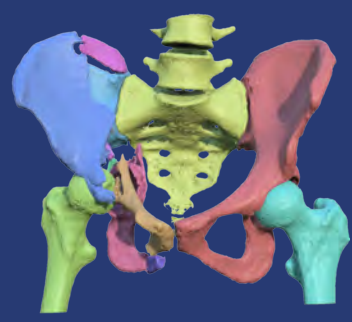
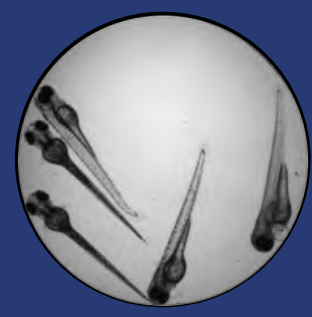
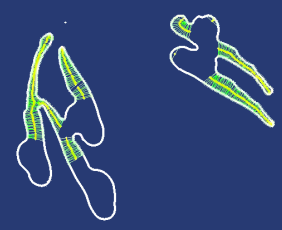
Centre for Image Analysis
Uppsala University

ANNUAL REPORT



2016

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Annual Report 2016

Centre for Image Analysis

Centrum för bildanalys

Cover: Illustrations from the three PhD theses presented at Centre for Image Analysis (CBA) during 2016. Further information in Section 4.2.

Fei Liu — Hand-held Augmented Reality for Facility Maintenance
In Augmented Reality for Building Inspection a system was developed to automatically identify high-level façade features for co-registration and augmentation of visible images with thermal IR images.

Johan Nysjö — Interactive 3D Image Analysis for Cranio-Maxillofacial Surgery Planning and Orthopedic Applications
Iso-surface rendering of a fractured pelvic bone in a 3D computed tomography (CT) image. The individual bones and bone fragments have been segmented with BoneSplit, an interactive segmentation tool that combines efficient graph-based segmentation with intuitive 3D texture painting.

Omer Ishaq — Image Analysis and Deep Learning for Applications in Microscopy
A group of zebrafish embryos in a microscopy image and medial skeletons generated for zebrafish outlines.

Cover design:
Anton Axelsson

Edited by:
Marine Astruc, Gunilla Borgefors, Filip Malmberg, Lena Nordström, Ingela Nyström, Leslie Solorzano, **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 digtal humanities, life sciences, and medicine. In addition to our own research, CBA contributes to image technology promotion and application in other research units and society nationally as well as internationally.

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 38 researchers were active at the CBA in 2016: 16 PhD students and 22 seniors (of which 3 are Professor Emeritus). Many of us also have other duties – such as, teaching, appointments within the Faculty, and leave for work outside academia – so the effective work time in CBA research corresponded to about 25 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. A successful example of collaboration we have is with the Division of Radiology, where two of our staff members work part time at the Uppsala University Hospital in order to be close to radiology researchers and also have funding from there. Among our staff members, we are pleased that Petter Ranefall qualified as Docent at UU bringing the total number of CBA docents to fourteen.

The activity level in 2016 was high with a total of 72 ongoing research projects involving 38 international and around 50 national collaboration partners. This resulted in 4 PhD theses during the year as well as 24 journal papers and 22 fully reviewed conference papers.

We are active in organizing conferences and seminars. Gunilla Borgefors continued to serve as Chair of the committee organizing the prestigious Celsius-Linné Lectures for Uppsala University.

Since 1986, Uppsala has every sixth year hosted the annual national symposium organized by the Swedish Society for Automated Image Analysis (SSBA). In 2016, SSBA celebrated its 40-year anniversary and the symposium was hosted by CBA with Robin Strand as General Chair. CBA accounted for almost a quarter of the 140 participants — a proof as good as any that CBA is the largest image analysis group in Sweden.

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 was elected Vice-chair in 2016. Carolina Wählby served on the board of Swedish Bioimaging.

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 2016, 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 are looking 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 is

elected member and Ingela Nyström is elected as well as board member 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 is Vice-Chair of the Council for Research Infrastructure (RFI) within the Swedish Research Council. 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/AR2016.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 in, for example, 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. Some of our projects lead to entrepreneurial efforts, which we interpret as a strength of our resaerch.

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. See Section 5 for details on and illustrations of all our research projects on the diverse topics.

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

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

Figure 1: Wordcloud of the journal and reviewed conference proceedings titles and abstracts.

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. Reorganisations in several stages at both universities have led to that CBA now belongs to only UU hosted by the Dept. of Information Technology in the Division for Visual Information and Interaction (Vi2) where the two subjects Computerised Image Processing and Human-Computer Interaction are joined. Ingela Nyström is currently heading both Vi2 and CBA.

The Board of the Disciplinary Domain of Science and Technology (TekNat) established a new instruction for CBA in November 2016 with description of objectives, mission, organization, board and roles of the director. The board appointed is

- Teo Asplund, Dept. of Information Technology *(PhD student representative)*
- Anders Brun, Dept. of Information Technology
- Elna-Marie Larsson, Dept. of Surgical Sciences; Radiology
- Nikolai Piskunov, Dept. of Physics and Astronomy *(Vice-chair)*
- Robin Strand, Dept. of Information Technology
- Carolina Wählby, Dept. of Information Technology *(Chair)*
- Maria Ågren, Dept. of History

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
- Digital humanities
- 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 40.8 million SEK for 2016, where the largest cost is personnel. To cover this, 40% came from UU faculty funding, 33% from external sources, and 18% from undergraduate education. The remaining 9% 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 summarises the overall economy for Vi2 in 2016. 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 2016 in kSEK.

Income		**Costs**	
UU	18037	Personnel	25551
UU undergraduate education	7963	Equipment	201
Governmental grants[1]	12724	Operating expenditure[4]	2067
Non-governmental grants[2]	2937	Rent	2102
Contracts[3]	3637	University overhead	10868
Financial netto	0		
Total income	**45298**	**Total cost**	**40789**

[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

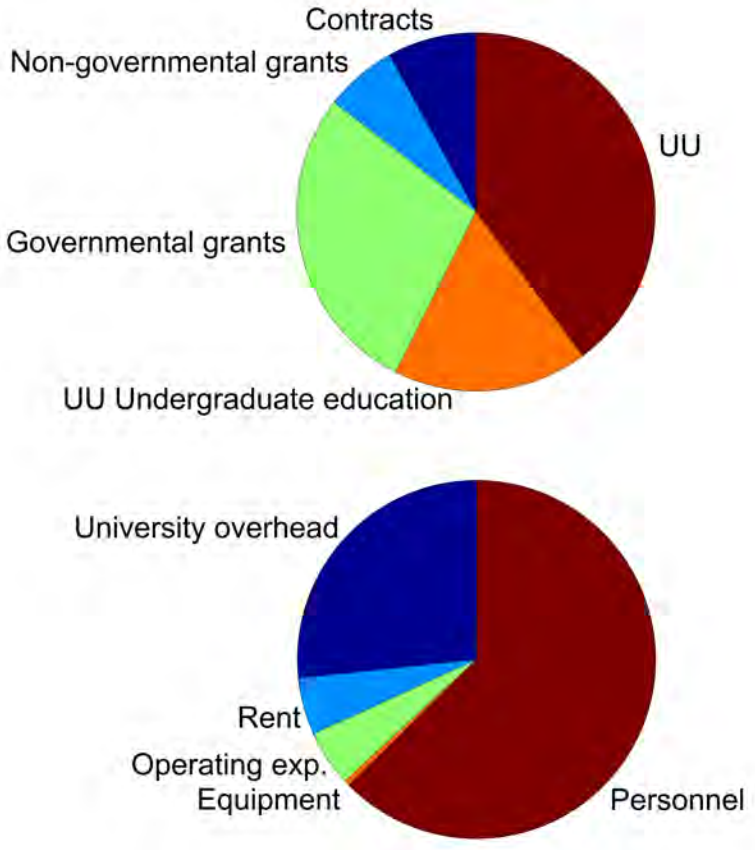

Figure 2: Vi2 income (top) and costs (bottom) for 2016.

2.2 Staff, CBA

Amin Allalou, PhD, Researcher, 160919– (part time)
Teo Asplund, Graduate Student
Marine Astruc, Graduate Student
Christophe Avenel, PhD, Researcher –160930
Ewert Bengtsson, Professor Emeritus
Ludovic Blache, PhD, PostDoc, 161010–
Maxime Bombrun, PhD, PostDoc, 160111–
Gunilla Borgefors, Professor
Eva Breznik, Graduate Student, 160901–
Anders Brun, PhD, Researcher
Ingrid Carlbom, Professor Emeritus
Anders Hast, Docent and Excellent Teacher, Lecturer
Omer Ishaq, Graduate Student, –160731
Christer O. Kiselman, Professor Emeritus
Fei Liu, Graduate Student, University of Gävle –161031
Kristína Lidayová, Graduate Student
André Liebscher, PhD, PostDoc, 160219–161231
Joakim Lindblad, PhD, Researcher (part time)
Filip Malmberg, PhD, Researcher
Damian Matuszewski, Graduate Student
Marco Mignardi, PhD, PostDoc
Bo Nordin, PhD, Researcher/Senior Lecturer, (part time) –160830
Lena Nordström, Administration
Fredrik Nysjö, Graduate Student
Johan Nysjö, Graduate Student –161231
Ingela Nyström, Professor, Director
Pontus Olsson, PhD, Researcher –160518
Gabriele Partel, Graduate Student, 160901–
Kalyan Ram, Graduate Student
Petter Ranefall, PhD, Docent 161011–, 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
Leslie Solorzano, Graduate Student 161026–
Robin Strand, Docent, Researcher
Amit Suveer, Graduate Student
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
14. Petter Ranefall, 2016, UU

CBA staff appointed Excellent Teachers

1. Anders Hast 2014, UU

3 Undergraduate education

CBA is responsible for undergraduate courses in Image Analysis, Computer Graphics, and Visualisation, see courses 1–5 below, in addition to that we teach or give guest lectures in many other courses. We are also either supervisors or reviewers for many Master theses, as our subjects are useful for many industries or other research groups and also popular with the students. This year, however, there were only five completed Master theses and two Bachelor thesis.

