
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Luleå, Sweden, (SSBA)

3. **Feature Space De-Noising for Text Recognition**
   Authors: **Fredrik Wahlberg, Anders Brun**
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Luleå, Sweden, (SSBA)

4. **Orbital Morphology in Crouzon-Pfeiffer and Apert Syndromes before and after Surgical Correction: Study by 3D Cephalometry, Semi-Automatic Segmentation and 3D Shape Comparison**
   Authors: Roman Khonsari(1), **Johan Nysjö**, Benjamin Way(2), Tharsika Karunakaran(2), **Ingela Nyström**, Guillaume Odri(3), David Dunaway(2), R. Ewans(2), Raphael Olszewski(4), Jonathan Britto(2)
   (1) CHU Pitié-Salpê triére, Paris, France
   (2) Great Ormond Street Hospital, London, United-Kingdom
   (3) University of Nantes, Nantes, France
   (4) University of Leuven, Brussels, Belgium
   In Proceedings: Computer Assisted Radiology and Surgery (CARS), Fukuoka, Japan, pages 192-193
   Comment: Extended abstract review

5. **Custom Mandibular Implant Design with Deformable Models and Haptics**
   Authors: **Fredrik Nysjö, Pontus Olsson**, Jan-Michaél Hirsch(1), **Ingrid B. Carlbom**
   (1) Dept. of Surgical Sciences, Oral & Maxillofacial Surgery, UU
   In Proceedings: Computer Assisted Radiology and Surgery (CARS), Fukuoka, Japan, pages 246-247
   Comment: Extended abstract review

6. **The Giga-pixel Challenge: Full Resolution Image Analysis – Without Losing the Big Picture : An Open-Source Approach for Multi-Scale Analysis and Visualization of Slide-Scanner Data**
   Authors: **Petter Ranefall(1), Alexandra Pacureanu(1), Christophe Avenel**, Anne E. Carpenter(2), **Carolina Wählby**(1,2)
   (1) Science for Life Laboratory, SciLifeLab, UU
   (2) Imaging Platform, Broad Institute of Harvard and MIT, Cambridge, MA, USA
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Luleå, Sweden

7. **MiniTEM - a Desk-Top TEM for Fast and Easy Image Acquisition and Analysis**
   Authors: **Ida-Maria Sintorn(1), Gustaf Kylberg**, Lars Haag(1), Rickard Nordström(1), Mats Uppström(1), Jan Fulin(1), Johan Åkesson(1), Kristoffer Danielsson(1), Michal Drštička(2), Eva Coufalová(2)
   (1) Vironova AB, Stockholm, Sweden
   (2) Delong Instruments, Brno, Czech Republic
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Luleå, Sweden

8. **MiniTEM – Making Ultra-Structural Pathology Easier and Accessible**
   Authors: **Ida-Maria Sintorn(1), Gustaf Kylberg**, Lars Haag(1), Rickard Nordström(1), Martin Ryner(1), Anca Dragomir(2), Kjell Hultenby(3), Eva Coufalová(4), Michal Drštička(4)
   (1) Vironova AB, Stockholm, Sweden
   (2) Dept. of Immunology, Genetics and Pathology, UU
   (3) Karolinska Institutet, Huddinge, Stockholm
   (4) Delong Instruments, Brno, Czech Republic
   In Proceedings: Nordic Symposium on Digital Pathology, Linköping, Sweden

9. **Low Voltage Mini TEM**
   Authors: Eva Coufalová(1), Martin Mynář(1), Michal Drštička(1), Petr Štěpán(1), **Ida-Maria Sintorn(2)**
   (1) Delong Instruments, Brno, Czech Republic
   (2) Vironova AB, Stochkolm, Sweden
   In Proceedings: 18th International Microscopy Congress, Prague, Czech Republic
   Comment: Abstract review

10. **Automated Multi-Scale Image Acquisition for Efficient Particle Detection and Analysis Using the Mini-TEM**
    Authors: **Ida-Maria Sintorn(1), Gustaf Kylberg(1)**, Rickard Nordström(1), Petr Štěpán(2), Vladimir Kolařík(2), Eva Coufalová(2), Michal Drštička(2)
    (1) Vironova AB, Stockholm, Sweden
    (2) Delong Instruments, Brno, Czech Republic
    In Proceedings: 18th International Microscopy Congress, Prague, Czech Republic
    Comment: Abstract review

11. **The Mini-TEM: High Quality Imaging and Analysis of Biological Specimen**
    Authors: **Ida-Maria Sintorn(1), Gustaf Kylberg(1)**, Rickard Nordström(1), Mats Uppström(1), Jan Fulin(1), Johan Åkesson(1), Kristoffer Danielsson(1), Petr Štěpán(2), Vladimir Kolařík(2), Michal Drštička(2), Eva Coufalová(2)
    (1) Vironova AB, Stockholm, Sweden
    (2) Delong Instruments, Brno, Czech Republic
    In Proceedings: 18th International Microscopy Congress, Prague, Czech Republic
    Comment: Abstract review

12. **A Desk-Top Low Voltage TEM for High Quality Imaging of Biological Specimen**
    Authors: **Ida-Maria Sintorn(1), Gustaf Kylberg(1)**, Martin Ryner, Rickard Nordström(1), Mats Uppström(1), Jan Fulin(1), Petr Štěpán(2), Vladimir Kolařík(2), Michal Drštička(2), Eva Coufalová(2)
    (1) Vironova AB, Stockholm, Sweden
    (2) Delong Instruments, Brno, Czech Republic
    In Proceedings: XV International Conference on Electron Microscopy, Cracow, Poland
    Comment: Abstract review

13. **Understanding phase contrast artefacts in micro computed absorption tomography**
    Authors: **Erik L. G. Wernersson**, M.N. Boone(1), J. Vand den Bulcke(1), L. Van Hoorebeke(1), **Cris L. Luengo Hendriks**
    (1) Ghent University
    In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Luleå, Sweden, (SSBA)

6.6 Other publications

Authors affiliated with CBA are in bold. See also Section 3.2 for Master theses finished during 2014.

1. **CBA Annual Report 2013**
   Editors: **Gunilla Borgefors**, **Omer Ishaq**, **Filip Malmberg**, **Lena Nordström**, **Ingela Nyström**, **Ida-Maria Sintorn**, **Robin Strand**
   Publisher: Centre for Image Analysis, 101 pages

2. **Short descriptions of International Conferences and Journals on Information Technology**
   Editors: **Gunilla Borgefors**
   Publisher: Centre for Image Analysis, Internal Report No. 53, 44 pages

7 Activities

In addition to research and teaching, as documented elsewhere in this annual report, our time is taken up with many other things. In this section, we list the most important of those. The biggest effort, that involved most of us, was the joint organisation of the 22nd International Conference of Pattern Recognition in Stockholm, together with Linköping and Lund Universities. We also organised a number of smaller meetings, locally or in conjunction with larger international conferences.

Seminars are a necessary and enjoyable part of scientific work. We have a lively seminar series with, usually two seminars every Monday afternoon. Most are held by ourselves, but we often also have guest speakers. This year, there were 36 seminars at CBA. We ourselves are also often invited to give seminars at other places.

