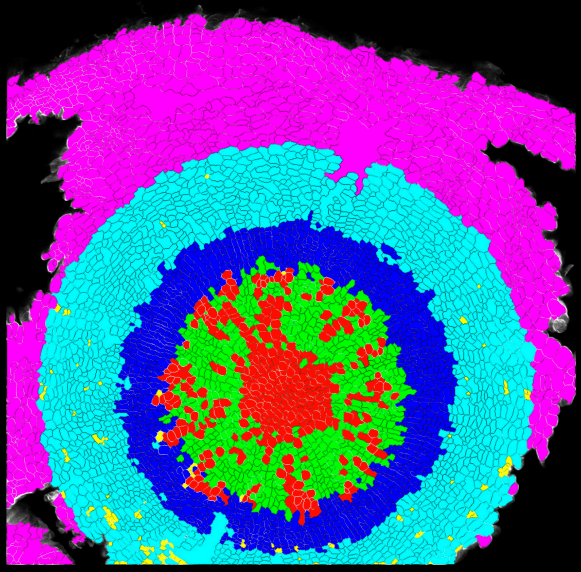
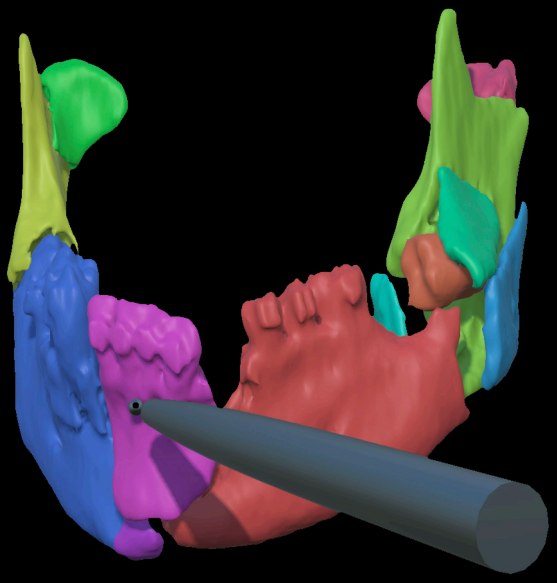
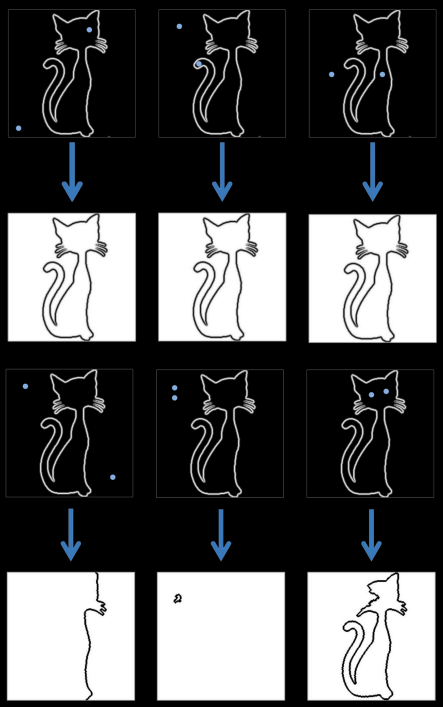
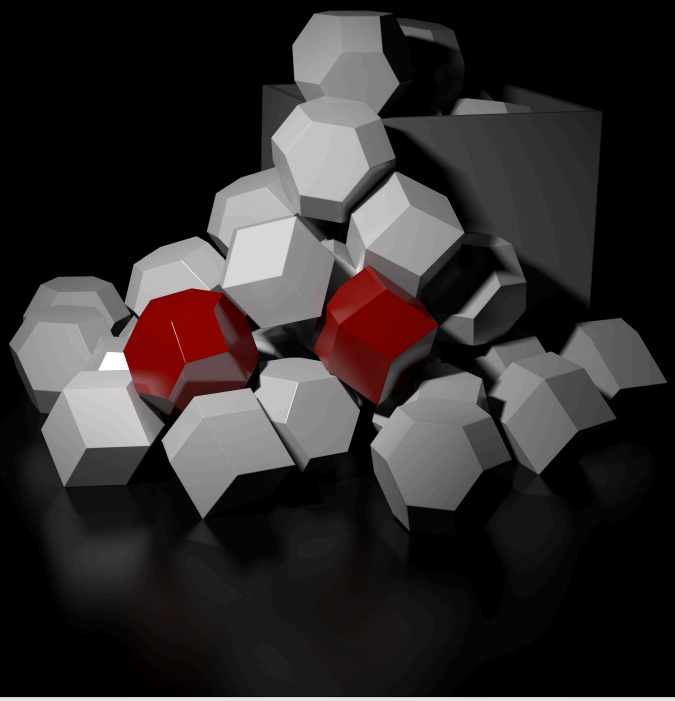
Centre for Image Analysis
Uppsala University

ANNUAL REPORT 2015









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Annual Report 2015

Centre for Image Analysis

Centrum för bildanalys

Cover: Illustrations from the four PhD theses presented at Centre for Image Analysis (CBA) during 2015. Further information in Section 4.2.

top left
Azadeh Fakhrzadeh — Fluorescent images of hypocotyl and stem of Arabidopsis plant.
Linear SVM classification result for 21-day old (dag) hypocotyls: xylem vessels (red) and parenchyma (green), cells of the cambial zone (dark blue), phloem fibers (yellow), phloem (blue), cortical cells (purple).

top right
Pontus Olsson — Haptic interaction with a 3D model of a mandible with fractures.

bottom left
Bettina Selig — "Watershed cats"
The seeded watershed reliably detects the boundary between neigbouring regions, when one seed is placed anywhere in each of the two regions. When both seeds are placed in the same region, the seeded watershed might find parts of the boundary. The stochastic watershed utilizes these two features to create a probability density function of the most salient contours in an image.

bottom right
Elisabeth Linnér — Illustration of different voxel shapes; cubes, rhombic dodecahedra, and truncated octahedra.

Cover design:
Anton Axelsson

Edited by:
Marine Astruc, Gunilla Borgefors, Filip Malmberg, Lena Nordström, Ingela Nyström, Sajith Kecheril Sadanandan, **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. 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. Today, we are hosted by the Disciplinary Domain of Science and Technology and belong to one of five divisions within the Dept. of Information Technology (IT), the Division of Visual Information and Interaction (Vi2). The organizational matters are further outlined in Section 2.

A total of 36 people were working at the CBA in 2015: 16 PhD students, 18 researchers, one technical staff, and one administrator. Additionally, 16 Master students completed their thesis work with supervision from CBA. This does not mean, however, that we had 36 full-time persons at CBA; many of us have split appointments, part time at CBA and part time elsewhere, adding up to around 30 full-time equivalents. The number of staff in the CBA corridor fluctuates over the year thanks to that we have world class scientists visiting CBA and CBA staff visiting their groups, for longer or shorter periods, as an important ingredient of our activities. Among our staff members, we are pleased that Nataša Sladoje qualified as Docent at UU bringing the total number of CBA docents to thirteen.

The activity level in 2015 was high with a total of 64 ongoing research projects involving 39 international and around 50 national collaboration partners. This resulted in 4 PhD theses during the year as well as 21 journal papers and 25 fully reviewed conference papers.

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.

We are active in organizing conferences and seminars. Gunilla Borgefors has served as Chair of the committee organizing the prestigious Celsius-Linné Lectures for Uppsala University. On May 26, CBA organized a seminar in honour of one of the founders of CBA, Ewert Bengtsson as he became Professor Emeritus. In October, we were part of the organizing and program committees of the Swedish Medical Engineering Days that were held in Uppsala with a few hundred participants. We also hosted the 9th workshop on medical image analysis for early detection of cervical cancer as part of our long standing collaboration with India in that field.

Also this year, we participated in the annual national symposium organized by the Swedish Society for Automated Image Analysis (SSBA), which in March 2015 was held in Ystad. CBA accounted for a quarter of the participants by 23 registrations — a proof as good as any that CBA is the largest image analysis group in Sweden. In 2016, we are hosting the 40-year anniversary symposium for SSBA with Robin Strand as general chair.

We are very active in international and national societies and are pleased that our leaders are recognised in these societies. Ingela Nyström is President of IAPR, the International Association of Pattern Recognition, during 2014–2016. 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 since 2009. Ewert Bengtsson has served on the board of Swedish Bioimaging and as

he now is retiring from that position, Carolina Wählby is taking over. Researchers at CBA were asked to give invited talks at 7 conferences at the international level.

During the last few years, we have been active on both national and local level to establish biomedical image analysis and biomedical engineering as more well-supported strategic research areas. During 2015, we finally succeeded in having a new national "strategic innovation area" Medtech4Health established. On the local level, the UU Faculties of Science and Technology and Medicine and Pharmacy agreed to establish a new Centre for Medical Engineering at the UU Hospital. We look forward to the increased funding and collaboration opportunities we expect to be the results of these new structures.

CBA has several elected members of learned socities. Ewert Bengtsson, Gunilla Borgefors, and Christer Kiselman are elected members of the Royal Society of Sciences in Uppsala. Christer Kiselman and Ingela Nyström are elected members of the Royal Society of Arts and Sciences of Uppsala. In addition, Ewert Bengtsson and Gunilla Borgefors are elected members of the Royal Swedish Academy of Engineering Sciences (IVA). Nyström continued to coordinate the strategic research programme in the e-science field, eSSENCE. She is also Vice-Chair of the Council for Research Infrastructure (RFI) within the Swedish Research Council. Carolina Wählby received the prestigious Thureus Prize from the Royal Society of Sciences in Uppsala. Gunilla Borgefors is Editor-in-Chief for the journal Pattern Recognition Letters. 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.

This annual report is available in printed form as well as on the CBA webpage, see `http://www.cb.uu.se/annual_report/AR2015.pdf`

1.2 Summary of research

The objective of CBA is to carry out research and education in computerized 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. We also have interdisciplinary collaboration with the humanities mainly through our projects on handwritten text recognition. We are also developing new methods for perceptualisation, combining computer graphics, haptics, and image processing. Our research is organized 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.

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. One of our PhD theses this year was on image processing on optimal volume sampling lattices.

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 as well as with research centers in the US and India. We have close collaboration with the strategic research programme SciLifeLab through which a research platform in quantitative microscopy is formed, 19 of our projects were associated with and partially funded through SciLifeLab. We also have support from the strategic research programme eSSENCE.

On a macroscopic scale, we are working with interactive segmentation and perceptualisation of 3D CT and MR images also including the use of haptics for the interaction. 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. We are developing methods for rapid segmentation of elongated structures such as vascular systems and airway trees. We have also created a prototype of a system for maxillo-craniofacial surgery planning in which you can see, feel, and manipulate virtual 3D

objects as if they were real. This project has obvious synergy with the Human-Computer Interaction research performed within the Vi2 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 16 such projects. In Section 3.1, we present these theses.

For fun, we have collected all the titles of this year's reviewed publications and made a wordcloud from them, to see which words emerge as most important, see Figure 1.

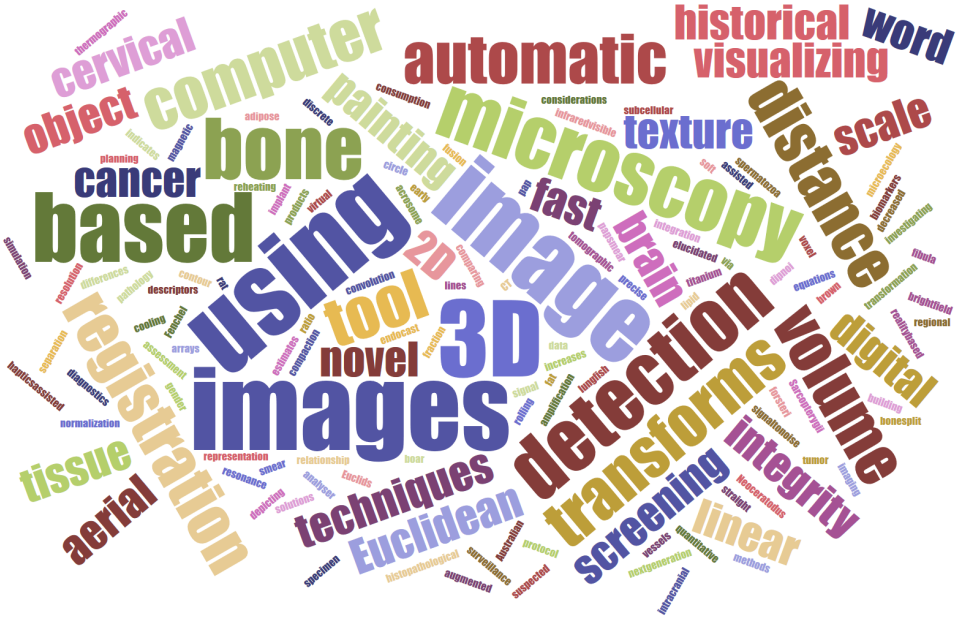


Figure 1: Wordcloud of the journal and reviewed conference proceedings titles. Wordcloud generated with www.jasondavies.com/wordcloud/.

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, the annual reports, lists of all publications since CBA was founded 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 to Uppsala University (UU) and Swedish University of Agricultural Sciences (SLU), administered through UU. In 2011 this was changed so that the UU part of CBA became a division within the Dept. of Information Technology and in 2012 there was a merger with Human-Computer Interaction forming the new Division for Visual Information and Interaction (Vi2) with Ingela Nyström as head both for Vi2 and CBA. At the end of 2014 SLU left the collaboration so that CBA now belongs to only UU now. The only remaining link to SLU is that they are financing a Guest Professor Chair at UU for Gunilla Borgefors.

During 2014 there was a joint council *Centrumråd*, with representatives for the two universities, consisting of:

- 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

That council had its last meeting in February 2015. Currently, there are ongoing discussions within UU about what the status of CBA will be in the future, one option is to formalize our strong collaborations with medicine and pharmacy and possibly also with the humanities to have a centre for image analysis with interdisciplinary application focus within UU.

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

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 centre formations in special cases are worth investing in for many years. As image analysis currently is finding widespread application in research in many fields as well as in society in general, we believe there is a need for a centre with strong application profile based on equally strong roots in fundamental image analysis research.

2.1 Finances

After the re-organization, where CBA became part of the Division of Visual Information and Interaction (Vi2) at the Dept. of Information Technology, the CBA economy is not separate, but integrated in activities as well as organization. Hence, we report how this is financed as a whole. The total expenditure for Vi2 was 38.3 million SEK for 2015. The largest cost in our budget is personnel, which is 63 % of the total cost. Operating cost and rent each cost around 6% while university overhead is 25%. Our equipment costs are far below one percent. To cover this, 34% came from UU faculty funding, 39% from external sources, and 20% from undergraduate education. The remaining 7% were covered by funds balanced from previous years.

Even though CBA as a centre does not organise undergraduate education, Vi2 offers undergraduate education with several courses on Image Analysis, Computer Graphics, and Scientific Visualization as well as Human-Computer Interaction themes. 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 2015. The same numbers for income and costs are also given as pie charts in Figure 2. 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 2015 in kSEK.

Income		**Costs**	
UU	13021	Personnel	23997
UU undergraduate education	7598	Equipment	120
Governmental grants[1]	10130	Operating expenditure[4]	2378
Non-governmental grants[2]	601	Rent	2051
Contracts[3]	4435	University overhead	9733
Financial netto	-14		
Total income	**35771**	**Total cost**	**38279**

[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

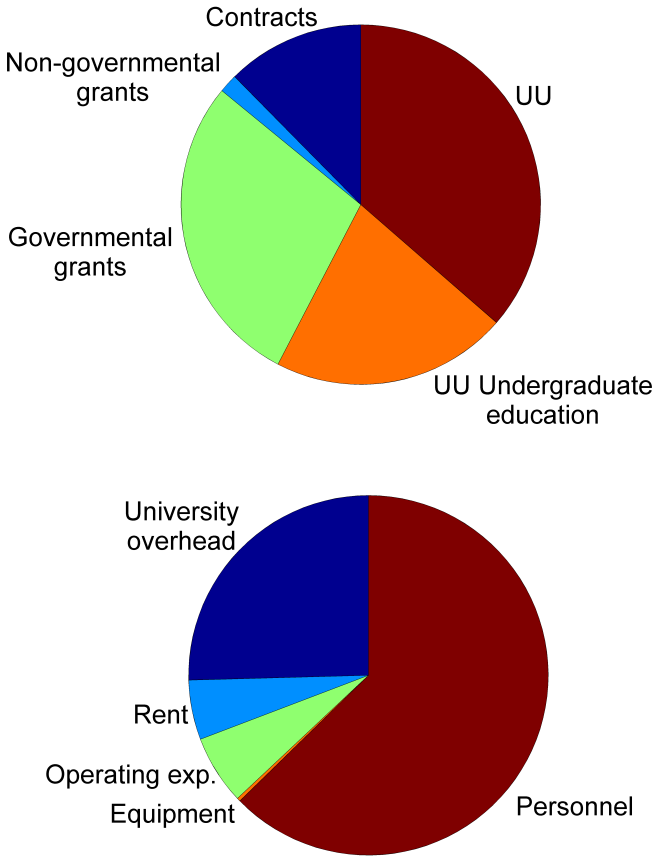


Figure 2: Vi2 income (top) and costs (below) for 2015.

2.2 Staff, CBA

Teo Asplund, Graduate Student 150401–
Marine Astruc, Graduate Student 150518–
Christophe Avenel, PhD, PostDoc –150901
Ewert Bengtsson, Professor Emeritus
Gunilla Borgefors, Professor
Anders Brun, PhD, Researcher
Ingrid Carlbom, Professor Emeritus
Azadeh Fakhrzadeh, Graduate Student –150731, SLU
Anders Hast, Docent and Excellent Teacher, Lecturer
Omer Ishaq, Graduate Student
Christer O. Kiselman, Professor Emeritus
Elisabeth Linnér, Graduate Student –151231
Fei Liu, Graduate Student, University of Gävle
Cris Luengo, Docent, Researcher –151130
Kristína Lidayová, Graduate Student
Joakim Lindblad, Researcher 151001–, (part time)
Filip Malmberg, PhD, Researcher
Damian Matuszewski, Graduate Student
Marco Mignardi, PhD, PostDoc 150901–
Bo Nordin, PhD, Researcher/Senior Lecturer, (part time)
Lena Nordström, Administration
Fredrik Nysjö, Research Engineer –150930, Graduate Student 151001–
Johan Nysjö, Graduate Student
Ingela Nyström, Professor, Director
Pontus Olsson, Graduate Student –151031, Researcher 151119–
Kalyan Ram, Graduate Student
Petter Ranefall, PhD, Bioinformatician
Sajith Sadanandan Kecheril, Graduate Student
Stefan Seipel, Professor, (part time) UU and University of Gävle
Ida-Maria Sintorn, Docent, Associate Senior Lecturer
Nataša Sladoje, Docent, Researcher
Robin Strand, Docent, Researcher
Amit Suveer, Graduate Student 150401–
Fredrik Wahlberg, Graduate Student
Tomas Wilkinson, Graduate Student
Carolina Wählby, Professor

The letters after the name indicate the employer for each person:
UU — Uppsala University
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
13. Nataša Sladoje, 2015, UU

CBA staff appointed Excellent Teachers

1. Anders Hast 2014, UU

3 Undergraduate education

CBA gives undergraduate courses in Image Analysis, Computer Graphics, and Visualisation, some of them specifically oriented towards medical applications. We also provide teachers for other courses at the Department of Information Technology. Course responsible teacher is written in bold in the list below.

Over the years many students have chosen to do their Master Thesis at or associated with CBA and this continues. Figure 3 shows the number of completed Master thesis projects at CBA during 2001–2015. This year there were 16 Master theses with someone from us as either supervisor or reviewer (or both). About one third was on Image Analysis, one third on Visualisation, and one third on Applications of these fields. Also, about one third were our own projects, one third was together with another university department, and one third together with industry.

1. **Computer Assisted Image Analysis II, 10 hp**
   Anders Brun, Kristina Lidayova, **Cris Luengo**, Filip Malmberg, Ida-Maria Sintorn, Nataša Sladoje, Robin Strand, Tomas Wilkinson
   Period: 20150120–0311

2. **Medical Informatics, 5 hp**
   Filip Malmberg, **Robin Strand**
   Period: 20150120–0319

3. **Object Oriented Programming with C++, 10 hp**
   Bo Nordin
   Period: 20150201–0531

4. **Computer Graphics, 10 hp**
   Anders Hast, Kristina Lidayova, Johan Nysjö, Tomas Wilkinson
   Period: 20150324–0605

5. **Database Design I, 5 hp**
   Damian Matuszewski
   Period: 20150831–1025

6. **Bioimaging and Cell Analysis, 7.5 hp**
   Petter Ranefall, Ida-Maria Sintorn, Robin Strand
   Period: 20150831–0925

7. **Computers and Programming, 10 hp**
   Bo Nordin
   Period: 20150901–20160119

8. **Scientific Visualization, 5 hp**
   Anders Hast, Johan Nysjö
   Period: 20150901–1023

9. **Computer Assisted Image Analysis I, 5 hp**
   Marine Astruc, **Filip Malmberg**, Kristina Lidayova, Robin Strand, Tomas Wilkinsson
   Period: 20151027–1214

10. **Scientific Computing I, 5 hp**
    Teo Asplund
    Period: 20151027–1217

11. **Scientific Visualisation (SeSE), 5 hp**
    Fredrik Nysjö
    Period: 20151102–1120

3.1 Master theses

1. **Improved Path Opening by Preselection of Paths**
   Student: Teo Asplund
   Supervisor: Cris Luengo
   Reviewer: Robin Strand
   Publisher: UPTEC IT 15014
   Abstract: Enhancing long, thin, sinuous structures in images is a common problem in image analysis. Mathematical morphology is often used to solve this problem. One approach is known as the path opening. The goal of this project was to investigate whether a preselection of a limited number of paths, based on the upper skeleton of the image, could be used to find an approximate, faster path opening. In this thesis, a new, graph-based algorithm, that is the result of this investigation, is presented. The new algorithm is compared with the traditional path opening and, to some extent, with the parsimonious path opening. Experiments suggest that the implemented algorithm is faster for increasing path length, and runs in linear time with respect to image size. They also suggest that the new algorithm is similar to the traditional path opening when measuring length distributions, while being orders of magnitude faster, thereby making it comparable in speed to the parsimonious path opening, while mitigating the problem of blind spots that the parsimonious path opening suffers from.

2. **Real-Time Fish Type Recognition in Underwater Images for Sustainable Fishing**
   Student: Fritjof Jonsson
   Supervisor: Vladimir Curic, Dept. of Cell and Molecular Biology, Computational and Systems Biology
   Reviewer: Ida-Maria Sintorn
   Publisher: UPTEC IT 14019
   Abstract: It has been investigated if it is possible to selectivly catch farmed salmon (Salmo salar L., 1758) and sea trout (Salmo trutta L., 1758) without disturbing the wild fish. A image analysis software that can separate wild from farmed salmon and salmon from sea trout has been developed. This is interesting since the advent of hydro power stations has obstructed the natural migration of these species to their natal river streams. Even though ladders have been built, fewer fish find their way back up stream. This has lead to farming of salmon and sea trout to compensate for a lower population. However, this is bad for the natural genetic variation and it would be desirable if only the wild fish could enter the rivers. The software could be installed in traps at fish ladders to help with this problem. It is common to cut the adipose fin from the farmed salmon and the lack of this fin has been used as a key character to separate farmed from wild salmon. A real-time algorithm was developed which could recognize the farmed fish with high accuracy by searching for presence or absence of the adipose fin. Additionally, two morphometric measurements were compared in order to investigate if it is possible to separate salmon from sea trout using image analysis. Preliminary tests show that it was possible to separate the species by looking at the ratio between the height of the caudal fin and the height of the caudal peduncle.

3. **Procedural Modeling of Rocks**
   Student: Anders Söderlund
   Supervisor: Stefan Seipel
   Reviewer: Anders Hast
   Publisher: UPTEC IT 15024
   Abstract: Gaming and other virtual environments are a big part of today's society, but manual modeling of terrains used in such environments can be a lengthy and tedious process. This thesis serves to explore a few methods of procedurally generating models of rocks or boulders that could be used in such contexts. This includes geometry and shading. A couple of different methods are explored. Sphere inflation, inspired by a classic sphere modeling method, involves "inflating" a base mesh (usually a platonic solid) to grow towards the boundaries of a sphere using an iterative subdivision approach, halting at a predetermined level of iteration. The second approach, recursive subdivision of segmented edges, involves dividing a base mesh into edge segments based on a predefined segment size, subdividing a polygon with pre-segmented edges with a recursive subdivision method based on the sphere inflation subdivision scheme. The segmented edges method is followed by a corner cutting step to "carve" the base mesh into a shape approaching a rock. The segmented edge method was not successfully finished within due time, but the sphere inflation method shows promise in generating fairly believable rock models. The shading includes GLSL based fragment and vertex shaders employing a Perlin noise based procedural granite 3D texture.

4. **Calving Events Detection and Quantification from Time-lapse Images: A Case Study of Tunabreen Glacier, Svalbard**
   Student: Sigit Adinugroho
   Supervisor: Dorothée Vallot, Dept. of Earth Sciences
   Reviewer: Robin Strand
   Publisher: UPTEC IT 15038
   Abstract: A fully automated method for detecting and measuring calving regions of a glacier is an important tool to gather massive statistical data of calving events. A new framework to achieve the goals is presented in this thesis. First, time-lapse images are registered to the first image in the set. Registration process makes use of the M-Estimator Sample Consensus (MSAC) method to estimate a transformation model that relates a pair of Speeded-Up Robust Features (SURF). Then, the terminus of a glacier is separated from other objects by a semi-automatic Chan-vese level-set segmentation. After that, calving regions in a terminus are detected as a combined difference of Local Binary Patterns (LBP) of two successive images. Clustered points that form a difference image are transformed into polygons representing changed regions by applying the α-shape method. Finally, the areas of changed regions are estimated by the pixel scaling method. The results highlight the performance of the method under normal conditions and reveal the impact of various weather conditions to the performance of the method.
5. **Interactive Methods for Procedural Texture Generation with Noise**
   Student: Boris Kachscovsky
   Supervisor: Martin Strandgren, Goo Technologies, Stockholm
   Reviewer: Anders Hast
   Publisher: UPTEC IT 15045
   Abstract: Many computer graphics applications have used procedural noise since the 1980s, but there are still very few tools which allow non programming-oriented users to make procedural textures. This paper attempts to provide a framework for building and creating procedural noise based textures, in a way that can be easily abstracted and understood by those users. A careful study is conducted of Perlin Noise, and similar interfaces and tools are examined in order to create a framework centered around composable parts and semantic abstractions. The framework is then used to build a proof-of-concept interface which exemplifies some of the conclusions drawn from the study. The proof-of-concept interface successfully creates an environment which can be used to create procedural textures, and serves as a guide for future interfaces in the field.
6. **Exploring Eye Tracking Techniques On Smartphones**
   Student: Iosif Karkanis
   Supervisor: Edith Ngai, Division of Computer Systems, Dept. of IT, UU
   Reviewer: Anders Hast
   Publisher: UPTEC IT 15052
   Abstract: Eye tracking is a major field in medical sector, especially in psychiatry for giving an insight of the patients with mental disorders. Nowadays, the existence of mobile devices with powerful hardware can provide an opportunity to investigate if it is possible to track the eye using these devices without using any additional hardware. This thesis will try to explore the possibility of tracking the center of the pupil using mobile devices. To achieve that, the eye tracking algorithms of template matching and eye detection using image gradients, are implemented in these devices. The application was also implemented as a background service and as a stand-alone activity in order to investigate the performance and usability for these two methods. Both template matching and eye detection using image gradients algorithms show promising results in terms of performance and accuracy respectively.
7. **Visual Representation by Triangulation**
   Student: Max Pihlström
   Supervisor: Anders Hast
   Reviewer: Anders Brun
   Publisher: UPTEC IT 15061
   Abstract: In this thesis the triangulation is treated as a general-purpose visual representation by investigation of various domain-specific methods such as triangulation interpolation, mesh flows, vertex neighborhood feature measures and re-triangulation for spatial transformations. Suggested new methods include an effective cost for image interpolation based on work by Sederberg et al. and a ridge-edge measure related to the Harris edge detector.

8. **Designing a User Interface for the Pico Image Processor**
   Student: Staffan Edström
   Supervisor: Lars Oestricher, Division of Visual Information and Interaction
   Reviewer: Stefan Seipel
   Publisher: UPTEC IT 15078
   Abstract: The Pico image editor was developed at Bell Labs in 1984. The program includes a small pseudo-mathematical image transformation language. Although being well-designed, the functionality of the program does not meet modern standards. It only works on greyscale images and it runs in a command-line interface. To make it work on modern digital images the program must be extended with color support and additional features. The task also includes finding a solution for incorporating the functionality of the program and displaying the images in a modern graphical user interface where usability and effectiveness are prioritised. By using principles of image processing theory and graphical user interface design theory an extended version of the Pico program and a graphical user interface was created. It was built as a web browser application using HTML, CSS and JavaScript. The dynamic parts of the prototype program were built using the Nodejs framework. It has extended functionality combined with an easy to use interface. The program can be used for educational purposes to demonstrate the principles of image processing and as a creative tool for generating images and creating art.

9. **Improving the Fast Evaluation of the Robust Stochastic Watershed**
   Student: Abdul Rahman Khankan
   Supervisor: Cris Luengo
   Reviewer: Filip Malmberg
   Publisher: UPTEC IT 15085
   Abstract: The stochastic watersheds algorithm was first proposed by Angulo and Jeulin (2007) as a marker-controlled watershed-based stochastic segmentation method using Monte Carlo simulation. This project is based on the work of Selig et al. (2015), Fast Evaluation of the Robust Stochastic Watershed, which was the extension of Malmberg and Luengo Hendriks (2014) and Malmberg et al. (2014) who introduced an exact and efficient evaluation method of the stochastic watershed. The algorithm proposed running the exact evaluation method three times after adding noise to the input image then averaging the three edge probabilities together. Their method was identical in terms of average F-measure, but it was an order of magnitude shorter. This project aimed to propose an improved version of Selig et al.'s algorithm which is better in terms of accuracy and faster in terms of processing time. The final result was an algorithm that is matching in accuracy but about 25% faster.
   Comment: Bachelor thesis

10. **Kidney Dynamic Model Enrichment**
    Student: Nils Olofsson
    Supervisor: Marc Daniel, Aix-Marseille Université, CNRS, LSIS UMR
    Reviewer: Anders Hast
    Publisher: UPTEC F 15003
    Abstract: This thesis explores and explains a method using discrete curvature as a feature to find regions of vertices that can be classified as being likely to indicate the presence of an underlying tumor on a kidney surface mesh. Vertices are tagged based on curvature type and mathematical morphology is used to form regions on the mesh. The size and location of the tumor is approximated by fitting a sphere to this region. The method is intended to be employed in noninvasive radiotherapy with a dynamic soft tissue model. It could also provide an alternative to volumetric methods used to segment tumors. A validation is made using the images from which the kidney mesh was constructed, the tumor is visible as a comparison to the method result.

    The dynamic kidney model is validated using the Hausdorff distance and it is explained how this can be computed in an effective way using bounding volume hierarchies.

    Both the tumor finding method and the dynamic model show promising results since they lie within the limit used by practitioners during therapy.

11. **Segmentation and Beautification of Handwriting using Mobile Devices**
Student: Jesper Dürebrandt
Supervisor: André Strindby, Bontouch
Reviewer: Anders Brun
Publisher: UPTEC F 15016
Abstract: Converting handwritten or machine printed documents into a computer readable format allows more efficient storage and processing. The recognition of machine printed text is very reliable with today's technology, but the recognition of offline handwriting still remains a problem to the research community due to the high variance in handwriting styles. Modern mobile devices are capable of performing complex tasks such as scanning invoices, reading traffic signs, and online handwriting recognition, but there are only a few applications that treat offline handwriting.

    This thesis investigates the segmentation of handwritten documents into text lines and words, how the legibility of handwriting can be increased by beautification, as well as implementing it for modern mobile devices. Text line and word segmentation are crucial steps towards implementing a complete handwriting recognition system.

    The results of this thesis show that text line and word segmentation along with handwriting beautification can be implemented successfully for modern mobile devices and a survey concluding that the writing on processed documents is more legible than their unprocessed counterparts. An application for the operating system iOS is developed for demonstration.

12. **Measurement of Dispersion Barriers Through SEM Images**
Student: Basel Aiesh
Supervisor: Cris Luengo, Åsa Nyflött, Stora Enso, Karlstad
Reviewer: Ida-Maria Sintorn
Publisher: UPTEC F 15017
Abstract: In this thesis digital image analysis is applied to Scanning Electron Microscope imagesof dispersion barriers to measure specific properties. The thin barriers are used asprotection for paperboard packaging and are made of polymers and fillers. The orientation, area, length and density distributions of the fillers determine the functionality and quality of the barrier. Methods built on image analysis tools are developed with the objective to measure these quantities. Input for the methods are Scanning Electron Microscope images showing the cross-section of the barriers. To make the images relevant for the methods they are preprocessed by reducing noise and distinguishing fillers from the background.

    For measuring the orientation distribution of the fillers two different methods are implemented and compared. The first one is based on a structure tensor and the other one applies a covariance matrix. The structure tensor is preferable because of its flexibility and better performance for complex images. The area and length distributions are measured by applying mathematical morphology together withsoft-clipping. The density distribution is obtained by filtering the underlying image twice with a uniform filter which creates a heat map.