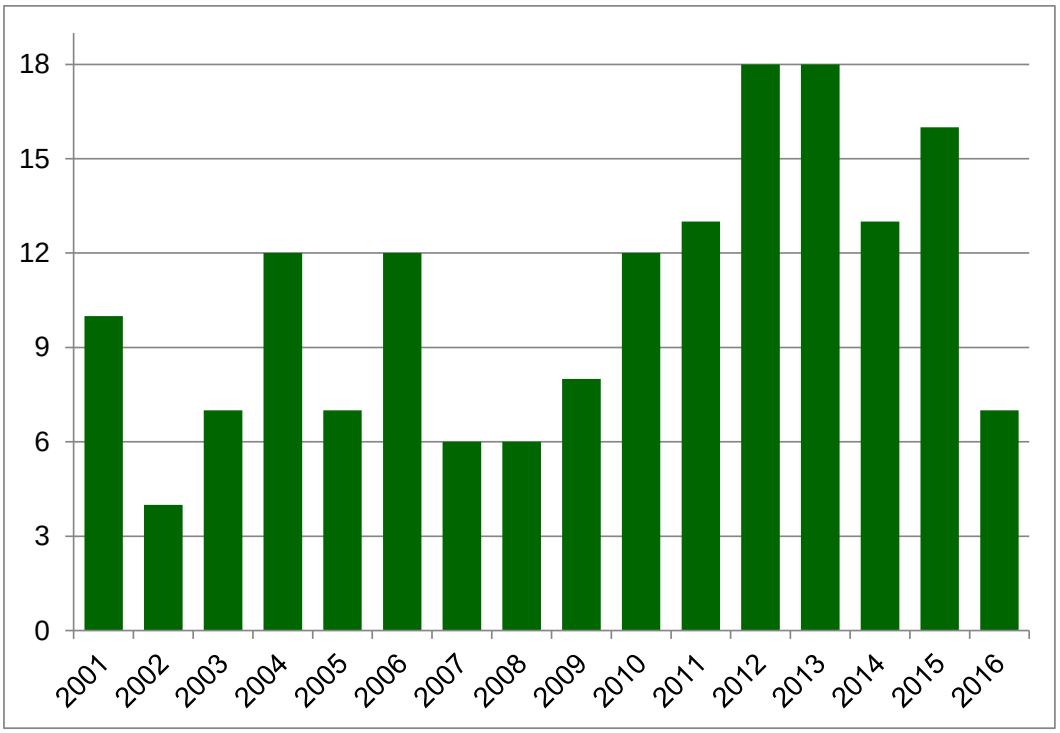

Figure 3: The number of Master theses from CBA 2001-2016.

1. **Computer Assisted Image Analysis II, 10 hp**
   Maxime Bombrun, Anders Brun, Filip Malmberg, Damian Matuszewski, Kalyan Ram, Ida-Maria Sintorn, **Nataša Sladoje**, Sajith Kecheril Sadanandan, Robin Strand, Carolina Wählby
   Period: 20160120–0318

2. **Medical Informatics, 5 hp**
   Filip Malmberg, **Robin Strand**
   Period: 20160119–0311

3. **Computer Graphics, 10 hp**
   Anders Hast, Kristina Lidayova, Fredrik Nysjö, Johan Nysjö, Tomas Wilkinson
   Period: 20160324–0605

4. **Scientific Visualization, 5 hp**
   Anders Hast, Fredrik Nysjö
   Period: 20160831–1011

5. **Computer Assisted Image Analysis I, 5 hp**
   Marine Astruc, Anders Brun, Kristina Lidayova, Damian Matuszewski, **Robin Strand**, Tomas Wilkinsson
   Period: 20151024–1219

6. **Advanced Electron Microscopy, 5 hp**
   Ida-Maria Sintorn
   Period: 20160215–20160313
   Comment: Sintorn contributed with one lecture on image processing and one assignment.

7. **Advanced Interaction Design, 5 hp**
   Fredrik Nysjö
   Period: 20160217–20160217
   Comment: Nysjö gave one guest lecture on haptics.

8. **Intelligent Interactive Systems, 5hp**
   Fredrik Wahlberg, Kalyan Ram
   Period: 20160321–20160603
   Comment: Wahlberg and Ram were lab assistants.

9. **Surgical Planning in Facial Reconstruction, 0.5 hp**
   Fredrik Nysjö
   Period: 20160615–20160615
   Comment: Nysjö was teacher and lab assistant

10. **Bioimaging and Cell Analysis, 7.5 hp**
    Maxime Bombrun, André Liebscher and Carolina Wählby
    Period: 20160829–0923
    Comment: Bombrun, Liebscher and Wählby gave lectures and computer exercises on image processing.

11. **Programming, 10 hp**
    Teo Asplund, Marine Astruc
    Period: 20160829–1216
    Comment: Asplund and Astruc were lab assistants.

3.1 Bachelor theses

1. **Defining New Boundaries in QGIS Based on Existing Definitions**
   Student: Erik Englund
   Supervisor: Magnus Gunnarsson, Data Ductus, Uppsala
   Reviewer: Anders Hast
   Publisher: UPTEC IT 16068
   Comment: Bachelor thesis
   Abstract: Handling geographical data is a common necessity at many organisations today. At The Church of Sweden, the parishes needs to be divided into election districts prior to an election in 2017. In order to streamline this process, there has been a request for a system tool which can load and reuse previously stored election district divisions. In addition, a tool which can be used to draw boundaries along elements of a background map has been wished for. A tool like this would be beneficial in cases where a neighborhood might have grown since the last election, and the Church would not like to split the neighborhood in two. A plugin to the open-source program Quantum Geographical Information System was developed which guides a user through the process of dividing a parish into election districts based on an earlier definition. Furthermore, different image-processing algorithms were examined in order to find a suitable solution to implementing a new drawing tool which could follow elements in a map. The developed plugin will probably be helpful in further elections beyond 2017 as well, however a tool to draw boundaries along map features is yet to be implemented.

2. **Improved Visualization of Rock Carvings**
   Student: Filip Hedman
   Supervisor: Filip Malmberg
   Reviewer: Anders Hast
   Publisher: UPTEC IT 16089
   Comment: Bachelor thesis
   Abstract: Digitizing rock carvings is a way to archive historically important sites and to makethe data

available for interpretation all around the world. Laser scanning has becomea very useful tool to capture the details of the rocks, and this thesis aim to answerhow we can use different filters on the captured 3D data to visualize patterns fromthe rock carvings, while minimizing the noise from the surrounding geometry.Different coloring methods are evaluated to accentuate the rock carvings, while amedian filter is implemented to reduce the noise of the renderings. The results showthat it is indeed possible to perform this kind of visualization, and that some methodsare more suitable for the task than others. The results of this thesis will hopefully make the choice of method easier for other researchers in forthcoming projects.

3.2 Master theses

1. **Runway Detection in LWIR Video: Real Time Image Processing and Presentation of Sensor Data**
   Student: Erasmus Cedernaes
   Supervisor: Joakim Lindèn, SAAB AB, Stockholm
   Reviewer: Anders Hast
   Publisher: UPTEC F 16044
   Abstract: Runway detection in long wavelength infrared (LWIR) video could potentially increase the number of successful landings by increasing the situational awareness of pilots and verifying a correct approach. A method for detecting runways in LWIR video was therefore proposed and evaluated for robustness, speed and FPGA acceleration.

   The proposed algorithm improves the detection probability by making assumptions of the runway appearance during approach, as well as by using a modified Hough line transform and a symmetric search of peaks in the accumulator that is returned by the Hough line transform.

   A video chain was implemented on a Xilinx ZC702 Development card with input and output via HDMI through an expansion card. The video frames were buffered to RAM, and the detection algorithm ran on the CPU, which however did not meet the real-time requirement. Strategies were proposed that would improve the processing speed by either acceleration in hardware or algorithmic changes.

2. **Video Quality Metric Improvement Using Motion and Spatial Masking**
   Student: Henrik Näkne
   Supervisor: Jack Enhorn, Ericsson, Stockholm
   Reviewer: Anders Hast
   Publisher: UPTEC F 16002
   Abstract: Objective video quality assessment is of great importance in video compression and other video processing applications. In today's encoders Peak Signal to Noise Ratio or Sum of Absolute Differences are often used, though these metrics have limited correlation to perceived quality. In this paper other block-based quality measures are evaluated with superior performance on compression distortion when evaluating correlation with Mean Opinion Scores. The major results are that Block-based Visual Information Fidelity with optical flow and intra-frame Gaussian weighting outperforms PSRN, VIF, and SSIM. Also, a block-based weighted Mean Squared Error method is proposed that performs better than PSRN and SSIM, however not VIF and BB-VIF, with the advantage of high locality, which is useful in video encoding. The previously mentioned weighting methods have not been evaluated with SSIM, which is proposed for further studies.