Attending international and national conferences is important for presenting our work, and even more so for getting new ideas and forming new partnerships. This year, we gave nine oral and six poster presentations. The poster presentations are often the more valuable for getting new contacts. Our scientists were special invited speakers at eight different conferences. There were also 21 presentations at non-reviewed conferences and some of us ”just” participated.

We have very many visitors and often visit other groups ourselves, but we here only record those of a longer duration. Two of our scientists visited France for co-operation in mathematical morphology and our hand-written text recognition group had a two-month visitor from Spain.

Finally, we list a plethora of miscellaneous engagements in professional organisations, conferences, scientific journals, university committees and reviewing everything from conference papers to docent applications. In Figure 26, we show the logos of the scientific organisations where we have a role – the larger the logo the more people involved. The highlights of this year is that Ingela Nyström became President of the International Association of Pattern Recognition, with member societies from 47 countries and that Ewert Bengtsson join Gunilla Borgefors as Fellow of IEEE.

7.1 ICPR 2014

An activity which should specifically be mentioned is the organization of the 22nd International Conference on Pattern Recognition (ICPR 2014). The ICPR conference is the main event of the International Asociation of Pattern recognition (IAPR, `http://www.iapr.org/`).

ICPR 2014 was held on August 24–28, 2014, at the Stockholm Waterfront Congress Centre in Stockholm, Sweden. Despite its long history — the series started in 1973 — this was the first time the conference was held in Sweden. ICPR 2014 was hosted by the Swedish Society for Automated Image Analysis (SSBA) and supported by Linköping University, Lund University, and Uppsala University. A majority of the CBA staff were active in roles from positions of responsibility such as Finance Chair, Local Arrangements Chair and Invited Speakers Chair to many volunteers. It was concluded that ICPR 2014 was a successful event with as many as 1215 participants from 58 countries attending.

Scientifically, ICPR 2014 had five tracks:

- Computer Vision
- Pattern Recognition and Machine Learning
- Image, Speech, Signal and Video Processing
- Document Analysis, Biometrics and Pattern Recognition Applications
- Biomedical Image Analysis

For each track, there was an Invited Speaker and all together there was approximately 200 oral presentations and 600 poster presentations. The accepted papers presented at the conference are published by IEEE Explore in the ICPR 2014 proceedings.

For more information, see program and other details at `http://www.icpr2014.org/`.

Organizing committee

General Chair: Professor Magnus Borga, Linköping University
Program Chair: Professor Anders Heyden, Lund University
Program Co-Chair: Professor Denis Laurendeau, Université Laval, Canada

Local Arrangements Chair: Professor Ingela Nyström, Uppsala University
Local Arrangements Co-Chair: Professor Aysin Baytan Ertuzun, Boğaziçi University, Turkey
Finance Chair: Professor Ewert Bengtsson, Uppsala University
Invited Speakers Chair: Professor Gunilla Borgefors, Uppsala University
International Liaison Chair: Professor Kim Boyer, Rensselaer Polytechnic Institute, USA
Workshops, Tutorials and Contests Co-Chairs: Assoc. Professor Cris Luengo, Uppsala University; Dr. Ola Friman, SICK IVP
Publicity Chair: Assoc. Professor Hedvig Kjellström, KTH Royal Institute of Technology
Sponsor and Exhibitions Chair: Dr. Anders Åström, Combitech AB
Publications Chair: Professor Michael Felsberg, Linköping University
Poster Session Chair: PhD student Elisabeth Linnér, Uppsala University
Awards Chair: Assoc. Professor Robin Strand, Uppsala University
Webmaster: PhD student Johan Nysjö, Uppsala University
Official Photographer: PhD student Kristína Lidayová, Uppsala University
Volunteers from CBA: Christophe Avenel, Anders Brun, Vladimir Ćurić, Azadeh Fahkrzadeh, Filip Malmberg, Damian Matuszewski, Kalyan Ram, Petter Ranefall, Sajith Sadanandan Kecheril, Fredrik Wahlberg, and Tomas Wilkinson

7.2 Organized conferences and workshops

1. **Principles of Evolution**
   Organisers: Gunilla Borgefors
   Address: EBC, UU
   Date: 20140214
   Comment: Organized by the Celsius-Linné committee the day after the Celsius-Linné lectures. Borgefors is its Chair. See `http://www.teknat.uu.se/research/celsius-linne/`.

2. **Session, "Haptics and its Applications", in conjunction with SciFest 2014**
   Organisers: Pontus Olsson, Fredrik Nysjö, and Ingrid Carlbom
   Address: Fyrishov, Uppsala
   Date: 20140228–20140301
   Comment: Olsson, Nysjö and Carlbom ran a booth showing haptics and its applications.

3. **Session, "Advances in Computer-Aided Histopathology", in conjunction with ISBI 2014**
   Organisers: Carolina Wählby, Alexandra Pacureanu and Ingrid Carlbom
   Address: Renaissance Beijing Capital Hotel in Beijing, China
   Date: 20140429–20140502
   Comment: Wählby, Pacureanu and Carlbom organized a special session on Advances in Computer-Aided Histopathology. Ewert Bengtsson was one of the invited speakers.

4. **Tutorial, "Digital Geometry, Topology and Applications" in conjunction with ICPR**
   Organisers: Gunilla Borgefors, Robin Strand
   Address: Waterfront Congress Center, Stockholm
   Date: 20140824
   Comment: The tutorial was organized by Gunilla Borgefors, Robin Strand, Punam Saha and Gabriella Sanniti di Baja.

5. **3rd eSSENCE Academy**
   Organisers: Ingela Nyström, eSSENCE
   Address: Umeå University
   Date: 20141015–20141016
   Comment: 90 researchers within the e-Science community gathered for this workshop to present, discuss, and find synergies among researchers from Lund University, Umeå University, and Uppsala University.

7.3 Seminars held outside CBA

1. **Ewert Bengtsson**
   Date: 20140129
   Address: UU Hospital
   Title: Medical engineering in Uppsala
   Comment: Meeting to form the network ”Uppsala Forum för Medicinsk Teknik”

2. **Ewert Bengtsson**
   Date: 20140129
   Address: Blå Korset, UU Hospital
   Title: Uppsala Forum för Medicinsk Teknik (UFMT)

3. **Anders Hast**
   Date: 20140425
   Title: Swedish e-Science Education
   Comment: Fifth Annual SeRC Meeting on April 24–25

4. **Christer Kiselman**
   Date: 20140314
   Address: Sabancı University, Istanbul, Turkey
   Title: Lineal Convexity

5. **Ingela Nyström**
   Date: 20140507
   Address: Rudbeck laboratory, Uppsala
   Title: The Council for Research Infrastructures (RFI) –a decision-taking body within the Swedish Research Council (VR)
   Comment: Swedish Bioimaging 5th National Meeting.