    The developed methods are evaluated by applying them on fabricated binary test images with known properties. The methods are very accurate when applied on simple test images but for more complex test images with greater variation the accuracy decreases. However, for most applications the results are still on an acceptable level.

13. **Fourier Transform of BCC and FCC Lattices for MRI Applications**
Student: Leo Svenningsson
Supervisor: Elisabeth Linnér
Reviewer: Robin Strand
Publisher: UPTEC F 15046
Abstract: The Cartesian Cubic lattice is known to be sub optimal when considering band-limited signals but is still used as standard in three-dimensional medical magnetic resonance imaging. The optimal sampling lattices are the body-centered cubic lattice and the face-centered cubic lattice. This report discusses the possible use of these sampling lattices in MRI and presents verification of the non standard Fourier transform method that is required for MR image creation for these sampling lattices. The results show that the Fourier transform is consistent with analytical models.

14. **Scalable High Efficiency Video Coding: Cross-layer optimization**
Student: Ragnar Hägg
Supervisor: Usman Hakeem, Ericsson, Stockholm
Reviewer: Anders Hast
Publisher: UPTEC F 15047
Abstract: In July 2014, the second version of the HEVC/H.265 video coding standard was announced, and it included the Scalable High efficiency Video Coding (SHVC) extension. SHVC is used for coding a video stream with subset streams of the same video with lower quality, and it supports spatial, temporal and SNR scalability among others. This is used to enable easy adaption of a video stream, by dropping or adding packages, to devices with different screen sizes, computing power and bandwidth. In this project SHVC has been implemented in Ericsson's research encoder C65. Some cross-layer optimizations have also been implemented and evaluated. The main goal of these optimizations are to make better decisions when choosing the reference layer's motion parameters and QP, by doing multi-pass coding and using the coded enhancement layer information from the first pass.

15. **Efficient and Accurate Volume Rendering on Face-Centered and Body-Centered Cubic Grids**
Student: Karl-Oskar Smed
Supervisor: Elisabeth Linnér, Johan Nysjö
Reviewer: Robin Strand
Publisher: UPTEC F 15048
Abstract: The body centered cubic grid (BCC) and face centered cubic grid (FCC) offer improved sampling properties when compared to the cartesian grid. Despite this there is little software and hardware support for volume rendering of data stored in one of these grids. This project is a continuation of a project adding support for such grids to the volume rendering engine Voreen. This project has three aims. Firstly, to implement new interpolation methods capable of rendering at interactive frame rates. Secondly, to improve the software by adding an alternate volume storage format offering improved frame rates for BCC methods. And thirdly, because of the issues when comparing image quality between different grid types due to aliasing, to implement a method unbiased in terms of post-aliasing. The existing methods are compared to the newly implemented ones in terms of frame rate and image quality and the results show that the new volume format improve the frame rate significantly, that the new BCC interpolation method offers similar image quality at better performance compared to existing methods and that the unbiased method produces images of good quality at the expense of speed.

16. **Development of a Tablet Controlled Brush Simulation as an Extension of GIMP (Swedish)**
Student: David Ramnerö
Supervisor: Anders Hast
Reviewer: Christoffer Karlsson, Dept. of Engineering Sciences
Publisher: UPTEC TVE 15037
Abstract: The project was intended to produce a brush simulation plugin to the image processing program GIMP which would use a 6DOF drawing tablet for user input.Too ambitious goals coupled with compability issues between the resources used resulted in that no meaningful software was produced. Experience was however obtained, and this paper is intended to give an overview of relevant concepts for- and the process of creating a brush simulation.

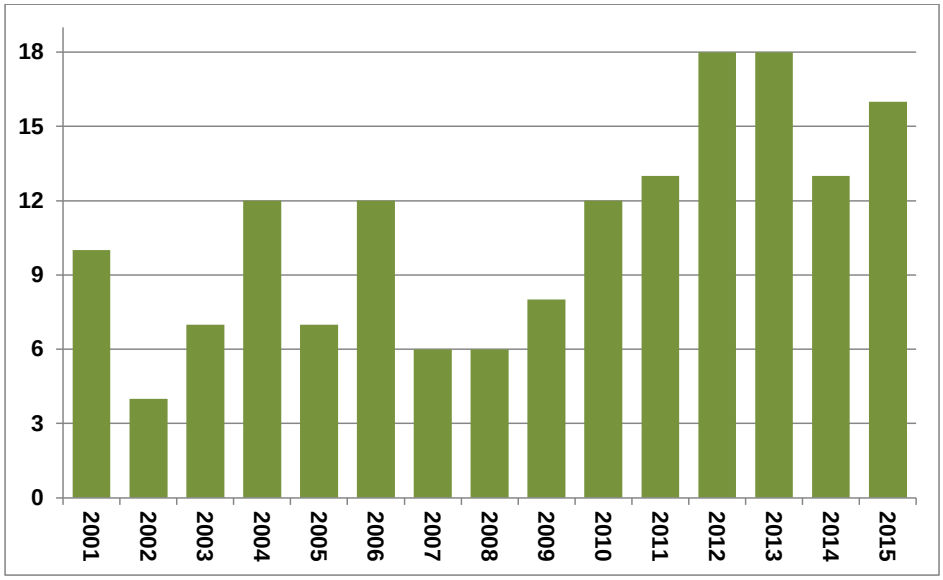


Figure 3: The number of Master theses from CBA.

4 Graduate education

In 2015 there were four dissertations at CBA. Two where on methods for segmenting and analysing plant and animal cells; one on creating a tool for surgery planning; and one on why discretising space by little boxes is not the best choice (voxels should be "rounder").

We give a number of PhD courses each year. Starting already around 1990 we have regularly given a course in Application oriented image analysis for PhD students and others that use image analysis as a tool in their own research and need a basic understanding of what they do. This year we organised a Summer school for PhD students from all over Sweden in Image processing using graphs that was sponsored by SSBA, the Swedish Society for Automated Image Analysis). For our own students there is an always ongoing course reading and discussing seminal old and new papers in our fields.

4.1 Graduate courses

1. **Scientific Data Presentation, 2 hp**
   Cris Luengo
   Period: 150504–0508
   Venue: The course was given at the UU Hospital.
   Description: The goal of the course is to give PhD students the ability to effectively present the data resulting from their experiments. This is a very important form of communication for any researcher, just as important as writing and speaking.

2. **Application Oriented Image Analysis, 5/8 hp**
   Ida-Maria Sintorn, Robin Strand, Carolina Wählby, Damian Matuszewski, Nataša Sladoje, Filip Malmberg
   Period: 151006–1201
   Venue: The course was given at CBA.
   Description: This course aims at giving doctoral students from across the faculty sufficient understanding to solve basic computerized image analysis problems. The course will also offer an introduction to a number of freely a vailable software tools, preparing the students to start using computerized image analysis in their own research.

   The focus of the course is on reaching a broad understanding of computerized image analysis and a basic understanding of the theory and algorithms behind the computerized image analysis methods. The course contained computerized image analysis methods and computer exercises, including computerized image analysis research methodology and computerized image analysis research ethics. The examination was divided into

   - three computer exercises, both to get familiar with the interfaces of common software and to solve realistic image processing problems,
   - a written exam on part 1,
   - a project (oral presentation and written report), where the course participants apply the collected knowledge to a project within their own domain,

   where the first to items were required for 5 credits and for all three items, the course gave 8 credits.

3. **Classical & Modern Papers**
   PhD students at CBA, **Cris Luengo** and **Nataša Sladoje**
   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. **SSBA Summer School: Image Processing Using Graphs**
   Filip Malmberg and **Johan Nysjö**
   Period: 150818–150820
   Venue: The course was given at CBA.
   Description: In recent years, graphs have emerged as a unified representation for image analysis and processing. Many powerful image processing methods have been formulated on pixel adjacency graphs, i.e., a graph whose vertex set is the set of image elements (pixels), and whose edge set is determined by an adjacency relation among the image elements. Due to its discrete nature and mathematical simplicity, this graph based image representation lends itself well to the development of efficient, and provably correct, methods for image processing. This course gives an overview of recent developments in this field. Topics covered include graph-based methods for:

   - Combinatorial optimization
   - Image segmentation
   - Image registration and stereo matching
   - Classification and clustering

   The course was sponsored by the Swedish Society for Automated Image Analysis (SSBA).

4.2 Dissertations

1. *Date:* 150306
   Image Segmentation using Snakes and Stochastic Watershed with applications to microscopy images of biological tissue
   Student: **Bettina Selig**
   Supervisor: Cris L. Luengo
   Assistant Supervisors: Gunilla Borgefors
   Opponent: Jesús Angulo, Center of Mathematical Morphology, MINES ParisTech
   Committee: Josef Bigun, Halmstad University; Michael Felsberg, Linköping University; Olen Tanyevych, University Paris-Est Créteil, Paris, France
   Publisher: Acta Universitatis agriculturae Sueciae, ISBN: 978-91-576-8230-7
   Abstract: The purpose of computerized image analysis is to extract meaningful information from digital images. To be able to find interesting regions or objects in the image, first, the image needs to be segmented. This thesis concentrates on two concepts that are used for image segmentation: the snake and the stochastic watershed. First, we focus on snakes, which are described by contours moving around on the image to find boundaries of objects. Snakes usually fail when concentric contours with similar appearance are supposed to be found successively, because it is impossible for the snake to push off one boundary and settle at the next. This thesis proposes the two-stage snake to overcome this problem. The two-stage snake introduces an intermediate snake that moves away from the influence region of the first boundary, to be able to be attracted by the second boundary. The two-stage snake approach is illustrated on fluorescence microscopy images of compression wood cross-sections for which previously no automated method existed. Further, we discuss and evolve the idea of stochastic watershed, originally a Monte Carlo approach to determine the most salient contours in the image. This approach has room for improvement concerning runtime and suppression of falsely enhanced boundaries. In this thesis, we propose the exact evaluation of the stochastic watershed (ESW) and the robust stochastic watershed (RSW), which address these two issues separately. With the ESW, we can determine the result without any Monte Carlo simulations, but instead using graph theory. Our algorithm is two orders of magnitude faster than the original approach. The RSW uses noise to disrupt weak boundaries that are consistently found in larger areas. It therefore improves the results for problems where objects differ in size. To benefit from the advantages of both new methods, we merged them in the fast robust stochastic watershed (FRSW). This FRSW uses a few realizations of the ESW, adding noise as in the RSW. Finally, we illustrate the RSW and the FRSW to segment in vivo confocal microscopy images of corneal endothelium. Our methods outperform the automatic segmentation algorithm in the commercial software NAVIS.

2. *Date:* 20150612
   Computerized Cell and Tissue Analysis
   Student: **Azadeh Fakhrzadeh**
   Supervisor: Cris L. Luengo
   Assistant Supervisor: Gunilla Borgefors; Lena Holm, Swedish University of Agricultural Sciences
   Opponent: Nasir Rajpoot, University of Warwick, United Kingdom
   Committee: Ingela Parmryd, Dept. of Medical Cell Biology, UU; Johan Lundin, Institute for Molecular Medicine Finland, Helsinki, Finland; Anders Heyden, Lund University; Petter Ranefall, CBA (Reserve Committee Member)
   Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-9269-4
   Abstract: The latest advances in digital cameras combined with powerful computer software enable us to store high-quality microscopy images of specimen. Studying hundreds of images manually is very time consuming and has the problem of human subjectivity and inconsistency. Quantitative image analysis is an emerging field and has found its way into analysis of microscopy images for clinical and research purposes. When developing a pipeline, it is important that its components are simple enough to be generalized and have predictive value. This thesis addresses the automation of quantitative analysis of tissue in two different fields: pathology and plant biology.

   Testicular tissue is a complex structure consisting of seminiferous tubules. The epithelial layer of a seminiferous tubule contains cells that differentiate from primitive germ cells to spermatozoa in a number of steps. These steps are combined in 12 stages in the cycle of the seminiferous epithelium in the mink. The society of toxicological pathology recommends classifying the testicular epithelial into different stages when assess-

ing tissue damage to determine if the dynamics in the spermatogenic cycle have been disturbed. This thesis presents two automated methods for fast and robust segmentation of tubules, and an automated method of staging them. For better accuracy and statistical analysis, we proposed to pool stages into 5 groups. This pooling is suggested based on the morphology of tubules. In the 5 stage case, the overall number of correctly classified tubules is 79.6%.

Contextual information on the localization of fluorescence in microscopy images of plant specimen help us to better understand differentiation and maturation of stem cells into tissues. We propose a pipeline for automated segmentation and classification of the cells in a whole cross-section of Arabidopsis hypocotyl, stem, or root. As proof-of-concept that the classification provides a meaningful basis to group cells for fluorescence characterization, we probed tissues with an antibody specific to xylem vessels in the secondary cell wall. Fluorescence intensity in different classes of cells is measured by the pipeline. The measurement results clearly show that the xylem vessels are the dominant cell type that exhibit a fluorescence signal.

3. *Date:* 20151016
Haptics with Applications to Cranio-Maxillofacial Surgery Planning
Student: **Pontus Olsson**
Supervisor: Ingrid Carlbom
Assistant Supervisor: Ewert Bengtsson and Stefan Johansson
Opponent: Blake Hannaford, University of Washington, USA
Committee: Daniel Buchbinder, Icahn School of Medicine at Mount Sinai, New York, NY, USA; Kristofer Gamstedt Dept. of Engineering Sciences;, UU Karljohan Lundin Palmerius, Linköping University; Charlotte Magnusson, Lund University; Lennart Thurfjell, Combinostics, Uppsala
Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-9339-4
Abstract: Virtual surgery planning systems have demonstrated great potential to help surgeons achieve a better functional and aesthetic outcome for the patient, and at the same time reduce time in the operating room resulting in considerable cost savings. However, the two-dimensional tools employed in these systems today, such as a mouse and a conventional graphical display, are difficult to use for interaction with three-dimensional anatomical images. Therefore surgeons often outsource virtual planning which increases cost and lead time to surgery.

Haptics relates to the sense of touch and haptic technology encompasses algorithms, software, and hardware designed to engage the sense of touch. To demonstrate how haptic technology in combination with stereo visualization can make cranio-maxillofacial surgery planning more efficient and easier to use, we describe our haptics-assisted surgery planning (HASP) system. HASP supports in-house virtual planning of reconstructions in complex trauma cases, and reconstructions with a fibula osteocutaneous free flap including bone, vessels, and soft-tissue in oncology cases. An integrated stable six degrees-of-freedom haptic attraction force model, snap-to-fit, supports semi-automatic alignment of virtual bone fragments in trauma cases. HASP has potential beyond this thesis as a teaching tool and also as a development platform for future research.

In addition to HASP, we describe a surgical bone saw simulator with a novel hybrid haptic interface that combines kinesthetic and vibrotactile feedback to display both low frequency contact forces and realistic high frequency vibrations when a virtual saw blade comes in contact with a virtual bone model.

We also show that visuo-haptic co-location shortens the completion time, but does not improve the accuracy, in interaction tasks performed on two different visuo-haptic displays: one based on a holographic optical element and one based on a half-transparent mirror.

Finally, we describe two prototype hand-worn haptic interfaces that potentially may expand the interaction capabilities of the HASP system. In particular we evaluate two different types of piezo-electric motors, one walking quasi-static motor and one traveling-wave ultrasonic motor for actuating the interfaces.

4. *Date:* 20151219
Image processing on optimal volume sampling lattices: Thinking outside the box
Student: **Elisabeth Linnér**
Supervisor: Robin Strand
Assistant Supervisor: Ewert Bengtsson
Opponent: Alexandre Falcão, Institute of Computing, University of Campinas, Brazil
Committee: Anders Ahnesjö, Dept. of Surgical Sciences, UU; Gunilla Kreiss, Dept. of Information Technology, UU; Ingemar Ragnemalm, Linköping University; Fredrik Kahl, Chalmers University of Technology,

Göteborg; Reiner Lenz, Linköping University
Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-9406-3
Abstract: This thesis summarizes a series of studies of how image quality is affected by the choice of sampling pattern in 3D. Our comparison includes the Cartesian cubic (CC) lattice, the body-centered cubic (BCC) lattice, and the face-centered cubic (FCC) lattice.

Our studies of the lattice Brillouin zones of lattices of equal density show that, while the CC lattice is suitable for functions with elongated spectra, the FCC lattice offers the least variation in resolution with respect to direction. The BCC lattice, however, offers the highest global cutoff frequency. The difference in behavior between the BCC and FCC lattices is negligible for a natural spectrum. We also present a study of pre-aliasing errors on anisotropic versions of the CC, BCC, and FCC sampling lattices, revealing that the optimal choice of sampling lattice is highly dependent on lattice orientation and anisotropy.

We suggest a new reference function for studies of aliasing errors on alternative sampling lattices. This function has a spherical spectrum, and a frequency content proportional to the distance from the origin, facilitating studies of pre-aliasing in spatial domain.

The accuracy of anti-aliased Euclidean distance transform is improved by application of more sofisticated methods for computing the sub-spel precision term. We find that both accuracy and precision are higher on the BCC and FCC lattices than on the CC lattice. We compare the performance of several intensity-weighted distance transforms on MRI data, and find that the derived segmentation result, with respect to relative error in segmented volume, depends neither on the sampling lattice, nor on the sampling density.

Lastly, we present LatticeLibrary, a open source C++ library for processing of sampled data, supporting a number of common image processing methods for CC, BCC, and FCC lattices. We also introduce BccFccRaycaster, a tool for visualizing data sampled on CC, BCC, and FCC lattices.

We believe that the work summarized in this thesis provide both the motivation and the tools for continuing research on application of the BCC and FCC lattices in image processing and analysis.

5 Research

Our research activities are conducted in a large number of projects, some large, some small. They are listed here, collected in five sub-groups. The first, Section 5.1, is analysis and visualisation in 3D, almost exclusively for medical applications. CBA is very active in the pan-Swedish large project SciLife Lab. Therefore we have collected all our related activities in Section 5.2. All develop analysis methods for microscope imagery. We also have many other such research projects, which are collected in Section 5.3. Even if it is much more difficult to get funding for image analysis and visualisation per se, we manage to have a number of theoretical projects running, that develop these subjects independently of any application, see Section 5.4. Finally, we do have a number of non-medical applications described in Section 5.5. The largest such application develops methods for analysis of old, handwritten texts.

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 3D analysis and visualization

1. **HASP: Haptics-Assisted Surgery Planning**
   Ingrid Carlbom, Pontus Olsson, Fredrik Nysjö, Johan Nysjö
   Partners: Daniel Buchbinder (Icahn School of Medicine at Mount Sinai, New York, NY, USA); Stefan Johansson (Division of Microsystems Technology, Uppsala University and Teknovest AB); Andreas Thor, Dept. of Surgical Sciences, Oral & Maxillofacial Surgery, UU Hospital; Andres Rodriguez Lorenzo, Dept. of Surgical Sciences, Plastic Surgery, UU Hospital.
   Funding: BIO-X ; Thuréus Stiftelsen
   Period: 1501–1512
   Abstract: This year our focus has been to build an integrated surgery planning system encompassing the entire planning process: from input of patient data to generation of saw guides and plates for the operating room. We employed a company, CHAS, which specializes in interface design. The result is a clear workflow, from data input, to bone segmentation, vessel segmentation, bone reconstruction, vessel reconstruction, soft tissue segmentation, and to the generation of guides and plates combined with descriptive icons representing the functions at each stage. We have transferred most of the old version of HASP into this new interface, and also begun to integrate BoneSplit (see below) for the bone segmentation.

   In May, Pontus, Fredrik, and Ingrid spent a week in NYC at the Mount Sinai Beth Israel Hospital hosted by Dr. Buchbinder, where we demonstrated HASP and got feedback and input for improvements from about ten CMF surgeons, fellows, and residents.

   In October, Pontus, Ingrid and her mentor Anders Lundqvist attended the yearly meeting of AAOMS, (American Association of Oral and Maxillofacial Surgeons) in Washington, DC, where Ingrid gave a talk on ”Surgical Training Using a Haptics-Assisted Cranio-Maxillofacial Planning System (HASP)”, and we demonstrated HASP to attendees.

   In December, Pontus and Daniel Buchbinder demonstrated HASP at the AO Foundation Meeting in Davos, Switzerland. On October 16, Pontus Olsson successfully defended his thesis ”Haptics with Applications to Cranio-Maxillofacial Surgery Planning”, a large portion of which concerned HASP.

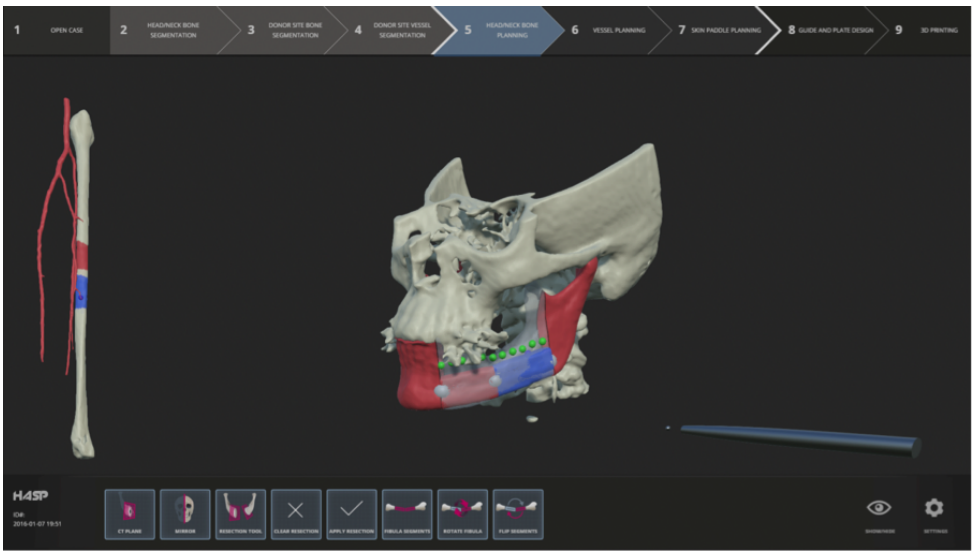


Figure 4: Example of Hasp user interface with fibula design.

2. **ProViz – Interactive Visualization of 3D Protein Images**
   Ida-Maria Sintorn, Ingela Nyström, Fredrik Nysjö, Johan Nysjö, Anders Brun, Gunilla Borgefors
   Partners: Dept. of Cell and Molecular Biology, Karolinska Institute; SenseGraphics AB, Dept. of Molecular Biology, Umeå University, Vironova 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 development of the ProViz software ended 2014. The project activity in 2015 has been to prepare and finalize the manuscript describing and demonstrating the ProViz software in several different applications.

3. **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 6) 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 5). 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. During 2015, we presented the Imiomics concept at the 23rd Annual meeting of the International Society for Magnetic Resonance in Medicine (MICCAI) in Toronto, Canada and at the Swedish conferences *Medicinteknikdagarna* (Medical Engineering Days) and *Röntgenveckan* (X-ray week). A manuscript describing a method for interactive manipulation of 3D deformation fields was presented at the Interactive Medical Image Computing (IMIC) workshop held in conjunction with the MICCAI conference.

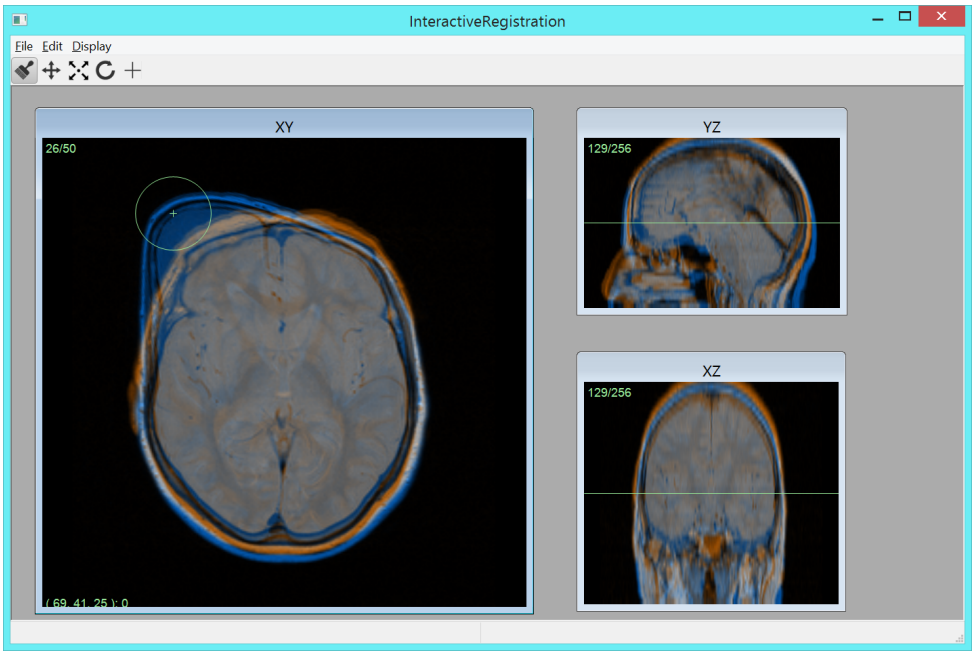


Figure 5: A screen-shot of the user interface of our software for interactive editing of a deformation field aligning two images. The target image and transformed source image are displayed using a colored overlay in three orthogonal views. The user can deform the source image by clicking and dragging in any of the views, as shown in the screen-shot.

4. **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 2015, manuscripts on open source software, segmentation and sampling have been written and submitted. Elisabeth Linnér successfully defended her thesis in December 2015.

5. **Computerized Image Analysis for Ophthalmologic Applications**
   Filip Malmberg
   Partners: Camilla Sandberg-Melin and Per Söderberg, Dept. of Neuroscience, UU
   Funding: Dept. of Information Technology, UU
   Period: 1501–
   Abstract: Ophtalmology is the study of the anatomy, physiology, and diseases of the eye. Optical coherence tomography (OCT) is a non-invasive technique for generating 3D images of the retina of the eye, allowing ophtalmologists to visualize the different structures of the retina. To complement visual inspection, this project aims to develop image analysis method for accurately measuring geometrical properties of the retina. These measurements help with early detection, diagnosis and treatment guidance for a wide range of retinal diseases and conditions.

   During 2015, we have developed a method for accurately measuring the shortest distance between the inner limit of the retina and the central limit of the pigment epithelium around the circumference of the optic nerve head in OCT images. The shortest distance between these boundaries reflects the nerve fiber layer thickness and measurement of this distance is interesting for follow-up of glaucoma.

6. **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 Uppsala University Hospital.

   During 2015, we have continued the development of *SmartPaint*, our publicly available software for interactive segmentation. The SmartPaint software can be downloaded from `http://www.cb.uu.se/~filip/SmartPaint/`. To date, this software has been downloaded more than 700 times.

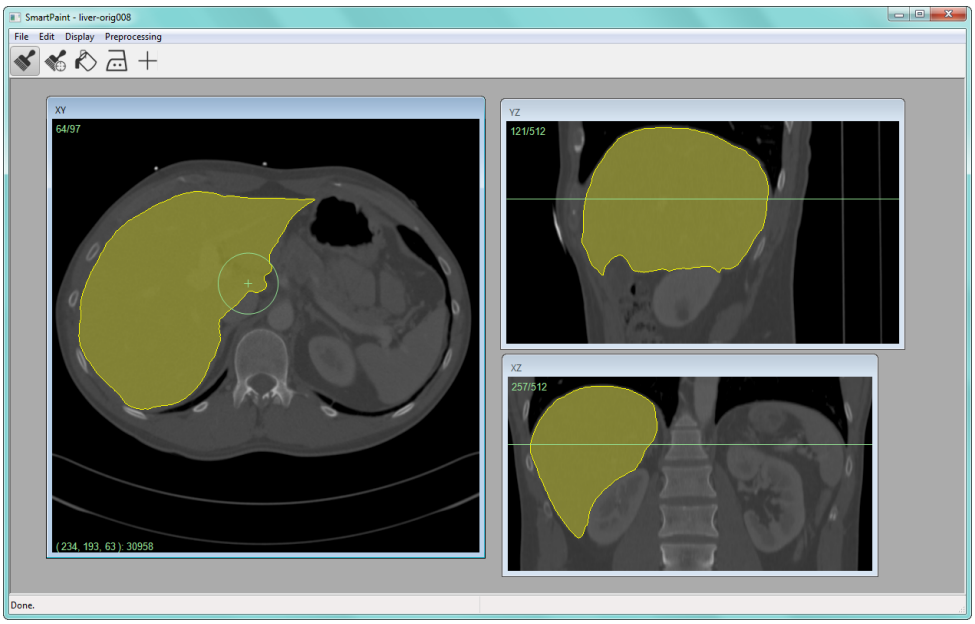
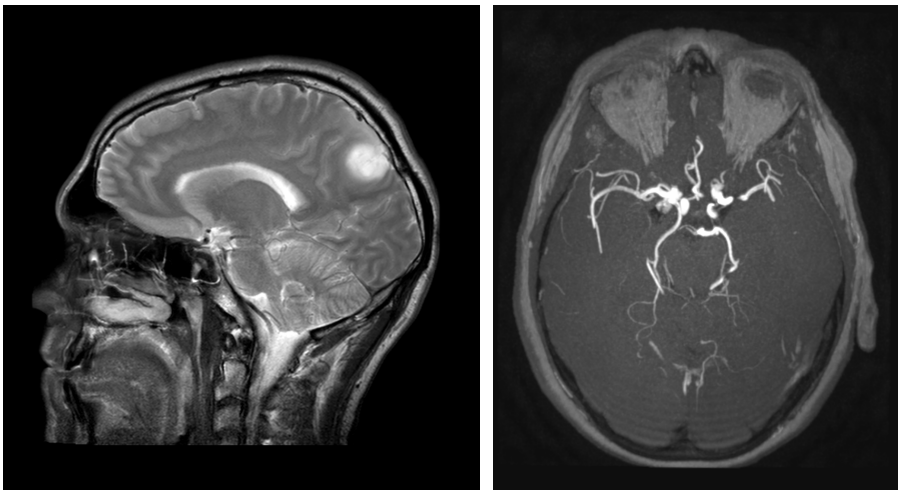


Figure 6: Screenshot from the *Smartpaint* software for interactive segmentation of volume images, developed at CBA. A radiologist segments the liver in a CT image by interactively "painting" the segmentation using a brush tool.

7. **Subtle Change Detection and Quantification in Magnetic Resonance Neuroimaging**
   Marine Astruc, Robin Strand, Filip Malmberg
   Partner: Johan Wikström, Elna-Marie Larsson and Raili Raininko, Dept. of Radiology, Oncology and Radiation Science, UU
   Funding: Swedish Research Council
   Period: 1505–
   Abstract: Many brain injuries and diseases can damage brain cells (nerve cells), which can lead to loss of nerve cells and, secondarily, loss of brain volume. Even slight loss of nerve cells can give severe neurological and cognitive symptoms. The increasing resolution in magnetic resonance (MR) neuroimaging allows detection and quantification of very small volume changes. Due to the enormous amount of information in a typical MR brain volume scan, interactive tools for computer aided analysis are absolutely essential for subtle change detection. Demonstration, localization and quantification of volume loss are needed in brain injuries (e.g. brain trauma) and in neurodegenerative diseases (e.g. many hereditary neurological diseases and dementia). Interactive tools available today are not sensitive enough for detection of small general or focal volume loss. We develop image processing methods for change detection and quantification in neuroimaging. This aim is to allow early diagnosis, detailed correct diagnosis, and accurate and precise analysis of treatment response.
8. **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–



(a) (b)

Figure 7: (a) Sagittal t2-weighted turbo spin echo image showing a brain tumor. (b) Axial slice of a 3D time-of-flight magnetic resonance angiography of the remnants of an intracranial aneurysm after treatment with coils.

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 and can be measured by segmenting the orbits in three-dimensional (3D) computed tomography (CT) images of the skull. This task is usually performed by manual slice-by-slice segmentation, which is both time-consuming and sensitive to operator errors. Semi-automatic segmentation methods could substantially reduce the operator time and improve the precision.

In this project, we are developing a semi-automatic system for segmenting the orbit (see Figure 8) in CT images. A prototype system was implemented in 2010 using 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`. The segmentation system combines deformable models with haptic 3D interaction and has been used to segment fractured and malformed orbits in several studies. We have extended the system with automatic registration-based techniques for performing size and shape analysis of the segmented orbits.

During 2015, we have mainly been focusing on completing orbit segmentation studies that have been carried out in collaboration with partners from Great Ormond Street Hospital, Pitie Salpetriere Hospital, and UU Hospital. Using our experiences from these and previous segmentation studies, we have also started to develop a new version of the segmentation system that replaces the deformable model with interactive 3D texture painting and sculpting tools. The aim is to make it easier for the user to edit the segmentation result and to improve the overall efficiency and precision of the segmentation.

9. **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

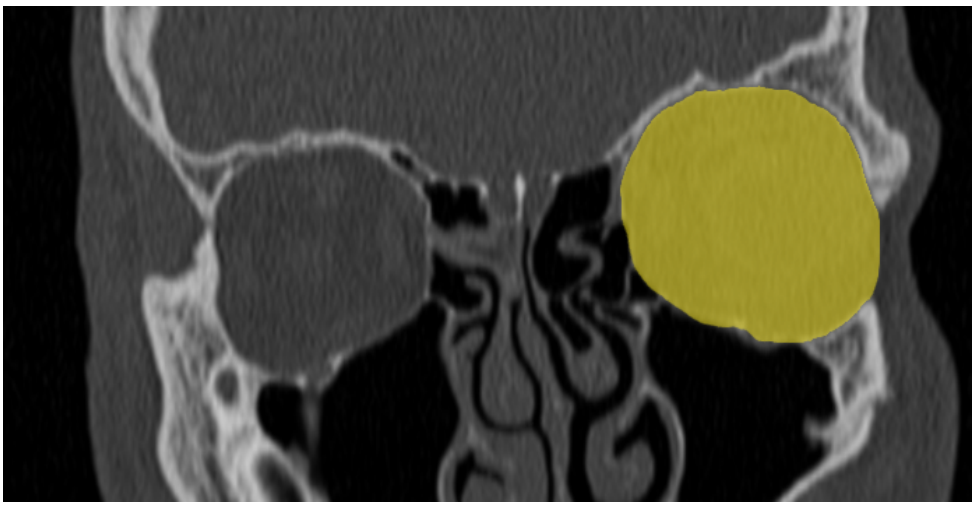


Figure 8: Cross-section of a segmented orbit in a 3D CT image.