3. **An Optimal Solution for Implementing a Specific 3D Web Application**
   Student: Mathias Nordin
   Supervisor: Jinyuan Jia, Tongji University, Shanghai, China
   Reviewer: Anders Hast
   Publisher: UPTEC IT 16060
   Abstract: WebGL equips web browsers with the ability to access graphic cards for extra processing power. WebGL uses GLSL ES to communicate with graphics cards, which uses different instructions compared with common web development languages. In order to simplify the development process there are JavaScript libraries handles the communication with WebGL. On the Khronos website there is a listing of 35 different JavaScript libraries that access WebGL. It is time consuming for developers to compare the benefits and disadvantages of all these libraries to find the best WebGL library for their need. This thesis sets up requirements of a specific WebGL application and investigates which libraries that are best for implmeneting its

requirements. The procedure is done in different steps. Firstly is the requirements for the 3D web application defined. Then are all the libraries analyzed and mapped against these requirements. The two libraries that best fulfilled the requirments is Three.js with Physi.js and Babylon.js. The libraries is used in two seperate implementations of the intitial game. Three.js with Physi.js is the best libraries for implementig the requirements of the game. A performance test showed that Babylon.js is better then Three.js with Physi.js at rendering an envirionemnt with bounching spheres.

4. **Landmark Detection for Mobile Eye Tracking**
   Student: Yufan Miau
   Supervisor: Martin Raubal, Swiss Federal Institute of Technology, Zurich, Switzerland
   Reviewer: Nataša Sladoje
   Publisher: UPTEC IT 16056
   Abstract: Mobile eye tracking studies in urban environments can provide important insights into several processes of human behavior, ranging from wayfinding to human-environment interaction. The analysis of this kind of eye tracking data are based on a semi-manual or even sometimes completely manual process, consuming immense post-processing time. In this thesis, we propose an approach based on computer vision methods that allows fully automatic analysis of eye tracking data, captured in an urban environment. We present our approach, as well as the results of three experiments that were conducted in order to evaluate the robustness of the system in open, as well as in narrow spaces. Furthermore, we give directions towards computation time optimization in order to achieve analysis on the fly of the captured eye tracking data, opening the way for human-environment interaction in real time.

5. **Towards Automatic Smartphone Analysis for Point-Of-Care Microarray Assays**
   Student: Julia Erkers
   Supervisor: Jesper Gantelius, Royal Institute of Technology, Stockholm
   Reviewer: Ida-Maria Sintorn
   Publisher: UPTEC X 15 017
   Abstract: Poverty and long distances are two reasons why some people in the third world countries hasdifficulties seeking medical help. A solution to the long distances could be if the medical carewas more mobile and diagnostically tests could be performed on site in villages. A new pointof-care test based on a small blood shows promising results both in run time and mobility.However, the method still needs more advanced equipment for analysis of the resultingmicroarray. This study has investigated the potential to perform the analysis within asmartphone application, performing all steps from image capturing to a diagnostic result. Theproject was approach in two steps, starting with implementation and selection of imageanalysis methods and finishing with implementing those results into an Android application. A final application was not developed, but the results gained from this project indicates that a smartphone processing power is enough to perform heavy image analysis within a sufficientamount of time. It also imply that the resolution in the evaluated images taken with a Nexus 6 together with an external macro lens most likely is enough for the whole analysis, but further work must be done to ensure it.

4 Graduate education

In 2016, there were three dissertations at CBA. The first was on using deep learning for analysis of microscopy images, the second on analysis of 3D images for planning of orthopaedic surgery, and the third on augmenting reality using a hand-held device. There was also one dissertation on digital geometry at University of Sciences, Techniques, and Technology in Bamako, Mali, where the main supervisor, Kiselman, came from us. During his PhD studies, Adama Koné from Mali spent several periods in Uppsala. In the graduate education, we offer courses for PhD students, both our own and for those using image analysis in their respective research topics.

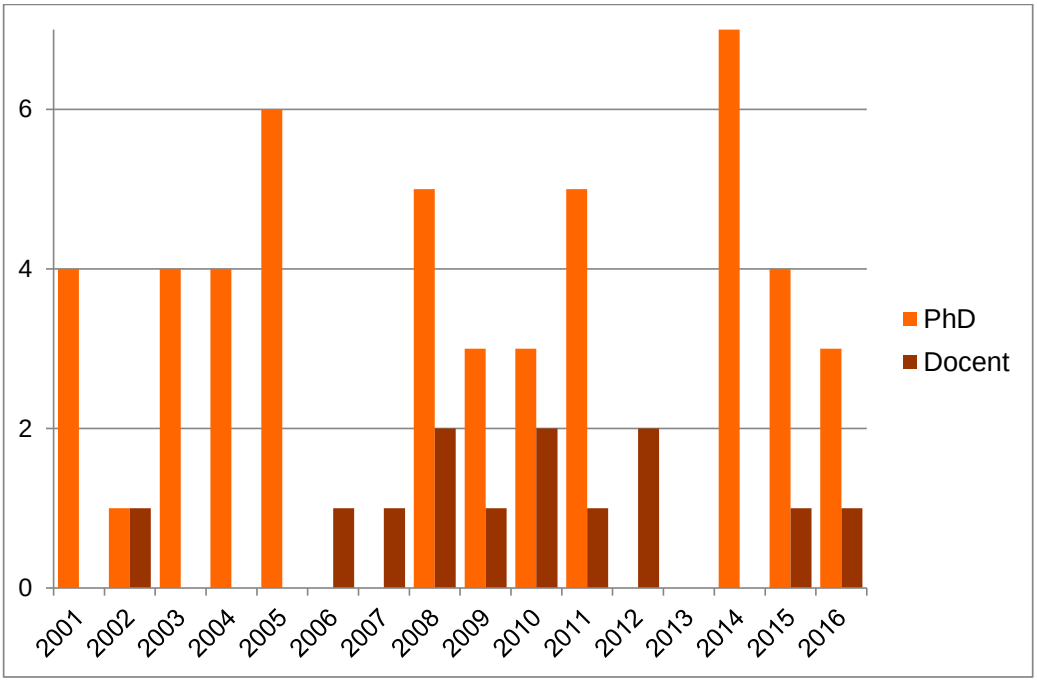

Figure 4: The number of new PhDs (orange) and docents (brown) at CBA 2001–2016.

4.1 Graduate courses

1. **Scientific Visualisation (SeSE), 5 hp**
   Anders Hast, Fredrik Nysjö
   Period: 20161031–1118
   Description: The expression "a picture is worth a thousand words" refers to the idea that complex stories can be described with just a single image. The expression is also valid in the scientific area and express what scientific visualization is about. When large and complex data sets are resulting from experiments and computations, visualisation is a way to give deeper insight and knowledge. The course Scientific Visualisation deals with methods that offer a way to see the unseen. In the course, the students learn how to select appropriate methods for a given data set, possibilities and limitations with methods, and to use visualisation toolkits. The focus is on using script programming in combination with VTK (the Visualization Toolkit) and this way creating great visualizations!

2. **Application Oriented Image Analysis, 5/8 hp**
   Kristina Lidayova, **Ida-Maria Sintorn, Robin Strand, Carolina Wählby**
   Period: 16101–1130
   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 and Modern Papers in Image Analysis**
   PhD students at CBA, **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.

4.2 Dissertations

1. *Date:* 20160114
   Digital Geometry Used for Discretizaton and Optimal Covering of Euclidean Objects
   Student: **Adama Arouna Koné**, Université des Sciences, des Techniques et des Technologies de Bamako, USTTB, Mali
   Supervisor: Christer Kiselman
   Assistant Supervisor: Ouaténi Diallo(1), Diby Diarra(1), Gunilla Borgefors
   (1) Université des Sciences, des Techniques et des Technologies de Bamako, USTTB, Mali
   Opponent: Fana Tangara(1), Sado Traoré(2)
   (1) Université des Sciences, des Techniques et des Technologies de Bamako, USTTB, Mali
   (2) Université Polytechnique á Bobo Dioulasso, Burkina Faso
   Committee: Christer Kiselman, Ouaténi Diallo, Diby Diarra(1), Mamadou Sy(3).
   (1) Université des Sciences, des Techniques et des Technologies de Bamako, USTTB, Mali
   (3) Université Gaston Berger, Saint-Louis, Sénégal
   Publisher: Université des Sciences, des Techniques et des Technologies de Bamako, USTTB.
   Comment: Original Thesis title: Géométrie digitale utilisée pour la discrétisation et le recouvrement optimal des objets euclidiens.
   Abstract: In the thesis two types of discretizations of Euclidean lines in the plane and hyperplanes in n-dimensional Euclidean space are studied. The lines and hyperplanes are covered by dilations of the discretized objects, using several different structuring elements. Precise results are obtained concerning the optimal dilations of the discrete objects that can serve in such coverings. These theorems generalize earlier results obtained by Jean-Marc Chassery and Isabelle Sivignon.

   The thesis also contains results on discrete convexity, a study using second order difference operators and convolution operators.

2. *Date:* 20160609
   Image Analysis and Deep Learning for Applications in Microscopy
   Student: **Omer Ishaq**
   Supervisor: Carolina Wählby
   Assistant Supervisor: Vladimir Ćurić
   Opponent: Bernd Rieger, Quantitative Imaging Group, Department of Imaging Physics, Delft University of Technology, The Netherlands
   Committee: Michelle K Knowles, Department of Chemistry and Biochemistry, University of Denver, USA; Peter Horvath, Synthetic and Systems Biology Unit, Hungarian Academy of Sciences, BRC, Szeged, Hungary; Atsuto Maki, Computer Vision and Active Perception Laboratory (CVAP), Kungliga Tekniska Högskolan (KTH), Sweden.
   Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-9567-1
   Abstract: Quantitative microscopy deals with the extraction of quantitative measurements from samples observed under a microscope. Recent developments in microscopy systems, sample preparation and handling techniques have enabled high throughput biological experiments resulting in large amounts of image data, at biological scales ranging from subcellular structures such as fluorescently tagged nucleic acid sequences to whole organisms such as zebrafish embryos. Consequently, methods and algorithms for automated quantitative analysis of these images have become increasingly important. These methods range from traditional image analysis techniques to use of deep learning architectures.