6. **Olof Lindahl**
   Date: 20140508
   Title: UFMT - Uppsala Forum on Medical Engineering
   Comment: A second seminar for the newly formed UFMT, Olof was one of the invited speakers, Bengtsson was co-chair of the event

7. **Elisabeth Linnér**
   Date: 20140514
   Address: Ångström laboratory
   Title: ForskarFika
   Comment: Seminar arranged by the students of the Master of Science in Engineering Physics program, to familiarize themselves with researchers and research at an early stage in their education.

8. **Cris Luengo**
   Date: 20140603
   Address: Division of Wood Science and Engineering, Luleå University of Technology, Skellefteå
   Title: Image analysis with mathematical morphology
   Comment: Invited seminar in conjunction with a Licentiate defence

9. **Vladimir Ćurić**
   Date: 20140610
   Address: University of Rennes, France
   Title: Distance functions and adaptive mathematical morphology

10. **Cris Luengo**
    Date: 20140624
    Address: Institute for Research in IT and Random Systems (IRISA), University of Bretagne Sud, Vannes, France
    Title: Image-based measurement with mathematical morphology

11. **Filip Malmberg**
    Date: 20140820
    Address: Elekta AB, Uppsala
    Title: Image Processing using Graphs

12. **Petter Ranefall**
    Date: 20140911
    Address: BMC, Uppsala
    Title: Quantitative Microscopy
    Comment: A delegation from the Eurasian National University in Kazakhstan visited BMC.

13. **Anders Hast**
    Date: 20141016
    Title: Swedish e-Science Education
    Comment: eSSENCE Academy in Umeå on October 15-16

14. **Gunilla Borgefors**
    Date: 20141113
    Address: Linköping University
    Title: Choosing colours for scientific presentations based on human colour perception – 10 simple rules

15. **Ewert Bengtsson**
    Date: 20141125
    Address: University of Karlstad
    Title: Research data storage system planned for UU
    Comment: Part of a meeting of Swedish university IT directors

7.4 Seminars at CBA

1. **Gunilla Borgefors**
   Date: 20140113
   Title: Choosing colours for scientific data presentation

2. **Alexandra Pacureanu**
   Date: 20140120
   Title: Analyzing gene expression in preserved tissue and imaging in 3D semi-transparent biological samples on a low budget

3. **Petter Ranefall**
   Date: 20140127
   Title: Experiences from working in the industry

4. **Patrik Malm**
   Date: 20140203
   Title: Rehearsal before the public defense of the thesis

5. **Calum MacAuley**
   Date: 20140206
   Title: Biomedical Optics for the Detection of Early Cancers
   Comment: Calum MacAuley is with the Integrative Oncology Department, University of British Columbia.

6. **Gustaf Kylberg**
   Date: 20140317
   Title: Automatic Virus Identification using TEM - Image Segmentation and Texture Analysis

7. **Walter Kropatsch**
   Date: 20140320
   Title: Presentation of the Pattern Recognition and Image Processing (PRIP) Group.
   Comment: Walter Kropatsch is with the Institute of Computer Graphics and Algorithms, Vienna University of Technology.

8. **Ingrid Carlbom**
   Date: 20140324
   Title: Picro-Sirius-HTX stain for blind color decomposition of histopathological prostate tissue

9. **Kalyan Ram Ayyalasomayajula**
   Date: 20140331
   Title: Document binarization using topological clustering guided Laplacian Energy Segmentation

10. **Azadeh Fakhrzadeh**
    Date: 20140407
    Title: Studying Arabidopsis cell structures using image analysis techniques

11. **Anant Madabhushi**
    Date: 20140410
    Title: Computational pathology: Squeezing the most out of digitized histopathology
    Comment: Madabhushi is with the Dept. of Biomedical Engineering, Case Western Reserve University.

12. **Anders Brun**
    Date: 20140414
    Title: From quill to bytes, datamining collections of historical documents

13. **Fredrik Nysjö**
    Date: 20140505
    Title: Custom Mandibular Implant Design with Deformable Models and Haptics

14. **Vladimir Ćurić**
    Date: 20140512
    Title: Distance Functions and Their Use in Adaptive Mathematical Morphology

15. **Ida-Maria Sintorn**
    Date: 20140519
    Title: MiniTEM - for fast and easy TEM imaging and analysis

16. **Richard Szeliski**
    Date: 20140528
    Title: Reflections on Image-Based Modeling and Rendering
    Comment: Richard Szeliski is with the Interactive Visual Media Group, Microsoft Research.

17. **Stefan Seipel**
    Date: 20140602
    Title: Not quite perfect spherical triangles and what they are good for

18. **Thu Tran**
    Date: 20140602
    Title: An interactive interface for multiple-resolution analysis of large images
    Comment: Master Thesis presentation.

19. **Erik Wernersson**
    Date: 20140609
    Title: Local orientation in images

20. **Elisabeth Linnér**
    Date: 20140616
    Title: Anti-Aliased Euclidean Distance Transform on 3D Sampling Lattices

21. **Several speakers**
    Date: 20140818
    Title: ICPR poster and oral presentation rehearsal

22. **Fredrik Nysjö and Anders Hast**
    Date: 20140901
    Title: Our new 2D and 3D projector

23. **Fillipe Dias Moreira de Souza**
Date: 20140902
Title: Pattern Theory-Based Interpretation of Activities
Comment: Fillipe Dias Moreira de Souza is with the Computer Vision & Pattern Recognition Group, Computer Science and Engineering, University of South Florida.

24. **Omer Ishaq**
Date: 20140908
Title: Ground-truth annotation for real data sets

25. **Pontus Olsson**
Date: 20140915
Title: A Novel Virtual Planning of Bone, Soft tissue and Vessels in Fibula Osteocutaneous Free Flap with the Uppsala Haptics-Assisted Surgery Planning (HASP) System

26. **Cris Luengo**
Date: 20140922
Title: Path Openings

27. **Carolina Wählby**
Date: 20140929
Title: An open-source platform for integration, automated analysis, and interactive visualization of tissue image data: TissueMaps

28. **Tomas Wilkinson**
Date: 20141006
Title: Visualizing Document Images using Image-based Word Clouds

29. **Marco Loog**
Date: 20141021
Title: Scale Selection for Supervised Image Segmentation
Comment: Marco Loog is with the Pattern Recognition Laboratory, Delft University of Technology.

30. **Bettina Selig**
Date: 20141027
Title: The Evolution of the Stochastic Watershed

31. **Lennart Thurfjell**
Date: 20141103
Title: Decision support in neurodegenerative diseases
Comment: Lennart Thurfjell is CEO at Combinostics.

32. **Ginevra Castellano**
Date: 20141110
Title: Socially intelligent robots: closing the loop in human-robot interaction

33. **Willy Wriggers**
Date: 20141125
Title: From Atoms to Living Organisms: Emergent Complexity of Multiscale Computational Modeling
Comment: Frank Batten Professor of Mechanical and Aerospace Engineering Program in Biomedical Engineering Old Dominion University, Norfolk, Virginia, USA.