Period: 1111–
Abstract: A distal radius fracture is a common type of wrist fracture that occurs between the joint and the shaft of the radius bone. Orthopedic surgeons routinely assess the displacement of such fractures by measuring the angulation between the joint and the shaft in plain X-ray images. The accuracy and precision of this method is, however, limited, since X-ray only provides a two-dimensional (2D) projection of the bones and the measured angle is three-dimensional (3D). In most clinical cases, conventional 2D X-ray measurements are satisfactory for making correct decisions about treatment, but when comparing two different methods of treatment, for example, two different operation techniques, the accuracy and precision of the 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 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 2015, we completed an extensive case study involving 40 CT scan sequences of fractures wrists. The aim of this study was to further evaluate the performance of our method and compare it with the conventional 2D X-ray measurement method. A manuscript about the study was submitted at the end of the year.

10. **Interactive Bone Segmentation**
Johan Nysjö, Filip Malmberg, Ida-Maria Sintorn, Ingela Nyström,
Partners: UU Hospital
Funding: TN-faculty, UU
Period: 1501–
Abstract: Restoring the skeletal anatomy after trauma is a complex task that can be facilitated by careful pre-operative planning based on 3D computed tomography (CT) images.

It is possible to assembly fractured bones virtually (using the HASP system developed at CBA) or print them as plastic models on a 3D printer, but this requires that the individual bone structures first have been extracted (segmented) from the CT image. Currently, this type of segmentation is often performed by manually marking the bones in 2D slice views, a process that is both tedious and time-consuming.

In 2015, we developed BoneSplit, an fast interactive tool for segmenting individual bones and bone fragments in CT images. This tool combines interactive 3D painting (see Figure 9) with efficient graph-based segmentation algorithms and makes it easy for the user to mark bones of interest and edit the segmentation result. The tool has been evaluated on complex trauma and tumor cases (provided by the UU hospital) and been used internally in the HASP project. An article about the tool was presented at the WSCG 2015 conference.

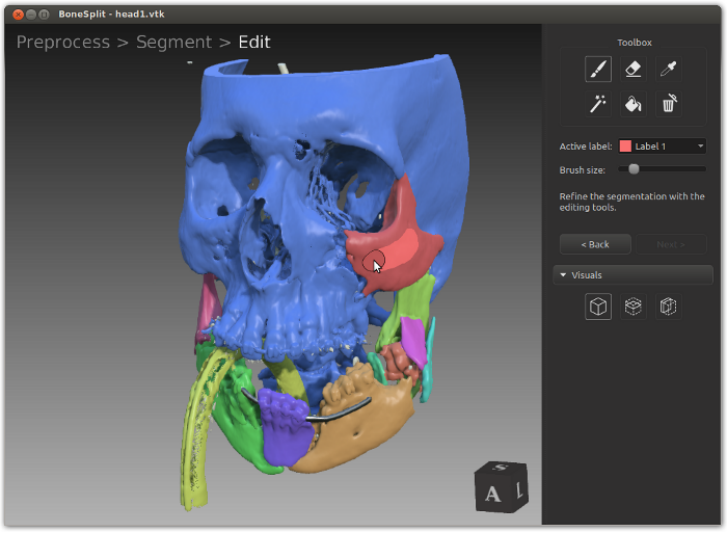


Figure 9: Screenshot of BoneSplit, our graph-based 3D painting tool for segmentating individual bones and bone fragments in CT images. The user marks bone structures of interest with the 3D brush and receives immediate update of the segmentation result.

11. **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 Computed Tomography Angiography (CTA) image as the input and produces a node-link representation of the vascular structures for the lower limbs. The method 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 and achieved an average of 96% overlap rate with ground truth. The average computational time is 121 sec/scan.

In year 2015 a paper summarizing this work was accepted to Special issue of Pattern Recognition Letters on skeletonization and its applications. During the year we continued our work on this project and we extended it with an additional third pass. This third pass extracts the vascular centerline of tiny vessels in cases where the blood artery is blocked. As the blood takes a different path and uses smaller arteries to continue the oxygen supply to the more distal parts, these small arteries are important from the medical point of view. However, they are hardly visible in the CT scan and their shape is more irregular and wriggled. Figure 10 shows the detected centerline in a cutout of the CTA scan of the lower limbs.

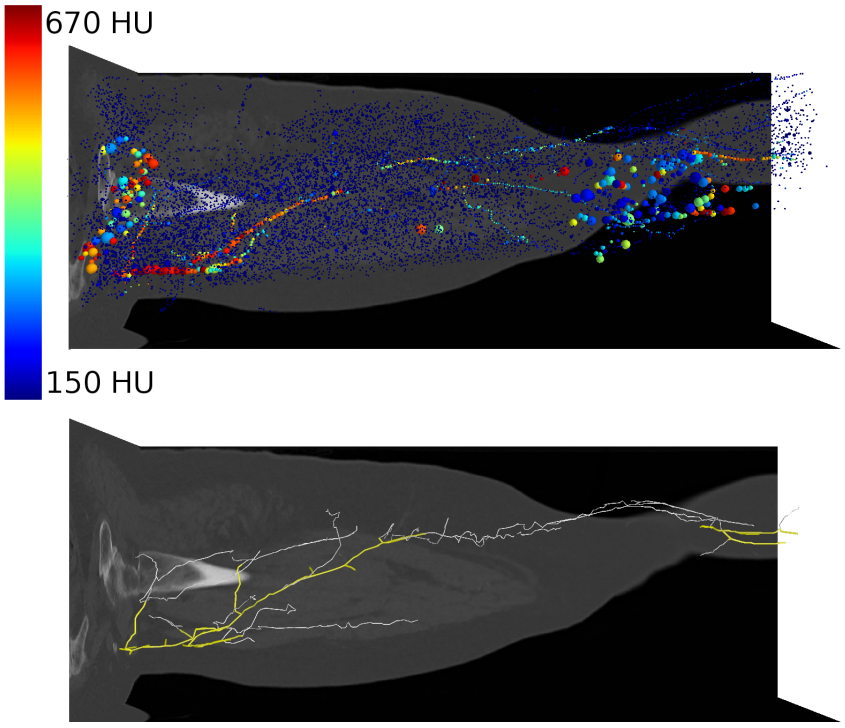


Figure 10: Upper image: The nodes detected in the algorithm step are represented by the spheres. The colour of the spheres shows the node's intensity. Lower image: Detected nodes are connected into graphs. The centerlines of the larger arteries are shown with the yellow graph. The white graph shows an alternative connection through tiny arteries between two parts of the same artery in the part where the occlusion is present.

12. **Airway Tree Skeleton Extraction From CT Images of Lungs**
Kristína Lidayová, Hans Frimmel, Ewert Bengtsson
Partner: Örjan Smedby, School of Technology and Health, KTH Royal nstitute of Technology, Stockholm, Sweden; Marcela Hernandez Hoyos, Duvan Alberto Gomez Betancur, Universidad de los Andes, Bogota, Colombia
Funding: VR grant to Örjan Smedby
Period: 1512–
Abstract: Acute Respiratory Distress Syndrome (ARDS) presents a high mortality rate in intensive care units. Fast and accurate analysis of lung aeration on CT images may contribute to reduce the mortality rate in ARDS. The important step in the process is the lung segmentation. However, the images acquired in the presence of ARDS are completely or partially lacking contrast, therefore the segmentation is challenging. One possibility is to use hybrid registration-based lung segmentation that combines airway-tree landmarks with gray-level information. The airway-tree landmarks are obtained from the airway-tree skeleton and therefore our project is focused on fast and precise airway-tree skeleton extraction from CT images of lungs.

13. **Ubiquitous Visualization in the Built Environment**
Stefan Seipel, Fei Liu, Torsten Jonsson
Partner: Dept. of Industrial Development, IT and Land Management, University of Gävle
Funding: University of Gävle(HiG); 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 performance studies in target position acquisition using mobile AR user interfaces. On the technology part this project has investigated and developed methods for 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 features which model the shapes of commonly present facade elements, such as windows. These features are generated by grouping edge line segments with the help of image perspective information, namely, vanishing points. The method adopts a forward selection algorithm for selecting feature correspondences needed to estimate the transformation model. 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. The most recent activities in this project have been concerned with studying user- and system performance when a video-see through AR is used for precise target designation. To that end, one user experiment has been carried out to establish the sources of errors in precision when acquiring target positions using a fixed screen, video-see through AR system. In this experiment a high-performance optical tracking system was used in a highly controlled indoor lab-environment in order to establish baseline precision and to identify sources of loss in precision. In a follow-up study, similar target designation tasks were used in an experiment to investigate a hand-held AR system that presents the augmented scenario including the user in a third-person AR view to the user. Such a system overcomes the need for remote target designation as it allows the user to directly interact with the augmented objects within arm's reach. The system was implemented using consumer level, commercial AR tools. The objec-

tive of this study was to a) identify levels of precision when using mainstream camera based tracking using optical markers; and b) to investigate potential user performance penalties encompassed by the required mental transformations when using the third person AR perspective. Results of those experiments are presently analyzed and prepared for publication.

5.2 SciLifeLab funded microscopic biomedical image analysis projects

14. **TissueMaps: Integrating spatial and genetic information via automated image analysis and interactive visualization of tissue data**
Carolina Wählby, Petter Ranefall, Omer Ishaq, Marco Mignardi
Partners: Mats Nilsson, Thomas Hauling, Xiaoyan Qian, Jessica Svedlund, Elin Lundin, SciLifeLab/Stockholm University, Ola Söderberg and Gaëlle Cane, SciLifeLab/Uppsala University
Funding: Science for Life Laboratory; TN-faculty, UU; International Postdoctoral fellowship to Marco Mignardi
Period: 1109–
Abstract: Digital imaging of tissue samples and genetic analysis by next generation sequencing are two rapidly emerging fields in pathology. The exponential growth in digital imaging in pathology is catalyzed by more advanced imaging hardware, comparable to the complete shift from analog to digital images that took place in radiology a couple of decades ago: Entire glass slides can be digitized at near the optical resolution limits in only a few minutes' time, and fluorescence as well as bright field stains can be imaged in parallel.

Genetic analysis, and particularly transcriptomics, is rapidly evolving thanks to the impressive development of next generation sequencing technologies, enabling genome-wide single-cell analysis of DNA and RNA in thousands of cells at constantly decreasing costs. However, most of today's available technologies result in a genetic analysis that is decoupled from the morphological and spatial information of the original tissue sample, while many important questions in tumor- and developmental biology require single cell spatial resolution to understand tissue heterogeneity.

In this project, we develop computational methods that bridge these two emerging fields. We combine spatially resolved high-throughput genomics analysis of tissue sections with digital image analysis of tissue morphology. Together with collaborators from the biomedical field, we work with advanced digital image processing methods for spatially resolved genomics (see Ke et al, Nature Methods 2013). Going beyond visual assessment of this rich digital data will be a fundamental component for the future development of histopathology, both as a diagnostic tool and as a research field. We published a review paper on spatially resolved genomics and proteomics in the Journal of Molecular Biology (Koos et al J Mol Bio 2015).

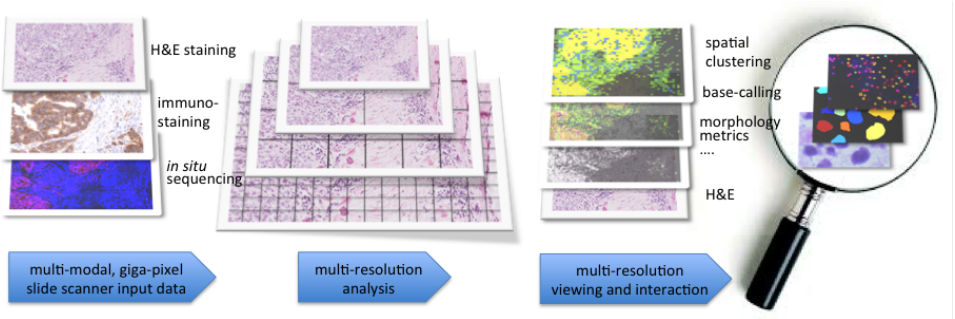


Figure 11: Illustration of the TissueMaps project: We combine spatially resolved genetic analysis with traditional tissue staining approaches, and work with multiple resolutions to enable detailed analysis while maintaining the global view of the tissue sample.

15. **Evaluation of the Effect of Compaction Oligonucleotides on the Strength and Integrity of Fluorescent Signals**
Omer Ishaq, Petter Ranefall, Carolina Wählby
Partners: Carl-Magnus Clausson, Linda Arngården, Ola Söderberg, Dept. of Immunology, Genetics and Pathology, UU
Funding: Science for Life Laboratory
Period: 1310–1506
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 fluorescent 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 fluorescent signals. A paper describing the method, including image analysis approaches for methods evaluation, was published in Nature Scientific Reports 2015.

16. **Detection of Fluorescent Signals using Deep Learning Architectures**
Omer Ishaq, Carolina Wählby
Partners: Vladimir Curic, Martin Linden, Johan Elf, Dept. of Cell & Molecular Biology, UU
Funding: Science for Life Laboratory, eSSENCE, VR junior researcher grant to Carolina Wählby
Period: 1501–
Abstract: Detection of fluorescent spots is an important component of bioimaging. A number of detection methods have been proposed. Recently, deep learning methods have become popular for a range of computer vision tasks and have resulted in competitive results. In this project we utilize a number of these deep learning methods and compare them against model-based spot detection methods. In addition, we also explore the effect of training both shallow- and deep-learning spot detection approaches on synthetic, semi-synthetic and real data and evaluate their performance on manually annotated real data in the form of quantitative results. The annotation of real data is facilitated by the development of a specialized annotation tool based on a two-alternative forced-choice (2AFC) approach. The annotation performance is validated through rater reliability statistics. The project has resulted in two manuscripts, one of which has been submitted to a conference and the other is being adapted for a journal publication. Figure 12 shows the interface of the two-alternative forced-choice (2AFC) tool developed for spot annotation.

17. **SciLifeLab Cancer Stem Cell Program**
Damian Matuszewski, Petter Ranefall, Carolina Wählby, Ida-Maria Sintorn
Partners: Sven Nelander, Ingrid Lönnstedt, Cecilia Krona, Linnèa Schmidt, 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 Lundgres, 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

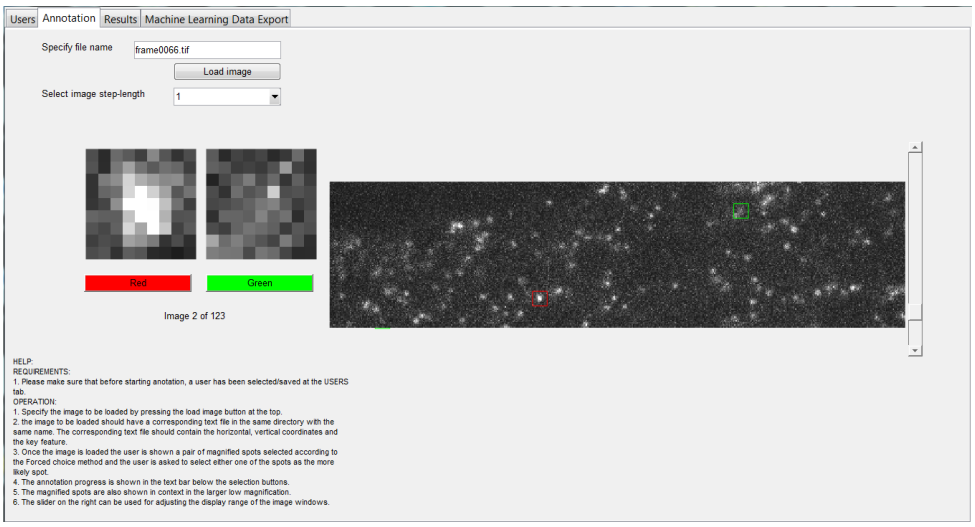


Figure 12: the interface of the two-alternative forced-choice (2AFC) tool developed for spot annotation.

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. Patient data is continuously collected, and close to one hundred primary cell lines have been established. The cultured cells are exposed to known and novel drug compounds at varying doses, and imaged by fluorescence as well as bright-field microscopy. In 2015 algorithms for cell cycle analysis and automatic selection of potentially effective treatments were developed, and presented at BioImage Informatics 2015 in Gaithersburg, MD, USA. Current research focus is on extracting meaningful morphological descriptors from the image data. As part of the project we also evaluate the infiltration of tumor cells upon injection of stem cells in mice brains.

18. **PopulationProfiler**
Damian Matuszewski, Carolina Wählby, Ida-Maria Sintorn
Partners: Jordi Carreras Puigvert, SciLifeLab and Helleday Laboratory, Karolinska Institutet, Stockholm
Funding: Science for Life Laboratory
Period: 1501–
Abstract: PopulationProfiler is a cross-platform open-source tool developed for data analysis in image-based screening experiments. The main idea is to reduce per-cell measurements to per-well distributions, each represented by a histogram. These can be optionally further reduced to sub-type counts based on gating (setting bin ranges) of known control distributions and local adjustments to histogram shape. Such analysis is necessary in a wide variety of applications, e.g. DNA damage assessment using foci intensity distributions, assessment of cell type specific markers, and cell cycle analysis. The source code, sample dataset and an executable program (for Windows only) are freely available at http://www.cb.uu.se/˜damian/PopulationProfiler.html.

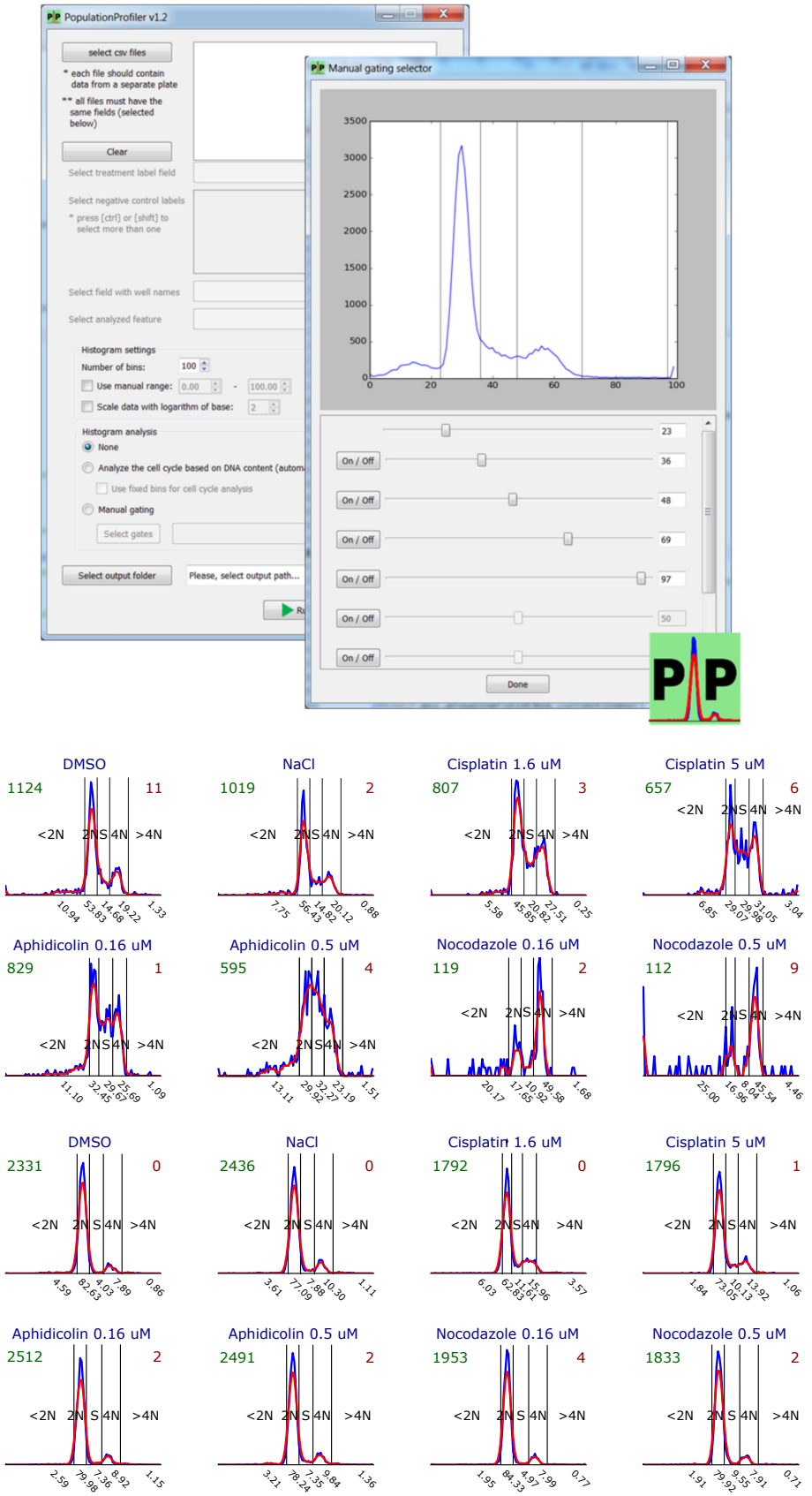


Figure 13: PopulationProfiler GUI and a sample visualization for cell cycle analysis.

19. **Segmentation and Tracking of E.coli Bacteria in Bright-Field Microscopy Images**
Sajith Kecheril Sadanandan, Carolina Wählby, Petter Ranefall
Partners: Johan Elf, David Fange, Alexis Boucharin, Dept. of Cell & Molecular Biology, UU; Klas E. G. Magnusson, Joakim Jaldén, ACCESS Linnaeus Centre, KTH.
Funding: Science for Life Laboratory, 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 project 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 methods were published in IEEE Journal of Selected Topics in Signal Processing (KS Sadanandan et al 2015).

20. **Global and Local Adaptive Gray-level Thresholding Based on Object Features**
Petter Ranefall, Sajith Kecheril Sadanandan, Carolina Wählby
Funding: Science for Life Laboratory
Period: 1501–1512
Abstract: We have developed two new algorithms for global and local adaptive thresholding based on object features such as size, ellipse fit, etc. The algorithms are efficient with little computational overhead compared to histogram based gray-level thresholding, but with much more stable results. This makes them very suitable for high-throughput analysis in microscopy applications like segmentation of cell nuclei or fluorescent spots. The algorithms have been implemented as plugins to ImageJ and CellProfiler and have been used in several different applications. We have written two papers that both are accepted for publication in Cytomerty A and at ISBI 2016.

21. **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: Science for Life Laboratory
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. We have also developed methods for length and volume measurements as well as quantification of macrophages, neutrophils, IK17 and the overlap with these expressions and stationary lipids. Our results confirm that zebrafish larvae represent a promising model system for early-stage atherosclerosis.

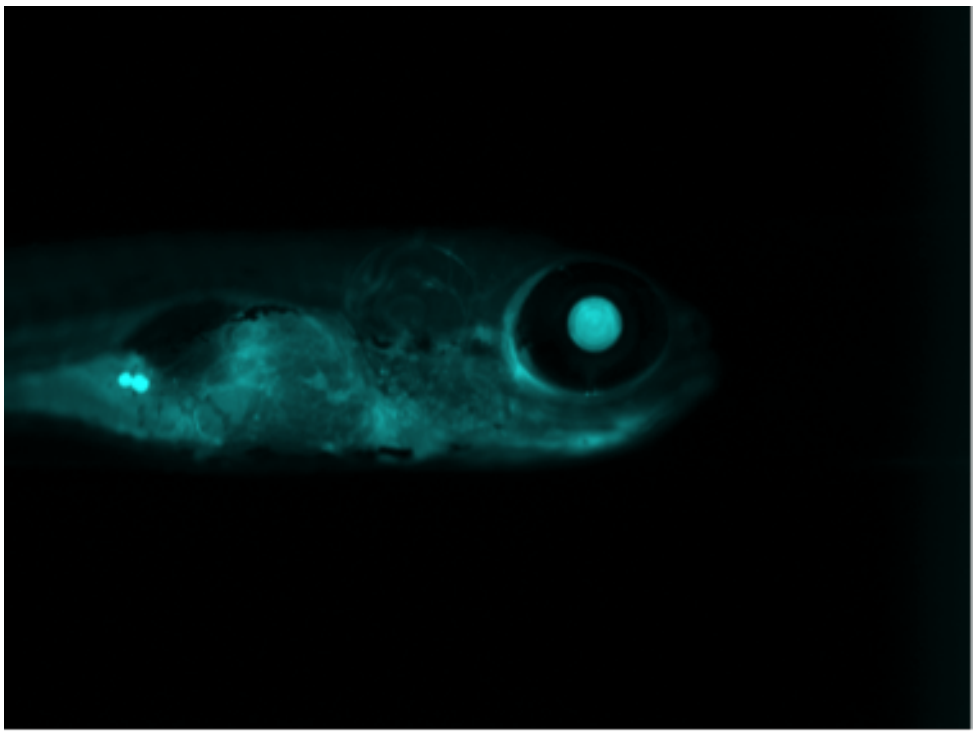


Figure 14: Fluorescence micrsocopy image of the upper half of the body of a zebrafish embryo. The large cright circular region is the eye of the fish, while the small bright spots are droplets of fat.

22. **Rat Spinal Cord**
    Petter Ranefall, Carolina Wählby
    Partners: Lada Stålhandske, Wei Sun, Georgy Bakalkin, Dept Pharm Biosci, UU
    Funding: Science for Life Laboratory
    Period: 1506–
    Abstract: Our collaborators newly established an way of staining the activity in the endogenous opioid system in the rat spinal cord, and the aim of the project is to quantify the ammount and localization of mRNA staining. We have developed image analysis approaches for quantifying the amount of cells with positive signals and associate those to manually outlined regions of interest within the spinal cord of rats. We have applied our new method for local adaptive thresholding based on ellipse fit to segment nuclei, and use ilastik to classify positive/negative cells.

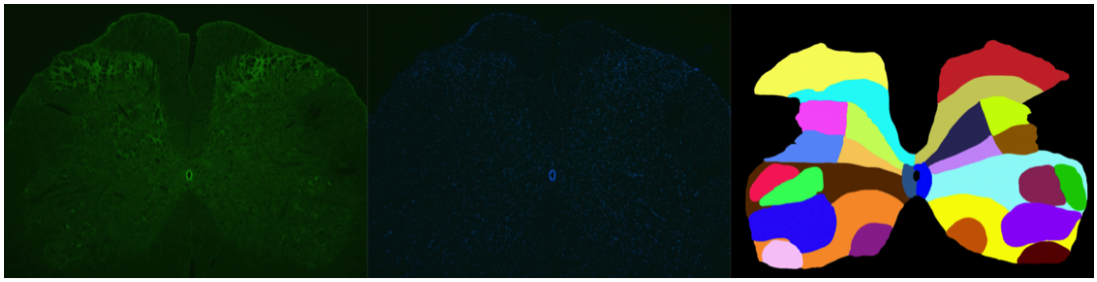


Figure 15: A cross section of a spinal cord of a rat. Left: general stain. Center: active cells. Right: manually drawn regions of interest representing different anatomical regions of the spine.

23. **Infiltration of T Cells in Thyroid Glands**
Petter Ranefall, Carolina Wählby
Partners: Susanne Kerje, Dept of Medical Biochemistry and Microbiology, UU
Funding: Science for Life Laboratory
Period: 1504–
Abstract: The aim of the project is to estimate the degree of infiltration of T cells in thyroid glands of chicken in order to better understand auto-immunity and rare genetic disease. We have developed an image analysis pipeline, using ilastik, CellProfiler, and some Python scripts, that extracts the regions of interest from the full glass slide images and classifies the tissue into infiltration or normal. The whole dataset contained 558 slides and the analysis was run on a powerful local server at the BMC.

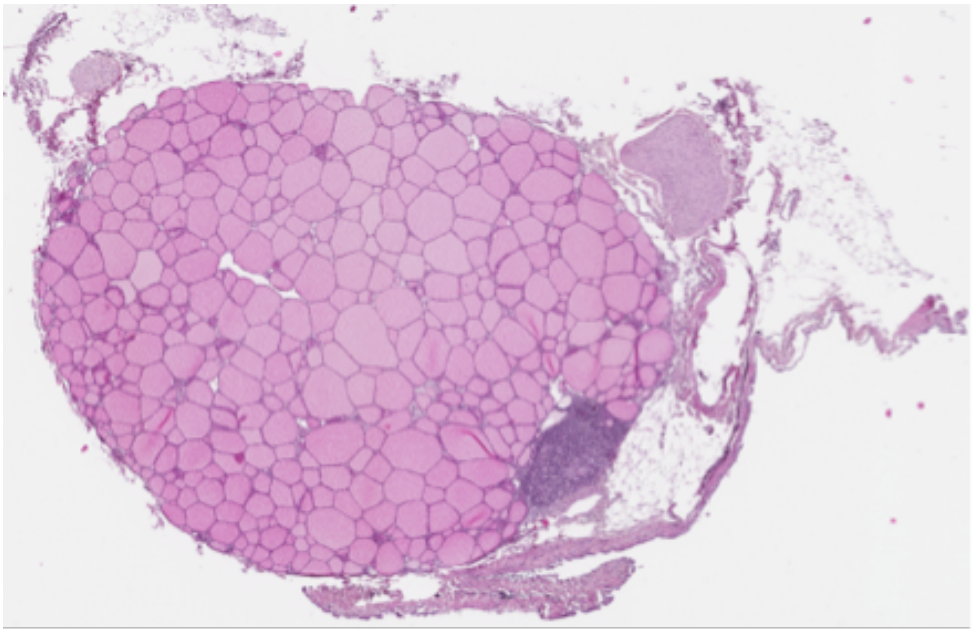


Figure 16: A thyroid gland from a chicken, and infiltrating T-cels.

24. **Ubiquitin Screen**
Petter Ranefall, Carolina Wählby
Partners: Johan Boström, Jordi Carreras Puigvert, Mikael Altun, Molecular Biochemistry and Biophysics, KI
Funding: Science for Life Laboratory
Period: 1502–
Abstract: Ubiquitin is a small protein that is found in almost all cellular tissues in humans and other eukaryotic organisms, which helps to regulate the processes of other proteins in the body. Cultured cells respond to treatments such as silencing of genes or exposure to radiation and/or drugs by changing their morphology, giving us hints on mechanisms of action. We develop methods for image-based high-throughput screening to identify subtle changes in individual cells, not accessible by bulk-methods, here focusing on the ubiquitin pathway.

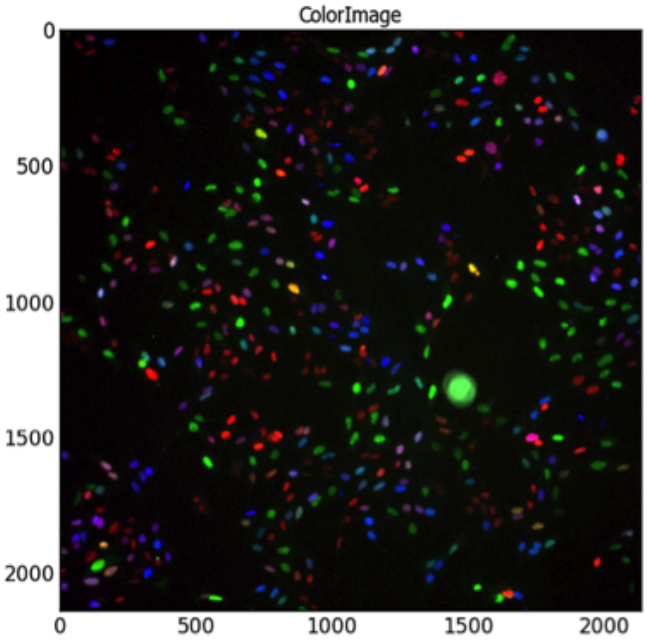


Figure 17: Fluorescence micrsocopy image of cultured cells, where the different colors reflect the cell cycle status.

25. **Cell Distribution and Protein Expression in the Ectocervix**
Petter Ranefall, Carolina Wählby
Partners: Anna Gibbs, Maria Röhl, Annelie Tjernlund, Dept. of Medicine, KI
Funding: Science for Life Laboratory
Period: 1504–
Abstract: This research project is focused on mucosal immunology in the female genital tract and HIV. The female genital mucosa presents a comprehensive natural immune defense against HIV infection, although during exposure to a high dose of virus this is not enough to protect the individual against viral transmission. Some individuals have a stronger resistance against HIV than others and therefore it is highly important to investigate which factors that contribute to an effective local protection against sexual infection. The aim of this study is to quantify gene expression in the target cells of HIV in ectocervix, and measure the distance to the vaginal lumen, as well as epithelial thickness. These parameters will be compared in women involved in sex work between the groups of HIV-infected, highly HIV exposed HIV uninfected that seems to be resistant, and HIV uninfected women who have been involved in sex work for a short period.