   Many biomedical microscopy assays result in fluorescent spots. Robust detection and precise localization of these spots are two important, albeit sometimes overlapping, areas for application of quantitative image analysis. We demonstrate the use of popular deep learning architectures for spot detection and compare them against more traditional parametric model-based approaches. Moreover, we quantify the effect of pre-training and change in the size of training sets on detection performance. Thereafter, we determine the potential of training deep networks on synthetic and semi-synthetic datasets and their comparison with networks trained on manually annotated real data. In addition, we present a two-alternative forced-choice based tool for assisting in manual annotation of real image data. On a spot localization track, we parallelize a popular compressed sensing based localization method and evaluate its performance in conjunction with different optimizers, noise conditions and spot densities. We investigate its sensitivity to different point spread function estimates.

Zebrafish is an important model organism, attractive for whole-organism image-based assays for drug discovery campaigns. The effect of drug-induced neuronal damage may be expressed in the form of zebrafish shape deformation. First, we present an automated method for accurate quantification of tail deformations in multi-fish micro-plate wells using image analysis techniques such as illumination correction, segmentation, generation of branch-free skeletons of partial tail-segments and their fusion to generate complete tails. Later, we demonstrate the use of a deep learning-based pipeline for classifying micro-plate wells as either drug-affected or negative controls, resulting in competitive performance, and compare the performance from deep learning against that from traditional image analysis approaches.

3. *Date:* 20160930
Interactive 3D Image Analysis for Cranio-Maxillofacial Surgery Planning and Orthopedic Applications
Student: **Johan Nysjö**
Supervisor: Ingela Nyström
Assistant Supervisor: Filip Malmberg and Ida-Maria Sintorn
Opponent: Jayaram K. Udupa, University of Pennsylvania, USA
Committee: Magnus Borga, Linköping University; Einar Heiberg, Lund University; Fredrik Kahl, Chalmers University of Technology; Daniel Nowinski, Uppsala University; Anders Ynnerman, Linköping University
Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-9668-5
Abstract: Modern medical imaging devices are able to generate highly detailed three-dimensional (3D) images of the skeleton. Computerized image processing and analysis methods, combined with real-time volume visualization techniques, can greatly facilitate the interpretation of such images and are increasingly used in surgical planning to aid reconstruction of the skeleton after trauma or disease. Two key challenges are to accurately separate (segment) bone structures or cavities of interest from the rest of the image and to interact with the 3D data in an efficient way. This thesis presents efficient and precise interactive methods for segmenting, visualizing, and analysing 3D computed tomography (CT) images of the skeleton. The methods are validated on real CT datasets and are primarily intended to support planning and evaluation of cranio-maxillofacial (CMF) and orthopedic surgery.

   Two interactive methods for segmenting the orbit (eye-socket) are introduced. The first method implements a deformable model that is guided and fitted to the orbit via haptic 3D interaction, whereas the second method implements a user-steered volumetric brush that uses distance and gradient information to find exact object boundaries.

   The thesis also presents a semi-automatic method for measuring 3D angulation changes in wrist fractures. The fractured bone is extracted with interactive mesh segmentation, and the angulation is determined with a technique based on surface registration and RANSAC.

   Lastly, the thesis presents an interactive and intuitive tool for segmenting individual bones and bone fragments. This type of segmentation is essential for virtual surgery planning, but takes several hours to perform with conventional manual methods. The presented tool combines GPU-accelerated random walks segmentation with direct volume rendering and interactive 3D texture painting to enable quick marking and separation of bone structures. It enables the user to produce an accurate segmentation within a few minutes, thereby removing a major bottleneck in the planning procedure.

4. *Date:* 20161007
Hand-held Augmented Reality for Facility Maintenance
Student: **Fei Liu**, University of Gävle
Supervisor: Stefan Seipel
Assistant Supervisor: Julia Åhlen, University of Gävle; Ewert Bengtsson
Opponent: Xiangyu Wang, Curtin University, Perth, Australia
Committee: Christer Sjöström, Gävle, University of Gävle; Else Nygren, UU; Thomas Porathe, Norwegian University of Science and Technology in Trondheim, Norway; Ida-Maria Sintorn, UU; Camilla Forsell, Linköping University
Publisher: Acta Universitatis Upsaliensis, ISBN: 978-91-554-9669-2
Abstract: Buildings and public infrastructures are crucial to our societies in that they provide habitations, workplaces, commodities and services indispensible to our daily life. As vital parts of facility management, operations and maintenance (O&M) ensure a facility to continuously function as intended, which take up the longest time in a facility's life cycle and demand great expense. Therefore, computers and information

technology have been actively adopted to automate traditional maintenance methods and processes, making O&M faster and more reliable.

Augmented reality (AR) offers a new approach towards human-computer interaction through directly displaying information related to real objects that people are currently perceiving. People's sensory perceptions are enhanced (augmented) with information of interest naturally without deliberately turning to computers. Hence, AR has been proved to be able to further improve O&M task performance.

The research motif of this thesis is user evaluations of AR applications in the context of facility maintenance. The studies look into invisible target designation tasks assisted by developed AR tools in both indoor and outdoor scenarios. The focus is to examine user task performance, which is influenced by both AR system performance and human perceptive, cognitive and motoric factors.

Target designation tasks for facility maintenance entail a visualization-interaction dilemma. Two AR systems built upon consumer-level hand-held devices using an off-the-shelf AR software development toolkit are evaluated indoors with two disparate solutions to the dilemma – remote laser pointing and the third person perspective (TPP). In the study with remote laser pointing, the parallax effect associated with AR "X-ray vision" visualization is also an emphasis.

A third hand-held AR system developed in this thesis overlays infrared information on façade video, which is evaluated outdoors. Since in an outdoor environment marker-based tracking is less desirable, an infrared/visible image registration method is developed and adopted by the system to align infrared information correctly with the façade in the video. This system relies on the TPP to overcome the aforementioned dilemma.

5 Research

Our research activities are conducted in a large number of projects — some large, some small. Image analysis and visualization is our own subjects, but most of what we do is applications where these subjects are necessary, mostly together with partners that need our expertize. Of course, working in applications surprisingly often leads to new, general methods in our basic field.

One application area is digital humanities. The largest application at present is developing methods for analysis of old, handwritten texts, see Section 5.1. In Section 5.2, we list our theoretical projects that develop our core subjects independently of any specific application. Apart from digital humanities, almost all of our applications are biomedical. Analysis of the ever increasing types of medical images is a natural application, for diagnosis and understanding. In surgical planning visualization becomes important and we also develop haptic presentations of the data. These projects are found in Section 5.3. At a smaller scale, we develop methods for light microscopy in general and for understanding cell biology. Most of these project are run within the large Swedish co-operation project SciLifeLab, see Section 5.4. Finally, we have a few projects aimed at electron microscopy that produces very different images from light microscopy and thus needs other approaches.

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 Digital Humanities

1. **Colour and Space in Cultural Heritage (COSCH)**
   Anders Brun, Anders Hast, Nataša Sladoje, Ewert Bengtsson, Kalyan Ram
   Funding: COST
   Period: 20120101–20161106
   Abstract: True, precise and complete documentation of artefacts is essential for conservation and preservation of our cultural heritage (CH). By ensuring access to the best possible documentation of artefacts this COST Action contributes to the enhanced understanding of material CH and help its long-term preservation. Documentation of CH involves researchers, scientists and professionals from multiple disciplines and industries. CBA has been active in the COSCH network, visited meetings, participating in summer schools. Anders Brun, Nataša Sladoje and Ewert Bengtsson have been active in the managing committee of the network.

2. **Recognition and Image Analysis for Natural History Collections**
   Anders Brun, Tomas Wilkinson
   Partners: Stefan Daume, Swedish Museum of Natural History; Alicia Fornes, Universitat Autonoma de Barcelona, Spain
   Funding: Swedish Research Council
   Period: 20140101–Current
   Abstract: 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. Adding automatic recognition of text, would speed up this process considerably and make the digitized data more useful for further data mining.

Figure 5: Project 1, Colour and Space in Cultural Heritage (COSCH)

Figure 6: Project 2, Recognition and Image Analysis for Natural History Collections

3. **Recognition and Datamining for Handwritten Text Collections**
   Anders Brun, Ewert Bengtsson, Fredrik Wahlberg, Tomas Wilkinson, Kalyan Ram, Anders Hast
   Partners: Carl Nettelblad, Dept. of Information Technology, Lasse Martensson, Dept. of Business and Economics Studies, Högskolan i Gävle; Mats Dahllöf, Dept. of Linguistics and Philology, UU; Alicia Fornés, Universitat Autonoma de Barcelona, Spain; Jonas Lindström, Dept. of History, UU
   Funding: UU; Swedish Research Council; Riksbankens Jubileumsfond
   Period: 20140101–Current
   Abstract: This cross disciplinary initiative takes its point of departure in the analysis of handwritten text manuscripts using computational methods from image analysis and linguistics. It sets out to develop a manuscript analysis technology providing automatic tools for large-scale transcription, linguistic analysis, digital paleography and generic data mining of historical manuscripts. The mission is to develop technology that will push the digital horizon back in time, by enabling digital analysis of handwritten historical materials for both researchers and the public. Promising results during the year include a novel word spotting algorithms, continuing the development of large scale analysis of medieval letters and clustering based transcription of documents.