34. **Erik Wernersson**
Date: 20141126
Title: Rehearsal before the public defense of the PhD thesis

35. **Christophe Avenel**
Date: 20141208
Title: Uppsala Automatic Prostate Malignancy Grading System: An Overview

36. **Alicia Fornés**
Date: 20141215
Title: Recognition of the Historical Marriage License Books of the Cathedral of Barcelona
Comment: Alicia Fornés spent a two-month period with us during Fall 2014

7.5 Conference participation

7.5.1 Special invited speaker

1. *Conference:* Swedish Natural History Museum Digitization Symposium
   Anders Brun
   Date: 20140109
   Address: Stockholm
   Title: Challenges and advances in OCR and handwriting recognition

2. *Conference:* IEEE International Symposium on Biomedical Imaging (ISBI 2014)
   Ewert Bengtsson
   Date: 20140428–20140502
   Address: Renaissance Beijing, Capital Hotel, Beijing, China
   Title: Quantitative and Automated Microscopy – Where Do We Stand after 80 Years of Research?

3. *Conference:* Symposium for Lars-Olof Sundelöf
   Christer Kiselman
   Date: 20140604
   Address: Ångström Laboratory
   Title: Mathematical spaces ("Matematiska rum")
   Comment: The talk will be published in a proceedings volume honoring Lars-Olof Sundelöf

4. *Conference:* Constructive Approximation of Functions
   Christer Kiselman
   Date: 20140630–20140705
   Address: Bedlewo, Poland
   Title: Weak Lineal Convexity

5. *Conference:* IMC
   Carolina Wählby
   Date: 20140907–20140910
   Address: International Microscopy Congress (IMC) in Prague, Czech Republic.
   Title: Quantitaive microscopy – extracing relevant information from biomedical image data

6. *Conference:* SBI2
   Carolina Wählby
   Date: 20140911–20140912
   Address: Society of Biomolecular Imaging and Informatics SBI2, at the JB Martin Conference Center at Harvard Medical School, Boston, MA, USA.
   Title: Combining image-based in situ RNA screening with quantitative analysis of cell and tissue morphology
   Comment: Carolina Wählby was honored with the 'SBI2 President's innovation award' for her presentation.

7. *Conference:* Bringing Maths To Life – BMTL
   Carolina Wählby
   Date: 20141027–20141029
   Address: Naples, Italy
   Title: Image processing and analysis in microscopy and life science

8. *Conference:* 2nd High Throughput Cell Biology: from screening to applications
   Carolina Wählby
   Date: 20141117–20141118
   Address: Institut Curie - Research Centre, Paris, France.
   Title: Characterizing solid tumors by image-based high throughput screening of cancer stem cells

7.5.2 Oral presentations – refereed conferences

1. *Conference:* ISBI 2014
   Ingrid Carlbom
   Date: 20140428–20140502
   Address: Beijing, China
   Title: Picro-Sirius-HTX Stain for Blind Color Decomposition of Histopathological Prostate Tissue
   Comment: Carlbom also organized a special session on "Advances in Computer-Aided Histopathology"

2. *Conference:* Swedish Bioimaging Annual Meeting
   Carolina Wählby
   Date: 20140507
   Address: Rudbeck Laboratory and SciLifeLab Navet, UU
   Title: The Centre for Image Analysis
   Comment: Wählby organized the meeting together with Lena Claesson-Welsh. Several other members of CBA attended the meeting.

3. *Conference:* WSCG
   Anders Hast
   Date: 20140602–20140605
   Address: Plzen, Czech Republic
   Title: Invariant Interest Point Detection Based on Variations of the Spinor Tensor

4. *Conference:* Computer Assisted Radiology and Surgery
   Fredrik Nysjö
   Date: 20140625–20140628
   Address: Fukuoka, Japan
   Title: Custom Mandibular Implant Design with Deformable Models and Haptics

5. *Conference:* International Conference on Geometry and Graphics (ICGG)
   Anders Hast
   Date: 20140805–20140808
   Address: Innsbruck, Austria
   Title: How to Promote Student Creativity and Learning using Tutorials in Teaching Graphics and Visualisation

6. *Conference:* 22nd International Conference on Pattern Recognition
   Omer Ishaq
   Date: 20140824–20140828
   Address: Stockholm
   Title: An Evaluation of the Faster STORM Method for Super-resolution Microscopy

7. *Conference:* 18th IAPR International Conference on Discrete Geometry for Computer Imagery (DGCI)
   Elisabeth Linnér
   Date: 20140910–20140912
   Address: Siena, Italy
   Title: Anti-Aliased Euclidean Distance Transform on 3D Sampling Lattices

8. *Conference:* 18th IAPR International Conference on Discrete Geometry for Computer Imagery (DGCI)
   Filip Malmberg
   Date: 20140910–20140912
   Address: Siena, Italy
   Title: Exact Evaluation of Stochastic Watersheds: From Trees to General Graphs

9. *Conference:* International Conference on Image Analysis and Recognition (ICIAR 2014)
   Nataša Sladoje
   Date: 20141022–20141024
   Address: Vilamoura, Algarve, Portugal
   Title: An evaluation of potential functions for regularized image deblurring
   Comment: Buda Bajic, PhD student and co-author of the paper, gave this oral presentation

7.5.3 Poster presentations – refereed conferences

1. *Conference:* 22nd International Conference on Pattern Recognition (ICPR)
   Elisabeth Linnér
   Date: 20140824–20140828
   Address: Stockholm
   Title: A Graph-Based Implementation of the Anti-Aliased Euclidean Distance Transform

2. *Conference:* 22nd International Conference on Pattern Recognition (ICPR)
   Anders Hast
   Date: 20140825–20140828
   Address: Stockholm
   Title: Robust and Invariant Phase Based Local Feature Matching

3. *Conference:* International Conference on Frontiers in Handwriting Recognition
   Kalyan Ram
   Date: 20140901–20140904
   Address: Creete, Greece
   Title: Document binarization using topological clustering guided Laplacian Energy Segmentation

4. *Conference:* International Conference on Frontiers in Handwriting Recognition
   Fredrik Wahlberg
   Date: 20140901–20140904
   Address: Creete, Greece
   Title: Scribal Attribution using a Novel 3-D Quill-Curvature Feature Histogram

5. *Conference:* 18th IAPR International Conference Discrete Geometry for Computer Imagery (DGCI)
   Robin Strand
   Date: 20140910–20140912
   Address: Siena, Italy
   Title: The Minimum Barrier Distance – Stability to seed point position

6. *Conference:* 8th International BioImage Informatics Meeting
   Sajith Sadanandan Kecheril
   Date: 20141008–20141010
   Address: Provinciehuis, Leuven, Belgium
   Title: Segmentation and tracking of E.coli bacteria in phase contrast microscopy images

7.5.4 Oral presentations – non-refereed conferences

1. *Conference:* Swedish Symposium on Image Analysis (SSBA 2014)
   Anders Hast
   Date: 20140310–20140312
   Address: Luleå University of Technology
   Title: A Feature Detector based on the Structure Tensor with a Scale Space Dimension

2. *Conference:* Swedish Symposium on Image Analysis (SSBA 2014)
   Kristína Lidayová
   Date: 20140310–20140312
   Address: Luleå University of Technology
   Title: Fast Vessel Centerline Tree Extraction Algorithm