26. **Segmentation of Neurons**
Petter Ranefall, Carolina Wählby
Partners: Laureanne Pilar Lorenzo, Niklas Dahl, Dept of Immunology, Genetics and Pathology, UU
Funding: Science for Life Laboratory
Period: 1402–
Abstract: The goal of this project is to analyze neurons grown from stem cells in vitro.

The aim is to assess the percentage of neurons (using B-tubulin) and certain neuron subtypes (GABA) by immunofluorescence. We used CellProfiler to segment the cells and CellProfiler Analyst to classify positive cells.

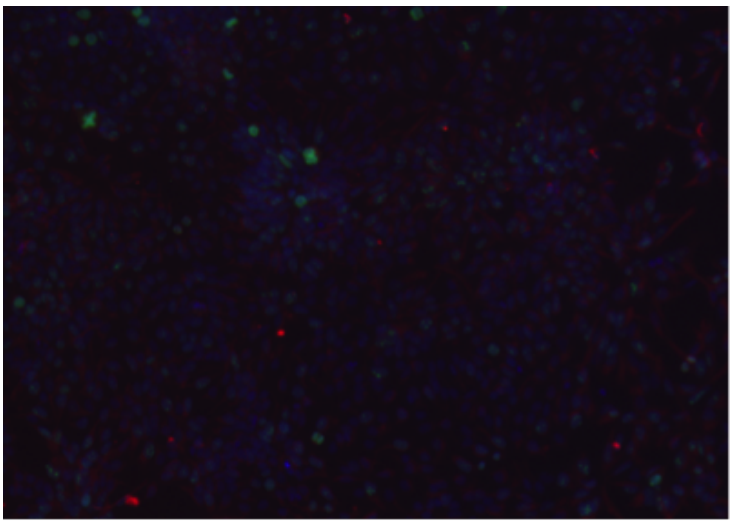


Figure 18: Fluorescence microscopy image of cultured neurons.

27. **Cell Time-Lapse Analysis**
Petter Ranefall, Carolina Wählby
Partners: Grigorios Kyriatzis, Jennifer Feenstra, Theresa Vincent, Physiology and Pharmacology, KI
Funding: Science for Life Laboratory
Period: 1410–
Abstract: The aim of the project is to interpret differences in migration-proliferation of cells with different treatments and express those in a quantitative manner. We used a 'scratch assay' approach, or 'wound healing assay' as it sometimes is called, where cells are grown in wells, and then the surface is 'scratched' and loose cells are washed away. Then the wells are imaged, possibly followed by adding a drug substance, and imaging the wells again at a suitable time interval. The area filled at time point T is a measure of the migration speed.

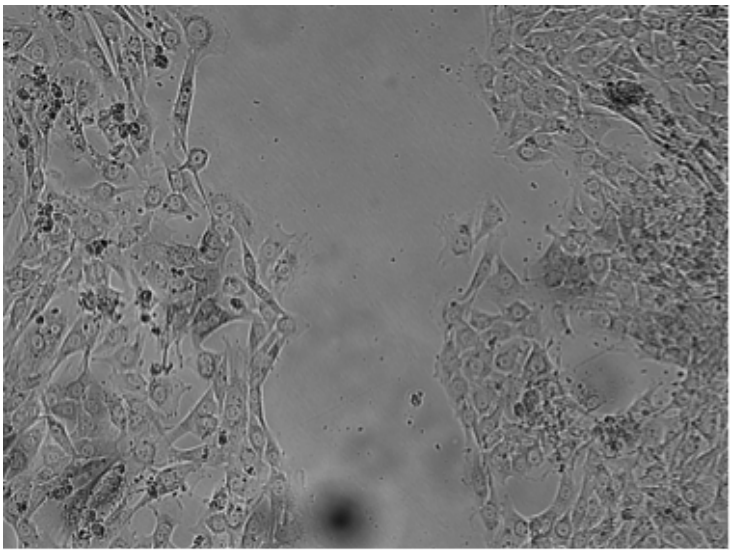


Figure 19: Bright field microscopy image of cultured cells growing (and moving) on a glass surface.

28. **Kidney Morphology and Topology of the Glomerular Filtration Barrier**
Petter Ranefall, Carolina Wählby
Partners: David Unnersjö Jess, Hans Gunnar Blom, Dept of Applied Physics, KTH
Funding: Science for Life Laboratory
Period: 1510–
Abstract: Our collaborators have developed a super-resolution immunofluorescence microscopy protocol for the study of the filtration barrier in the kidney. The aim of the project is to quantitatively evaluate the morphology and topology of the glomerular filtration barrier in the kidney. The most promising approach for analyzing these challenging 3D images seems to be a 3D version of the adaptive local thresholding based on ellipse fit.

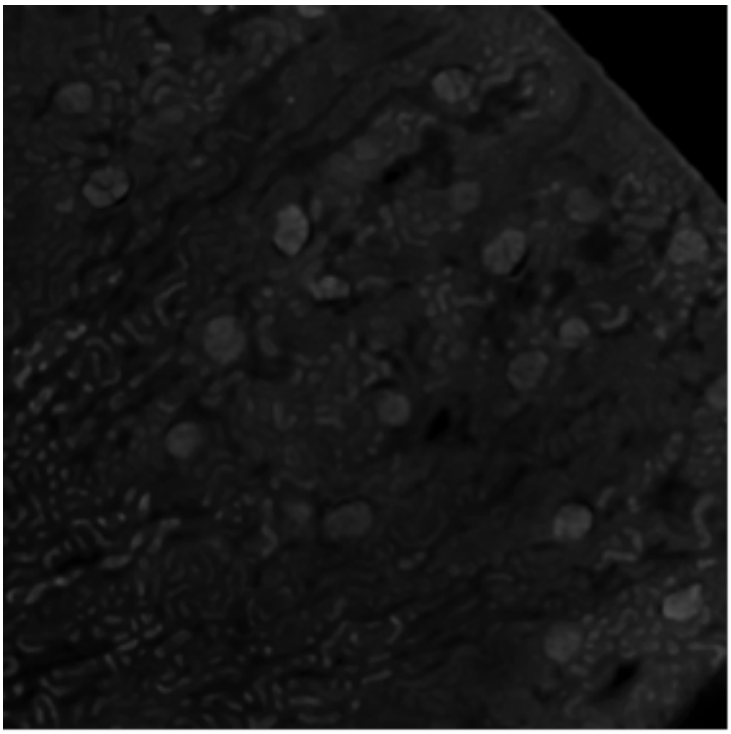


Figure 20: 2D projection of a super resolution image of the glomerular filtration barrier of the kidney.

29. **Vascular Networks**
Petter Ranefall, Carolina Wählby
Partners: Elisabet Olin, Ross Smith, Chiara Testini, Lena Claesson-Welsh, Dept of Immunology, Genetics and Pathology, UU
Funding: Science for Life Laboratory
Period: 1406–
Abstract: In this project we analyze vascular networks in the mouse brain, retina networks and cell junction activations. We have several applications where we skeletonize the networks and extract branch points in the skeleton. For the cell junction activations we have initially used an approach where we compute the area of the activated junctions (green) between the cells and use that as a measurement of activation.

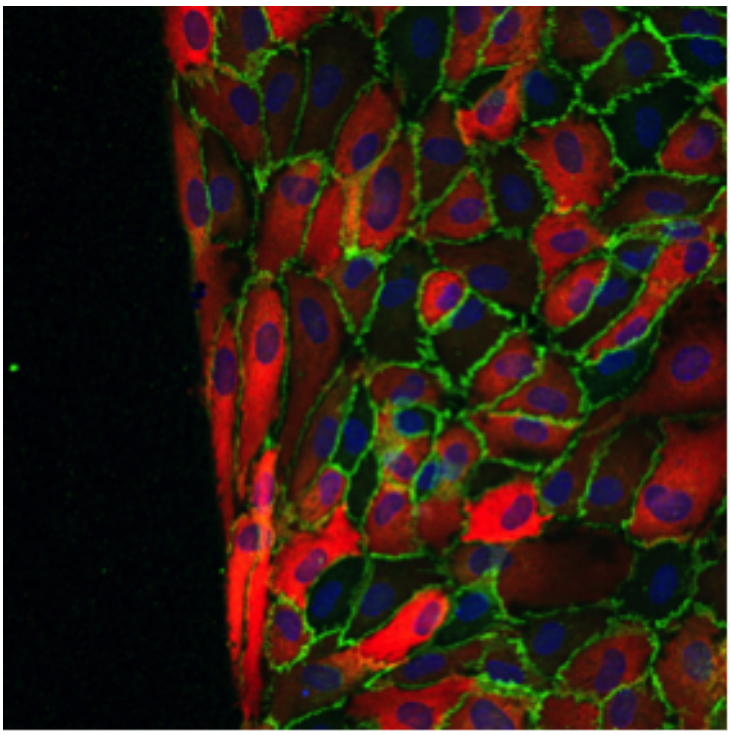


Figure 21: Fluorescence microscopy image of cultured cells, where cell nuclei are stained in blue, cytoplasms in red, and cell junctions in green.

30. **Objective Automated Quantification of Fluorescence Labeling in Histologic Sections of Rat Lens**
Carolina Wählby, Nanna Zhou Hagström
Partners: Per Söderberg and Nooshin Talebizadeh, Dept. of Neuroscience, UU
Funding: Science for Life Laboratory
Period: 1501–
Abstract: The lens epithelium of the eye is a single layer of cells covering the anterior face of the lens. In this project we study how UV light affects the lens epithelial cells by quantitatively analyzing fluorescent signal from biomarkers in cell nuclei and cytoplasms. We have developed an automated method to delineate lens epithelial cells and to quantify expression of fluorescent signal of biomarkers in each nucleus and cytoplasm of lens epithelial cells in a histological section.

31. **A Model System for Analysis of Spinal Cord Injury**
Carolina Wählby
Partners: Nils Hailer and Nikos Schizas, Dept. of Surgical Sciences, UU
Funding: Science for Life Laboratory
Period: 1501–
Abstract: Following spinal cord injury neurons die due to neurotoxicity and inflammation. We study these effects in a model system with spinal cord slice cultures, aiming to find methods to reduce neurotoxicity. Our focus is quantitative image analysis methods that delineate activated cells and quantify protein expression as a response to injury and treatment.

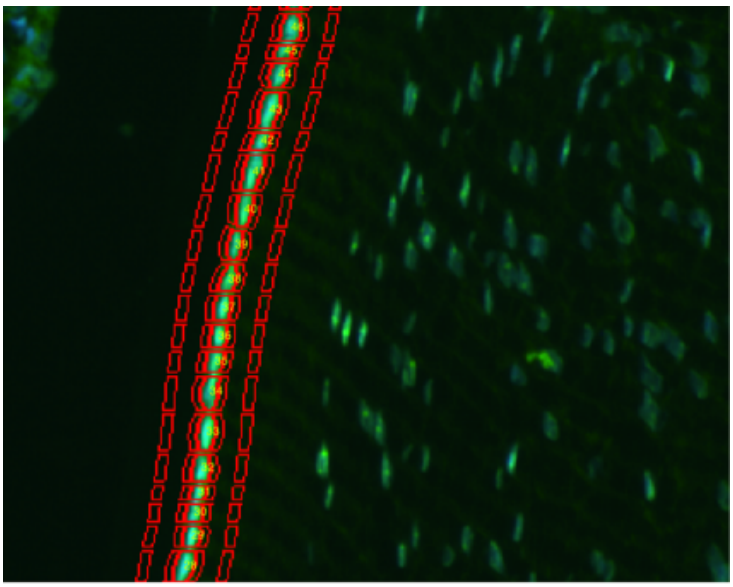


Figure 22: The bright cells in the lens epithelium are automatically delineated and regions of interest surrounding the cells are extracted in order to compensate for local variations in tissue thickness and staining.

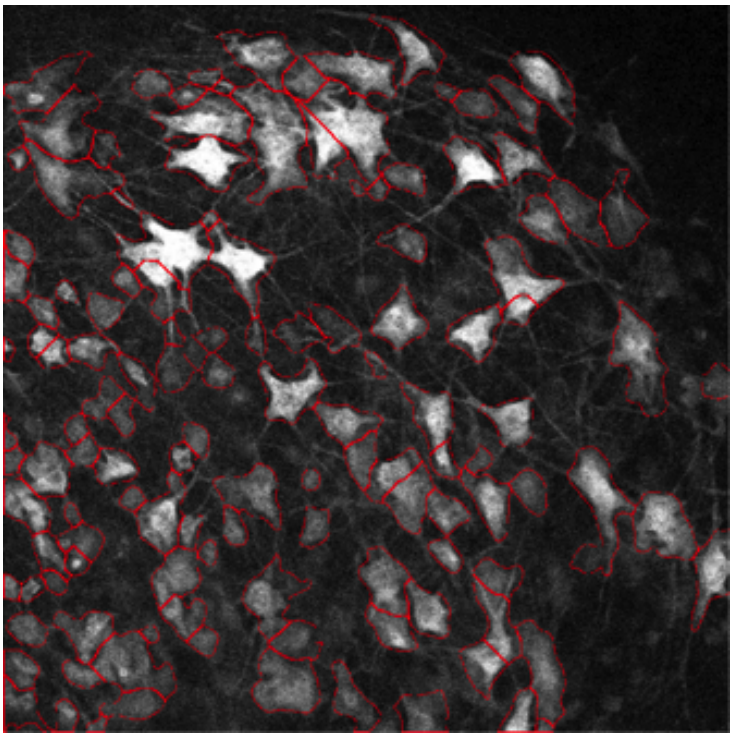
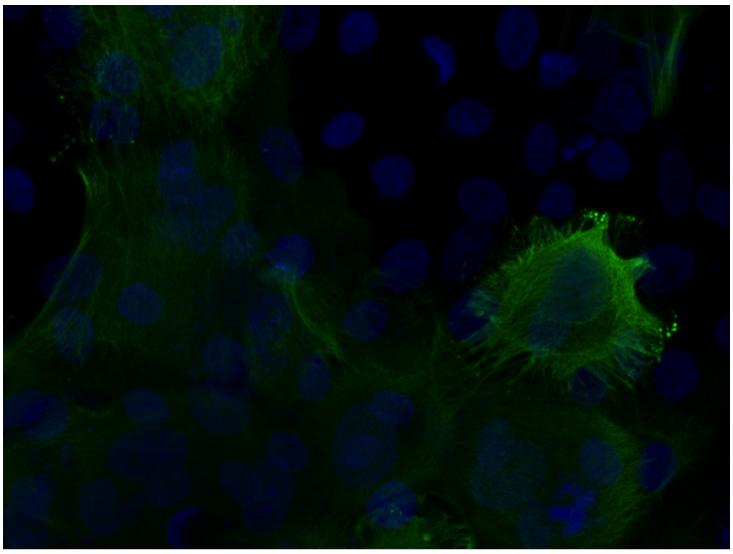


Figure 23: Confocal microscopy image with delineated neurons (red lines).

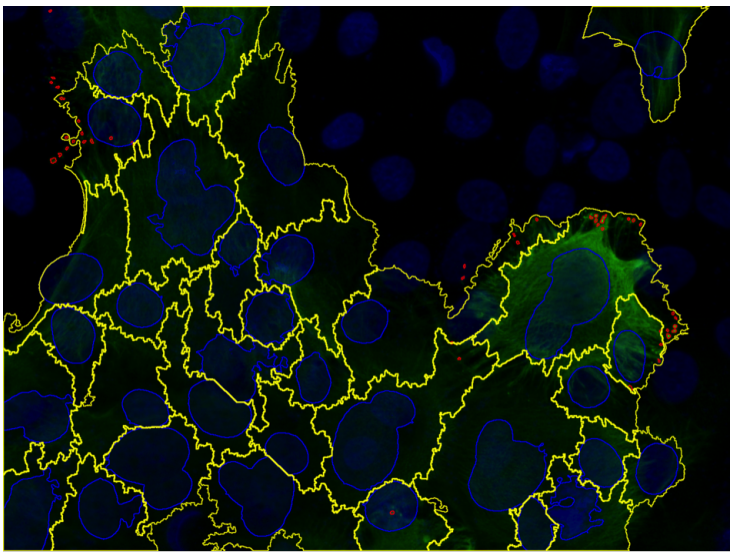
32. **Analysis of Keratin Aggregates**
Petter Ranefall, Carolina Wählby
Partners: Hanqian Zhang and Hans Törmä, Dept. of Medical Sciences, Dermatology and Venereology
Funding: Science for Life Laboratory

Period: 1510–

Abstract: Epidermolytic hyperkeratosis (EH) is a rare genetic skin disorder caused by mutation of keratin 1 or 10, and characterized by blistering in the epidermis and hyperkeratosis. The skin may blister easily following mechanical injury and exposure to heat etc. Immortalized keratinocyte cell lines were established by our collaborators at the Dept. of Medical Sciences, Dermatology and Venereology, and these cell lines show promise as a screening model to test new potential drugs for treating EH patients. Large-scale screening requires robust, efficient and effective image analysis methods, and we are currently developing methods to analyze keratin aggregates in cultured EH cells.



(a)



(b)

Figure 24: (a) Immunostaining of keratin 10 on EH keratinocytes after heat stress. The white arrows direct some keratin aggregates. (b) Overlay outlines of identified nuclei, cells, keratin aggregates upon raw image in blue, yellow, red, respectively, by using CellProfiler.

5.3 Other microscopic biomedical image analysis projects

33. **Automated Image Acquisition and Analysis in the MiniTEM Instrument**
Ida-Maria Sintorn, Gunilla Borgefors, Ewert Bengtsson
Partners: Vironova AB; Delong Instruments, Brno, Czech Republic
Funding: Eurostars 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.

Jointly with the partners Vironova and Delong Instruments the MiniTEM instrument has been developed in a Eurostars funded project. The MiniTEM instrument is a desk-top low voltage TEM designed for biological samples, with a high degree of automation regarding instrument alignment, image acquisition and analysis. It is 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). Since the prototype launch in 2014, the instrument and the image acquisition and analysis methods have been further developed and fine-tuned.

During 2015, applications using automated image acquisition and subsequent analysis were presented at SCANDEM2015 - the Annual Conference of the Nordic Microscopy Society, Jyväskylä, Finland, and at MC 2015 - the Microscopy Conference, Göttingen, Germany. The MiniTEM instrument was also used for the TEM analysis in the paper ”Asymmetric supercapacitors based on carbon nanofibre and polypyrrole/nanocellulose composite electrodes”, published in RSC Advances.

34. **Automated Multiscale Analysis of TEM Images for Improved Cost-Effective Diagnosis of Cilia Disorders**
Amit Suveer, Nataša Sladoje, Joakim Lindblad, Ida-Maria Sintorn
Partners: Anca Dragomir, Anders Ahlander, Dept. of Immunology, Genetics and Pathology, UU
Funding: Biomed SPARC Project initiative
Period: 1504–
Abstract: Dysfunctional immotile cilia are often due to genetic disorders, and results in respiratory infections, reduced female fertility and infertility in males. Transmission Electron Microscopy (TEM) is the standard technique for diagnosing cilia disorders. A highly manual and time consuming procedure is performed by an expert pathologist at the microscope to set a diagnosis. In this project, we are aiming at developing approach for automating the TEM imaging and analysis to significantly reduce the time and efforts required by an expert pathologist for diagnosis and enables improved and more accurate diagnosis.

Our strategy includes automated navigation of a microscope for systematically traversing a specimen (illustrated in Fig. 25a), and acquire low magnification (LM) images, exemplified in Fig. 25b. A fast automated analysis of such low resolution images leads to detection of regions highly populated with cilia; one such region is shown in Fig. 25c (in a mid-magnification (MM), only used for illustration). Once such a region is detected, high magnification (HM) images, see Fig. 25d are acquired and used for the final cilia detection and super resolution reconstruction to enhance the fine structural details used to

set a diagnosis.

The overview of the project, with some preliminary results was presented at Medicinteknikdagarna'15, Uppsala, Sweden in October 2015. Initial results related to the super resolution reconstruction were presented at the 5th International Conference on Image Processing Theory, Tools and Applications IPTA'15, Orleans, France in November 2015. Results related to analysis and cilia detection at LM will be presented at the International Symposium for Biomedical Imaging, ISBI'16, Prague, Czech Republic in April 2016.

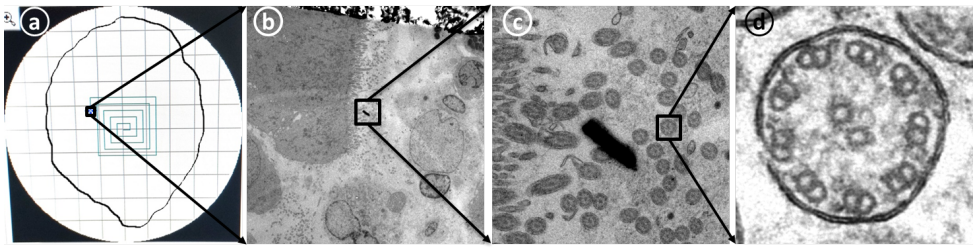


Figure 25: A sequence of images illustrating the vast search space in cilia detection, as well as images of different magnifications used in the automated analysis. a) Sample grid with FOV = 2.5 mm. b) Section of LM image with FOV = 30.3 μm c) section of MM image with FOV = 3.8 μm d) Single cilium HM image with FOV = 300 nm.

35. **CerviScan**
Ewert Bengtsson, Bo Nordin
Partners: Rajesh Kumar, Centre for Development of Advanced Computing (CDAC), Thiruvananthapuram, Kerala, India; K. Sujathan, Regional Cancer Centre, Thiruvananthapuram, Kerala, India
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.

The original research funding has expired. Plans for the next phase of the project, focusing on dedicated hardware, are awaiting the result of funding applications in India and Sweden. In the meantime we have had funding for our collaboration from the Swedish

Research Links Programme. The initial term for that funding expired at the end of 2015 but a new period has been granted for 2016-2018.

The project has resulted in several recent publications. Patrik Malm defended his PhD thesis closely linked to this project in February 2014. During 2015 two workshops were held within the project, one in India in March and one in Uppsala in October.

36. **Analysis of Sperm Vitality**
Ewert Bengtsson, Patrik Malm
Partners: Garcìa-Olalla, O., Alegre, E., Fernández-Robles, L. University of León, Industrial and Informatics Engineering School, León, Spain.
Funding: UU Faculty
Period: 13–15
Abstract: In our work on cervical cell image analysis in the CerviScan project we developed methods for Fourier shape analysis of cell nuclei. In collaboration with our partners in this project we tested whether those methods also could contribute to determine whether sperms to be used for artificial insemination were vital i.e. could be classified as acrosome-intact or acrosome-damaged. It turned out that the shape analysis when combined with previously used texture based features could lead to a classification accuracy of 99.13%, significantly better than previously used approaches. The results were published in the CMPB journal during 2015.

37. **Image Analysis in the ExDIN Digital Pathology Networks**
Ewert Bengtsson, Carolina Wählby, Petter Ranefall
Partners: RxEye company, Groups at Karolinska Institute plus county council pathology labs.
Funding: Vinnova
Period: 15–16
Abstract: The ExDIN project aims at developing an operational collaborative network structure for doing routine histopathological diagnoses using digital images transmitted over networks rather than the traditional way, optically through a microscope. When the histopathological slides are scanned and made available over the network it becomes much easier to apply various computer assisted image analysis approaches than when the routine analysis is done directly in a microscope in which case computer analysis requires separate scanning steps. Our role in the project is to investigate the state-of-the-art in computer assisted image analysis applied to histopathological diagnosis. Are there any methods available today that are sufficiently mature and robust to be applied routinely in this way? We are carrying out a literature study to answer this question but have also taken the initiative of a special issue of the Cytometry journal addressing this question. For 2016 we are planning a pilot study demonstrating how existing image analysis methods could be applied to images from the EDIN network.

38. **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: 1009–1506
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 have developed automatic and interactive methods to analyse the relevant structures in the histology images of testis, and published them in PLOS ONE.

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 have developed a texture-based classification method to determine each tubule's stage. These results have been submitted for publication.

39. **CADESS, A Decision Support System for the Prognostication of Prostate Cancer**
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; Dept. of Surgical Sciences; Vinnova VFT-1; Handelsbankens Innovationsstiftelse
Period: 1501–1512
Abstract: CADESS is a proprietary technology combining consensus-graded tissue data and a new tissue stain with powerful AI and Machine Learning tools: knowledge-based systems, deep learning, and sophisticated classifiers for automatic malignancy grading.

The 13 pathologists completed the grading begun in 2014 of the 650 prostate tissue images that each contained one dominant pattern. We observe a similar grade variation in this dataset as seen in other studies. Below we illustrate one case of divergence in our data, using a 2D projection of a high-dimensional graph that illustrates the agreement of the Gleason score $\leq$ 3+4 versus $\geq$ 4+3. Each pathologist is represented by a circle and the distance between each pair of pathologists represents the percentage of agreement. A shorter distance represents a closer agreement.

In September, 2015 the pathologists met in Uppsala to reach a consensus grade for these images. While during the meeting we managed to reach a complete consensus for 92% of the images, we reached no consensus on 3% of the images, for which the pathologists were almost evenly divided between Gleason score $\leq$ 3+4 and $\geq$ 4+3. This is the most crucial demarcation line for prognostication. We are in the process of analyzing the cause of this grading divergence.

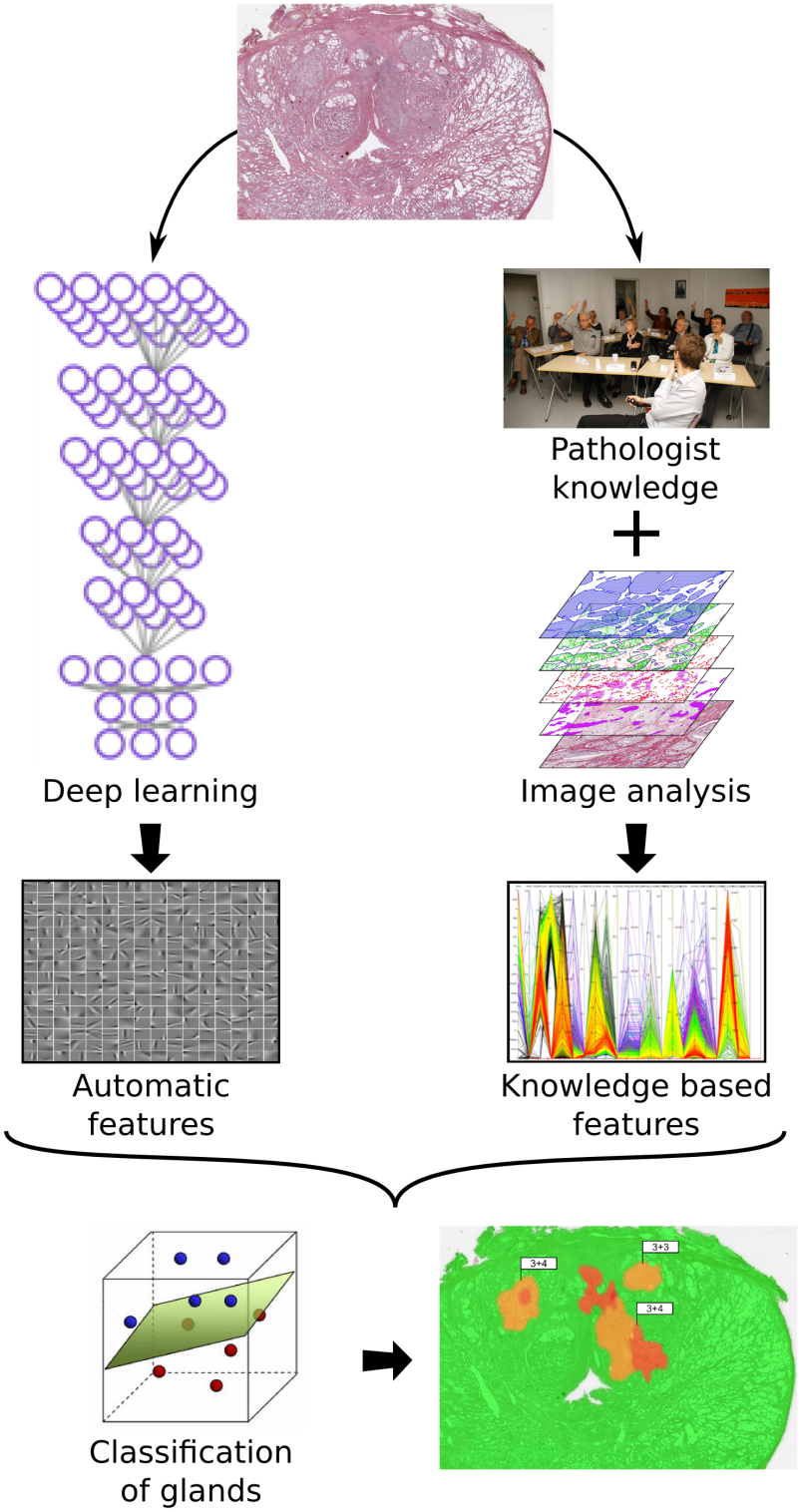


Figure 26: The user gives a Gleason Score below the image or indicates PIN or benign as the primary pattern

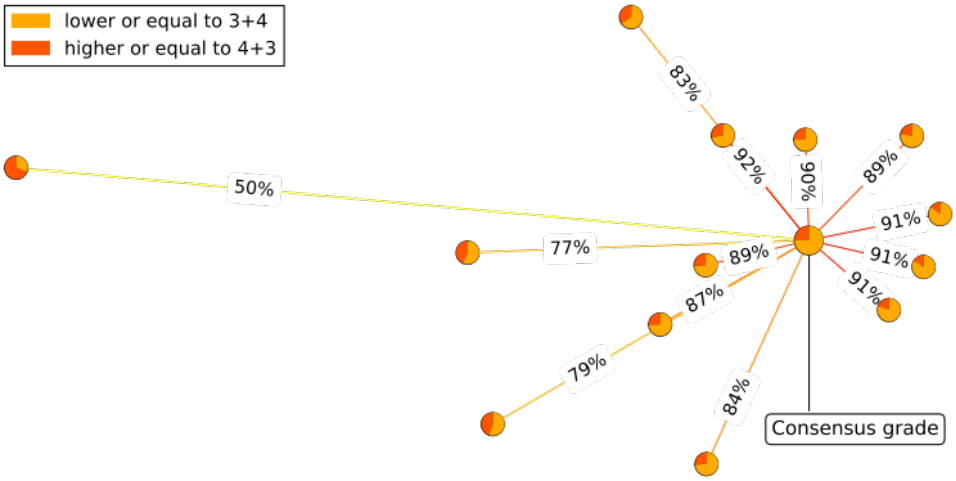


Figure 27: The user gives a Gleason Score below the image or indicates PIN or benign as the primary pattern

40. **Advanced Methods for Reliable and Cost Efficient Image Processing in Life Sciences**
Nataša Sladoje, Ewert Bengtsson, Ida-Maria Sintorn
Partners: Joakim Lindblad, Marija Delić Faculty of Technical Sciences, University of Novi Sad, Serbia
Funding: VINNOVA; UU TN-faculty
Period: 1308–
Abstract: Within this project 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.

Efficient utilization of available image data to characterize barely resolved structures, is crucial in both the considered applications. We rely on theoretical work within the framework of discrete mathematics, which 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.

During 2015, we have studied ways to incorporate fuzzy set theory into the framework of Local binary pattern (LBP) descriptors, popular in texture classification in recent years. We proposed, and evaluated, two new LBP descriptors, α-LBP and its improved variant IαLBP. We have observed particularly good performance of the proposed descriptors on images from the Virus dataset. We have summarized the results of this study in a paper published in Proceedings of the 9th IEEE International Symposium on Image and Signal Processing and Analysis (ISPA), IEEE, and presented in Zagreb, Croatia, in September.

We have also proposed a simple and fast method for microscopy image enhancement and quantitatively evaluated its performance on a database containing cell images obtained from microscope setups of several levels of quality. The method utilizes an efficiently and accurately estimated relative modulation transfer function to generate images of higher quality, starting from those of lower quality, by filtering in the Fourier domain. We have observed that images enhanced by the proposed method exhibit high similarity, both visually and in terms of information content, with acquired high quality images. This is

an important result for the development of a cost-effective screening system for cervical cancer. The results are published in proceedings of the 19th Scandinavian Conference on Image Analysis (SCIA), in Lecture Notes in Computer Science series, and presented in Copenhagen in June.

41. **Utilizing out of Focus Information for Improved Liposome Delineation in Cryo-EM Images**
Petter Ranefall, Carolina Wählby
Partners: Gustaf Kylberg, Ida-Maria Sintorn, Vironova
Funding: SSF
Period: 1501–1504
Abstract: Analysis of focus-series of different liposome samples. The aim was to investigate whether out of focus images were useful for finding seeds or markers for the liposomes in the in focus images. We have applied a new approach where we utilize a combination of several out of focus images for segmentation, not just finding one appropriate out of focus setting. The proposed approach has shown initial promising results and is at least as fast as the previous approach. As it turned out during the acquisition of data for the project the practical benefits were not immediately reached. However, with automation work in electron microscopy performed at Vironova these types of focus series will be easier to acquire.