4. **Writer Identification and Dating**
   Anders Brun, Fredrik Wahlberg, Anders Hast
   Partners: Lasse Martensson, Dept. of Business and Economics Studies, Högskolan i Gävle; Mats Dahllöf, Dept. of Linguistics and Philology, UU; Alicia Fornés, Universitat Autonoma de Barcelona, Spain
   Funding: UU; Swedish Research Council; Riksbankens Jubileumsfond
   Period: 201401–Current
   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 are using this information to identify single writers and perform style based dating of historical manuscripts. During 2016 we continuted to analyze over 10000 manuscript pages form the collection Svenskt Diplomatarium, from Riksarkivet. Using our newest methods, based on recent trends in deep learning, we are able to estimate the production date of a manuscript in this collection with a median error of less than 12 years.

5. **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: SLU; Stockholm University
   Period: 200901–Current
   Abstract: This project is a collaboration with researchers at SU and SLU. It aims to derive information about rural and city landscapes 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. This is an ongoing collaboration, which has so far resulted in one patent and one journal publication on the detection of damaged forest from aerial photographies.

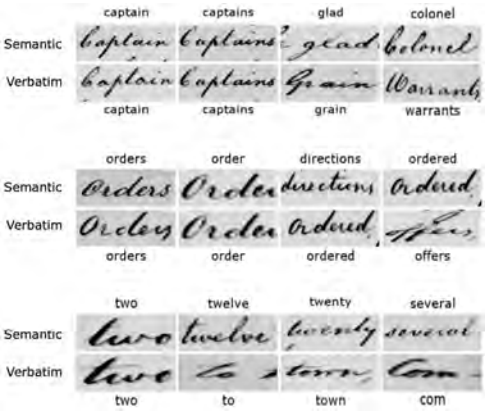

Figure 7: Project 3, Recognition and Datamining for Handwritten Text Collections

Figure 8: Project 4, Writer Identification and Dating

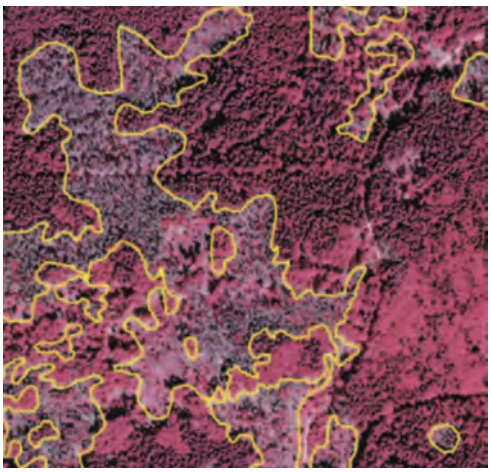

Figure 9: Project 5, Image Analysis for Landscape Analysis

6. **Color Names**
   Gunilla Borgefors
   Funding: UU
   Period: 20160701–Current
   Abstract: Color is a very important aspect of both image analysis and visualization. Therefore, naming colors is also important. An individual may know perfectly well what they mean by ”blue”, but may be very surprised by the definition of someone else. And even more so to discover that there are many languages that do not even have a term for blue. While Russian does not have a single term for blue, but two distinct ones. In this project I investigate the results from color semantics to get a better understanding on how different people handle color names and what the consequences for how the brain handles colors are.

7. **Lungfish Brain-Endocast Relationship**
   Robin Strand, Johan Nysjö
   Partners: Alice M. Clement and Per E. Ahlberg, Dept. of Organismal Biology, UU
   Funding: TN-faculty
   Period: 201501–Current
   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. During 2016, a paper describing a new method, based on image registration, for analyzing the brain-neurocranial spatial relationship in an extant lungfish to a fossil endocast was published in Royal Society Open Science Journal.

8. **Predictive Modelling of Real Time Video of Outdoor Scenes Captured With a Moving Handheld Camera**
   Nataša Sladoje, Joakim Lindblad
   Partner: Joakim Lindblad, Protracer AB, Stockholm
   Funding: Swedish Governmental Agency for Innovation Systems (VINNOVA); Protracer AB
   Period: 201510–Current
   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 modelling (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.

9. **Werner Fenchel, a Pioneer in Convexity Theory and a Migrant Scientist**
   Christer Kiselman
   Funding: Kingdom of Sweden
   Period: 20130101–20161231
   Abstract: Werner Fenchel (1905–1988) was a pioneer inconvexity theory and in particular the use of duality there. When asked about his views on the many terms used to express this duality he described in a private letter (1977) the whole development from Legendre and onwards, as well as his preferences concerning the choice of terms. A survey of basic notions of convexity theory is sketched, as well as the background for Fenchel’s leaving Germany and moving to Denmark and later to Sweden.

Figure 10: Project 6, Color names

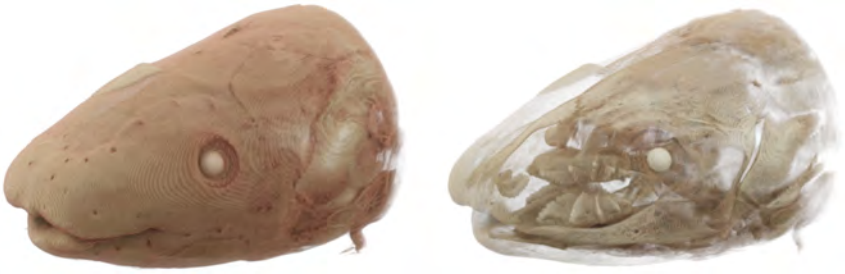

Figure 11: Project 7, Lungfish brain-endocast relationship

Figure 12: Project 8, Predictive Modelling of Real Time Video of Outdoor Scenes Captured With a Moving Handheld Camera

10. **Mathematical Concepts and Their Linguistic Expression in a Multicultural Setting**
Christer Kiselman
Partners: Adama Arouna Koné, Université des Sciences, des Techniques et des Technologies de Bamako; Lars Mouwitz, National Center for Mathematics Education, NCM, Göteborg University; Fanja Rakontondrajao, Université d'Antananarivo; Amites Rasho, Shiva Samieinia, Stockholm University; Xiaoqin Wang
Funding: Hania: Man In The Middle AB (MITM). Christer: Kingdom of Sweden. Adama: Université des Sciences, des Techniques et des Technologies de Bamako. Lars: Kingdom of Sweden. Fanja: Université d'Antananarivo. Shiva: Stockholm University; The Ruth and Nils-Erik Stenbäck foundation
Period: 20161201–Current
Abstract: To study the relation between mathematical concepts and their expression in several languages. Special attention is devoted to the use of non-native languages.

5.2 Mathematical and Geometrical Theory

11. **Precise Image-Based Measurements through Irregular Sampling**
Teo Asplund, Robin Strand, Gunilla Borgefors
Partners: Cris Luengo-Flagship Biosciences Inc., Westminster, Colorado, USA, Matthew Thurley-Luleå University of Technology, Luleå, Sweden
Funding: Swedish Research Council
Period: 20150401–Current
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: (1) The output depends on local suprema/infima, but it is very likely that local extrema fall between sampling points. (2) 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. (3) 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 such data without resampling and interpolating.

12. **Complex Convexity**
Christer Kiselman
Funding: Université de Nice 19671001–19680930; Uppsala University 19681001–20060430; Kingdom of Sweden 20060501–
Period: 19671001–Current
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 Yurii Zelinskii, 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. A current activity is a study of one-sided regularity of subsets of $\mathbf{R}^n$ or $\mathbf{C}^n$. Preliminary results on this kind of regularity were presented at a conference on 2015 September 16.

13. **Discrete Convolution Equations**
Christer Kiselman
Funding: Kingdom of Sweden.
Period: 20120111–Current
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 study of quasicrystals is part of this project.

14. **How to Best Fold a Triangle**
Christer Kiselman
Partner: Bo Senje, Halmstad University, Halmstad, Sweden; Martin Herschend, Dept. of Mathematics, UU
Funding: Uppsala University 2005–20060430; Kingdom of Sweden 20060501– .
Period: 200504–Current
Abstract: We fold a triangle once along a straight line and study how small the area of the folded figure can be. It can always be as small as the fraction $2-\sqrt{2}$ of the area of the original triangle. This is best possible: For every positive number ε there are triangles that cannot be folded better than $2-\sqrt{2}-\varepsilon$.