3. *Conference:* Swedish Symposium on Image Analysis (SSBA 2014)
   Sajith Sadanandan Kecheril
   Date: 20140310–20140312
   Address: Luleå University of Technology
   Title: Segmentation of E.coli bacteria in brightfield microscopy images

4. *Conference:* Swedish Symposium on Image Analysis (SSBA 2014)
   Petter Ranefall
   Date: 20140311–20140312
   Address: Luleå University of Technology
   Title: The Giga-pixel Challenge: Full Resolution Image Analysis – Without Losing the Big Picture

5. *Conference:* Swedish Symposium on Image Analysis (SSBA 2014)
   Anders Hast
   Date: 20140311–20140312
   Address: Luleå University of Technology
   Title: A Feature Detector based on the Structure Tensor with a Scale Space Dimension

6. *Conference:* Swedish Symposium on Image Analysis (SSBA 2014)
   Filip Malmberg
   Date: 20140311–20140312
   Address: Luleå University of Technology
   Title: An Interactive Tool for Deformable Registration of Volume Images

7. *Conference:* Swedish Symposium on Image Analysis (SSBA 2014)
   Johan Nysjö
   Date: 20140311–20140312
   Address: Luleå University of Technology
   Title: Analyzing orbital size and shape before and after surgical correction

8. *Conference:* Swedish Symposium on Image Analysis (SSBA 2014)
   Ida-Maria Sintorn
   Date: 20140311–20140312
   Address: Luleå University of Technology
   Title: miniTEM - a desk-top TEM for fast and easy image acquisition and analysis

9. *Conference:* Swedish Symposium on Image Analysis (SSBA 2014)
   Fredrik Wahlberg
   Date: 20140311–20140312
   Address: Luleå University of Technology
   Title: Feature space de-noising for text recognition

10. *Conference:* Analysis Day in Memory of Mikael Passare
    Christer Kiselman
    Date: 20140924
    Address: Stockholm University

Title: Discrete convolution operators, the Fourier transformation, and its tropical counterpart: the Fenchel transformation

7.5.5 Poster presentations – non-refereed conferences

1. *Conference:* Veterinary Sciences' Faculty Research Day
   Cris Luengo
   Date: 20140129
   Address: SLU Ultuna
   Title: A sampling of bio-medical projects at the Centre for Image Analysis

2. *Conference:* Swedish Bioimaging Meeting
   Ida-Maria Sintorn
   Date: 20140507
   Address: Rudbeck laboratory, UU
   Title: miniTEM- fast and easy TEM imaging and analysis

3. *Conference:* 8th International BioImage Informatics Meeting
   Damian Matuszewski
   Date: 20141008–20141010
   Address: Leuven, Belgium
   Title: Investigating phenotypic differences and drug response among glioblastoma stem cell cultures

4. *Conference:* 8th International BioImage Informatics Meeting
   Petter Ranefall
   Date: 20141008–20141010
   Address: Leuven, Belgium
   Title: Full Resolution Image Analysis – Without losing the Big Picture

5. *Conference:* SciLife Day October 2014
   Omer Ishaq
   Date: 20141010
   Address: Uppsala
   Title: Quantification of Zebrafish Tail Deformation

6. *Conference:* Medicinteknikdagarna (Medical Enigneering Days)
   Kristína Lidayová
   Date: 20141014–20141016
   Address: Svenska Mässan, Göteborg
   Title: Fast Vessel Centerline Tree Extraction Algorithm

7. *Conference:* eSSENCE
   Petter Ranefall
   Date: 20141015–20141016
   Address: Umeå University
   Title: Large-Scale Analysis of Cells and Tissue

8. *Conference:* 10th IEEE International Conference on e-Science
   Damian Matuszewski
   Date: 20141020–20141024
   Address: Guarujá, Sao Paulo, Brazil
   Title: Investigating phenotypic differences and drug response among glioblastoma stem cell cultures

9. *Conference:* Nordic Symposium on Digital Pathology
   Petter Ranefall
   Date: 20141105–20141106
   Address: Linköping
   Title: Comb. image-based in situ RNA sequencing with quantitative analysis of cell and tissue morphology

10. *Conference:* Nordic Symposium on Digital Pathology
    Anders Hast
    Date: 20141105–20141106
    Address: Linköping
    Title: Multi-instance learning as a useful tool in grading histopathological tissues

11. *Conference:* Frontiers in Cell migration
Sajith Sadanandan Kecheril
Date: 20141212
Address: ScilifeLab, UU
Title: Segmentation and tracking of E.coli bacteria in phase contrast microscopy images

7.5.6 Attended conferences

1. *Conference:*Swedish Symposium on Image Analysis (SSBA 2014)
   Christophe Avenel, Anders Brun, Ewert Bengtsson, Omer Ishaq, Elisabeth Linnér, Robin Strand, Gunilla Borgefors, Carolina Wählby, Cris Luengo, Ingela Nyström, Kalyan Ram, Fredrik Wahlberg, Tomas Wilkinson
   Date: 20140310–20140312
   Address: Luleå University of Technology

2. *Conference:* EU COST-Action TD 1201: Colour and Space in Cultural Heritage (COSH)
   Anders Brun
   Date: 20140331–20140402
   Address: University of Eastern Finland, Joensuu

3. *Conference:* Multispectral tissue imaging & intelligent analysis
   Petter Ranefall
   Date: 20140402
   Address: Fluorescence Tissue Profiling Facility at SciLifeLab

4. *Conference:* SciLife Day April 2014
   Omer Ishaq, Petter Ranefall
   Date: 20140410
   Address: Solna

5. *Conference:* Big data and e-Science in Medical Science
   Petter Ranefall
   Date: 20140423
   Address: Ehrling-Persson hall, Aula Medica, Karolinska Institutet

6. *Conference:* Phenotypic based drug discovery industry saviour or wasteful distraction
   Petter Ranefall
   Date: 20140429
   Address: Apotekarsocieteten, Wallingatan 26A, Stockholm

7. *Conference:* Swedish Bioimaging 5th National Meeting
   Ewert Bengtsson, Omer Ishaq, Cris Luengo, Petter Ranefall, Sajith Sadanandan, Robin Strand
   Date: 20140507
   Address: Rudbecksalen, IGP and Navet, SciLifeLab, Uppsala

8. *Conference:* 23rd Annual Meeting of the International Society for Magnetic Resonance in Medicine (ISMRM) 2014
   Robin Strand
   Date: 20140510–20140516
   Address: Milano, Italy

9. *Conference:* SBI - Swedish Bioimaging strategic seminar day
   Ewert Bengtsson
   Date: 20140519
   Address: Svenska Läkaresällskapet, Stockholm
   Comment: A whole day seminar to discuss future strategy for Swedish Bioimaging with several invited speakers. Bengtsson participated as a member of the board. The seminar was chaired by Örjan Smedby.

10. *Conference:* Sundelöf symposium
    Gunilla Borgefors
    Date: 20140604
    Address: Ångström Laboratory, UU
    Comment: Organized by Royal Society of Sciences in Uppsala to celebrate Sundelöf's 31 years as its secretary.