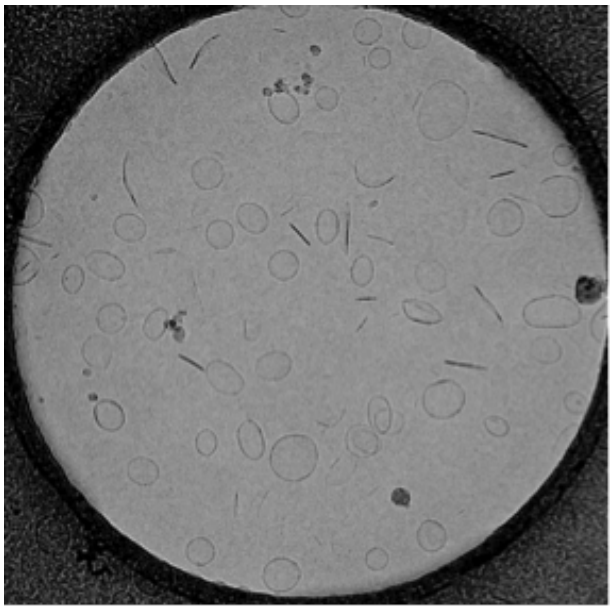


Figure 28: Electron microscopy image of liposomes.

42. **Lungfish brain-endocast relationship**
Robin Strand, Johan Nysjö, Petter Ranefall, Carolina Wählby, Filip Malmberg
Partners: Alice M. Clement and Per E. Ahlberg, Dept. of Organismal Biology, UU
Funding: TN-faculty
Period: 1501–
Abstract: Lungfish, the closest living group of fish to the tetrapods, first appeared in the geological record over 400 million years ago. Palaeoneurological investigations show that lungfish appear to have had a close fit between the brain and the cranial cavity that housed it. In this project, we describe and quantify the spatial relationship between the brain

and the neurocranium in lungfish. We have developed a software tool based on distance transforms to both analyse and present the data.

5.4 General theory and tools

43. **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 an image segmentation method 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. We have also proposed 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.

During 2015, we published a paper describing a method for combining the perturbation-based approach with the deterministic algorithm. We also submitted a manuscript describing a method for exact evaluation of stochastic watersheds applied to supervised, or *targeted*, image segmentation.

44. **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: 1101–1506
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 presented a paper at the International Symposium on Mathematical Morphology (ISMM) describing the very first adaptive Hit-or-Miss transform. We showed how making this filter adaptive makes it better at detecting faint signals in a noisy background.

45. **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 2015, a manuscript on optimal path extraction and spatially-varying cost functions was accepted for the DGCI 2016 conference.

46. **Precise Image-Based Measurements through Irregular Sampling**
Teo Asplund, Robin Strand, Cris Luengo, Gunilla Borgefors
Partner: Matthew Thurley, Luleå University of Technology, Luleå
Funding: Swedish Research Council
Period: 1604–
Abstract: Operations within mathematical morphology depend strongly on the sampling grid, and therefore in general produce a result different from the corresponding continuous-domain operation. Ideally image-based measurements are sampling invariant, however the morphological operators are not, because firstly: the output depends on local suprema/infima, but it is very likely that local extrema fall between sampling points. Secondly: the operators produce lines along which the derivative is not continuous, thereby introducing infinitely high frequencies which make the result not band limited. Therefore the result cannot be represented using the classical sampling theorem. Finally: the structuring element is limited by the sampling grid.

To tackle these issues we will use irregular sampling to capture local maxima and minima and increase the sampling density in areas with a non-continuous derivative. Another benefit of moving towards mathematical morphology on irregularly sampled data is that this allows us to use morphological operators on irregularly sampled data without resampling and interpolating.

47. **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.

During 2015, we have studied performances of energy minimization based restoration methods for enhancing images degraded with blur and one of the three considered noise types - Gaussian, Poisson and mixed Poisson-Gaussian. In the case of degradation with Poisson noise, we observe both a Bayesian approach, and an approach based on Anscombe variance stabilizing transformation (VST), and we compared their performances. For the restoration of images degraded with blur and mixed Poisson-Gaussian noise we consider generalized Anscombe VST. For all the three considered types of noise, we explored utilization of Huber potential function in regularization, both in combination with Bayesian and with VST approach.

We have summarized the results obtained in a large empirical study on images affected

by different levels of Gaussian, Poisson and mixed Gaussian-Poisson noise and different sizes of the Point Spread Functions in a paper which is currently under evaluation. We concluded that restoration utilizing Huber potential function outperforms classical Total Variation regularization, and that, for higher levels of noise (lower counts), VST approach outperforms Bayesian.

We have presented some of these results at the Swedish Symposium on Image Analysis, organized in Ystad in March 2015.

We have also observed so-called blind deblurring methods, applicable when the Point Spread Function (PSF) is unknown, and both the PSF and the original image have to be simultaneously reconstructed. We were particularly focused on a noise model which is a mixture of Poisson (signal dependent) and Gaussian (signal independent) noise. We have proposed a blind deconvolution method, based on regularized energy minimization, for images degraded by such mixed noise. We have applied it to Transmission Electron Microscopy images of cilia and summarized the results in a paper which we will present at the IEEE International Symposium on Biomedical Imaging, ISBI 2016.

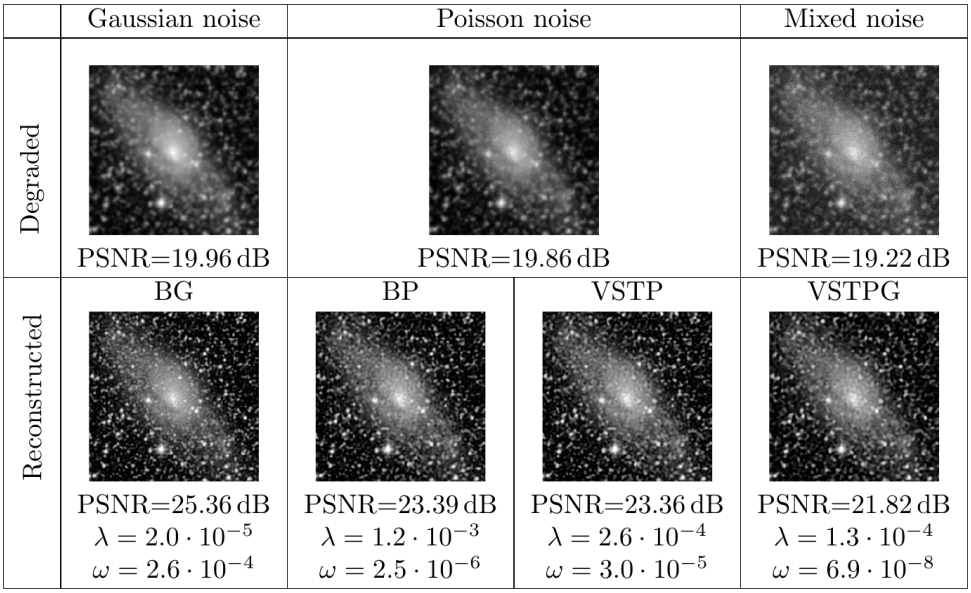


Figure 29: (Top) An astronomical image degraded with blur and different types of noise. (Bottom) Reconstructed images by using spectral projected gradient to minimize different Huber regularized energy functions. Regularization parameters λ and ω are optimized to maximize the peak signal-to-noise ratio.

48. **Coverage Model and its Application to High Precision Medical Image Processing**
Nataša Sladoje
Partners: Joakim Lindblad, Vladimir Ilić, Faculty of Technical Sciences, University of Novi Sad, Serbia
Funding: TN-faculty, UU
Period: 1409–
Abstract: The coverage model, which we have been developing for several years now, provides a framework for representing objects present in digital images as spatialfuzzy 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 2015, we have developed two algorithms of linear time complexity for estimating the Euclidean Distance Transform (EDT) with sub-voxel precision. Due to discretization effects, distance transforms defined on a binary image have limited precision, including reduced rotational and translational invariance. We have showed that significant improvement in performance of EDTs can be achieved if voxel coverage values are utilized and the position of an object boundary is estimated with sub-voxel precision. The study is published in the Pattern Recognition Letters journal.

We have also proposed a method for computing, in linear time, the exact EDT of sets of points s.t. one coordinate of a point can be assigned any real value, whereas other coordinates are restricted to discrete sets of values. The proposed distance transform is applicable to objects represented by grid line sampling, and readily provides sub-pixel precise distance values. The method shows very good performance and exhibits a number of appealing properties, such as simple implementation, easy parallelization, straightforward extension to higher dimensions. The results of this study are published in proceedings of the 12th International Symposium on Mathematical Morphology (ISMM), and presented in Reykjavik, Iceland, in May.

In 2015, our work on the coverage model included development of a coverage segmentation method for extracting thin structures in 3D images. The method needs a reliable crisp segmentation as an input and uses information from local linear unmixing and the crisp segmentation to create a high-resolution crisp reconstruction of the object, which can then be used as a final result, or down-sampled to a coverage segmentation at the starting image resolution. We suggested implementation that enables low memory consumption and processing time, and by that applicability of the method on real CTA data. The study is published in proc. of the 5th Intern. Conference on Image Processing Theory, Tools and Applications, IPTA 2015, and presented in Orleans, France, in November.

49. **Predictive Modelling of Real Time Video of Outdoor Scenes Captured With a Moving Handheld Camera**
Nataša Sladoje
Partner: Joakim Lindblad, Protracer AB, Stockholm
Funding: Swedish Governmental Agency for Innovation Systems (VINNOVA); UU; TN-faculty
Period: 1510–
Abstract: This project is inspired by the growing market demand for real time matchmoving technologies in sports broadcasting. Matchmoving, also referred to as video tracking or camera tracking, is a technique that allows 3D computer graphics to be inserted into a live broadcast to enhance the visual experience for the viewing audience. The major technological and functional limitation of existing real time matchmoving technology is its reliance on cameras installed on stands and on a known background settings. Within this project, we will work towards development of a software for robust predictive modeling (statistical analysis) of real time video of outdoor scenes captured with a moving handheld camera. We want to be able to identify, track and trace sub-pixel sized objects moving at speed within a free moving video stream. This is a collaborative project with Protracer AB, the world-leading provider of ball tracking technology.

Figure 30: Protracer is a world leading provider of ball tracking technology. Products include real-time tracking and display of golf shots in TV broadcasts. This project aims to bring their technology to a more dynamic environment.

50. **Feature Point Descriptors for Image Stitching**
Anders Hast, Ida-Maria Sintorn, Damian Matuszewski, Carolina Wählby
Partner: Vironova AB; Dept. of Electronic Computers RSREU, Ryazan, Russia
Funding: TN-faculty; UU; Science for Life Laboratory
Period: 1501–
Abstract: When microscopy images are to be put together to form a larger image than one field of view, images are stitched together based on key point features in the images. Several methods for matching these images exist, but are often general in the sense that they can handle scale and rotation, which are not present in this particular case. Therefore, these methods are like cracking a nut with a sledge hammer, and we have investigated how simpler and therefore more efficient and also faster methods can be developed and applied for solving this task. Several key point descriptors have been investigated that are based on new sampling strategies and also new ways of combining these samples, using for instance elements of the Fourier transform, instead of histograms of gradients etc. A paper describing two versions of fast and simple feature point descriptor with or without rotation invariance was presented at the WSCG conference.

The whole pipeline of matching has been investigated and several improvements have been suggested. We have shown that for instance RANSAC can be substituted by a fast clustering method, which makes computation of the transformation between images and false positives removal not only faster, but also deterministic, which otherwise is a problem with RANSAC as it is based on a random sampling approach. This alternative to RANSAC was presented at the second workshop on Features and Structures (FEAST), co-located with the International Conference on Machine Learning, Lille, France, in July.

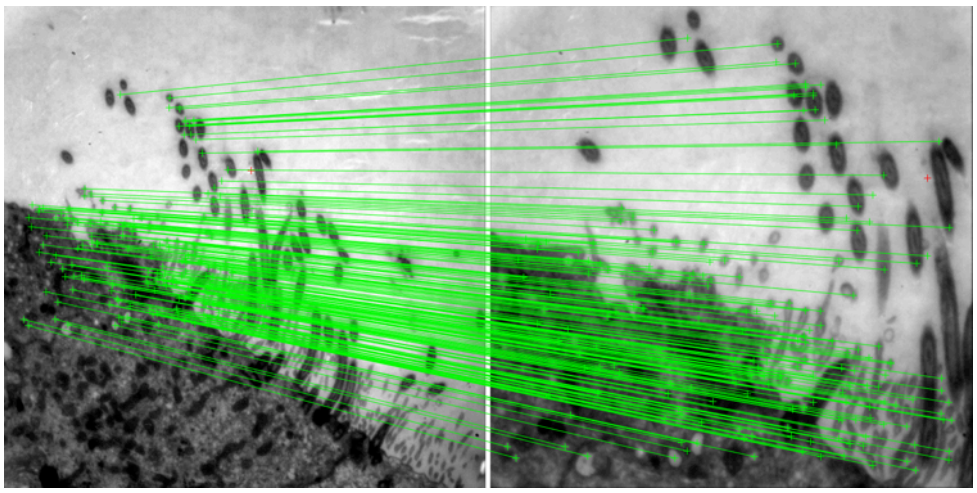


Figure 31: Sample results of region matching in TEM images.

51. **Regional Orthogonal Moments for Texture Analysis**
Ida-Maria Sintorn, Carolina Wählby, Amit Suveer
Partner: Vironova AB; Dept. of Immunology, Genetics and Pathology, UU
Funding: Swedish Research Council
Period: 1501–
Abstract: The purpose of this project is to investigate and systematically characterize a novel approach for texture analysis, which we have termed Regional Orthogonal Moments (ROMs). The idea is to combine the descriptive strength and compact information representation of orthogonal moments with the well-established local filtering approach for texture analysis. We will explore ROMs and quantitative texture descriptors derived from the ROM filter responses, and characterize them with special consideration to noise, rotation, contrast, scale robustness, and generalization performance, important factors in applications with natural images. In order to do this we will utilize and expand available image texture datasets and adapt machine learning methods for microscopy image prerequisites. The two main applications for which we will validate the ROM texture analysis framework are viral pathogen detection and identification in MiniTEM images, related to project 33 and glioblastoma phenotyping of patient specific cancer stem cell cultures for disease modeling and personalized treatment, see project 17.

52. **Digital Hyperplanes**
Christer Kiselman
Partner: Adama Koné, Université des Sciences, des Techniques et des Technologies de Bamako, USTTB, Bamako I (Mali)
Period: 1001–
Abstract: Digital planes in all dimensions are studied. The general goal is to generalize to any dimension the results of Kiselman's 2011 paper in Mathematika. An important part of the study was finished with Adama's thesis, presented on 2016 January 16. There are, however, several possible generalizations to be investigated.

53. **Convexity of Marginal Functions in the Discrete Case**
Christer Kiselman
Partner: Shiva Samieinia, KTH
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, joint with Shiva, was accepted on 2015 April 11. Several generalizations are now being studied.

54. **Euclid's Straight Lines**
Christer Kiselman
Period: 0701-1503
Abstract: This project was 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. Finished with a publication in Normat.

55. **Discrete Convolution Equations**
Christer Kiselman
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 are studied. Now duality of convolution will be investigated. A paper was published on 2015 May 07 in Mathematika. A second paper was submitted on 2015 December 31.

56. **Mathematical Spaces / Mathematical Rooms**
Christer Kiselman
Partner: Hania Uscka-Wehlou
Period: 1310-1503
Abstract: A survey of mathematical spaces, mathematical terminology, Euclidean and digital geometry, discretization of space and time, tropical mathematics, mathematical morphology, research policy, evaluation of research. Finished with a publication in Sundelöfs Societet.

57. **Complex Convexity**
Christer Kiselman
Period: 6710–
Abstract: A bounded open set with boundary of class C^1 which is locally weakly lineally convex is weakly lineally convex, but, as shown by Yuriĭ Zelinskiĭ, this is not true for unbounded domains. We construct explicit examples, Hartogs domains, showing this.

Their boundary can have regularity $C^{1,1}$ or C^∞. Obstructions to constructing smoothly bounded domains with certain homogeneity properties are presented.

There are several publications in this project. The latest manuscript was accepted on 2015 May. A current activity is a study of one-sided regularity of subsets of $\mathbf{R}^n$ or $\mathbf{C}^n$, presented in an invited lecture at Stockholm University on September 16.

58. **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: ERC grant to Bernd Rieger
Period: 0807–1506
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.

During 2015 we looked for and obtained funding to port the DIPlib library to C++ and modernise its infrastructure. When this port is finished, DIPlib and DIPimage will become open source projects.

5.5 Other applications

59. **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: 1402–1506
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-cellular resolution. In this project, we developed tools to create the first such map for a plant species. We prepared thin sections of the root, hypocotyl and stem of the plant at various stages between sprouting and maturity. These sections were fluorescently stained such that the cell walls could be visualised in the confocal microscope. Each section also received a FISH (fluorescent in situ hybridization) stain for a particular protein. Sections were then imaged at a magnification that allowed most of the section to fit in the field of view.

    This yielded several thousand cells in each image. Next, we developed a fully automatic segmentation and quantification pipeline that allowed measurement of relative amount and quality of the stained protein in each sub-cellular area (wall and lumen were separated, and each divided into four regions: inner, outer and two lateral). Cells were automatically classified into the various cell types, which allowed statistics of expression over each of the cell types, for example. We imaged several thousand sections, from both wild-type and mutant samples, stained for hundreds of different genes. The methods and some preliminary results will appear in Frontiers in Plant Science.

60. **Stereo Visualisation of Historical Aerial Photographies**
Anders Hast
Partners: Andrea Marchetti, IIT, CNR, Pisa, Italy. Andrea Fusiello, Francesco Malapelle, University of Udine, Italy.
Period: 1101–
Abstract: Stereo images are important as they give a much better understanding of what is actually seen on the ground than single photos ever can. The important factor is the depth cue that helps understanding the content and adds the ability to distinguish between bushes and trees, stones and pillars, hills and valleys etc. During the operation Crossbow, the English meticulously photographed Europe during WWII to obtain stereo photos, which helped them in their search for military objects. This rich source of information that is now provided by the AFN in Rome, as well as other archives can be utilised by archeologists in a similar way. There are however still challenges to be faced in order to create useful stereo images that we have addressed and there are many possibilities and advantages. Together with IIT at CNR in Pisa, Italy, we have published papers in two international conferences discussing these things, namely Computer Applications and Quantitative Methods in Archaeology (CAA) in Siena, Italy and Digital Heritage in Granada, Spain. Moreover, in a collaboration with the University of Udine in Italy, we have published a new method for synthesising new views from photos at the International Conference on 3D Imaging in Liege, Belgium, making it possible to look at the stereo pairs from different views, which is otherwise not possible. A collaboration with several universities in Spain lead to a publication in which it was investigated how tumulus can

be searched in what is now submerged megalithic landscape. All this, thanks to the fact that historical aerial photos are available and can be converted into stereo representation.

61. **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.

62. **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. During 2015 we successfully analyzed over 10000 manuscript pages form the collection Svenskt Diplomatarium, from Riksarkivet. Using our newest methods, combining both image and text information, we are able to estimate the production date of a manuscript in this collection with a median error of less than 12 years. We were also successful in applying for a new grant from Riksbankens jubileumsfond, securing five new years of funding and a total budget of 13.4 MSEK. The title of the application was ”New Eyes on Sweden’s Medieval Scribes. Scribal Attribution using Digital Palaeography in the Medieval Gothic Script” and has Lasse Mårtensson as PI.

63. **Optical Character Recognition of Handwritten Texts**
Anders Brun, Ewert Bengtsson, Fredrik Wahlberg, Tomas Wilkinson, Kalyan Ram, Anders Hast
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; Jonas Lindström, Dept. of History, UU
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. We submitted several grant applications and continued a collaboration with the Swedish Museum of Natural History. The application to Riksbankens jubileumsfond was successful, resulting in a new spinn-off project that will add support for five new year of research on digital paleography. Promising results during the year include a novel word segmentation algorithm, refinements of

image based word clouds, novel algorithms for word spotting, continuing the development of large scale analysis of medieval letters and cluster based transcription of documents. The most recent work was presented on the Digikult event in Gothenburg and we have also been featured in the university newspaper Universen.

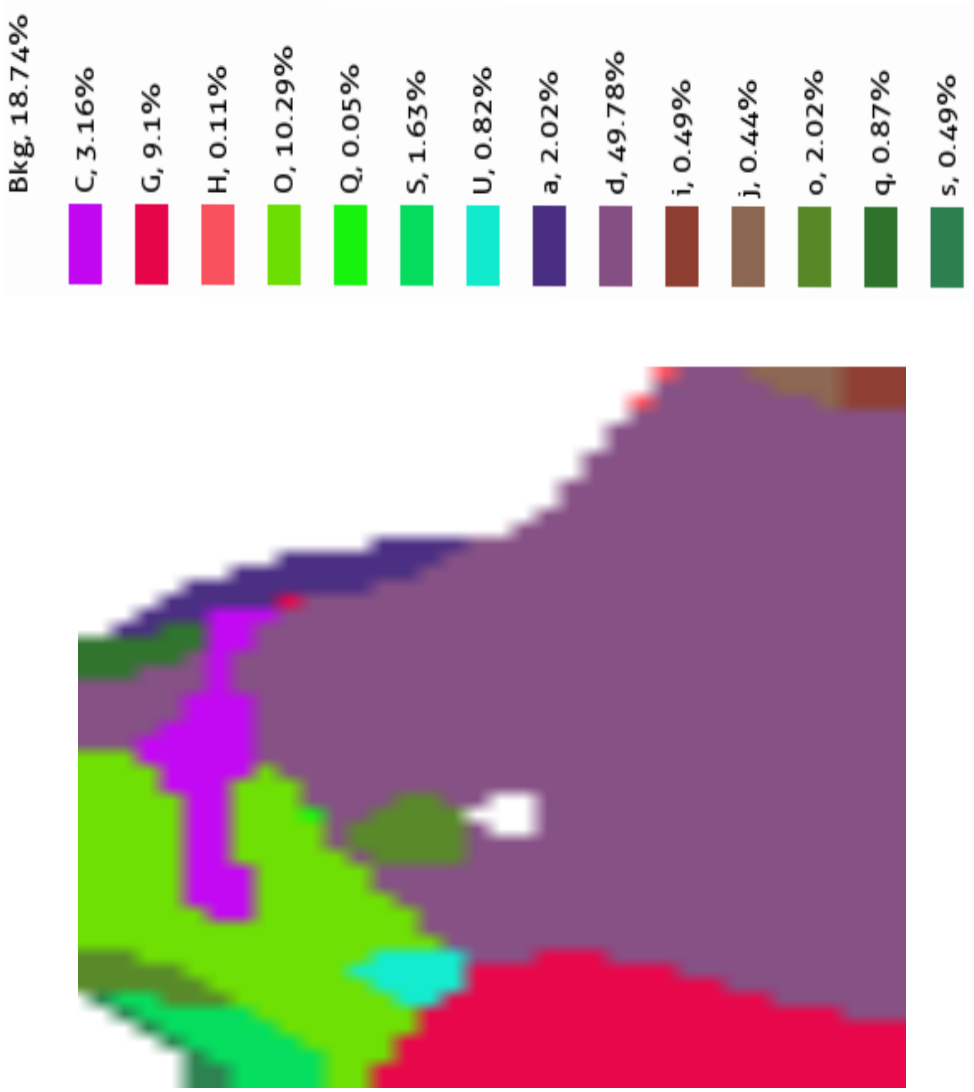
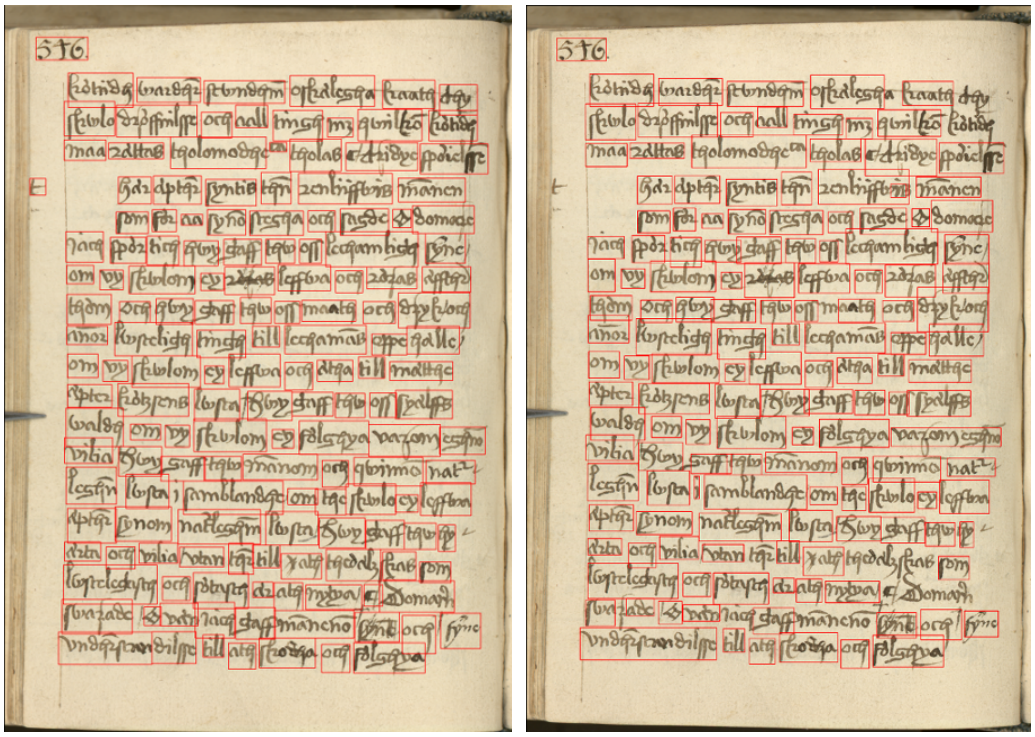


Figure 32: The figure shows classification of each pixel of the alphabet 'd' as background pixel or as a part of one of lower or upper case character based on dense-SIFT feature with Markov Random Field.

64. **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.



(a) (b)

Figure 33: Word segmentation results on a page from C61, a manuscript presumed to be written in the early 16th century in old Swedish. (a) shows the ground truth word segmentation and (b) shows the results of our algorithm.

5.6 Cooperation partners

International

Dept. of Sciences, Museum Victoria, Victoria, Australia

Universidad de los Andes, Bogota, Colombia

Delong Instruments, Brno, Czech Republic

Visiopharm, Hørsholm, Denmark

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

IRCCyN, University of Nantes, France

University of South Brittany, Vannes, France

Pitie Salpetriere Hospital, France

IRISA, University of Bretagne-Sud, Vannes, France

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

Dept. of Computer Science, University of Debrecen, Hungary

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

Health and Software Technology Group, Centre for Development of Advanced Computing, Thiruvananthapuram, India

Division of Cancer Research, Regional Cancer Centre, Thiruvananthapuram, India

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

Consiglio Nazionale delle Ricerche, IIT, Pisa, Italy

Universitat Autònoma de Barcelona, Italy

Department of Electrical Engineering, Mechanical Engineering and Management, DIEGM, University of Udine, Italy

STMicroelectronics, AST Lab, Agrate Brianza, Italy

Université de Bamako, Mali

Rotterdam Eye Hospital, The Netherlands

Rotterdam Ophthalmic Institute, The Netherlands

Quantitative Imaging Group, Delft University of Technology, The Netherlands

IPATIMUP, Institute of Molecular Pathology and Immunology of the University of Porto, Portugal

Dept. of Pathology and Oncology of the Medical Faculty of the University of Porto, Portugal

Dept. of Electronic Computers RSREU, Ryazan, Russia

Mathematical Institute, Serbian Academy of Sciences and Arts, Serbia

Faculty of Technical Sciences, University of Novi Sad, Serbia

University of León, Spain

Industrial and Informatics Engineering School, León, Spain

Geography and History Faculty, University of Santiago de Compostela, Spain

Archeology section of the municipality of Ourense, Ourense, Spain

Unilever Research and Development, Colworth House, Bedford, UK

King's College London, Institute of Psychiatry, London, UK

Great Ormond Street Hospital, UK

NIHR Biomedical Research Centre for Mental Health and NIHR Biomedical Research Unit for Dementia, London, UK

University of Wales Trinity Saint David, Cultural Astronomy and Astrology, Lampeter Campus, UK

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

Icahn School of Medicine at Mount Sinai, New York, NY, USA

Mount Sinai Beth Israel Medical Center, New York, NY, USA

National

Dept. of Cell and Molecular Biology, UU

Dept. of Chemistry, UU

Dept. of Earth Science, UU

Dept. of Immunology, Genetics and Pathology, UU

Dept. of Information Technology, UU

Dept. of Linguistics and Philology, UU

Dept. of Medical Cell Biology, UU

Dept. of Medical Sciences, UU

Dept. of Orthopedics, UU Hospital

Dept. of Organismal Biology, Evolutionary Biology Centre

Dept. of Plastic- and Maxillofacial Surgery, UU Hospital

Dept. of Radiology, Oncology and Radiation Science, UU

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

Dept. of Surgical Sciences, Plastic Surgery, UU

Dept. of Surgical Sciences, UU

Dept. of Theoretical Chemistry, UU

SciLifeLab, Stockholm

SciLifeLab, UU

Division of Microsystems Technology, UU

Nanotechnology and Functional Materials, The Ångström Laboratory, UU

Dept. of Anatomy, Physiology and Biochemistry, SLU

Dept. of Ecology, SLU

Dept. of Economics, SLU

Dept. of Clinical Sciences, SLU

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

Dept. of Mathematics School of Engineering Sciences, KTH, Stockholm

The Royal Institute of Technology, KTH, Stockholm

School of Technology and Health, KTH, Stockholm

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

Karolinska Institute, Stockholm

Swedish Museum of Natural History, Stockholm

Dept. of Industrial Development, IT and Land Management, University of Gävle

Dept. of Building, Energy and Environmental Engineering, University of Gävle

University of Gävle

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

The Sahlgrenska Academy, Institute of Odontology, Department of Prosthodontics/Dental Materials Science, University of Gothenburg, Göteborg,

Innventia, Stockholm

Vironova AB, Stockholm

PiezoMotors AB, Uppsala

Technovest AB

SenseGraphics AB, Kista

AstraZeneca, Mölndal, Sweden

Dentsply IH AB, Mölndal

Umeå Plant Science Centre, Umeå University.

UPPMAX, UU

Uppsala University Hospital

6 Publications

The most lasting impact of everything we do is the articles we publish. This year we produced 21 articles in scientific journals and 25 in conference proceedings, all fully peer reviewed. By chance this is exactly the same number as last year's, see Figure 34. The 21 journal papers are spread over 19 different journals, the 25 proceedings are spread over 19 different conferences. This wide spread of places were we publish have become typical, as we apply our methods on a very wide field of applications and have co-operation partners from many different areas. Here it should perhaps be noted that in our field, conference proceedings often have higher importance and higher rejection rates than the journals (see for example the ranking by Google Scholar).

In 2015 we also wrote three book chapters, had eleven papers in non-reviewed proceedings (mostly the annual Swedish meeting) and nine other articles of very various kinds.

Authors affiliated with CBA are in bold.

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 7.7, 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.

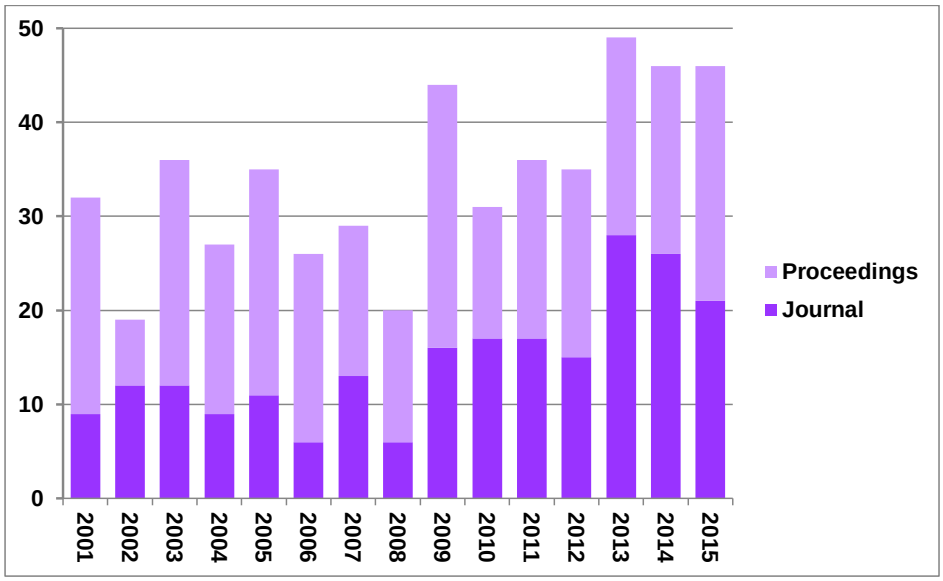


Figure 34: The number of publications from CBA 2001-2015.

6.1 Book chapters

1. **Virtual cranio-maxillofacial surgery planning with stereo graphics and haptics**
   Author: **Ingela Nyström, Pontus Olsson, Johan Nysjö, Fredrik Nysjö, Filip Malmberg, Stefan Seipel**, Jan-Michaél Hirsch(1), **Ingrid B. Carlbom**
   (1) Dept. of Surgical Sciences, Oral and Maxillofacial Surgery, Uppsala University, Uppsala, Sweden
   Book: Computer-Assisted Musculoskeletal Surgery -Thinking and Executing in 3D, pages 29-42
   Editors: Lucas E. Ritacco, Federico E. Milano, Edmund Chao
   Publisher: Springer Verlag
   Abstract: Cranio-maxillofacial surgery to restore normal skeletal anatomy in patients with serious facial

conditions is both complex and time consuming. There is, however, ample evidence that careful pre-operative planning leads to a better outcome with a higher degree of function and reduced morbidity and at the same time reduced time in the operating room. We are building a cranio-maxillofacial surgery planning system that, based on patient specific three-dimensional CT data, allows the surgeon to plan the surgical procedure without the help of a technician. Using a combination of stereo visualization with six degrees-of-freedom, high-fidelity haptic feedback, the system allows the surgeon to test alternative surgical solutions, move bone fragments, and design patient-specific implants and plates. Our goal is a system where the surgeon, after minimal training, can plan a complex procedure in less than an hour. Preliminary tests indicate that this goal is achievable.