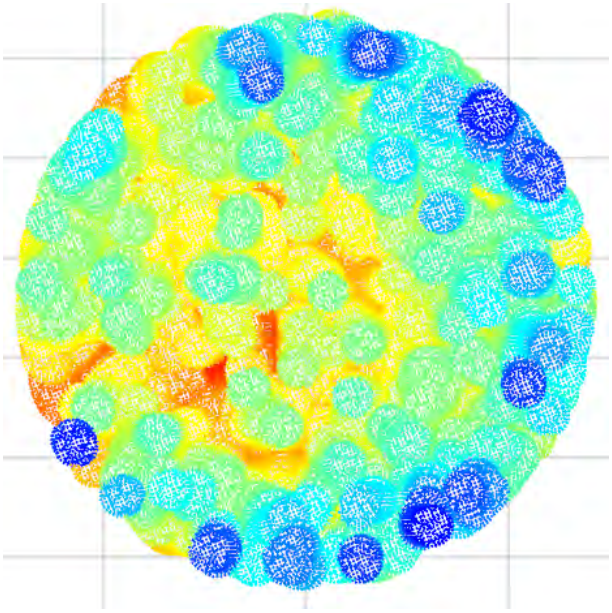

Figure 13: Project 11, Precise Image-Based Measurements through Irregular Sampling

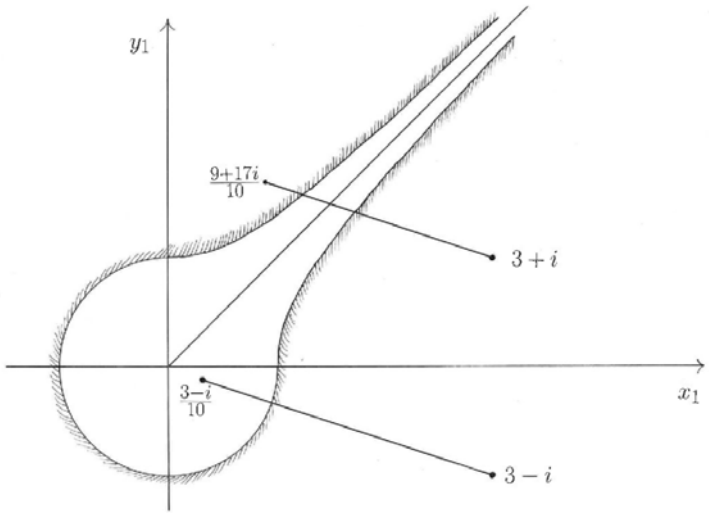

Figure 14: Project 12, Complex Convexity

15. **Existence of Continuous Right Inverses to Linear Mappings in Elementary Geometry.**
Christer Kiselman
Partner: Erik Melin, Comsol AB, Stockholm, Sweden
Funding: Christer: Uppsala University 2005–20060430; Kingdom of Sweden 20060501– . Erik: Uppsala University 2005–2008.
Period: 20050908–Current
Abstract: A linear mapping of a compact convex subset of a finite-dimensional vector space always possesses a right inverse, but may lack a continuous right inverse even if the set is smoothly bounded. Examples showing this are given as well as conditions guaranteeing the existence of a continuous right inverse, also for other sets.

16. **Digital Hyperplanes**
Christer Kiselman
Partner: Adama Arouna Koné, Université des Sciences, des Techniques et des Technologies de Bamako, USTTB, Bamako I.
Funding: Christer: Kingdom of Sweden. Adama: International Science Programme (ISP) 2011–2016; Université des Sciences, des Techniques et des Technologies de Bamako, USTTB, Bamako I 2011– .
Period: 20100101–Current
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 (11-1).

17. **Feature Point Descriptors for Image Stitching**
Anders Hast, Ida-Maria Sintorn, Damian J. Matuszewski, Carolina Wählby
Partners: Vironova AB; Dept. of Electronic Computers RSREU, Ryazan, Russia
Funding: TN-faculty; UU; Science for Life Laboratory
Period: 201501–Current
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. Currently our paper describing the whole pipeline is under journal revision.

18. **The Stochastic Watershed**
Filip Malmberg, Cris Luengo, Robin Strand
Funding: TN-faculty
Period: 20110201–Current
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 2016, a paper describing a method for exact evaluation of stochastic watersheds applied to supervised, or *targeted*, image segmentation, was accepted for publication in Discrete Applied Mathematics.

19. **Digital Distance Functions and Distance Transforms**
Robin Strand, Gunilla Borgefors
Partners: Benedek Nagy - Dept. of Computer Science, Faculty of Informatics, University of Debrecen, Hungary; Nicols Normand, IRCCyN - University of Nantes, France
Funding: TN-faculty, UU
Period: 19930901–Current
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 2016, a paper on optimal path extraction and spatially-varying cost functions was presented at the DGCI 2016 conference.

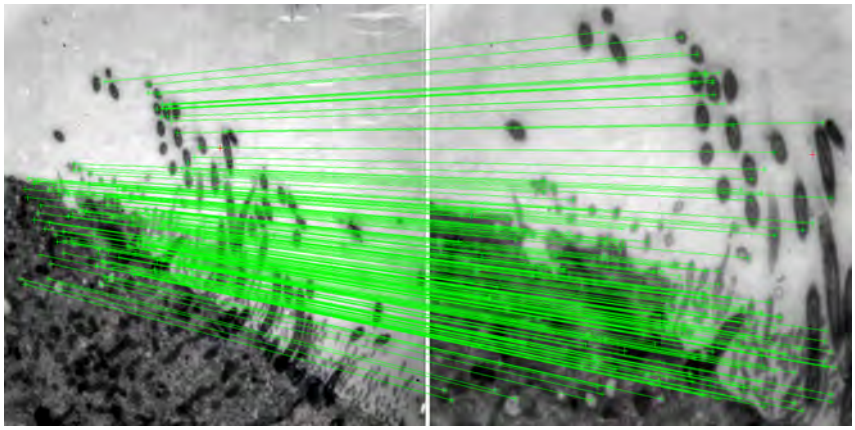

Figure 15: Project 17, Feature Point Descriptors for Image Stitching

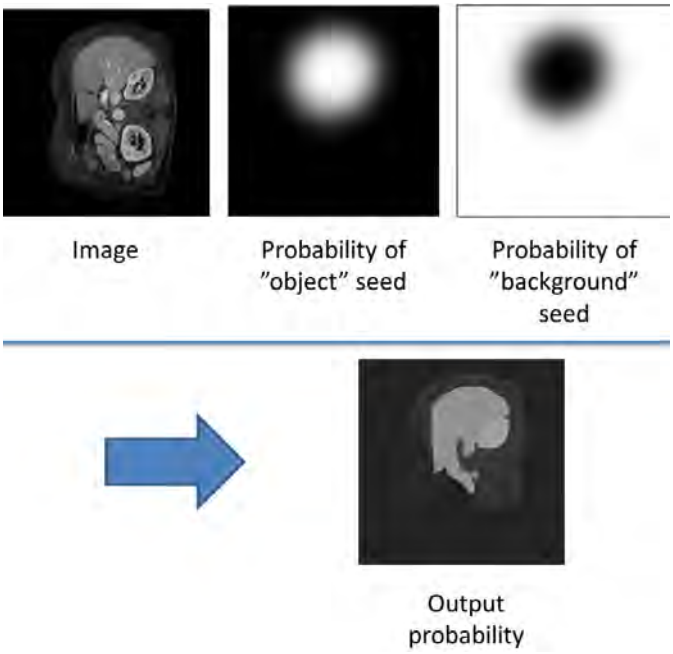

Figure 16: Project 18, The Stochastic Watershed

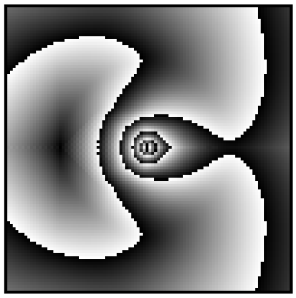

Figure 17: Project 19, Digital Distance Functions and Distance Transforms

20. **Analysis and Processing of Three-Dimensional Images on Optimal Lattices**
Robin Strand, Johan Nysjö
Funding: TN-faculty, UU
Period: 201005–Current
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 2016, a paper describing a software for processing and viewing 3D data on optimal sampling lattices was published in SoftwareX.

21. **Image Enhancement Based on Energy Minimization**
Nataša Sladoje, Joakim Lindblad
Partner: Buda Bajić, Faculty of Engineering, University of Novi Sad, Serbia
Funding: Swedish Governmental Agency for Innovation Systems (VINNOVA); TN-faculty, UU; Swedish Research Council
Period: 201409–Current
Abstract: A common approach to solve the ill-posed problem of image restoration is to formulate it as an energy minimization problem. A priori knowledge is, typically, included through a regularization component. Total variation is among most popular approaches, due to simplicity and generally good performance. During 2016, we have studied performance of energy minimization based restoration for enhancing images degraded with blur and different types of noise - Gaussian, Poisson and mixed Poisson-Gaussian. We have observed both direct maximization of a posteriori probability (MAP) and developed approaches based on Anscombe variance stabilizing transformation (VST). Our empirical study on restoration of images degraded by signal-dependent noise and different levels of blur was published in SPIE Journal of Electronic Imaging. We have extended our methods to blind restoration, where the unknown point spread function is estimated simultaneously during the restoration process. Work on that has been presented at the ISBI conference in Prague and at the SSBA symposion in Uppsala. We have also developed a super-resolution method which, based on VST, provides single image super-resolution reconstruction of images degraded with mixed Poisson-Gaussian noise. The associated conference paper was selected as one of the ”Best reviewed papers” at the IPTA conference in Oulu.

22. **Skeletonization**
Gunilla Borgefors
Partners: Punam Saha-Dept. of Electrical and Computer Engineering and Dept. of Radiology, University of Iowa, Iowa City, USA, Gabriella Sanniti di Baja-Institute for high performance computing and networking, CNR, Naples Italy
Funding: UU
Period: 20131001–Current
Abstract: Skeletonization has been a useful tool for many different image analysis and manipulation tasks since its inception fifty years ago. The purpose of this project is to collect information about the many different skeletonization methods that have been invented and to spread the knowledge about them and their usefulness. This year Saha and Borgefors edited a Special Issue of Pattern Recognition Letters ”Skeletonization and its Applications” with twelve papers on the current state-of-the-art, including a review Chapter that we wrote ourselves. In 2017 a book will be published that extends this special issue, including new contributions and a longer survey paper.