11. *Conference:* Mathematics in Emerging Nations: Achievements and Opportunities (MENAO)
    Christer Kiselman

Date: 20140812
Address: Seoul, South Korea

12. *Conference:* International Congress of Mathematicians (ICM)
Christer Kiselman
Date: 20140813–20140821
Address: Seoul, South Korea

13. *Conference:* 22nd International Conference on Pattern Recognition (ICPR 2014)
Christophe Avenel,Anders Brun, Filip Malmberg, Damian Matuszewski, Kristína Lidayová, Elisabeth Linnér, Cris Luengo, Carolina Wählby, Robin Strand, Gunilla Borgefors, Kalyan Ram, Fredrik Wahlberg,Tomas Wilkinson
Date: 20140824–20140828
Address: Stockholm

14. *Conference:* International Conference on Frontiers in Handwriting Recognition
Anders Brun, Tomas Wilkinson
Date: 20140901–20140904
Address: Creete, Greece

15. *Conference:* Discrete Geometry for Computer Imagery (DGCI)
Gunilla Borgefors, Christer Kiselman
Date: 20140910–20140912
Address: Siena, Italy
Comment: Borgefors participated in the Steering Committee Meeting

16. *Conference:* 8th International BioImage Informatics Meeting
Petter Ranefall, Sajith Sadanandan and Damian Matuszewski
Date: 20141008–20141010
Address: Leuven, Belgium

17. *Conference:* SciLifeLab Day
Carolina Wählby and Ida-Maria Sintorn
Date: 20141010
Address: The Main University Building, UU

18. *Conference:* Medicinteknikdagarna (Medical Engineering Days)
Ewert Bengtsson
Date: 20141014–20141016
Address: Gothenburg Congress Centre
Comment: Served on program committee and was organizer and session chair/co-chair for two sessions

19. *Conference:* 10th IEEE International Conference on e-Science
Ingela Nyström
Date: 20141020–20141024
Address: Guaruja, Sao Paulo, Brazil
Comment: Nyström was chairing the session ”Cyberinfrastructure”.

20. *Conference:* SSF The Foundation for Strategic Research 20 year celebration
Ewert Bengtsson
Date: 20141029–20141029
Address: Museum of modern art, Stockholm
Comment: Presentations on research funding strategies historically and today. SSF was the most important financing body in the development of CBA in the 90-ies.

21. *Conference:* Nordic symposium on Digital Pathology
Ewert Bengtsson
Date: 20141105–20141106
Address: Linköping Conference Centre

22. *Conference:* CIM Workshop on Mathematics and Medicine
Cris Luengo, Nataša Sladoje, Filip Malmberg, Gunilla Borgefors, Ingela Nyström, Robin Strand
Date: 20141106–20141107
Address: ITC, UU

23. *Conference:* IT Dept. research strategy day
Ewert Bengtsson, Anders Brun, Ingela Nyström, Robin Strand
Date: 20141117–20141117
Address: Blåsenhus UU
Comment: Bengtsson was responsible for the organisation of this full day event and chaired half the day. Nyström and Brun were responsible for the brain storming on quality of PhD education.

24. *Conference:* Prostate Cancer Research Meeting
Ingrid Carlbom
Date: 20141124–20141125
Address: The Royal Palace of Rosersberg Conference Hotel, Stockholm
Comment: Christophe Avenel gave a talk on our Prostate Malignancy Grading research

25. *Conference:* AIMday Imaging
Carolina Wählby
Date: 20141216–20141216

7.6 Visiting scientists

1. **Alicia Fornés**
Address: Computer Center Vision, University of Barcelona, (Cerdanyola) Barcelona, Spain
Host: Anders Brun
Date: 20141101–20141221 (2 months)
Topic: Handwritten Text Recognition

7.7 Visits to other research groups

1. **Vladimir Ćurić**
Host: Sébastien Lefèvre
Address: University of South Brittany, Vannes, France
Date: 20140601–20140630 (1 month)
Topic: Mathematical morphology and applications

2. **Cris Luengo**
Host: Sébastien Lefèvre
Address: Institute for Research in IT and Random Systems (IRISA), University of Bretagne Sud, Vannes, France
Date: 20140617–20140626 (10 days)
Topic: Mathematical morphology and applications
Comments: Visit financed by the Frö programme of the French Embassy in Stockholm.

7.8 Committees

Figure 26: Societies in which CBA staff are involved.

Ewert Bengtsson
International:

- Senior lifetime member of the Institute of Electrical and Electronics Engineers (IEEE), 2004–
  Comment: Member since 1974. Elevated to Lifetime Fellow as per 20150101.
- Member of the International Society for Optical Engineering (SPIE), 2004–
- Member of the International Society for Analytical Cytology (ISAC), 2000–
- Associate Editor of *Computer Methods and Programs in Biomedicine,* 2012–2014
  Comment: Published by Elsevier. Bengtsson was Editorial Board member 1995–2011.
- Editorial Board member of *Machine Graphics & Vision,* 1994–
  Comment: Published by the Polish Academy of Sciences.
- Management Committee, EU COST Action TD1201: "Colour and Space in Cultural Heritage, COSCH" 2013–
  Comment: Bengtsson is responsible for coordinating the Swedish participation.
- Finance Chair of ICPR 2014, International Conference on Pattern Recognition, Stockholm, August 2014
- Expert evaluator for proposals to the Italian Ministry of Education, Industry and Research, Office V

National:

- Member of the Royal Swedish Academy of Engineering Sciences (IVA), 2006–
  Comment: Division VII: Basic and Interdisciplinary Engineering Sciences.
- Member of the Royal Society of Sciences in Uppsala (Kungliga Vetenskaps-Societeten), 1998–
  Comment: Elected member of the oldest scientific society in Sweden (founded 1710).

- Coordinating group of Medtech4Health, 2012–2014
  Comment: Medtech4Health is a national Swedish initiative to build a Strategic Innovation Area in medical engineering. And to apply for Vinnova Funding. The application was turned down in June 2014.
- Board of Swedish Bioimaging, 2012–
  Comment: A Swedish network for researchers in biomedical imaging and image analysis.
- Scientific board of Swedish Association for Medical Engineering and Physics, "Svensk förening för medicinsk teknik och fysik" 2013–
- Program Committee, Swedish Medical Engineering Days, "Medicinteknikdagarna", Gothenburg, 2014.
- Scientific board of Hillevi Fries Research Scholarship Foundation, 2006–
  Comment: A Swedish foundation that accepts applications and gives out research grants for urology research.
- Board of UpGIS, the network for Geographical Information Systems at UU, 1999–
- UU Library Council member, 2011–
- Chair of UU committee to propose a new strategy for handling long term storage of scientific data, 2013–2014
- Chair of a joint committee by the Faculty of Science and Technology and the Faculties of Medicine and Pharmacy to develop a strategic plan for medical engineering research and education at UU. 201409–201501
- Representative of UU IT on the ICT committee of Uppsala Municipality, 2013–2014
- Expert advisor to the head of the Information Technology Unit of UU administration, 2013–
- Board of the Dept. of Information Technology, UU, 2012–
- Head of Research ("forskningsprefekt") at the Dept. of Information Technology, UU, 2013–
- Head of the research program "Image analysis and man-machine interaction," Dept. of Information Technology, UU, 1996–2014
- PhD education responsible professor for "Computerized Image Processing", 1996–2014
- Licentiate Thesis, Matilda Landgren, Opponent, 20140131
- Expert for evaluating chair in medical engineering for Linköping University
- Expert evaluator of Dr Rodrigo Morenos application to become docent at Linköping university