2. **Image segmentation, processing and analysis in microscopy and life science**
   Author: **Carolina Wählby**
   Book: Mathematical Models in Biology: Bringing Mathematics to Life, 16 pages
   Editors: Valeria Zazzu, Maria Brigida Ferraro, Mario R. Guarracino
   Publisher: Springer International Publishing
   Abstract: Microscopes have been used for more than 400 years to understand biological and biomedical processes by visual observation. Science is the art of observing, but science also requires measuring, or quantifying, what is observed. Research based on microscopy image data therefore calls for methods for quantitative, unbiased, and reproducible extraction of meaningful measurements describing what is observed. Digital image processing and analysis is based on mathematical models of the information contained in image data, and allows for automated extraction of quantitative measurements. Automated methods are reproducible and, if applied consistently and accurately across experiments with positive as well as negative controls, also unbiased. Digital image processing is further motivated by the development of scanning microscopes and digital cameras that can capture image data in multiple spatial-, time-, and spectral-dimensions, making visual assessment cumbersome or even impossible due to the complexity and size of the collected data. The process of analyzing a digital image is usually divided into several steps, where the objects of interest are first identified, or "segmented", followed by extraction of measurements and statistical analysis. This chapter starts from the basics of describing images as matrices of pixel intensities. Emphasis is thereafter put on image segmentation, which is often the most crucial and complicated step. A number of common mathematical models used in digital image processing of microscopy images from biomedical experiments are presented, followed by a brief description of large-scale image-based biomedical screening.

3. **Matematiska rum. (The Swedish title means both "Mathematical Spaces" and "Mathematical Rooms".)**
   Author: **Christer O. Kiselman**
   Book: Sundelöfs Societet, pages 25–42
   Editors: Mats Almgren, Ulla Birgegård, Kristina Glimelius
   Publisher: Royal Society of Sciences in Uppsala
   Abstract: This essay starts by commenting on mathematical terms in several languages, especially those that concern mathematical spaces. It discusses successful mathematical models based on real numbers and then proceeds to discrete models, which have quite different properties. Knotted carpets and mosaics are actually predecessors of digital geometry. With the development of computers, discrete models have become even more important. Finally, some warnings of a more personal character are issued.

6.2 Journal articles

1. **Comparing and visualizing titanium implant integration in rat bone using 2D and 3D techniques**
   Authors: Anna Arvidsson(1,2), **Hamid Sarve**, Carina B. Johansson(2)
   (1) Dentsply IH AB, Molndal, Sweden
   (2) The Sahlgrenska Academy, Institute of Odontology, Dept. of Prosthodontics/Dental Materials Science, University of Gothenburg, Göteborg, Sweden
   Journal: Journal of Biomedical Materials Research. Part B - Applied biomaterials, Vol. 103, No. 1, pages 12–20
   Abstract: The aim was to compare the osseointegration of grit-blasted implants with and without a hydrogen fluoride treatment in rat tibia and femur, and to visualize bone formation using state-of-the-art 3D visualization techniques. Grit-blasted implants were inserted in femur and tibia of 10 Sprague-Dawley rats (4 implants/rat). Four weeks after insertion, bone implant samples were retrieved. Selected samples were imaged in 3D using Synchrotron Radiation-based CT (SRCT). The 3D data was quantified and visualized using two novel visualization techniques, thread fly-through and 2D unfolding. All samples were processed to cut and ground sections and 2D histomorphometrical comparisons of bone implant contact (BIC), bone area (BA), and mirror image area (MI) were performed. BA values were statistically significantly higher for test implants than controls ($p<0.05$), but BIC and MI data did not differ significantly. Thus, the results partly indicate improved bone formation at blasted and hydrogen fluoride treated implants, compared to blasted implants. The 3D analysis was a valuable complement to 2D analysis, facilitating improved visualization. However, further studies are required to evaluate aspects of 3D quantitative techniques, with relation to light microscopy that traditionally is used for osseointegration studies.

2. **Compaction of rolling circle amplification products increases signal integrity and signal-to-noise ratio**
   Authors: Carl-Magnus Clausson(1), Linda Arngården(1), **Omer Ishaq(2)**, Axel Klaesson(1), Malte Kühnemund(1), Karin Grannas(1), Björn Koos(1), Xiaoyan Qian(3), **Petter Ranefall(2)**, Tomasz Krzywkowski(3), Hjalmar Brismar(4), Mats Nilsson(1,3), **Carolina Wählby(2)**, Ola Söderberg(1)
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   (4) Science for Life Laboratory, Royal Institute of Technology, Solna, Sweden
   Journal: Scientific Reports, Vol. 5, Article ID 12317, 10 pages
   Abstract: Rolling circle amplification (RCA) for generation of distinct fluorescent signals in situ relies upon the self-collapsing properties of single-stranded DNA in commonly used RCA-based methods. By introducing a cross-hybridizing DNA oligonucleotide during rolling circle amplification, we demonstrate that the fluorophore-labeled RCA products (RCPs) become smaller. The reduced size of RCPs increases the local concentration of fluorophores and as a result, the signal intensity increases together with the signal-to-noise ratio. Furthermore, we have found that RCPs sometimes tend to disintegrate and may be recorded as several RCPs, a trait that is prevented with our cross-hybridizing DNA oligonucleotide. These effects generated by compaction of RCPs improve accuracy of visual as well as automated in situ analysis for RCA based methods, such as proximity ligation assays (PLA) and padlock probes.

3. **Brain - endocast relationship in the Australian lungfish, *Neoceratodus forsteri*, elucidated from tomographic data (Sarcopterygii: Dipnoi)**
   Authors: Alice M. Clement(1,2), **Johan Nysjö, Robin Strand**, Per E. Ahlberg(1)
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   (2) Dept. of Sciences, Museum Victoria, Victoria, Australia
   Journal: PLoS ONE, Vol. 10, No. 10, e0141277
   Abstract: Although the brains of the three extant lungfish genera have been previously described, the spatial relationship between the brain and the neurocranium has never before been fully described nor quantified. Through the application of virtual microtomography (mu CT) and 3D rendering software, we describe aspects of the gross anatomy of the brain and labyrinth region in the Australian lungfish, Neoceratodus forsteri and compare this to previous accounts. Unexpected characters in this specimen include short olfactory peduncles connecting the olfactory bulbs to the telencephalon, and an oblong telencephalon. Furthermore, we illustrate the endocast (the mould of the internal space of the neurocranial cavity) of Neoceratodus, also

describing and quantifying the brain-endocast relationship in a lungfish for the first time. Overall, the brain of the Australian lungfish closely matches the size and shape of the endocast cavity housing it, filling more than four fifths of the total volume. The forebrain and labyrinth regions of the brain correspond very well to the endocast morphology, while the midbrain and hindbrain do not fit so closely. Our results cast light on the gross neural and endocast anatomy in lungfishes, and are likely to have particular significance for palaeoneurologists studying fossil taxa.

4. **Computer assisted pap smear analyser for cervical cancer screening using quantitative microscopy**
   Authors: Rajasekharan Usha Deepak(1), Ramakrishnan Rajesh Kumar(1), Neendoorthalackal Balakrishnan Byju(1), Pundluvalu Nataraju Sharathkumar(1), Chandran Pournami(1), Salam Sibi(1), **Ewert Bengtsson**, Kunjuraman Sujathan(2)
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   (2) Division of Cancer Research, Regional Cancer Centre, Medical College Campus, Thiruvananthapuram, Kerala, India
   Journal: Journal of Cytology & Histology, Vol. 6, No. S3, 010
   Abstract: Cervical cancer is the third most common cancer among women. The bulk of the cancer burden is on low and middle income countries where screening is mostly opportunistic rather than systematic. Among the number of screening methods, cytology based screening using Pap smear test is by far the most widely followed and accepted method. In countries where organized screening using Pap test has been introduced, incidence and mortality caused by the disease has significantly subsided. Although the method is effective in controlling the disease, it poses a serious challenge in practical implementation owing to the fact that the method is resource intensive requiring trained professionals skilled enough to identify a handful of abnormal cells among few hundred thousand cells. This motivates the need for automating the screening methodology. Since the 1960-ies numerous projects have developed such automated screening systems leading also to a couple of commercial products. Still these have had limited impact on the screening situation in most of the world. This paper describes a screening system developed by our group in an effort of creating a cost effective screening system that could be widely deployed. The systems digitizes Pap smear slides and carries out cell level and smear level analysis on digitized smear and finally classifies the smear as either normal or suspicious. Clearly normal smears were screened out without any human intervention while suspicious smears were sent for expert cytologist review. A low cost monolayer slide preparation technique has also been identified which produces monolayer slides of quality comparable to that of commercial systems at much lesser cost. The computer aided Pap smear analyzer was validated at the Regional Cancer Centre (RCC), Thiruvananthapuram, India since May 2011. Since then a total of 1107 smears covering all abnormal and normal categories has been evaluated with a specificity of 60% and overall sensitivity of 80%. The system produces even higher sensitivity of 93% and 95% in HSIL and SCC grades respectively. Each slide used for validation has undergone two arm blind reviews, first by conventional manual cytology by qualified cytologists and second by automated Pap smear analysis. The accuracy of the automated analysis was benchmarked by using the manual review result as gold standard. The system has been found to reduce the workload of cytologist to almost 60% and has been designed to be operated by a semi-skilled person. A fully automated system can be builtbased on the results obtained by the present system by adding a slide loader, scanner, bar-code reader, sensors etc. which when designed and build cost effectively can increase slide processing throughput and reduce the dependency on human labour thereby significantly reducing the cost per slide making it feasible to extend screening to many more.

5. **Acrosome integrity assessment of boar spermatozoa images using an early fusion of texture and contour descriptors**
   Authors: Oscar García-Olalla(1), Enrique Alegre(1), Laura Fernández-Robles(1), **Patrik Malm, Ewert Bengtsson**
   (1) University of León, Industrial and Informatics Engineering School, León, Spain
   Journal: Computer Methods and Programs in Biomedicine, Vol. 120, No. 1, pages 49–64
   Abstract: The assessment of the state of the acrosome is a priority in artificial insemination centres since it is one of the main causes of function loss. In this work, boar spermatozoa present in gray scale images acquired with a phase-contrast microscope have been classified as acrosome-intact or acrosome-damaged, after using fluorescent images for creating the ground truth. Based on shape prior criteria combined with Otsu's thresholding, regional minima and watershed transform, the spermatozoa heads were segmented and registered. One of the main novelties of this proposal is that, unlike what previous works stated, the obtained

results show that the contour information of the spermatozoon head is important for improving description and classification. Other of this work novelties is that it confirms that combining different texture descriptors and contour descriptors yield the best classification rates for this problem up to date. The classification was performed with a Support Vector Machine backed by a Least Squares training algorithm and a linear kernel. Using the biggest acrosome intact-damaged dataset ever created, the early fusion approach followed provides a 0.9913 F-Score, outperforming all previous related works.

6. **Precise Euclidean distance transforms in 3D from voxel coverage representation**
   Authors: Vladimir Ilic(1), Joakim Lindblad(1), **Nataša Sladoje(1)**
   (1) Faculty of Engineering, University of Novi Sad, Novi Sad, Serbia
   Journal: Pattern Recognition Letters, Vol. 65, pages 184–191
   Abstract: Distance transforms (DTs) are, usually, defined on a binary image as a mapping from each background element to the distance between its centre and the centre of the closest object element. However, due to discretization effects, such DTs have limited precision, including reduced rotational and translational invariance. We show in this paper that a significant improvement in performance of Euclidean DTs can be achieved if voxel coverage values are utilized and the position of an object boundary is estimated with sub-voxel precision. We propose two algorithms of linear time complexity for estimating Euclidean DT with sub-voxel precision. The evaluation confirms that both algorithms provide 4-14 times increased accuracy compared to what is achievable from a binary object representation.

7. **Euclid's straight lines**
   Authors: **Christer O. Kiselman**
   Journal: Nordisk Matematisk Tidskrift (Normat), Vol. 60, No. 4, pages 145–169
   Abstract: 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.

8. **Estimates for solutions to discrete convolution equations**
   Authors: **Christer O. Kiselman**
   Journal: Mathematika, Vol. 61, No. 2, pages 295–308
   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-centred tesselations of 3-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 et al. is generalized to general discrete supports, using only elementary methods. We also study the asymptotic growth of sequences and arrays using the Fenchel transformation.

9. **Next-generation pathology: surveillance of tumor microecology**
   Authors: Björn Koos(1), Masood Kamali-Moghaddam(1), Leonor David(2,3), Manuel Sobrinho-Simoes(2,3), Anna Dimberg(1), Mats Nilsson(4), **Carolina Wählby**, Ola Söderberg(1)
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   (4) Science for Life Laboratory, Dept. of Biochemistry and Biophysics, Stockholm University, Solna, Sweden
   Journal: Journal of Molecular Biology, Vol. 427, No. 11, pages 2013–2022
   Abstract: A tumor is a heterogeneous population of cells that provides an environment in which every cell resides in a microenvironmental niche. Microscopic evaluation of tissue sections, based on histology and immunohistochemistry, has been a cornerstone in pathology for decades. However, the dawn of novel technologies to investigate genetic aberrations is currently adopted in routine molecular pathology. We herein describe our view on how recent developments in molecular technologies, focusing on proximity ligation assay and padlock probes, can be applied to merge the two branches of pathology, allowing molecular

profiling under histologic observation. We also discuss how the use of image analysis will be pivotal to obtain information at a cellular level and to interpret holistic images of tissue sections. By understanding the cellular communications in the microecology of tumors, we will be at a better position to predict disease progression and response to therapy.

10. **A histopathological tool for quantification of biomarkers with sub-cellular resolution**
Authors: **Andreas Kårsnäs(1)**, **Robin Strand**, Johan Doré(1), Thomas Ebstrup(1), Michael Lippert(1), Kim Bjerrum(1)
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Journal: Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization, Vol. 3, No. 1, pages 25–46
Abstract: Quantification of protein expression levels with sub-cellular resolution in histological images is important in many applications, such as biomarker discovery and cancer treatment. The use of computer-assisted analysis of digital images of tissue samples can be an alternative to the more labour-intensive manual identification and classification, and numerous are the methods that have been developed to quantify protein expression in tissue images, offering both objectivity and reproducibility. The problem with many of these methods is that they are not made accessible for the pathology community and when they are, the users often experience a trade-off between simplicity of use and flexibility for complex research applications. This paper presents a software tool that can be used for extracting and quantifying sub-cellular data from whole-slide images (WSIs) using computerised image analysis. It can be used for detection, classification and quantification of sub-cellular structures, such as nuclei, cytoplasm, membrane and gene probes in histological images. The tool is built to provide a simple and intuitive interface and it is therefore easy enough to learn for a user to handle without prior knowledge of image analysis. The involved image analysis methods are stable for biological variations and variations in staining intensity and are fast enough to analyse WSIs successfully within reasonable time. To illustrate how the presented tool is used to combine the different methods using the graphical user interface, four use cases are presented that represent common tasks in histopathology.

11. **Infrared-visible image registration for augmented reality-based thermographic building diagnostics**
Authors: **Fei Liu(1), Stefan Seipel(1)**
(1) Dept. of Industrial Development, IT and Land Management, University of Gävle, Gävle, Sweden
Journal: Visualization in Engineering, Vol. 3, No. 16, 15 pages
Abstract:

Background

In virtue of their capability to measure temperature, thermal infrared cameras have been widely used in building diagnostics for detecting heat loss, air leakage, water damage etc. However, the lack of visual details in thermal infrared images makes the complement of visible images a necessity. Therefore, it is often useful to register images of these two modalities for further inspection of architectures. Augmented reality (AR) technology, which supplements the real world with virtual objects, offers an ideal tool for presenting the combined results of thermal infrared and visible images. This paper addresses the problem of registering thermal infrared and visible façade images, which is essential towards developing an AR-based building diagnostics application.

Methods

A novel quadrilateral feature is devised for this task, which models the shapes of commonly present façade elements, such as windows. The features result from grouping edge line segments with the help of image perspective information, namely, vanishing points. Our method adopts a forward selection algorithm to determine feature correspondences needed for estimating the transformation model. During the formation of the feature correspondence set, the correctness of selected feature correspondences at each step is verified by the quality of the resulting registration, which is based on the ratio of areas between the transformed features and the reference features.

Results and conclusions

Quantitative evaluation of our method shows that registration errors are lower than errors reported in similar studies and registration performance is usable for most tasks in thermographic inspection of building façades.

12. **Magnetic resonance imaging cooling - reheating protocol indicates decreased fat fraction via lipid consumption in suspected brown adipose tissue**
Authors: Elin Lundström(1), **Robin Strand(1)**, Lars Johansson(1), Peter Bergsten(2), Håkan Ahlström(1), Joel Kullberg(1)
(1) Dept. of Radiology, Uppsala University, Uppsala, Sweden
(2) Dept. of Medical Cell Biology, Uppsala University, Uppsala, Sweden
Journal: PLoS ONE, Vol. 10, No. 4, e0126705, 13 pages
Abstract:

Objectives

To evaluate whether a water-fat magnetic resonance imaging (MRI) cooling-reheating protocol could be used to detect changes in lipid content and perfusion in the main human brown adipose tissue (BAT) depot after a three-hour long mild cold exposure.

Materials and Methods

Nine volunteers were investigated with chemical-shift-encoded water-fat MRI at baseline, after a three-hour long cold exposure and after subsequent short reheating. Changes in fat fraction (FF) and R2*, related to ambient temperature, were quantified within cervical-supraclavicular adipose tissue (considered as suspected BAT, denoted sBAT) after semi-automatic segmentation. In addition, FF and R2* were quantified fully automatically in subcutaneous adipose tissue (not considered as suspected BAT, denoted SAT) for comparison. By assuming different time scales for the regulation of lipid turnover and perfusion in BAT, the changes were determined as resulting from either altered absolute fat content (lipid-related) or altered absolute water content (perfusion-related).

Results

sBAT-FF decreased after cold exposure (mean change in percentage points = -1.94 pp, P = 0.021) whereas no change was observed in SAT-FF (mean = 0.23 pp, P = 0.314). sBAT-R2* tended to increase (mean = 0.65 s-1, P = 0.051) and SAT-R2* increased (mean = 0.40 s-1, P = 0.038) after cold exposure. sBAT-FF remained decreased after reheating (mean = -1.92 pp, P = 0.008, compared to baseline) whereas SAT-FF decreased (mean = -0.79 pp, P = 0.008, compared to after cold exposure).

Conclusions

The sustained low sBAT-FF after reheating suggests lipid consumption, rather than altered perfusion, as the main cause to the decreased sBAT-FF. The results obtained demonstrate the use of the cooling-reheating protocol for detecting changes in the cervical-supraclavicular fat depot, being the main human brown adipose tissue depot, in terms of lipid content and perfusion.

13. **Simulation of bright-field microscopy images depicting pap-smear specimen**
Authors: **Patrik Malm, Anders Brun, Ewert Bengtsson**
Journal: Cytometry Part A, Vol. 87, No. 3, pages 212–226
Abstract: As digital imaging is becoming a fundamental part of medical and biomedical research, the demand for computer-based evaluation using advanced image analysis is becoming an integral part of many research projects. A common problem when developing new image analysis algorithms is the need of large datasets with ground truth on which the algorithms can be tested and optimized. Generating such datasets is often tedious and introduces subjectivity and interindividual and intraindividual variations. An alternative to manually created ground-truth data is to generate synthetic images where the ground truth is known. The challenge then is to make the images sufficiently similar to the real ones to be useful in algorithm development. One of the first and most widely studied medical image analysis tasks is to automate screening for cervical cancer through Pap-smear analysis. As part of an effort to develop a new generation cervical cancer screening system, we have developed a framework for the creation of realistic synthetic bright-field microscopy images that can be used for algorithm development and benchmarking. The resulting framework has been assessed through a visual evaluation by experts with extensive experience of Pap-smear images. The results show that images produced using our described methods are realistic enough to be mistaken for real microscopy images. The developed simulation framework is very flexible and can be modified to mimic many other types of bright-field microscopy images.

14. **Intracranial volume normalization methods: considerations when investigating gender differences in regional brain volume**
Authors: Richard Nordenskjöld(1), **Filip Malmberg**, Elna-Marie Larsson(1), Andrew Simmons(2,3), Håkan Ahlström(1), Lars Johansson(1,4), Joel Kullberg(1)
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Journal: Psychiatry Research, Vol. 231, No. 3, pages 227–235
Abstract: Intracranial volume (ICV) normalization of regional brain volumes (v) is common practice in volumetric studies of the aging brain. Multiple normalization methods exist and this study aimed to investigate when each method is appropriate to use in gender dimorphism studies and how differences in v are affected by the choice of method. A new method based on weighted ICV matching is also presented. Theoretical reasoning and simulated experiments were followed by an evaluation using real data comprising 400 subjects, all 75 years old, whose ICV was segmented with a gold standard method. The presented method allows good visualization of volume relation between gender groups. A different gender dimorphism in volume was found depending on the normalization method used for both simulated and real data. Method performance was also seen to depend on the slope (B) and intercept (m) from the linear relation between v and ICV (v=B.ICV+m) as well as gender distribution in the cohort. A suggested work-flow for selecting ICV normalization method when investigating gender related differences in regional brain volume is presented.

15. **BoneSplit - a 3D texture painting tool for interactive bone separation in CT images**
Authors: **Johan Nysjö, Filip Malmberg, Ida-Maria Sintorn, Ingela Nyström**
Journal: Journal of WSCG, Vol. 23, No. 2, pages 157–166
Abstract: We present an efficient interactive tool for separating collectively segmented bones and bone fragments in 3D computed tomography (CT) images. The tool, which is primarily intended for virtual cranio-maxillofacial (CMF) surgery planning, combines direct volume rendering with an interactive 3D texture painting interface to enable quick identification and marking of individual bone structures. The user can paint markers (seeds) directly on the rendered bone surfaces as well as on individual CT slices. Separation of the marked bones is then achieved through the random walks segmentation algorithm, which is applied on a graph constructed from the collective bone segmentation. The segmentation runs on the GPU and can achieve close to real-time update rates for volumes as large as $512\hat{3}$. Segmentation editing can be performed both in the random walks segmentation stage and in a separate post-processing stage using a local 3D editing tool. In a preliminary evaluation of the tool, we demonstrate that segmentation results comparable with manual segmentations can be obtained within a few minutes.

16. **Haptics-assisted virtual planning of bone, soft tissue, and vessels in fibula osteocutaneous free flaps**
Authors: **Pontus Olsson, Fredrik Nysjö**, Andrés Rodríguez-Lorenzo(1), Andreas Thor(1,2), Jan-Michaél Hirsch(1,2), **Ingrid B. Carlbom**
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(2) Dept. of Surgical Sciences, Oral and Maxillofacial Surgery, Uppsala University, Uppsala, Sweden
Journal: Plastic and Reconstructive Surgery - Global Open, Vol. 3, No. 8, e479, 9 pages
Abstract:

Background: Virtual surgery planning has proven useful for reconstructing head and neck defects by fibula osteocutaneous free flaps (FOFF). Benefits include improved healing, function, and aesthetics, as well as cost savings. But available virtual surgery planning systems incorporating fibula in craniomaxillofacial reconstruction simulate only bone reconstruction without considering vessels and soft tissue.

Methods: The Haptics-Assisted Surgery Planning (HASP) system incorporates bone, vessels, and soft tissue of the FOFF in craniomaxillofacial defect reconstruction. Two surgeons tested HASP on 4 cases they had previously operated on: 3 with composite mandibular defects and 1 with a composite cervical spine defect. With the HASP stereographics and haptic feedback, using patient-specific computed tomography angiogram data, the surgeons planned the 4 cases, including bone resection, fibula design, recipient vessels selection, pedicle and perforator location selection, and skin paddle configuration.

Results: Some problems encountered during the actual surgery could have been avoided as they became evident with HASP. In one case, the fibula reconstruction was incomplete because 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.

Conclusions: 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 function and aesthetics and reduces operating room time.

17. **Digital topology and geometry in medical image processing: a survey**
Authors: Punam K. Saha(1), **Robin Strand, Gunilla Borgefors**
(1) Departments of Electrical and Computer Engineering and Radiology, University of Iowa, Iowa City, USA
Journal: IEEE Transactions on Medical Imaging, Vol. 34, No. 9, pages 1940–1964
Abstract: Digital topology and geometry refers to the use of topologic and geometric properties and features for images defined in digital grids. Such methods have been widely used in many medical imaging applications, including image segmentation, visualization, manipulation, interpolation, registration, surface-tracking, object representation, correction, quantitative morphometry etc. Digital topology and geometry play important roles in medical imaging research by enriching the scope of target outcomes and by adding strong theoretical foundations with enhanced stability, fidelity, and efficiency. This paper presents a comprehensive yet compact survey on results, principles, and insights of methods related to digital topology and geometry with strong emphasis on understanding their roles in various medical imaging applications. Specifically, this paper reviews methods related to distance analysis and path propagation, connectivity, surface-tracking, image segmentation, boundary and centerline detection, topology preservation and local topological properties, skeletonization, and object representation, correction, and quantitative morphometry. A common thread among the topics reviewed in this paper is that their theory and algorithms use the principle of digital path connectivity, path propagation, and neighborhood analysis.

18. **Fully automatic evaluation of the corneal endothelium from in vivo confocal microscopy**
Authors: **Bettina Selig**, Koenraad A. Vermeer(1), Bernd Rieger(2), Toine Hillenaar(3), **Cris L. Luengo Hendriks**
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(2) Quantitative Imaging Group, Dept. of Imaging Physics, Delft University of Technology, Delft, The Netherlands
(3) Rotterdam Eye Hospital, Rotterdam, The Netherlands
Journal: BMC Medical Imaging, Vol. 15, No. 13, 15 pages
Abstract:

Background: Manual and semi-automatic analyses of images, acquired in vivo by confocal microscopy, are often used to determine the quality of corneal endothelium in the human eye. These procedures are highly time consuming. Here, we present two fully automatic methods to analyze and quantify corneal endothelium imaged by in vivo white light slit-scanning confocal microscopy.

Methods: In the first approach, endothelial cell density is estimated with the help of spatial frequency analysis. We evaluate published methods, and propose a new, parameter-free method. In the second approach, based on the stochastic watershed, cells are automatically segmented and the result is used to estimate cell density, polymegathism (cell size variability) and pleomorphism (cell shape variation). We show how to determine optimal values for the three parameters of this algorithm, and compare its results to a semi-automatic delineation by a trained observer.

Results: The frequency analysis method proposed here is more precise than any published method. The segmentation method outperforms the fully automatic method in the NAVIS software (Nidek Technologies Srl, Padova, Italy), which significantly overestimates the number of cells for cell densities below approximately 1200 mm^{-2}, as well as previously published methods.

Conclusions: The methods presented here provide a significant improvement over the state of the art, and make in vivo, automated assessment of corneal endothelium more accessible. The segmentation method proposed paves the way to many possible new morphometric parameters, which can quickly and precisely be determined from the segmented image.

19. **Effect of pre-fixation delay and freezing on mink testicular endpoints for environmental research**
Authors: Ellinor Spörndly-Nees(1), Elisabeth Ekstedt(1), Ulf Magnusson(2), **Azadeh Fakhrzadeh, Cris L. Luengo Hendriks**, Lena Holm(1)
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(2) Dept. of Clinical Sciences, Faculty of Veterinary Medicine and Animal Science, Swedish University of Agricultural Science, Uppsala, Sweden
Journal: PLoS ONE, Vol. 10, No. 5, e0125139, 17 pages
Abstract: There is growing interest in using wild animals to monitor the real-life cocktail effect of environmental chemicals on male reproduction. However, practical difficulties, such as long distances to the laboratory, generally prolong the time between euthanisation and specimen handling. For instance, tissue fixation is often performed on frozen material or on material where deterioration has started, which may affect tissue morphology. This study examined the effect of pre-fixation delay and freezing on mink testicular endpoints in order to determine robust endpoints in suboptimally handled specimens. Sexually mature farmed mink (n=30) selected at culling were divided into six groups and subjected to different time intervals between euthanisation and fixation or freezing: 0 hours (fixed immediately post mortem), 6 hours, 18 hours, 30 hours, 42 hours, or frozen 6 hours post mortem and thawed overnight. Unaffected endpoints when pre-fixation storage was extended to 30 hours included: area and diameter of the seminiferous tubules, length and weight of the testes, and acrosomes marked with Gata-4. Epithelial height, Sertoli cells marked with Gata-4 and cell morphology were affected endpoints after 6 hours of storage. Freezing the tissue prior to fixation severely altered cell morphology and reduced testicular weight, tubular diameter and area. Morphological changes seen after 6 hours included shredded germ cells and excess cytoplasm in seminiferous tubular lumen, chromatin rearrangements and increased germ cell death. Extended delay before fixation and freezing affected many endpoints in the mink testicular tissue. Some of these endpoints may mimic chemically induced effects, which is important to consider when evaluating specimens from wild animals for environmental toxicity.

20. **Asymmetric supercapacitors based on carbon nanofibre and polypyrrole/nanocellulose composite electrodes**
Authors: Petter Tammela(1), Zhaohui Wang(2), Sara Frykstrand(1), Peng Zhang(1), **Ida-Maria Sintorn(3)**, Leif Nyholm(2), Maria Strømme(1)
(1) Nanotechnology and Functional Materials, The Ångström Laboratory, Uppsala University, Uppsala, Sweden
(2) Dept. of Chemistry, Ångström Laboratory, Uppsala University, Uppsala, Sweden
(3) Vironova AB, Stockholm, Sweden
Journal: RSC Advances, Vol. 5, No. 21, pages 16405–16413
Abstract: Asymmetric, all-organic supercapacitors (containing an aqueous electrolyte), exhibiting a capacitance of 25 F g^{-1} (or 2.3 F cm^{-2}) at a current density of 20 mA cm^{-2} and a maximum cell voltage of 1.6 V, are presented. The devices contain a composite consisting of polypyrrole covered Cladophora cellulose fibres (PPy-cellulose) as the positive electrode while a carbon nanofibre material, obtained by heat treatment of the same PPy-cellulose composite under nitrogen gas flow, serves as the negative electrode. Scanning and transmission electron microscopy combined with X-ray photoelectron spectroscopy data show that the heat treatment gives rise to a porous carbon nanofibre material, topologically almost identical to the original PPy-cellulose composite. The specific gravimetric capacitances of the carbon and the PPy-cellulose electrodes were found to be 59 and 146 F g^{-1}, respectively, while the asymmetric supercapacitors exhibited a gravimetric energy density of 33 J g^{-1}. The latter value is about two times higher than the energy densities obtainable for a symmetric PPy-cellulose device as a result of the larger cell voltage range accessible. The capacitance obtained for the asymmetric devices at a current density of 156 mA cm^{-2} was 11 F g^{-1} and cycling stability results further indicate that the capacity loss was about 23% during 1000 cycles employing a current density of 20 mA cm^{-2}. The present results represent a significant step forward towards the realization of all-organic material based supercapacitors with aqueous electrolytes and commercially viable capacitances and energy densities.

21. **Estimation of linear deformations of 2D and 3D fuzzy objects**
Authors: Attila Tanács(1), **Joakim Lindblad(2), Nataša Sladoje(2)**, Zoltan Kato(1)
(1) Dept. of Image Processing and Computer Graphics, University of Szeged, Szeged, Hungary
(2) Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
Journal: RSC Advances, Vol. 5, No. 21, pages 16405–16413
Abstract: Registration is a fundamental task in image processing, it is used to determine geometric correspondences between images taken at different times and/or from different viewpoints. Here we propose a general framework in n-dimensions to solve binary shape/object matching problems without the need of establishing additional point or other type of correspondences. The approach is based on generating and solving polynomial systems of equations. We also propose an extension which, provided that a suitable segmentation method can produce a fuzzy border representation, further increases the registration precision. Via numerous synthetic and real test we examine the different solution techniques of the polynomial systems of equations. We take into account a direct analytical, an iterative least-squares, and a combined method. Iterative and combined approaches produce the most precise results. Comparison is made against competing methods for rigid-body problems. Our method is orders of magnitude faster and is able to recover alignment regardless of the magnitude of the deformation compared to the narrow capture range of others. The applicability of the proposed methods is demonstrated on real X-ray images of hip replacement implants and 3D CT volumes of the pelvic area. Since the images must be parsed through only once, our approach is especially suitable for solving registration problems of large images.

6.3 Refereed conference proceedings

Authors affiliated with CBA are in bold.

1. **Calving events detection and quantification from time-lapse images in Tunabreen glacier**
   Authors: Sigit Adinugroh(1), Dorothée Vallot(2), Pontus Westrin(2), **Robin Strand**
   (1) Dept. of Information Technology, UU, Uppsala, Sweden
   (2) Dept. of Earth Science, UU, Uppsala, Sweden
   In Proceedings: Proceedings of 2015 International Conference on Information & Communication Technology and Systems (ICTS), pages 61–66
   Abstract: An automatic observation method for calving activity is an absolute necessity for researchers to collect statistical data for deeper understanding of the activity that is well known as a contributing factor for sea level rise. In this paper a new framework for calving event detection and area estimation is presented. First, a set of time-lapse images are registered where the first image in sequence acts as a reference for others. Registration process exploits M-estimator Sample Consensus (MSAC)to build transformation model based on matched Speeded-UpRobust Features (SURF) features. After that, terminus of glacier is extracted by a semi-automatic Chan-vese segmentation. Then, calving regions in a terminus are recognized as textural difference of two consecutive images. Since the difference forms a clustered points, -shape reconstruction is applied to form polygons representing changed areas. Finally, the areas of changed regions are estimated by referring to a Global Digital Elevation Map(GDEM) data. Experimental result on noise-free images confirms the effectiveness of the proposed framework.