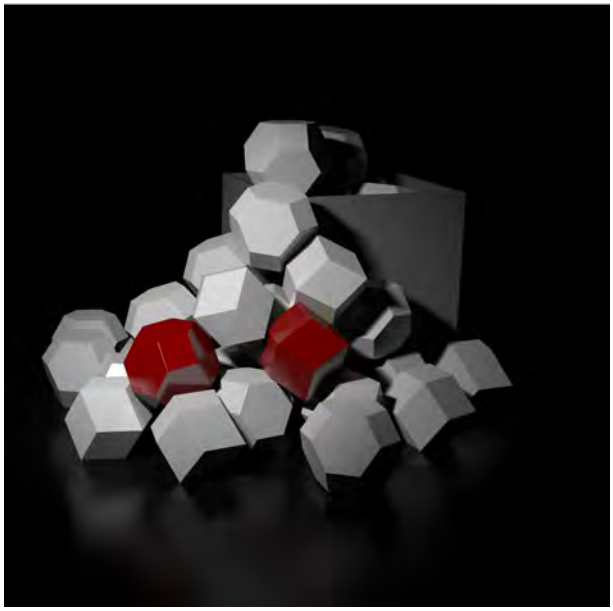

Figure 18: Project 20, Analysis and Processing of Three-Dimensional Images on Optimal Lattices

Figure 19: Project 21, Image Enhancement Based on Energy Minimization

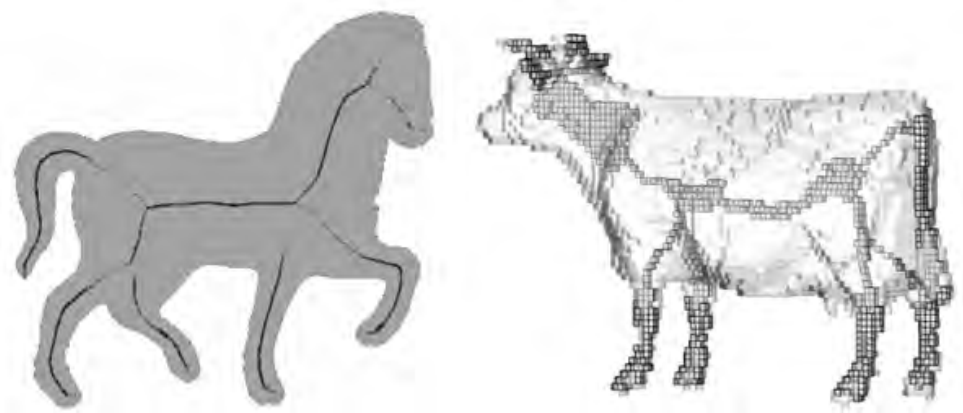

Figure 20: Project 22, Skeletonization

23. **Regional Orthogonal Moments for Texture Analysis**
Ida-Maria Sintorn, Carolina Wählby
Partners: Vironova AB; Sven Nelander, Dept. of Immunology, Genetics and Pathology, UU
Funding: Swedish Research Council
Period: 201501–Current
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, and glioblastoma phenotyping of patient specific cancer stem cell cultures for disease modeling and personalized treatment. During 2016, a paper comparing and evaluating several ROM filter banks on a number of different texture datasets was submitted and is awaiting the review response.

5.3 Medical image analysis, diagnosis and surgery planning

24. **Imiomics – Large-Scale Analysis of Medical Volume Images**
Robin Strand, Filip Malmberg
Partners: Joel Kullberg, Håkan Ahlström, Division of Radiology, Dept. of Surgical Sciences, UU
Funding: Faculty of Medicine, UU
Period: 20120801–Current
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 a large scale analysis method, which is enabled by image registration methods. These methods utilize, for example, segmented tissue 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. 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 2016, a manuscript on a non-parametric registration method was submitted and another manuscript describing the Imiomics concept was accepted for journal publication.

25. **Subtle Change Detection and Quantification in Magnetic Resonance Neuroimaging**
Marine Astruc, Robin Strand, Filip Malmberg
Partners: Johan Wikström, Elna-Marie Larsson and Raili Raininko, Dept. of Surgical Sciences, Radiology, UU
Funding: Swedish Research Council
Period: 20150501–Current
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. The aim is to allow early diagnosis, detailed correct diagnosis, and accurate and precise analysis of treatment response.

26. **Interactive Segmentation and Analysis of Medical Images**
Filip Malmberg, Robin Strand, Ingela Nyström
Partners: Joel Kullberg, Håkan Ahlström, Division of Radiology, Dept. of Surgical Sciences, UU
Funding: TN-faculty, UU
Period: 20110601–Current
Abstract: Three-dimensional (3D) 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 Surgical Sciences at the Uppsala University Hospital. A publicly available software for interactive segmentation, *SmartPaint*, can be downloaded from `http://www.cb.uu.se/~filip/SmartPaint/`. To date, this software has been downloaded about 900 times.

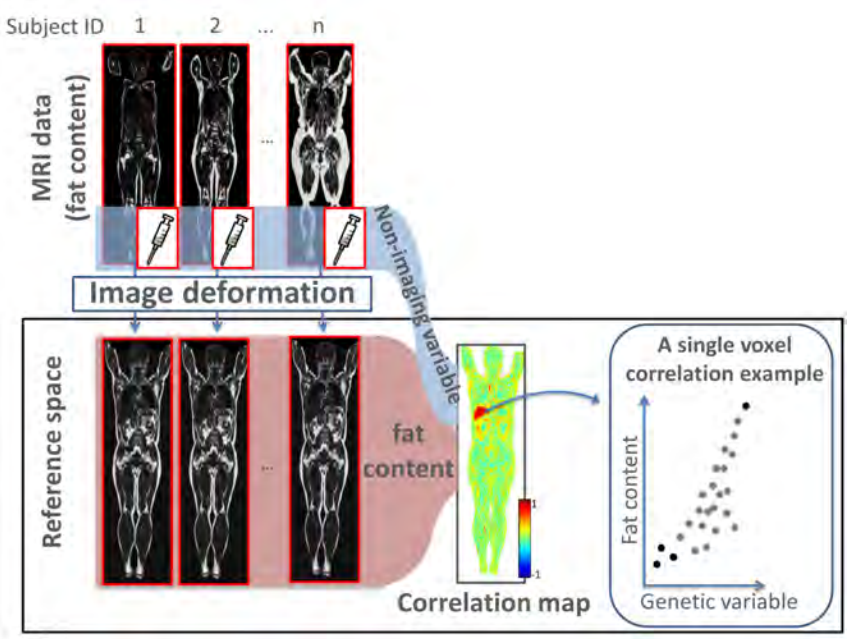

Figure 21: Project 24, Imiomics – Large-Scale Analysis of Medical Volume Images

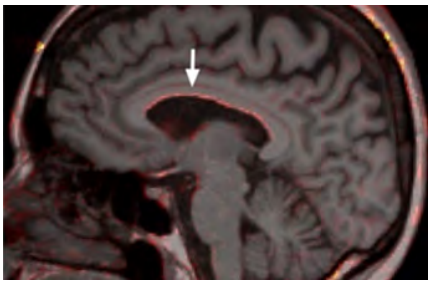

Figure 22: Project 25, Subtle Change Detection and Quantification in Magnetic Resonance Neuroimaging

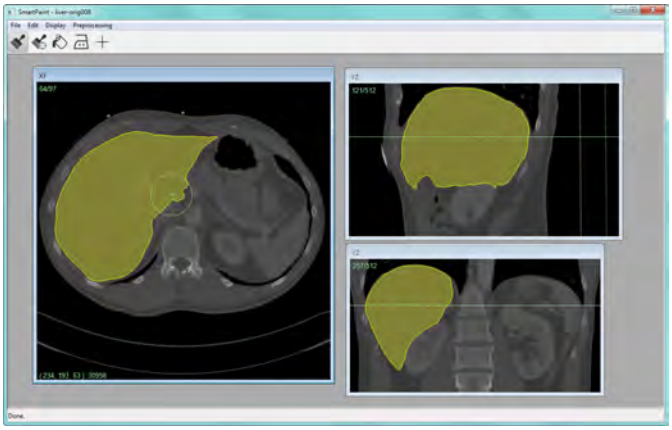

Figure 23: Project 26, Interactive Segmentation and Analysis of Medical Images

27. **Comparison of Articular Osteochondrosis in Domestic Pigs and Wild Boars by Image Processing**
Robin Strand
Partners: Pernille Etterlin, Stina Ekman, Dept. of Biomedical Sciences and Veterinary Public Health, Swedish Univeristy of Agricultural Sciences; Kristin Olstad, Dept. of Companion Animal Clinical Sciences, Norwegian University of Life Sciences; Charles Ley, Dept. of Clinical Sciences, Swedish University of Agricultural Sciences
Funding: Gerhard Forsells stipendiestiftelse; TN-faculty, UU
Period: 20150101–Current
Abstract: Articular osteochondrosis (OC) often develops in typical locations within joints and the characterization of OC distribution in the pig tarsus is incomplete. Prevalence of OC is high in domestic pigs but is presumed to be low in wild boars. In this project, we develop methods based on image registration for 3D analysis of OC distribution. In 2016, a paper was accepted for publication in Veterinary Pathology.