Gunilla Borgefors
International:

- Fellow of the International Association for Pattern Recognition (IAPR), 1998–
  Comment: 1st Vice President 1994–96, Secretary 1990–94, etc., etc.
- Fellow of the Institute of Electrical and Electronics Engineers, Inc. (IEEE), 2007–
  Comment: Member since 1997. Senior member 1998.
- Editor-in-Chief of *Pattern Recognition Letters,* 2011–
  Comment: Published by Elsevier. PRL is an official journal of the International Association of Pattern Recognition. Borgefors was Associate Editor/Area Editor 2004–2010.
- 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 Russian Academy of Sciences.
- Editorial Board of the book series Computational Imaging and Vision, 2003–
  Comment: Published by Springer.
- Steering committee for Discrete Geometry for Computer Imagery (DGCI) conferences, 2000–

- Steering committee for International Symposium on Mathematical Morphology (ISMM), 2011–
- Programme Committee, International Conference on Computer Vision and Graphics (ICCVG 2014), Warsaw, Poland, 20140915–17
- Dissertation committee of Darryl McClymont, School of Information Technology and Electrical Engineering, University of Queensland, Brisbane, Australia, 20140901–20141016
  Comment: Title: Computer assisted detection and characterisation of breast cancer in MRI

National:

- Member of the Royal Swedish Academy of Engineering Sciences (IVA), 2011–
  Comment: Division VII: Basic and Interdisciplinary Engineering Sciences.
- Member No. 19 of the Royal Society of Sciences in Uppsala (Kungliga Vetenskaps–Societeten), 2000–
  Comment: Elected member of 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.
- Board/Steering Committee for Onsala Space Observatory, 2011–
- Chair of the Celsius-Linné committee, TN-faculty, UU, 2013–
  Comment: The committee selects the speakers for the annual Celsius and Linné lectures and organizes the following one-day Symposium. Member since 2007.
- Advisory Board for CBA 2012–2014
  Comment: One of two representatives for SLU.
- Member of the Docent committee of the Faculty of Science and Technology, UU, 2014–
- Scientic expert committee for the Vinnova project DTC (Detection–Taget Tracking–Classification) at SSAB Dynamics and Linköping University, running 2014-16 and headed by our alumni Tomas Brandtberg.
- Expert evaluator for the application of Andrew Mehnert to become associate professor (docent) at Chalmers, Göteborg, 20140401–20140512
- Expert evaluator for an Associate Professor (lektor) in Image reproduction at Dept. of Science and Technology, Linköping University, Campus Norrköping, 20140601–20140707
- Dissertation committee of Patrik Boberg, Luleå Technical University, Luleå, 20140612
  Comment: Title: Imaging and Analysis Methods for Automated Weld Inspection
- Dissertation committee of Jimmy Azar, Dept. of Information Technology, UU, 20141020
  Comment: Title: Automated Tissue Image Analysis Using Pattern Recognition

Anders Brun
International:

- Management Committee member, COSCH, Colour & Space in Cultural Heritage, EU COST Action TD 1201.

National:

- Board member, SSBA, 2014–
  Comment: Elected at SSBA yearly meeting

Ingrid Carlbom
International:

- Member of the Institute of Electrical and Electronics Engineers (IEEE), 1987–
- Member of Association for Computing Machinery (ACM), 1971–
- Member of ACM Special Interest Group on Computer Graphics and Interactive Techniques (SIGGRAPH), 1976–
- Member of SIGMA XI, The Scientific Research Society, 1979–

- Programme Committee, IEEE International Symposium on Biomedical Imaging (ISBI), 2014, 20140429–20140502
- Session organizer: ”Advances in Computer-Aided Histopathology” at IEEE International Symposium on Biomedical Imaging (ISBI’14) held in Beijing, China, 20140428-20140502

Anders Hast
National:

- Dissertation Committee of Andreas Kårsnäs, 20140412
  Comment: PhD Thesis title: ”Image Analysis Methods and Tools for Digital Histopathology Applications Relevant to Breast Cancer Diagnosis”

Christer Kiselman
International:

- Program Committe for Discrete Geometry for Computer Imagery (DGCI 2014), 20140101–20140912
- Reference Group of the International Science Programme, 20140811
  Comment: Meeting in Seoul, South Korea
- Evaluation of research at LIRIS, Lyon, 20140901–20150108
  Comment: LIRIS is the acronym of Laboratoire d’InfoRmatique en Image et Systèmes d’information. Appointed by l’Agence d’évaluation de la recherche et de l’enseignement supérieur (AERES) (from 20141114 Haut Conseil d’évaluation de la recherche et de l’enseigment supérieur (HCERES)).

National:

- Dissertation Committee of Vladimir Ćurić, Dept. of Information Technology, UU, 20140523
  Comment: Thesis title: Distance Functions and Their Use in Adaptive Mathematical Morphology

Kristína Lidayová, Elisabeth Linnér, Johan Nysjö, Pontus Olsson and Tomas Wilkinson

- Editors, SSBAktuellt, the newsletter of the Swedish Society for Automated Image Analysis

Kristína Lidayová
International:

- Programme Committee, 1st International Conference on Bioimaging, BIOIMAGING 2014, Eseo, Angers, Loire Valley, France, 20140303–20140306

Cris Luengo
International:

- Senior member of the Institute of Electrical and Electronics Engineers (IEEE) 2010–
  Comment: Member since 2001.
- Member of the International Society for Analytical Cytology (ISAC), 2006–
- Area Editor for Pattern Recognition Letters 2013–
  Comment: Published by Elsevier. PRL is an official journal of the International Association of Pattern Recognition. Luengo was Associate Editor 2011–2012.
- Steering Committee, International Symposium on Mathematical Morphology, 2013–.
- Organizing Committee; Workshops, Tutorials and Contests Co-Chair; and Programme Committee, 22nd International Conference on Pattern Recognition, Stockholm, August 2014.
- Programme Committee, 22nd International Conference on Intelligent Systems for Molecular Biology, Boston, MA, 20140711–15.

National:

- Advisory Board for CBA 2012–
  Comment: One of two representatives for SLU.