2. **Blur detection and visualization in histological whole slide images**
   Authors: **Christophe Avenel, Ingrid Carlbom**
   In Proceedings: Proceedings 10th International Conference on Mass Data Analysis of Images and Signals, Leipzig, Germany: IBaI
   Abstract: Digital pathology holds the promise of improved workflow and also of the use of image analysis to extract features from tissue samples for quantitative analysis to improve current subjective analysis of, for example, cancer tissue. But this requires fast and reliable image digitization. In this paper we address image blurriness, which is a particular problem with very large images or tissue micro arrays scanned with whole slide scanners, since autofocus methods may fail when there is a large variation in image content. We introduce a method to detect, quantify and dis-play blurriness from whole slide images (WSI) in real-time. We describe a blurriness measurement based on an ideal high pass filter in the frequency domain. In contrast with other method our method does not require any prior knowledge of the image content, and it produces a continuous blurriness map over the entire WSI. This map can be displayed as an overlay of the original data and viewed at different levels of magnification with zoom and pan features. The computation time for an entire WSI is around 5 minutes on an average workstation, which is about 180 times faster than existing methods.

3. **Adaptive hit or miss transform**
   Authors: Vladimir Curic(1), Sébastien Lefèvre(2), **Cris L. Luengo Hendriks**
   (1) Dept. of Cell and Molecular Biology, Uppsala University, Uppsala, Sweden
   (2) IRISA, University of Bretagne-Sud, Vannes, France
   In Proceedings: Mathematical Morphology and Its Applications to Signal and Image Processing, LNCS vol. 9082, Springer, pages 741–752
   Editors: Atli Jón Benediktsson, Jocelyn Chanussot, Laurent Najman, Hugues Talbot
   Abstract: The Hit or Miss Transform is a fundamental morphological operator, and can be used for template matching. In this paper, we present a framework for adaptive Hit or Miss Transform, where structuring elements are adaptive with respect to the input image itself. We illustrate the difference between the new adaptive Hit or Miss Transform and the classical Hit or Miss Transform. As an example of its usefulness, we show how the new adaptive Hit or Miss Transform can detect particles in single molecule imaging.

4. **αLBP - a novel member of the Local Binary Pattern family based on α-cutting**
   Authors: Marija Delić(1), Joakim Lindblad(1), **Nataša Sladoje(2)**
   (1) Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
   (2) Mathematical Institute, Serbian Academy of Sciences and Arts, Serbia
   In Proceedings: IEEE Proceedings 9th International Symposium on Image and Signal Processing and Analysis (ISPA), pages 13–18
   Abstract: Local binary pattern (LBP) descriptors have been popular in texture classification in recent years. They were introduced as descriptors of local image texture and their histograms are shown to be well performing texture features. In this paper we introduce two new LBP descriptors, αLBP and its improved variant IαLBP. We evaluate their performance in classification by comparing them with some of the existing LBP descriptors - LBP, ILBP, shift LBP (SLBP) and with one ternary descriptor - LTP. The texture descriptors are evaluated on three datasets - KTH-TIPS2b, UIUC and Virus texture dataset. The novel descriptor outperforms the other descriptors on two datasets, KTH-TIPS2b and Virus, and is tied for first place with ILBP on the UIUC dataset.

5. **Recreating with photogrammetric techniques a submerged megalithic landscape: the case of the salas reservoir**
   Authors: Benito V. Estévez(1), Miguel C. Pazos(2), José María E. Franco(3), **Anders Hast**
   (1) University of Wales Trinity Saint David, Cultural Astronomy and Astrology, Lampeter Campus, UK
   (2) Geography and History Faculty, University of Santiago de Compostela, Santiago de Compostela, Spain
   (3) Archeology section of the municipality of Ourense, Ourense, Spain
   In Proceedings: 3 Encontro Internacional de Arqueoloxia de Vilalba, pages 9–16 *Abstract:* The objective of this study is to try to reconstruct the megalithic landscape located at Val do Sala, that nowadays is situated under the water due to the construction of a dam at the seventies from the last century. The choice of this area is due to the several allusions that makes reference to the big amount of tumulus at this area. Though the employment of different photogrammetric techniques over historical photographs, it was possible to reconstruct this megalithic landscape. We also think that the methodology proposed might be a new step in the study of lost monuments, or that are beginning to disappear.

6. **Mathematics + computer science = true**
   Authors: **Anders Hast**
   In Proceedings: The Fifth International Scientific Colloquium Mathematics and Children, pages 85–93
   Abstract: Mathematics is a fundamental tool for many sciences. Even so, they are often taught as completely separate topics in higher education. Sometimes math problems are taken from sciences like physics or from real life examples and even if some parts of the mathematics needed is briefly explained when teaching sciences, it is often assumed that the knowledge and understanding of mathematics has already been acquired to a sufficient level before the course starts. However, it is easy to see that a deeper understanding of the mathematics behind the problem in question, also helps in acquiring a better and most of all a deeper understanding of the problem itself. So, the question therefore is how this can be done in computer science in higher education? In other words, how can computer science benefit from including some teaching of mathematics and vice versa? Examples from a mixed course in mathematics and computer graphics will be given and experiences from teaching graphics and mathematics will be discussed. Moreover, experiences from other levels of education will be given and also an overview of how Uppsala University in Sweden supports teachers with a variety of pedagogical and didactic courses as well as other initiatives.

7. **Interest point detection based on the extended structure tensor with a scale space parameter**
   Authors: **Anders Hast**
   In Proceedings: International Conference on Computer Vision Theory and Applications, electronic publication, 8 pages
   Abstract: Feature extraction is generally based on some kind of interest point detector, such as Harris, the determinant of the Hessian or difference of Gaussians, just to mention a few. The first two are based on tensors, while the latter computes the difference of two images in scale space. It is proposed herein to combine the structure tensor with a scale space parameter, yielding a 3×3 structure tensor. The determinant of this tensor can be simplified and it will be shown how two rather different detectors can be obtained from this new formulation. It is shown under what conditions they will be less invariant to scale and rotations than previous approaches. It will also be shown that they find different points and why this could be useful for making the matching faster and also how the subsequent RANSAC could be implemented in parallel,

working on different sets of matches.

8. **Swedish eScience Education - a graduate school in eScience**
   Authors: **Anders Hast**, Michael Hanke(1), Hans O. Karlsson(2)
   (1) Dept. of Mathematics School of Engineering Sciences, KTH, Royal Institute of Technology Stockholm, Sweden
   (2) Dept. of Chemistry - Ångström Laboratory, Theoretical Chemistry and UPPMAX - Uppsala Multidisciplinary Centre for Advanced Computational Science, Uppsala University, Uppsala, Sweden
   In Proceedings: IEEE Proceedings, 11th International Conference on e-Science, pages 31–35
   Abstract: Swedish eScience Education (SeSE) is a national graduate school in eScience in Sweden. It comes from the collaboration between two major research initiatives in eScience and the school has turned out to be very successful. It has made it possible for students at different universities to get access to education that is not normally available at their home universities. With SeSE they get access to education by the top experts within their respective field. We argue why such graduate school is important and how it is different from training offered by many HPC centres in Europe. Furthermore, examples of courses and their structure is discussed as well as lessons learned from SeSE and its two predecessors in Sweden.

9. **Stereo visualisation of historical aerial photos - a valuable digital heritage research tool**
   Authors: **Anders Hast**, Andrea Marchetti(1)
   (1) Istituto di Informatica e Telematica Consiglio Nazionale delle Ricerche, Pisa, Italy
   In Proceedings: Digital Heritage, electronic publication, 4 pages
   Abstract: We demonstrate with several examples how historical aerial photos can benefit from being viewed in stereo and how this can be useful as tool in digital heritage research. The main reason why stereo images are important is that they give a much better understanding of what is actually in the scene than single photos can. The important factor is the depth cue that helps understanding the content and adds the ability to distinguish between objects such as houses and trees and the ground as well as estimating heights of objects. There are however still challenges but also possibilities that will be discussed.

10. **A simple and efficient feature descriptor for fast matching**
    Authors: **Anders Hast**, Victoria Sablina(1), Gustav Kylberg(2), **Ida-Maria Sintorn(2)**
    (1) Dept. of Electronic Computers, Ryazan State Radio Engineering University RSREU, Ryazan, Russia
    (2) Vironova AB, Stockholm, Sweden
    In Proceedings: WSCG, pages 135–142
    Editors: V. Skala
    Abstract: A very simple but efficient feature descriptor is proposed for image matching/registration applications where invariance is not important. The descriptor length is only three times the height of the local region in which the descriptor is calculated, and experiments were conducted to compare it to the SURF descriptor. In addition, it is shown, how the sampling can be modified in order to obtain a rotation invariant descriptor, while still keeping it simple and efficient. Examples from stitching in microscopy and stereo processing of pairs of photographs are given to prove the concept.

11. **Multimodal histological image registration using locally rigid transforms**
    Authors: **Andreas Kårsnäs, Robin Strand**
    In Proceedings: Proceedings Interactive Medical Image Computing (IMIC) Workshop, MICCAI, electronic publication
    Abstract: Evaluating multimodal histological images is an important task within cancer diagnosis. Using aligned consecutive sections is still the most straight-forward approach for combining multimodal data.

    To overcome the difficulties in aligning the sections, we present an interactive registration approach and show its usage for aligning TMA core images from consecutive sections stained for different biomarkers. In order to reduce distortion of local structures, a global deformable transform is approximated with locally more or less rigid transformations. This gives a trade-off between registration quality and distortion of local structures. The method divides the registration in an offline (global registration) and online step, where the local approximation is done in real-time within current field of view. This approach gives the viewer the ability to quickly adjust the rigidity from a deformable, well-aligned transformation to a rigid where structures ”look right”.

12. **Coverage segmentation of 3D thin structures**
Authors: **Kristína Lidayová**, Joakim Lindblad(1), **Nataša Sladoje(2)**, Hans Frimmel(3), Chunliang Wang(4), Örjan Smedby(4)
(1) Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
(2) Mathematical Institute, Serbian Academy of Sciences and Arts, Belgrade, Serbia
(3) Division of Scientific Computing, Dept. of Information Technology, Uppsala University, Sweden
(4) School of Technology and Health, KTH Royal Institute of Technology, Stockholm, Sweden
In Proceedings: IEEE Proceedings, 5th International Conference on Image Processing Theory, Tools and Applications (IPTA), Orléans, France, pages 23–28
Abstract: We present a coverage segmentation method for extracting thin structures in three-dimensional images. The proposed method is an improved extension of our coverage segmentation method for 2D thin structures. We suggest implementation that enables low memory consumption and processing time, and by that applicability of the method on real CTA data. The method needs a reliable crisp segmentation as an input and uses information from linear unmixing and the crisp segmentation to create a high-resolution crisp reconstruction of the object, which can then be used as a final result, or down-sampled to a coverage segmentation at the starting image resolution. Performed quantitative and qualitative analysis confirm excellent performance of the proposed method, both on synthetic and on real data, in particular in terms of robustness to noise.

13. **Microscopy image enhancement for cost-effective cervical cancer screening**
Authors: Joakim Lindblad(1), **Ewert Bengtsson, Nataša Sladoje(2)**
(1) Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
(2) Mathematical Institute, Serbian Academy of Sciences and Arts, Belgrade, Serbia
In Proceedings: Proceedings, 19th Scandinavian Conference on Image Analysis, LNCS vol. 9127, Springer, pages 440–451
Editors: Rasmus R. Paulsen, Kim S. Pedersen
Abstract: We propose a simple and fast method for microscopy image enhancement and quantitatively evaluate its performance on a database containing cell images obtained from microscope setups of several levels of quality. The method utilizes an efficiently and accurately estimated relative modulation transfer function to generate images of higher quality,starting from those of lower quality, by filtering in the Fourier domain.We evaluate the method visually and based on correlation coefficient and normalized mutual information. We conclude that enhanced images exhibit high similarity, both visually and in terms of information content, with acquired high quality images. This is an important result for the development of a cost-effective screening system for cervical cancer.

14. **Exact linear time Euclidean distance transforms of grid line sampled shapes**
Authors: Joakim Lindblad(1), **Nataša Sladoje(2)**
(1) University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
(2) Mathematical Institute, Serbian Academy of Sciences and Arts, Belgrade, Serbia
In Proceedings: Proceedings, 12th International Symposium on Mathematical Morphology and Its Applications to Signal and Image Processing (ISMM), Reykjavik, Iceland, LNCS vol. 9082, Springer, pages 645–656
Editors: Atli Jón Benediktsson, Jocelyn Chanussot, Laurent Najman, Hugues Talbot
Abstract: We propose a method for computing, in linear time, the exact Euclidean distance transform of sets of points s.t. one coordinate of a point can be assigned any real value, whereas other coordinates are restricted to discrete sets of values. The proposed distance transform is applicable to objects represented by grid line sampling, and readily provides sub-pixel precise distance values. The algorithm is easy to implement; we present complete pseudo code. The method is easy to parallelize and extend to higher dimensional data. We present two ways of obtaining approximate grid line sampled representations, and evaluate the proposed EDT on synthetic examples. The method is competitive w.r.t. state-of-the-art methods for sub-pixel precise distance evaluation.

15. **High-resolution reconstruction by feature distance minimization from multiple views of an object**
Authors: Joakim Lindblad(1), **Nataša Sladoje(2), Amit Suveer**, Anca Dragomir(3), **Ida-Maria Sintorn**
(1) Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
(2) Mathematical Institute, Serbian Academy of Sciences and Arts, Belgrade, Serbia
(3) Surgical Pathology, Uppsala University Hospital, Sweden
In Proceedings: IEEE Proceedings, 5th International Conference on Image Processing Theory, Tools and Applications (IPTA), Orléans, France, pages 29–34
Abstract: We present a method which utilizes advantages of fuzzy object representations and image processing techniques adjusted to them, to further increase efficient utilization of image information. Starting from a number of low-resolution images of affine transformations of an object, we create its suitably defuzzified high-resolution reconstruction. We evaluate the proposed method on synthetic data, observing its performance w.r.t. noise sensitivity, influence of the number of used low-resolution images, sensitivity to object variation and to inaccurate registration. Our aim is to explore applicability of the method to real image data acquired by Transmission Electron Microscopy, in a biomedical application we are currently working on.

16. **Automatic 3DS conversion of historical aerial photographs**
Authors: Francesco Malapelle(1), **Anders Hast**, Andrea Fusiello(1), B. Rossi(2), P. Fragneto(2), Andrea Marchetti(3)
(1) University of Udine, Dept. of Electrical Engineering, Mechanical Engineering and Management, DIEGM, Udine, Italy
(2) STMicroelectronics, AST Lab, Agrate Brianza, Italy
(3) Consiglio Nazionale delle Ricerche, IIT, Pisa, Italy
In Proceedings: IEEE proceedings, International Conference on 3D Imaging (IC3D), electronic publication, 6 pages
Abstract: In this paper we present a method for the generation of 3D stereo (3DS) pairs from sequences of historical aerial photographs. The goal of our work is to provide a stereoscopic display when the existing exposures are in a monocular sequence. Each input image is processed using its neighbours and a synthetic image is rendered, which, together with the original one, form a stereo pair. Promising results on real images taken from a historical photo archive are shown, that corroborate the viability of generating 3DS data from monocular footage.

17. **Interactive deformation of volume images for image registration**
Authors: **Filip Malmberg(1), Robin Strand(1)**, Joel Kullberg(1)
(1) Section of Radiology, Dept. of Surgical Sciences, Uppsala University, Uppsala, Sweden
In Proceedings: Proceedings, Interactive Medical Image Computing (IMIC) Workshop, MICCAI, electronic publication
Abstract: Deformable image registration, the task of finding a spatial transformation that aligns two or more images with each other, is an important task in medical image analysis. To a large extent, research on image registration has been focused on automatic methods. This is in contrast to, e.g., image segmentation, where interactive semi-automatic methods are common. Here, we propose a method for interactive editing of a deformation eld aligning two volume images. The method has been implemented in a software that allows the user to click and drag points in the deformed image to a new location, while smoothly deforming surrounding points. The method is fast enough to allow real-time display of the deformed volume image during user interaction, on standard hardware. The resulting tool is useful for initializing automatic methods, and to correct errors in automatically generated registrations.

18. **Teaching OpenGL and computer graphics with programmable shaders**
Authors: **Johan Nysjö, Anders Hast**
In Proceedings: SIGRAD, 3 pages
Abstract: This paper presents our approach and experiences of transferring an introductory computer graphics course from the fixed-function OpenGL pipeline to modern shader-based OpenGL. We provide an overview of the selected course structure and the C++-based programming environment that we use for assignments and projects, and discuss some of the technical and pedagogical challenges, e.g., multiplatform support and shader debugging, that we ran into. Based on course evaluations and the outcome of programming assignments, we conclude that introducing shaders early and skipping the fixed-function pipeline completely is a sound and viable approach. It requires more initial effort from teachers and students because of the added complexity of setting up and using shaders and vertex buffers, but offers a more interactive and powerful programming environment, which we believe helps promoting the creativity of students.

19. **Visuohaptic bone saw simulator: combining vibrotactile and kinesthetic feedback**
Authors: **Pontus Olsson, Fredrik Nysjö**, Neeru Singh(1), Andreas Thor(2), **Ingrid Carlbom**
(1) Mount Sinai Beth Israel Medical Center, New York, USA
(2) Faculty of Medicine, Dept. of Surgical Sciences, Oral and Maxillofacial Surgery, Uppsala University, Uppsala, Sweden
In Proceedings: Proceedings, 8th ACM SIGGRAPH Asia Technical Briefs, ACM, New York, NY, USA, Article 10, electronic publication, 4 pages
Abstract: The combination of stereo visualization and haptics provides a natural interface for surgical training simulators, an application which is inherently both highly visual and highly tactile. However, most off-the-shelf kinesthetic haptic devices, such as the popular Phantom devices, are not well-suited to display high-fidelity vibrotactile feedback for the high frequency force components in surgical tools such as a reciprocating bone saw. In these haptic devices, forces are mediated from the actuators to the user through a mechanical linkage, in which inertia, friction, and backlash may distort the feedback. In addition, sustained display of vibrations may cause undue wear of the device. We propose a hybrid solution combining kinesthetic feedback from an off-the-shelf haptic device with high-fidelity vibration feedback from a vibrotactile actuator, and show that the hybrid is able to reproduce vibrations of an actual surgical reciprocating saw within the full perceptible frequency range.

20. **Triangulation painting**
Authors: Max Pihlström(1), **Anders Hast, Anders Brun**
(1) Dept. of Information Technology, Uppsala University, Sweden
In Proceedings: SIGRAD, electronic publication, 4 pages
Abstract: In this paper a dynamic image representation is proposed by combining advantages of both raster and vector graphics in the triangulation. In order for a dynamic mesh to remain a triangulation, a method which maintains integrity of representation is devised. Together with techniques for synthesizing paint, the end result is a configurable scheme demonstrating potential as a viable alternative for digital painting and imaging in general.

21. **Fast evaluation of the robust stochastic watershed**
Authors: **Bettina Selig, Filip Malmberg, Cris L. Luengo Hendriks**
In Proceedings: Mathematical Morphology and Its Applications to Signal and Image Processing, LNCS vol. 9082, Springer, pages 705–716
Editors: Atli Jón Benediktsson, Jocelyn Chanussot, Laurent Najman, Hugues Talbot
Abstract: The stochastic watershed is a segmentation algorithm that estimates the importance of each boundary by repeatedly segmenting the image using a watershed with randomly placed seeds. Recently, this algorithm was further developed in two directions: (1) The exact evaluation algorithm efficiently produces the result of the stochastic watershed with an infinite number of repetitions. This algorithm computes the probability for each boundary to be found by a watershed with random seeds, making the result deterministic and much faster. (2) The robust stochastic watershed improves the usefulness of the segmentation result by avoiding false edges in large regions of uniform intensity. This algorithm simply adds noise to the input image for each repetition of the watershed with random seeds. In this paper, we combine these two algorithms into a method that produces a segmentation result comparable to the robust stochastic watershed, with a considerably reduced computation time. We propose to run the exact evaluation algorithm three times, with uniform noise added to the input image, to produce three different estimates of probabilities for the edges. We combine these three estimates with the geometric mean. In a relatively simple segmentation problem, F-measures averaged over the results on 46 images were identical to those of the robust stochastic watershed, but the computation times were an order of magnitude shorter.

22. **Large scale style based dating of medieval manuscripts**
Authors: **Fredrik Wahlberg**, Lasse Mårtensson(1), **Anders Brun**
(1) University of Gävle, Faculty of Education and Business Studies, Dept. of Humanities
In Proceedings: Proceedings, 3rd International Workshop on Historical Document Imaging and Processing, ACM Digital Library
Abstract: In this paper we propose a novel approach for manuscript dating based on shape statistics. Our goal was to develop a strategy well suited for a large scale dating effort where heterogeneous collections of thousands of manuscripts could be automatically processed. The proposed method takes the gray scale image as input, then uses the stroke width transform and a statistical model of the gradient image to find

ink boundaries. Finally, a distribution over common shapes, quantified using shape context descriptors, is produced for each manuscript image. The proposed method is binarization-free, rotational invariant and requires minimal segmentation. We evaluate our work on the 10000+ manuscripts collection "Svenskt diplomatariums huvudkartotek", consisting of charters from the medieval period of todays Sweden. The images, originally intended for web viewing, were of low quality and had compression artifacts. Due to unsupervised feature learning and regression, the collection could be dated with a median absolute error below 19 years even though we only used 5% of the labels in the estimator training.

23. **Visualizing document image collections using image-based word clouds**
Authors: **Tomas Wilkinson, Anders Brun**
In Proceedings: Proceedings, Advances in Visual Computing: Part I, 11th International Symposium, ISVC 2015, Las Vegas, NV, USA, LNCS vol. 9474, Springer, pages 297–306
Editors: George Bebis, Richard Boyle, Bahram Parvin, Darko Koracin, Ioannis Pavlidis, Rogerio Feris,Tim McGraw, Mark Elendt, Regis Kopper, Eric Ragan, Zhao Ye, Gunther Weber
Abstract: In this paper, we introduce image-based word clouds as a novel tool for a quick and aesthetic overviews of common words in collections of digitized text manuscripts. While OCR can be used to enable summaries and search functionality to printed modern text, historical and handwritten documents remains a challenge. By segmenting and counting word images, without applying manual transcription or OCR, we have developed a method that can produce word or tag clouds from document collections. Our new tool is not limited to any specific kind of text. We make further contributions in ways of stop-word removal, class based feature weighting and visualization. An evaluation of the proposed tool includes comparisons with ground truth word clouds on handwritten marriage licenses from the 17th century and the George Washington database of handwritten letters, from the 18th century. Our experiments show that image-based word clouds capture the same information, albeit approximately, as the regular word clouds based on text data.

24. **A novel word segmentation method based on object detection and deep learning**
Authors: **Tomas Wilkinson, Anders Brun**
In Proceedings: Proceedings, Advances in Visual Computing: Part I, 11th International Symposium, ISVC 2015, Las Vegas, NV, USA, LNCS vol. 9474, Springer, pages 231–240
Editors: George Bebis, Richard Boyle, Bahram Parvin, Darko Koracin, Ioannis Pavlidis, Rogerio Feris,Tim McGraw, Mark Elendt, Regis Kopper, Eric Ragan, Zhao Ye, Gunther Weber
Abstract: The segmentation of individual words is a crucial step in several data mining methods for historical handwritten documents. Examples of applications include visual searching for query words (word spotting) and character-by-character text recognition. In this paper, we present a novel method for word segmentation that is adapted from recent advances in computer vision, deep learning and generic object detection. Our method has unique capabilities and it has found practical use in our current research project. It can easily be trained for different kinds of historical documents, uses full gray scale information, does not require binarization as pre-processing or prior segmentation of individual text lines. We evaluate its performance using established error metrics, previously used in competitions for word segmentation, and demonstrate its usefulness for a 15th century handwritten document.

25. **Automatic water body extraction from remote sensing images using entropy**
Authors: Julia Åhlén(1), **Stefan Seipel**
(1) University of Gävle, Dept. of Building, Energy and Environmental Engineering, Gävle, Sweden
In Proceedings: Proceedings, 15th International Multidisciplinary Scientific GeoConference SGEM 2015., Vol. 2, pages 517–524
Abstract: This research focuses on automatic extraction of river banks and other inland waters from remote sensing images. There are no up to date accessible databases of rivers and most of other waters objects for modelling purposes. The main reason for that is that some regions are hard to access with the traditional ground through techniques and thus the boundary of river banks are uncertain in many geographical positions. The other reason is the limitations of widely applied method for extraction of water bodies called normalized-difference water index (NDWI). There is a novel approach to extract water bodies, which is based on pixel level variability or entropy, however, the methods work somewhat satisfactory on high spatial resolution images, there is no verification of the method performance on moderate or low resolution images. Problems encounter identification of mixed water pixels and e.g. roads, which are built in attachment to river banks and thus can be classified as rivers. In this work we propose an automatic extraction of

river banks using image entropy, combined with NDWI identification. In this study only moderate spatial resolution Landsat TM are tested. Areas of interest include both major river banks and inland lakes. Calculating entropy on such poor spatial resolution images will lead to misinterpretation of water bodies, which all exhibits the same small variation of pixel values as e.g. some open or urban areas. Image entropy thus is calculated with the modification that involves the incorporation of local normalization index or variability coefficient. NDWI will produce an image where clear water exhibits large difference comparing to other land features. We are presenting an algorithm that uses an NDWI prior to entropy processing, so that bands used to calculate it, are chosen in clear connection to water body features that are clearly discernible.As a result we visualize a clear segmentation of the water bodies from the remote sensing images and verify the coordinates with a given geographic reference.

6.4 Non-refereed conferences and workshops

Authors affiliated with CBA are in bold.

1. **Automated image acquisition and particle size distribution in the MiniTEM instrument**
   Authors: **Ida-Maria Sintorn**, Gustaf Kylberg(1), Lars Haag(1), Rickard Nordström(1)
   (1) Vironova AB, Stockholm, Sweden
   In Proceedings: Annual Conference of the Nordic Microscopy Society

2. **Your new default thresholding method?: a robust global gray-level thresholding method based on object features**
   Authors: **Petter Ranefall(1), Carolina Wählby(1)**
   (1) Science for Life Laboratory, Uppsala University, Uppsala, Sweden
   In Proceedings: BioImage Informatics Conference

3. **Writer identification using the quill-curvature feature in old manuscripts**
   Authors: **Fredrik Wahlberg, Anders Brun**, Lasse Mårtensson(1)
   (1) University of Gävle, Faculty of Education and Business Studies, Dept. of Humanities
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Ystad, Sweden, (SSBA)

4. **Investigating phenotypic differences and drug response among glioblastoma stem cell cultures from patients**
   Authors: **Damian J. Matuszewski, Ida-Maria Sintorn, Carolina Wählby**, Sven Nelander(1)
   (1) Dept. of Immunology, Genetics and Pathology, Uppsala University, Science for Life Laboratory, Biomedical center, Uppsala, Sweden
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Ystad, Sweden, (SSBA)

5. **Triangulation imaging**
   Authors: **Max Pihlström**
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Ystad, Sweden, (SSBA)

6. **Performance evaluation of potential functions for regularized image enhancement**
   Authors: Buda Bajić(1), **Joakim Lindblad, Nataša Sladoje**
   (1) Department of fundamental disciplines, University of Novi Sad, Novi Sad, Serbia
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Ystad, Sweden, (SSBA)

7. **Exact stochastic watersheds - a summary of recent advances**
   Authors: **Filip Malmberg, Robin Strand, Bettina Selig, Chris L. Luengo Hendriks**
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Ystad, Sweden, (SSBA)

8. **Topological clustering guided document binarization**
   Authors: **Kalyan Ram Ayyalasomayajula, Anders Brun**
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Ystad, Sweden, (SSBA)

9. **Towards image-based word clouds for large scale document visualization**
   Authors: **Tomas Wilkinson, Anders Brun**
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Ystad, Sweden, (SSBA)

10. **Clustering in 2D as a fast deterministic alternative to RANSAC**
    Editors: **Anders Hast**, Gustaf Kylberg
    In Proceedings: The second workshop on Features and Structures (FEAST), colocated with ICML

6.5 Other publications

Authors affiliated with CBA are in bold. In this section, we list other publications authored by CBA staff which are non-reviewed or not on image processing. See also Section 3.1 for Master theses finished during 2014.

1. **Kombineblo de vortelementoj en esperanto - rigardoj malantaŭen kaj antaŭen**
   Authors: **Christer Kiselman**
   Journal: Esperantologio / Esperanto Studies, Vol. 7, pages 73–125

2. **La lingvoj de Zamenhof (1878, 1881, 1887, 1905)**
   Authors: **Christer Kiselman**
   Journal: Literatura Foiro, No. 277, pages 260–265

3. **Hur kommer forskningen i Sverige att påverkas av utvärderingarna? [How will research in Sweden be influenced by the evaluations?]**
   Authors: **Christer Kiselman**
   Journal: Bulletinen. Svenska matematikersamfundets medlemsblad, Vol. 2015-10-15, pages 16–24

4. **Nash i Uppsala**
   Authors: **Christer Kiselman**
   Journal: Bulletinen. Svenska matematikersamfundets medlemsblad, Vol. 2015-10-15, pages 13–15

5. **To the memory of Lars H́ormander (1931–2012): Lars H́ormander—some early memories**
   Authors: **Christer O. Kiselman**
   Journal: Notices of the American Mathematical Society, Vol. 62, No. 8, pages 904–905

6. **Geraldo Mattos (1931–2014)**
   Authors: **Christer Kiselman**
   Journal: Esperantologio / Esperanto Studies, Vol. 7, page 126

7. **Experiments on large scale document visualization using image-based word clouds**
   Editors: **Tomas Wilkinson, Anders Brun**
   Publisher: Centre for Image Analysis, Technical Report 2015-022, 6 pages

8. **CBA annual report 2014**
   Editors: **Gunilla Borgefors, Omer Ishaq, Filip Malmberg, Lena Nordström, Ingela Nyström, Sajith Kecheril Sadanandan, Ida-Maria Sintorn, Robin Strand**
   Publisher: Centre for Image Analysis, 112 pages

7 Activities

Even if research and teaching are our main activities, considerable time is also used for other necessary activities. In this Section, we list the most important of those.

Seminars are a necessary and enjoyable part of scientific life. We have at least one seminar every Monday afternoon, together with guest seminars when we can get them. This year there were 41 seminars in our lively series, with an average attendance of over 20 people. Of course we also gave seminars elsewhere, for bigger or smaller groups.

Attending international and national conferences is important for getting new ideas and new contacts and keeping up with developments in the field. And also, of course, for presenting our own work to an admiring world. This year we gave 12 oral and 4 poster presentations at fully reviewed international conferences. We also gave 21 presentations at national and non-reviewed meetings.

We visit our research partners and they visit us, but here we only list visits lasting over a month. We had guest researchers from Germany, Mali, and Serbia and one of our PhD students spent three months in Colombia.

Last, but definitely not least, we are very active in professional organisations, as editors of scientific journals, in programme committees for international and national conferences, as members of dissertation committees, and as evaluators of projects and for positions.

7.1 Organized conferences and workshops

1. **Importance of Basic Research to Society - some examples**
   Organiser: Gunilla Borgefors
   Address: Ångström, Uppsala
   Date: 20150227
   Comment: Organized by the Celsius-Linné committee the day after the Celsius-Linné lectures. Borgefors is its Chair. See http://teknat.uu.se/celsius-linne/.

2. **Fest Seminar in Honour of Professor Ewert Bengtsson**
   Organisers: Carolina Wählby, Ingela Nyström, Lena Nordström
   Address: Polhemsalen and Eklundshof
   Date: 20150526
   Comment: CBA arranged a fest seminar to honour Ewert as he was awarded the title Professor Emeritus. More than 60 participants celebrated his eventful career. Invited speakers were Bo Sundqvist, Tommy Lindell, Gunilla Borgefors, Mia Lindegren, Örjan Smedby, and Lennart Thurfjell.

3. **womENcourage 2015**
   Co-organisers: Ida-Maria Sintorn
   Address: Norrlands nation and Main University Building, Uppsala
   Date: 20150924–20150926
   Attendees: 200
   Topic: Women in computing
   Comment: This was the 2nd ACM-W celebration of women in computing. It gathered graduate students, researchers and industry representatives from (mainly) Europe for an industry exhibition, scientific presentations and workshops with focus on women in IT and computing. Sintorn was local arrangements chair.

4. **9th Workshop on Medical Image Analysis for Early Detection of Cervical Cancer**
   Organisers: Ewert Bengtsson
   Address: Vi2, Uppsala
   Date: 20151026–20151106
   Comment: The workshop was part of a long joint collaboration project with two participants from India

7.2 Seminars held outside CBA

1. **Cris Luengo**
   Date: 20150416–20150419
   Address: Brooklyn, NY, USA
   Title: Tutorial
   Comment: Luengo presented a three-hour tutorial on "Image-based measurement" at International Symposium on Biomedical Imaging (ISBI 2015). The tutorial was recorded and made available online through SigView, the IEEE Signal Processing Society online video library.