- Search Committee for a junior faculty member in Machine Learning for the Dept. of Information Technology, UU, 2014–2015
- Opponent for licentiate defence of Tobias Pahlberg, Division of Wood Science and Engineering, Luleå University of Technology, Skellefteå, 20140214
  Comment: Title: Wood Fingerprints: Recognition of Sawn Wood Products. Supervisor: Olle Hagman.
- Dissertation committee of Janne West, Division of Radiological Sciences, Linköping University, 20140214
  Comment: Title: Quantitative Magnetic Resonance Imaging of the Brain: Applications for Tissue Segmentation and Multiple Sclerosis. Supervisor: Örjan Smedby.
- Dissertation committee of Richard Nordenskjöld, Dept. of Radiology, Oncology and Radiation Science, UU, 2014-06-10
  Comment: Title: Analysis of Human Brain MRI: Contributions to Regional Volume Studies. Supervisor: Joel Kullberg.
- Dissertation Committee of Susanne Bornelöv, 20141003
  Comment: Supervisor: Jan Komorowski
  Title: Rule-based models of transcriptional regulation and complex diseases
  Dept. of Cell and Molecular Biology, Computational and Systems Biology, UU
- Dissertation Committee of Scott Holcombe, 20141216
  Comment: Supervisor: Staffan Jacobsson Svärd
  Title: Gamma spectroscopy and gamma emission tomography for fuel performance characterization of irradiated nuclear fuel assemblies
  Dept. of Physics and Astronomy, Applied Nuclear Physics, UU

Ingela Nyström
International:

- President of the Executive Committee of International Association for Pattern Recognition (IAPR) 2014–
  Comment: 2nd Vice President 2008–2010, Secretary 2010–2014
- Local Arrangements Chair of the 22nd International Conference on Pattern Recognition (ICPR 2014), Stockholm, Sweden, August 2014
- Program Committee, 10th IEEE International Conference on e-Science, Sao Paulo, Brazil, October 2014

National:

- Member of the Royal Society of Arts and Sciences of Uppsala (Kungliga Vetenskapssamhället i Uppsala), 2012–
- Member of the Board of the Faculty of Science and Technology, UU, 2011–2014
- Member of the Docent committee of the Faculty of Science and Technology, UU, 2011–2014
- Member of a joint committee by the Faculty of Science and Technology and the Faculties of Medicine and Pharmacy to develop a strategic plan for medical engineering research and education at UU. 201409–201501
- Chair of the Advisory Board for the Centre for Image Analysis 2012–
  Comment: One of two representatives for UU.
- Member of the Council for Research Infrastructure (RFI), the Swedish Research Council, 2014–
- Evaluation Panel for grant applications to the Swedish Research Council: Infrastructures for e-Science ("Beredningsgrupp 4"), 2011—
- Expert evaluator for the application of Claes Lundström to become Associate Professor (Docent) at Linköping University, 20140301–20140407
- Dissertation committee of Khoa Tan Nguyen, Dept. of Science and Technology, Linköping University, Norrköping, 20140307
  Comment: Title: Supporting Quantitative Visual Analysis in Medicine and Biology in the Presence of Data Uncertainty

Alexandra Pacureanu
International:

- Programme Committee, IEEE International Symposium on Biomedical Imaging (ISBI), 2014, 20140429–20140502

Stefan Seipel
International:

- Board of reviewers for WSCG 2014 - International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision, Plzen, Czech Republic
- Board of UpGIS, the network of Geographical Information Systems at UU, 2013–
- Expert evaluator for grant applications to the Sweden-America Foundation, 20141001–28

National:

- Chair of the Swedish Computer Graphics Association (SIGRAD), 2012–
- Dissertation committee of Khoa Tan Nguyen, Dept. of Science and Technology, Linköping University, Norrköping, 20140307 *Comment:* Title: Supporting Quantitative Visual Analysis in Medicine and Biology in the Presence of Data Uncertainty
- Dissertation committee of Stefan Lindholm, Dept. of Science and Technology, Linköping University, Norrköping, 20141003
  Comment: Title: Medical Volume Visualization Beyond Single Voxel Values
- Dissertation committee of Lennart Svensson, Dept. of IT, 20141124
  Comment: Title: Image analysis and interactive visualization techniques for electron microscopy tomograms

Ida-Maria Sintorn
National:

- Treasurer of Swedish Society for Automated Image Analysis (SSBA), 2009–
  Comment: Board member 2008–.
- Dissertation Committee of Patrik Malm, Dept. of IT UU, 20140207
  Comment: Title: Image Analysis in Support of Computer-Assisted Cervical Cancer Screening
- Dissertation Committee of Carl-Magnus Clausson, Dept. of Immunology Genetcs and Pathology, UU, 20140328
  Comment: Title: Making Visible the Proximity Between Proteins
- Dissertation Committee of Peter Andersson, Dept. of Physics and Astronomy, UU, 20140604
  Comment: Title: Fast-neutron tomography using a mobile neutron generator for assessment of steam-water distributions in two-phase flows
- Dissertation Committee of Obaid Aftab, Dept. of Medical Sciences, UU, 20141125
  Comment: Title: High-throughput phenotypic and systemic profiling of in vitro growing cell populations using label-free microscopy and spectroscopy: Applications in cancer pharmacology

Nataša Sladoje
International:

- Associate Editor for Pattern Recognition Letters
  Comment: Published by Elsevier. PRL is an official journal of the International Association of Pattern Recognition.

National:

- Dissertation Committee of Lennart Svensson, Swedish University of Agricultural Sciences, 20141124
  Comment: Title: Image Analysis and Interactive Visualization Techniques for Electron Microscopy Tomograms

- Dissertation Committee of Anders Landström, Luleå University of Technology, 20141125
  Comment: Title: Elliptical Adaptive Structuring Elements for Mathematical Morphology

Robin Strand
International:

- Editorial Board member of *Journal of Discrete Mathematics,* 2013–
  Comment: Open access. Published by Hindawi Publishing Corporation.
- Programme Committee, 18th International Conference on Discrete Geometry for Computer Imagery (DGCI 2014), Sienna, Italy
- Programme Committee, 22nd International Conference on Pattern Recognition (ICPR 2014), Stockholm
- Awards Chair, 22nd International Conference on Pattern Recognition (ICPR 2014), Stockholm

National:

- Dissertation Committee of Gustaf Kylberg, UU, 20140321
  Comment: Title: Automatic Virus Identification using TEM – Image Segmentation and Texture Analysis
- Programme Committee, CIM Workshop on Mathematics and Medicine, 20141106-07, Uppsala

Fredrik Wahlberg
National:

- Member of the Uppsala Programming for Multicore Architecures Research Center (UPMARC)

Carolina Wählby
International:

- Dissertation committee of Barathy Mayurathan, Dept. of Statistics and Computer Science, Faculty of Science, University of Peradeniya, Sri Lanka, 20141104
  Comment: Title: Super resolution optical imaging – image analysis, multicolor development and biological applications
- Programme Committee, IEEE International Symposium on Biomedical Imaging (ISBI), 2014, 20140429–20140502

National:

- Dissertation committee of Daniel Rönnlund, Dept. of Experimental Biomolecular Physics, KTH, 20140228
  Comment: Title: Efficient and Compact Codebook Design for Scene Analysis and Object Localisation
- Dissertation committee of Arash Sanamrad, Dept. of Cell and Molecular Biology, UU, 20140905
  Comment: Title: Biological Insights from Single-Particle Tracking in Living Cells
- Member of the Electorial Board (“elektorsförsamlingen”) of the Faculty of Science and Technology, UU, 2014–2016