2. **Stefan Seipel**
   Date: 20150417
   Address: Swedish Land Survey, Gothenburg, Sweden
   Title: 3D Geodatabases and game-technology for property management

3. **Stefan Seipel**
   Date: 20150417
   Address: FPX - Future PositionX, Gävle
   Title: Research in Geospatial Information Science at Gävle University
   Comment: International GeoLifeRegion Workshop 2015

4. **Christer Kiselman**
   Date: 20150526
   Address: University of Iceland, Reykjavik
   Title: Mathematical Seminar; invited talk
   Comment: Discrete convolution operators, the Fourier transformation, and its tropical counterpart, the Fenchel transformation

5. **Filip Malmberg**
   Date: 20150529
   Address: Section of Radiology, Department of Surgical Sciences, UU
   Title: Datoriserad bildanalys inom oftalmiatrik (In Swedish)

6. **Damian Matuszewski**
   Date: 20150616
   Address: Nelander Lab, IGP, UU
   Title: Investigating phenotypic differences and drug response among glioblastoma stem cell cultures from patients

7. **Kristína Lidayová**
   Date: 20150828
   Address: School of Technology and Health, KTH, Stockholm
   Title: Fast Vascular Centerline Tree Extraction Algorithm

8. **Petter Ranefall**
   Date: 20151109
   Address: Inje University, Busan, South Korea
   Title: Quantitative Microscopy

9. **Stefan Seipel**
   Date: 20151111
   Address: Sandbacka Park, Sandbacka, Sweden
   Title: Visualisera fritt är stort men visualisera rätt är större (In Swedish)
   Comment: Presentation at Find-IT 2015

10. **Ingela Nyström**
    Date: 20151117
    Address: Swedish National Veterinary Institute (SVA), Uppsala
    Title: An image says more than a thousand words – Mathematics and IT meet veterinary medicine?
    Comment: Presentation at SVA Research Day 2015

11. **Petter Ranefall**
    Date: 20151119
    Address: EWHA Womans University, Seoul, South Korea
    Title: Quantitative Microscopy

12. **Filip Malmberg**
    Date: 20151210
    Address: Dept. of IT, UU
    Title: Computerized image analysis for ophthalmologic applications
    Comment: Follow up seminar for projects funded by the SPARC program.

7.3 Seminars at CBA

1. **Robin Strand**
   Date: 20150112
   Title: Large scale analysis of whole body images

2. **Damian Matuszewski**
   Date: 20150119
   Title: Computer vision for continuous plankton monitoring

3. **Sajith Kecheril Sadanandan**
   Date: 20150202
   Title: Segmentation and Tracking of E.coli Bacteria in Phase contrast microscopy images

4. **Karl Bengtsson Bernander**
   Date: 20150202
   Title: A Method for Detecting Resident Space Objects and Orbit Determination Based on Star Trackers and Image Analysis

5. **Fredrik Wahlberg**
   Date: 20150209
   Title: Identifying scribes

6. **Christer Oscar Kiselman**
   Date: 20150216
   Title: Thoughts on discretization
7. **Kristína Lidayová**
   Date: 20150223
   Title: Fast Vascular Centerline Tree Extraction Algorithm
8. **Bettina Selig**
   Date: 20150302
   Title: Image Segmentation using Snakes and Stochastic Watershed
9. **Adama Arouna Koné**
   Date: 20150302
   Title: Covering a Euclidean line or hyperplane by dilations of its discretization
10. **Jesús Angulo**
    Date: 20150305
    Title: Convolution in (max,min)-algebra and its role in mathematical morphology
11. **Johan Nysjö**
    Date: 20150309
    Title: Fast interactive bone segmentation through 3D painting
12. **Fei Liu**
    Date: 20150323
    Title: Infrared-Visible Image Registration for Augmented Reality-Based Building Diagnostics
13. **Kalyan Ram Ayyalasomayajula**
    Date: 20150330
    Title: Dense SIFT features for Character recognition
14. **Filip Malmberg**
    Date: 20150413
    Title: Solidchamfer – an entrepreneurial adventure
15. **Ingrid Carlbom**
    Date: 20150420
    Title: The History of Computer Graphics
16. **Petter Ranefall**
    Date: 20150427
    Title: Gray-level Thresholding Based on Object Features
17. **Elisabeth Linnér**
    Date: 20150511
    Title: Pre-aliasing on the CC, BCC and FCC sampling lattices
18. **Anders Brun**
    Date: 20150518
    Title: Features and Strategies for Text Recognition
19. **Marine Astruc**
    Date: 20150525

Title: Cluster detection and field-of-view quality rating applied to automated Pap-smear analysis

20. **Azadeh Fakhrzadeh**
    Date: 20150601
    Title: Computerized Cell And Tissue Analysis

21. **Stefan Seipel**
    Date: 20150608
    Title: How close to true is target positioning using Augmented Reality?

22. **Nasir Rajpoot**
    Date: 20150611
    Title: Glandular Morphometrics for the Profiling of Colorectal Adenocarcinoma

23. **Ida-Maria Sintorn**
    Date: 20150615
    Title: Image analysis of patient specific Glioblastoma cellines: a project update

24. **Leo Svenningsson**
    Date: 20150624
    Title: Fourier transform of BCC and FCC lattices for MRI applications

25. **Karl-Oskar Smed**
    Date: 20150624
    Title: Efficient and accurate volume rendering on face-centered and body-centered cubic grids

26. **Nataša Sladoje**
    Date: 20150824
    Title: αLBP – a Novel Member of the Local Binary Pattern Family Based on α–cutting

27. **Teo Asplund**
    Date: 20150831
    Title: Fast and Unbiased Path Openings

28. **Sabrina Rossberger**
    Date: 20150831
    Title: Automated Analyses of collective migrating Malaria Plasmodium Sporozoites

29. **Ingela Nyström**
    Date: 20150907
    Title: Experiences from being member of various boards and committees

30. **Marco Mignardi**
    Date: 20150914
    Title: Cellular barcoding for spatially resolved single-cell genomics

31. **Gunilla Borgefors**
    Date: 20150921
    Title: "Uniform Polyhedra" or "What's in the Vitrine?"

32. **Ewert Bengtsson**
    Date: 20150928
    Title: Will digital pathology bring computer assisted pathological diagnostics into routine medical care?

33. **Pontus Olsson**
Date: 20151012
Title: Haptics with Applications to Cranio-Maxillofacial Surgery Planning

34. **Max Viergever**
Date: 20151012
Title: Examples of current medical image analysis research at University medical centre Utrecht

35. **Blake Hannaford**
Date: 20151015
Title: Augmented User Interfaces in Robotic Surgery

36. **Fredrik Nysjö**
Date: 20151026
Title: Modeling of patient-specific cutting guides and fixation plates with haptics

37. **Rajesh Kumar**
Date: 20151026
Title: Ongoing medical imaging research projects at the Centre for Development of Advanced Computing, India

38. **Pekka Ruusuvuori and Leena Latonen**
Date: 20151102
Title: Image analysis for prostate cancer research

39. **Tomas Wilkinson**
Date: 20151109
Title: A Novel Word Segmentation Method Based on Object Detection and Deep Learning Date

40. **Christophe Avenel**
Date: 20151130
Title: The CADESS Consensus-Graded Prostate Tissue Dataset

41. **Alexandre Xavier Falcão**
Date: 20151217
Title: Medical Image Segmentation using Object Shape Models: A Critical Review on Recent Trends, and Alternative Directions

7.4 Conference participation

7.4.1 Special invited speaker

1. *Conference:* European BioImage Analysis Symposium (EUBIAS 2015)
Carolina Wählby
Date: 20150105–20150106
Address: Institut Curie, Paris, France
Title: Analysis of microscopy data using CellProfiler and CellProfiler Analyst

2. *Conference:* IEEE EMBS Chapter in Kerala meeting
Ewert Bengtsson
Date: 20150304–20150304

Address: CDAC, Thiruvananthapuram, Kerala, India
Title: Medical image analysis – the key to personalized medicine?

3. *Conference:* Digikult - Digitalt kulturarv i praktiken [Digital culture inheritance in practice]
Anders Brun
Date: 20150325–20150326
Address: Gothenburg, Sweden
Title: Storskalig Datautvinning från Historiska Handskrivna Texter (In Swedish)

4. *Conference:* HIMA Imaging Science and International Imaging
Ewert Bengtsson
Date: 20150505–20150507
Address: Wyndham Grand Downtown, Pittsburgh, USA
Title: Will Digital Pathology Bring Computer Assisted Pathological Diagnostics into Routine Medical Care?
Comment: This workshop was part of the 2015 Pathology Informatics Summit

5. *Conference:* Scandinavian Conference on Image Analysis (SCIA 2015)
Carolina Wählby
Date: 20150615–20150617
Address: IT University of Copenhagen, Denmark
Title: Image based drug discovery – challenges and opportunities at the microscopy scale.

6. *Conference:* 14th International Congress on Stereology and Image Analysis (14th ICSIA)
Cris Luengo
Date: 20150707–20150710
Address: Liege, Belgium
Title: Estimating length distributions

7. *Conference:* Swiss Image-Based Screening Conference 2015
Carolina Wählby
Date: 20150930–20151001
Address: Novartis Learning Center Horburg, Basel, Switzerland
Title: Fishing out relevant information from large scale experiments

8. *Conference:* International Conference on Image Processing Theory, Tools and Applications (IPTA 2015)
Joakim Lindblad, Nataša Sladoje
Date: 20151110–20151113
Address: Orleans, France
Title: High-resolution reconstruction by feature distance minimization from multiple views of an object

7.4.2 Oral presentations – refereed conferences

1. *Conference:* SIGRAD 2015
Johan Nysjö
Date: 20150601–20150602
Address: KTH, Stockholm, Sweden
Title: Teaching OpenGL and Computer Graphics with Programmable Shaders

2. *Conference:* WSCG 2015
Johan Nysjö
Date: 20150608–20150611
Address: Plzen, Czech Republic
Title: BoneSplit – A 3D Texture Painting Tool for Interactive Bone Separation in CT Images

3. *Conference:* Workshop on Historical Image Processing in conjunction with IC on Document Analysis and Recognition
Fredrik Wahlberg
Date: 20150822–20150826
Address: Nancy, France
Title: Large scale style based dating of medieval manuscripts

4. *Conference:* AAOMS (American Association for Oral and Maxillofacial Surgeons), Annual Meeting
Ingrid Carlbom
Date: 20150930–20151003
Address: Washington, DC, USA
Title: Surgical Training Using a Haptics-Assisted Cranio-Maxillofacial Planning System (HASP)
Comment: Carlbom and Pontus Olsson also demonstrated HASP with the help of Carlbom's mentor Anders Lundqvist.

5. *Conference:* Interactive Medical Image Computation (IMIC), MICCAI 2015 workshop
Robin Strand
Date: 20151009
Address: Munich, Germany
Title: Multimodal histological image registration using locally rigid transforms
Comment: Styrand gave an interactive demo presentation.

6. *Conference:* Interactive Medical Image Computation (IMIC), MICCAI 2015 workshop
Marine Astruc
Date: 20151009
Address: Munich, Germany
Title: Interactive Deformation of Volume Images for Image Registration
Comment: Astruc gave an interactive demo presentation.

7. *Conference:* SIGGRAPH Asia
Pontus Olsson
Date: 20151102–20151105
Address: Kobe, Japan
Title: Visuohaptic Bone Saw Simulator Combining Vibrotactile and Kinesthetic Feedback

8. *Conference:* International Conference on Image Processing: Theory, Tools & Applications (IPTA 2015)
Nataša Sladoje, Joakim Lindblad, Kristína Lidayová
Date: 20151110–20151113
Address: Orleans, France
Title: Coverage Segmentation of 3D Thin Structures

9. *Conference:* Internernational Conference on Image Processing: Theory, Tools & Applications (IPTA 2015)
Nataša Sladoje, Joakim Lindblad
Date: 20151110–20151113
Address: Orleans, France
Title: High-resolution reconstruction by feature distance minimization from multiple views of an object.

10. *Conference:* 2nd Digital Pathology Congress
Christophe Avenel
Date: 20151203–20151204
Address: London, U.K.
Title: The CADESS Consensus-Graded Prostate Tissue Dataset

11. *Conference:* 11th International Symposium on Visual Computing, (ISVC 2015)
Tomas Wilkinson
Date: 20151213–20151216
Address: Las Vegas, Nevada, USA
Title: Visualizing Document Image Collection using Image-based Word Clouds

12. *Conference:* 11th International Symposium on Visual Computing, (ISVC 2015)
Tomas Wilkinson
Date: 20151213–20151216
Address: Las Vegas, Nevada, USA
Title: A Novel Word Segmentation Method Based on Object Detection and Deep Learning

7.4.3 Poster presentations – refereed conferences

1. *Conference:* International Symposium on Mathematical Morphology (ISMM 2015)
Nataša Sladoje, Joakim Lindblad
Date: 20150527–20150529
Address: Reykjavik, Iceland
Title: Exact Linear Time Euclidean Distance Transforms of Grid Line Sampled Shapes

2. *Conference:* International Symposium on Mathematical Morphology (ISMM 2015)
Cris Luengo
Date: 20150527–20150529
Address: Reykjavik, Iceland
Title: Fast evaluation of the robust stochastic watershed

3. *Conference:* ISMRM 2015, International Society for Magnetic Resonance in Medicine
Robin Strand
Date: 20150530–20150605
Address: Toronto, Canada
Title: Imiomics: Bringing -omics to whole body imaging: Examples in cross sectional interaction between whole-body MRI and non-imaging data
Comment: Electronic poster presentation

4. *Conference:* 19th Scandinavian Conference on Image Analysis (SCIA 2015)
Nataša Sladoje, Joakim Lindblad
Date: 20150615–20150617

Address: Copenhagen, Denmark
Title: Microscopy Image Enhancement for Cost-Effective Cervical Cancer Screening

7.4.4 Oral presentations – non-refereed conferences

1. *Conference:* Swedish symposium on image analysis (SSBA 2015)
Buda Bajic
Date: 20150317–20150318
Address: Ystad Saltsjöbad
Title: Performance Evaluation of Potential Functions for Regularized Image Enhancement.

2. *Conference:* Swedish symposium on image analysis (SSBA 2015)
Filip Malmberg
Date: 20150317–20150318
Address: Ystad Saltsjöbad
Title: Exact Stochastic Watersheds – A Summary of Recent Advances

3. *Conference:* Swedish symposium on image analysis (SSBA 2015)
Damian Matuszewski
Date: 20150317–20150318
Address: Ystad Saltsjöbad
Title: Investigating phenotypic differences and drug response among glioblastoma stem cell cultures from patients

4. *Conference:* Swedish symposium on image analysis (SSBA 2015)
Max Pihlström
Date: 20150317–20150318
Address: Ystad Saltsjöbad
Title: Triangulation imaging

5. *Conference:* Swedish symposium on image analysis (SSBA 2015)
Kalyan Ram Ayyalasomayajula
Date: 20150317–20150318
Address: Ystad Saltsjöbad
Title: Topological clustering guided document binarization

6. *Conference:* Swedish symposium on image analysis (SSBA 2015)
Fredrik Wahlberg
Date: 20150317–20150318
Address: Ystad Saltsjöbad
Title: Writer identification using the quill-curvature feature in old manuscripts

7. *Conference:* Swedish symposium on image analysis (SSBA 2015)
Tomas Wilkinson
Date: 20150317–20150318
Address: Ystad Saltsjöbad
Title: Towards image-based word clouds for large scale document visualization

8. *Conference:* The pedagogical conference at the Faculty of Science and Technology, UU-TUK 2015
Cris Luengo

Date: 20150318
Address: UU
Title: Experiences activating the classroom

9. *Conference:* Position 2015
Stefan Seipel
Date: 20150417–20150419
Address: Stockholm, Sweden
Title: 4D Solar Planning for the Built Environment

10. *Conference:* LABEX review conference
Ewert Bengtsson
Date: 20150602–20150604
Address: Paris, France
Title: Evaluations of Labex projects
Comment: A large conference organized to do half-time evaluations of a big French research funding program, Bengtsson was one of the evaluators.

11. *Conference:* Analysis Day in Memory of Mikael Passare
Christer Kiselman
Date: 20150916
Address: Stockholm University
Title: One-sided regularity of lineally convex sets

12. *Conference:* MULTIMOT kickoff meeting
Carolina Wählby
Date: 20150917–20150918
Address: Biochemistry Department, Ghent University, Belgium
Title: Image-based cell phenotyping
Comment: Wählby took is member of the scientific advisory board of the project, see webpage http://multimot.org

13. *Conference:* Medicinteknikdagarna 2015
Kristína Lidayová
Date: 20151013–20151014
Address: Uppsala
Title: Skeleton extraction algorithm with focus on thin vessels

14. *Conference:* Medicinteknikdagarna 2015
Johan Nysjö
Date: 20151013–20151014
Address: Uppsala
Title: Fast interactive bone segmentation for virtual surgery planning and 3D printing

15. *Conference:* Medicinteknikdagarna 2015
Amit Suveer
Date: 20151013–20151014
Address: Uppsala
Title: Automated Electron Microscopy for Diagnosis of Genetic Cilia Disorder

16. *Conference:* BioImage Informatics Conference
Damian Matuszewski

Date: 20151014–20151016
Address: NIST, Gaithersburg, MD, USA
Title: Comparing cell cycle analysis using flow cytometry and image-based screening

17. *Conference:* ExDIN project konsortium conference
Ewert Bengtsson
Date: 20151015–20151015
Address: Hufvudsta Gård, Solna
Title: What can image analysis do for digital pathology?
Comment: In Swedish, actual title: Vad kan datoriserad bildanalys tillföra digital patologi?

18. *Conference:* 9th Workshop on Medical Image Analysis for Early Detection of Cervical Cancer
Nataša Sladoje, Joakim Lindblad
Date: 20151026–20151106
Address: Vi2, UU
Title: Overview of the activities and results related to the Indo-Swedish collaborative project
19. *Conference:* Smedby thank you conference
Ewert Bengtsson
Date: 20151217
Address: CMIV lecture theatre, Linköping University Hospital
Title: Uppsala + Linköping → world class results in medical image analysis
Comment: Was invited key speaker in this event organized as Örjan Smedy was leaving his position at Linköping University

7.4.5 Poster presentations – non-refereed conferences

1. *Conference:* BioImage Informatics
Petter Ranefall
Date: 20151014–20151016
Address: NIST, Gaithersburg, MD, USA
Title: Your New Default Thresholding Method?
2. *Conference:* 3rd Nordic Symposium on Digital Pathology
Christophe Avenel
Date: 20151103–20151104
Address: Linköping, Sweden
Title: Consensus Grading of the ProstNet Prostate Tissue Dataset

7.4.6 Attended conferences

1. *Conference:* EXDIN project kick-off conference
Ewert Bengtsson
Date: 20150112–20150113
Address: Åkeshovs slott, Stockholm
Comment: The start of the two year project on digital pathology
2. *Conference:* Medical Engineering in Uppsala
Ewert Bengtsson, Robin Strand
Date: 20150211
Address: Uppsala Academic Hospital
Comment: Bengtsson was one of the organizers of this event to discuss the plans for a Medical Engineering Research Center in Uppsala
3. *Conference:* Swedish Symposium on Image Analysis (SSBA 2015)
Christophe Avenel, Ewert Bengtsson, Gunilla Borgefors, Anders Brun, Anders Hast, Kristína Lidayová, Joakim Lindblad, Elisabeth Linnér, Nataša Sladoje, Ingela Nyström, Petter Ranefall, Ida-Maria Sintorn, Robin Strand, Carolina Wählby
Date: 20150316–20150318
Address: Ystad Saltsjöbad

4. *Conference:* MoMIC Mobile microscopy workshop
   Ewert Bengtsson
   Date: 20150326
   Address: Karolinska Institute, Stockholm
   Comment: A half day conference on new compact microscopy techniques

5. *Conference:* Vitalis workshop on digital pathology
   Ewert Bengtsson
   Date: 20150422
   Address: Göteborg
   Comment: A whole day conference on digital pathology organized by the ExDIN project, part of the huge Vitalis Fair

6. *Conference:* Inauguration of the 7T MR Camera
   Ingela Nyström
   Date: 20150519
   Address: Lund University

7. *Conference:* Swedish Bioimaging 6th National Meeting
   Ingela Nyström
   Date: 20150520
   Address: Lund University

8. *Conference:* Women in Science, Pathways to Excellence
   Nataša Sladoje, Joakim Lindblad
   Date: 20150522–20150522
   Address: UU

9. *Conference:* International Symposium on Mathematical Morphology (ISMM 2015)
   Teo Asplund, Gunilla Borgefors, Christer Kiselman, Adama Arouna Koné
   Date: 20150527–20150529
   Address: University of Iceland, Reykjavik, Iceland
   Comment: Borgefors was Session Chair. Koné's participation was supported by the International Science Programme.

10. *Conference:* IT in Uppsala 50 years
    Ewert Bengtsson
    Date: 20150527–20150527
    Address: Polacksbacken, UU
    Comment: The 50 year celebration and launching of the history book

11. *Conference:* 19th Scandinavian Conference on Image Analysis (SCIA 2015)
    Ewert Bengtsson, Ingela Nyström
    Date: 20150615–20150617
    Address: Copenhagen, Denmark
    Comment: Nyström Session Chair.

12. *Conference:* 11th IEEE International Conference on e-Science
    Ingela Nyström
    Date: 20150831–20150903
    Address: Ludwig-Maximilians-Universität Munich, Germany
    Comment: Nyström was Session Chair.

13. *Conference:* Society day of the Royal Society of Sciences in Uppsala
Gunilla Borgefors
Date: 20150901
Address: Gustavianum, Uppsala

14. *Conference:* International Conference on Image Analysis and Processing, ICIAP 2015
Gunilla Borgefors
Date: 20150909–20150911
Address: Genova, Italy
Comment: Borgefors was Session Chair

15. *Conference:* WomENcourage
Kristína Lidayová
Date: 20150924–20150926
Address: UU
Comment: Lidayová was main photographer of the conference.

16. *Conference:* AAOMS (American Association for Oral and Maxillofacial Surgeons), Annual Meeting
Pontus Olsson
Date: 20150928–20151003
Address: Washington, DC, USA.
Comment: Demonstrated the HASP (Haptics-Assisted Surgery Plannng) project

17. *Conference:* MICCAI 2015, International Conference on Medical Image Computing and Computer Assisted Intervention
Marine Astruc, Robin Strand
Date: 20151006–20151008
Address: Munich, Germany

18. *Conference:* CIM Workshop on Machine Learning
Nataša Sladoje, Joakim Lindblad
Date: 20151008–20151009
Address: UU

19. *Conference:* Nordic Digital Pathology Workshop
Ewert Bengtsson
Date: 20151103–20151104
Address: Linköping
Comment: Our two Indian guests Rajesh Kumar and Dr Sujathan also took part in this conference

20. *Conference:* Nordic Symposium on Digital Pathology
Petter Ranefall
Date: 20151103–20151104
Address: Linköping

21. *Conference:* AO Courses
Pontus Olsson
Date: 20151212–20151216
Address: Davos, Switzerland
Comment: Demonstrated the HASP (Haptics-Assisted Surgery Planning) project.

7.5 Visiting scientists

1. **Adama Arouna Koné**
   Address: University of Sciences, Techniques and Technologies, Bamako, Mali
   Host: Christer Kiselman
   Date: 20150124–20150612
   Topic: Research visit; thesis advising
   Comments: This was Adama's fourth visit to UU. All his visits have been supported by the International Science Program.

2. **Buda Bajic**
   Address: Faculty of Technical Sciences, University of Novi Sad, Serbia
   Host: Nataša Sladoje
   Date: 20150223–20150331
   Topic: Image restoration by energy minimization, PhD project

3. **Sabrina Rossberger**
   Address: Max-Planck-Institute for Intelligent Systems Heidelberg, Baden-Württemberg, Germany
   Host: Carolina Wählby
   Date: 20150901–20150930
   Topic: Visiting PostDoc

7.6 Visits to other research groups

1. **Kristína Lidayová**
   Address: PhD study visit at Los Andes University, Bogota, Colombia
   Host: Marcela Hernandez Hoyos
   Date: 20151123–20160229
   Topic: Pulmonary vessel segmentation and airway tree skeleton extraction from CT images of lungs

7.7 Committees

Ewert Bengtsson
International:

- Lifetime Fellow of the Institute of Electrical and Electronics Engineers (IEEE), 20150101–

  Comment: Member since 1974.
- Member of the International Society for Optical Engineering (SPIE), 2004–
- Member of the International Society for Analytical Cytology (ISAC), 2000–
- Editorial Board member of *Computer Methods and Programs in Biomedicine,* 1995–
  Comment: Published by Elsevier.
- Editorial Board member of *Machine Graphics & Vision,* 1994–
  Comment: Published by the Polish Academy of Sciences.
- Editorial Board Member of *Journal of Multimedia Information System*, 2014–
  Comment: Published by Korea Multimedia Society.
- Program Committee Bioimaging 2015, 12-15 January 2015, Lisbon, Portugal
- Management Committee, EU COST Action TD1201: "Colour and Space in Cultural Heritage, COSCH" 2013–
  Comment: Bengtsson is responsible for coordinating the Swedish participation.
- On the International Program Committee for WSCG 2015, 23rd International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision 2015.
- On the International Program Committee for BIOIMAGING 2015, International Conference on Bioimaging.
- Expert evaluator for proposals to the Canadian MITACS research funding program.
- Expert evaluator for proposals to Cancer Research UK funding program.
- Expert evaluator for proposals of funding for research infrastructures for the Academy of Finland.
- Expert evaluator for proposals to the "TALENT RESEARCH" (LA RICERCA DEI TALENTI) program to support Scientific Independence of Young Researchers by the Italian Ministry of University and Research
- Expert evaluator at the half time check point for the French Labex projects.

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).
- Board of Swedish Bioimaging, 2012–201512
  Comment: A Swedish network for research infrastructures 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", Uppsala, 2015.
- 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, 1999-2015
- UU Library Council member, 2011–2015
- Chair of UU committee to manage pilot studies for a proposed new strategy for handling long term storage of scientific data, 2015 –
- 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. 201409–201502
- Expert advisor to the head of the Information Technology Unit of UU administration, 2013–
- Board of the Dept. of Information Technology, UU, 2012–201505
- Head of Research ("forskningsprefekt") at the Dept. of Information Technology, UU, 2013–201503
- Expert for evaluating chair in medical engineering for Linköping University 201409–201502

Gunilla Borgefors

International:

- Fellow of the International Association for Pattern Recognition (IAPR), 1998–
  Comment: 1st Vice President 1994–96, Secretary 1990–94, etc., etc.
- Member of the Fellow Committee of the International Association for Pattern Recognition (IAPR), 2014–2015
- 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–
- Program committee, International Symposium on Mathematical Morphology, ISMM 2015, Reykjavik, Iceland, May 2015.
- Track Co-Chair, International Conference on Image Analysis and Processing, ICIAP 2015, Genoa, Italy, Sept. 2015.
  Comment: Track Chair together with Leila de Floriani
- Program committee, XX Iberoamerican Congress on Pattern Recognition, CIARP 2015, Montevideo, Uruguay, Nov. 2015.
- Pre-examiner of the dissertation manuscript of Arttu Miettinen, Dept. of Physics, University of Jyväskylä, Finland, Fall 2015.
  Comment: Title: Characterization of Three Dimensional Microstructure of Composite Materials by X-Ray Tomography

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.
- Member of the Docent committee of the Faculty of Science and Technology, UU, 2014–
- Scientific 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
- Dissertation committee for Anna Mikaelyan, School of information Technology, Halmstad University, 20150417
  Comment: Title: Compact orientation and frequency estimation with applications in biometry
- Dissertation committee for Erik Johansson, Dept. of Engineering Science and Mathematics, Luleå University of Technology, Campus Skellefteå, 20150521
  Comment: Title: computed tomography and fingerprint traceability in the wood industry

Anders Brun
International:

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

National:

- Board member, SSBA, 2014–
- Search Committee for a junior faculty member in Machine Learning for the Dept. of Information Technology, UU, 2015

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–

Christer Kiselman
International:

- Evaluation of research and education at Laboratoire d'InfoRmatique en Image et Systémes d'information (LIRIS) in Lyon, organized by Haut Conseil de l'évaluation de la recherche et de l'enseignement supérieur (HCERES), initially by Agence d'évaluation de la recherche et de l'enseignement supérieur (AERES), 201411 — 201501.
- Program Committee, Discrete Geometry for Computer Imagery, DGCI, 2015.
- Reference Group of the International Science Programme, 2002– .
- International Academy of Sciences, San Marino, 1983– .
- Internacia Scienca Akademio Comenius, 1986– .
- Academy of Esperanto, 1989 – 20151215.
- Polska Akademia Umiejetności (Polish Academy of Arts and Sciences), 2002– .
- Associate Member, Scandinavian Society for Iranian Studies, 2010– .

National:

- Evaluation of research at Linnaeus University, 20150801—20151020.
- Royal Academy of Arts and Sciences, Uppsala, 1983– .
- Royal Society of Sciences, Uppsala, 1984– .
- Royal Swedish Academy of Sciences, 1990– .

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

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

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 2013–2015
  Comment: Published by Elsevier. PRL is an official journal of the International Association of Pattern Recognition. Luengo was Associate Editor 2011–2012.
- Editorial Board, Mathematical Morphology - Theory and Applications, 2015–
  Comment: A new journal from De Gruyter Open.
- Steering Committee, International Symposium on Mathematical Morphology, 2013–.
- Program Committee, International Symposium on Mathematical Morphology (ISMM), 2015
- Program Committee, CIARP 2015

National:

- Advisory Board for CBA 2012–2015
  Comment: Representative for SLU.
- Search Committee for a junior faculty member in Machine Learning for the Dept. of Information Technology, UU, 2014–2015
- Scientific Committee, CIM Workshop on Machine Learning, 2015

Filip Malmberg
International:

- Deputy editor of *Pattern Recognition Letters,* 2015–
  Comment: Published by Elsevier. PRL is an official journal of the International Association of Pattern Recognition.
- Program commitee, XX Iberoamerican Conference on Pattern Recognition (CIARP 2015), Montevideo, Uruguay, November 2015.

National

- Organizing committee, "Medicinteknikdagarna" (Medical engineering days), Uppsala, October 2015.

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

National:

- Member of the Royal Society of Arts and Sciences of Uppsala (Kungliga Vetenskapssamhället i Uppsala), 2012–

- 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–
  Comment: Vice-Chair 2015–
- Evaluation Panel for grant applications to the Swedish Research Council: Infrastructures for e-Science ("Beredningsgrupp 4"), 2011–2015
- Dissertation committee of Jane Tufvesson, Dept. of Biomedical Engineering, Lund University, 20151207
  Comment: Title: Automatic Segmentation in Cranio-vascular Magnetic Resonance Images

Stefan Seipel
International:

- Board of reviewers for WSCG 2015 - 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–

National:

- Board of the Swedish Computer Graphics Association (SIGRAD), 2015
- Reviewer of three, and supervisor on three, Master's thesis projects at University of Gävle

Ida-Maria Sintorn
International:

- Organizing committee (local arrangements chair), "womEncourage", 2nd ACM-W Europe Celebration of Women in Computing, Uppsala, September 24–26, 2015.

National:

- Treasurer of Swedish Society for Automated Image Analysis (SSBA), 2009–
  Comment: Board member 2008–.
- Dissertation Committee of Linnea Ahlinder, Dept. of Engineering Sciences UU, 20150604
  Comment: Title: Raman spectroscopy and hyperspectral analysis of living cells exposed to nanoparticles

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.
- Program committee, 9th International Symposium on Image and Signal Processing and Analysis (ISPA), Croatia, 2015.

- Program committee, Intern. Conference on Bioimaging, BIOIMAGING 2016, Rome, Italy
- Dissertation committee for Marija Milojevic Jevric, Faculty of Technical Sciences, University of Novi Sad, Serbia, 20151002
  Comment: Title: The application of meta-heuristics to optimise load distribution in machine elements and assemblies

Robin Strand
International:

- Editorial Board member of *Journal of Discrete Mathematics,* 2013–
  Comment: Open access. Published by Hindawi Publishing Corporation.
- Program Committee, 17th International Workshop on Combinatorial Image Analysis (IWCIA 2015), Nov. 24–27 2015, Kolkata, India
- Program Committee, 12th International Symposium on Mathematical Morphology (ISMM 2015), May 27–29 2015, Reykavik, Iceland

National:

- Dissertation Committee of Marcus Björk, UU, 20150508
  Comment: Title: Contributions to Signal Processing for MRI
- Coordinator of biomedical information technology (biomed-IT) at the Dept. of IT

Fredrik Wahlberg
National:

- Member of the Uppsala Programming for Multicore Architecures Research Center (UPMARC), 2014–2015

Carolina Wählby
International:

- Scientific advisory board member of MULTIMOT, 20150917
  Comment: MULTIMOT is a H2020 EU funded project that aims to build an open data ecosystem for cell migration research, through standardization, dissemination and meta-analysis efforts.
- Scientific program committee, BioimageInformatics 2015.
- PhD thesis evaluation committee, Violeta N. Kovacheva, Dept. of Systems Biology, The University of Warwick, UK
  Comment: Title: Modelling and Analysis of the Tumor Microenvironment of Colorectal Cancer

National:

- Member of the Electorial Board ("elektorsförsamlingen") of the Faculty of Science and Technology, UU, 2014–2016
- Licentiate thesis Committee for Benjamin Holmgren, Dept. of Cell and Molecular Biology (ICM) BMC
  Comment: Thesis title: The role of the endolysosomal machinery in RNA interference and RNA transport in the nematode Caenorhabditis elegans.