28. **Image Processing for Virtual Design of Surgical Guides and Plates**
Fredrik Nysjö, Pontus Olsson, Filip Malmberg, Ingrid Carlbom, Ingela Nyström
Partners: Andreas Thor; Uppsala University Hospital; Andres Rodriguez Lorenzo, Uppsala University Hospital; Jan-Michael Hirsch, Uppsala University Hospital; Daniel Buchbinder, Mt Sinai-Beth Israel Hospital, New York
Funding: TN-faculty, UU
Period: 20150317–Current
Abstract: An important part of virtual planning for reconstructive surgery, such as cranio-maxillofacial (CMF) surgery, is the design of customized surgical tools and implants. In this project, we are looking into how distance transforms and constructive solid geometry can be used to generate 3D printable models of surgical guides and plates from segmented computed tomography (CT) images of a patient, and how the accuracy and precision of the modelling can be improved by using grayscale image information in combination with anti-aliased distance transforms. Another part of the project is to develop simple and interactive tools that allow a surgeon to create the models. We have implemented a set of design tools in our existing surgery planning system, HASP, and are currently testing them on surgeons.

29. **Skeleton-Based Vascular Segmentation at Interactive Speed**
Kristína Lidayová, Ewert Bengtsson
Partners: Hans Frimmel-Division of Scientific Computing, UU; Örjan Smedby and Chunliang Wang-School of Technology and Health, KTH
Funding: VR grant to Örjan Smedby
Period: 201207–Current
Abstract: Precise segmentation of vascular structures is crucial for studying the effect of stenosis 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 for a segmentation algorithm. During 2016 we focused on centerline tree detection in diseased peripheral arteries that are characterized by wide-spread stenosis and occlusion of the arteries. The algorithm now consists of four levels. The first two levels detect healthy arteries of varying sizes and the remaining two levels specialize in different types of vascular pathology: severe calcification and occlusion. An outline of the proposed algorithm is presented in the figure. The method has been tested on 25 CTA scans of the lower limbs, achieving an average overlap rate of 89% and it was successful in detecting very distal artery branches, e.g. in the foot. The algorithm has been submitted to Journal of Medical Imaging (JMI).

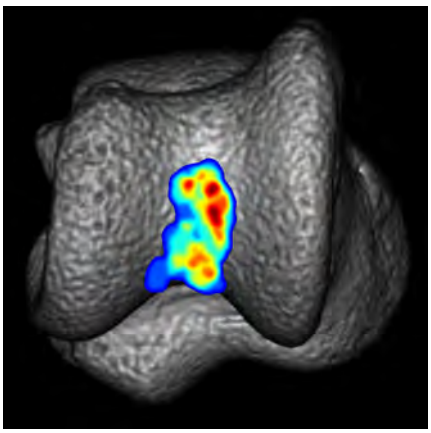

Figure 24: Project 27, Comparison of Articular Osteochondrosis in Domestic Pigs and Wild Boars by Image Processing

Figure 25: Project 28, Image Processing for Virtual Design of Surgical Guides and Plates

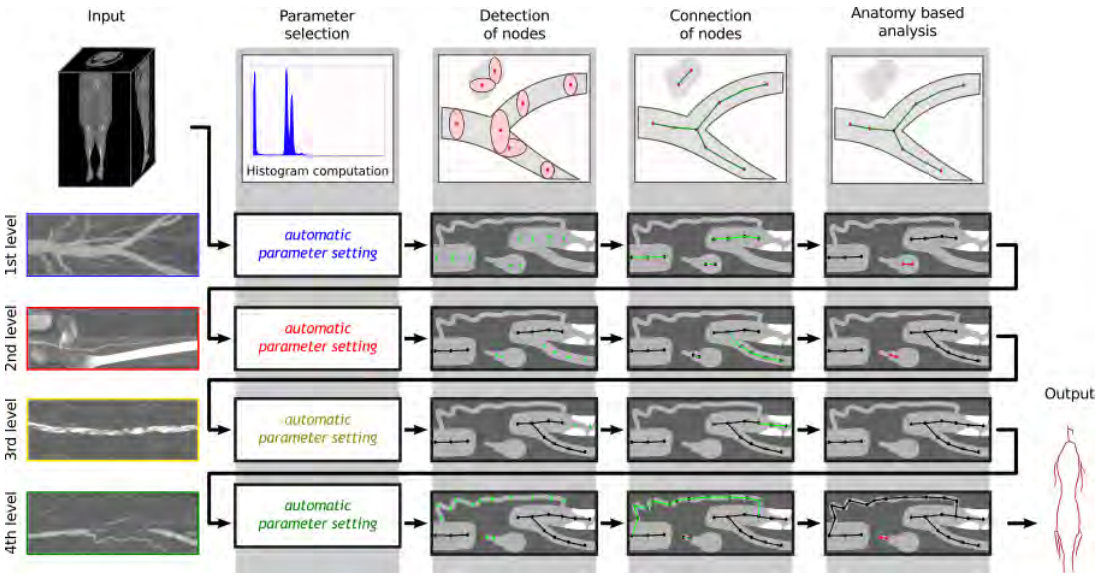

Figure 26: Project 29, Skeleton-Based Vascular Segmentation at Interactive Speed

30. **Computerized Image Analysis for Ophthalmologic Applications**
Filip Malmberg
Partners: Camilla Sandberg-Melin and Per Soderberg, Dept. of Neuroscience, UU
Funding: TN-faculty, UU
Period: 20150101–Current
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 2016, we have submitted a manuscript describing 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. The method has been evaulated on image data acquired at Gävle hospital.

31. **Airway Tree Segmentation in Subjects with Acute Respiratory Distress Syndrome**
Kristína Lidayová, Ewert Bengtsson
Partners: Hans Frimmel-Division of Scientific Computing, UU; Örjan Smedby-School of Technology and Health, KTH; Marcela Hernández Hoyos-Universidad de Los Andes, Bogotá, Colombia; Maciej Orkisz-University of Lyon, CREATIS, Lyon, France
Funding: VR grant to Örjan Smedby
Period: 201512–Current
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 reduce the mortality rate in ARDS. However, the accuracy of lung aeration analysis is hampered by two factors: the difficulty in delineating the outer boundary of the lungs (due to local lack of contrast), and the inclusion of internal structures not belonging to the parenchyma. To cope with both problems, an airway segmentation can be useful. We proposed a novel airway tree segmentation method that successfully deals with the challenges brought by ARDS. The method detects an approximate airway centerline tree and then applies the obtained intensity and distance information to restrict the region-growing segmentation and prevents it from leaking into the parenchyma. The method was evaluated on thoracic CT images of subjects with ARDS, acquired at significantly different mechanical ventilation conditions. It detected a large number of branches that serve as anatomic landmarks. The landmarks correspondences combined with gray-level information led to an improvement in the registration-based lung segmentations. In addition, the proposed method is fast which is valuable for a clinical use.

32. **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, MF-faculty, UU
Period: 20111101–20161231
Abstract: The conventional method for evaluating fractures on the radius bone in the wrist is to manually measure the angulation between the shaft and joint of the affected bone in plain X-ray images. The precision and accuracy of this measurement method is, however, limited, since X-ray only provides a static two-dimensional (2D) projection of the three-dimensional (3D) bone structures and it is difficult to find reliable landmarks on the bones. In this project, we are developing a semi-automatic method for measuring the angulation of wrist fractures in 3D computed tomography (CT) images. The user guides the method by indicating the approximate position and orientation of various parts of the radius bone. This information is subsequently used as input to automatic algorithms that make precise measurements. We combine a RANSAC-based method for estimating the long axis of the radius bone with a registration-based method for finding the orientation of the joint surface. During 2016, a paper about the 3D angle measurement method was published in Skeletal Radiology. The method was tested on 40 CT scan sequences of fractured wrists and found to have substantially higher intra- and inter-operator precision than conventional 2D X-ray measurements.

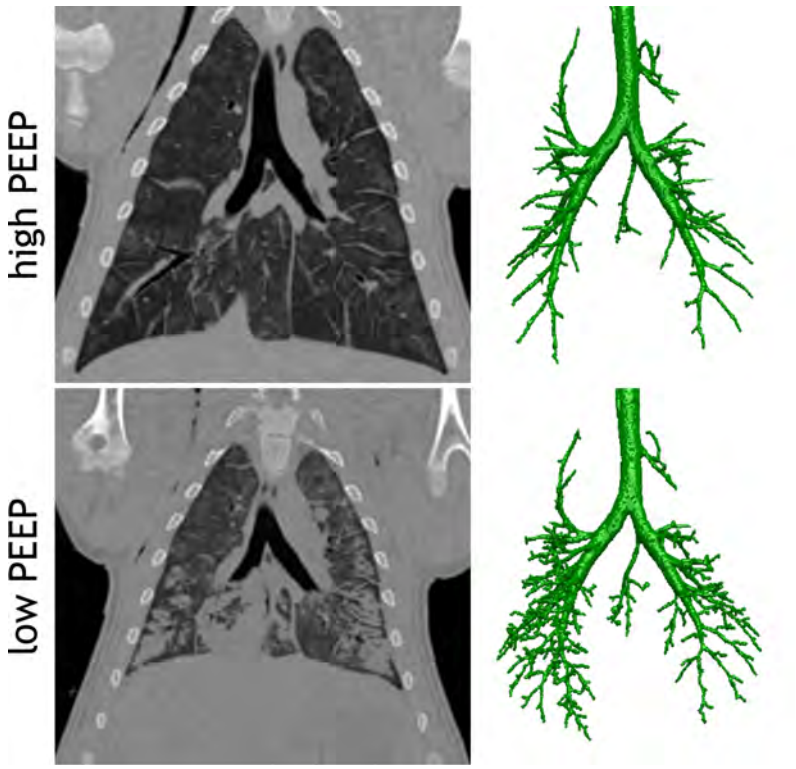

Figure 27: Project 31, Airway Tree Segmentation in Subjects with Acute Respiratory Distress Syndrome

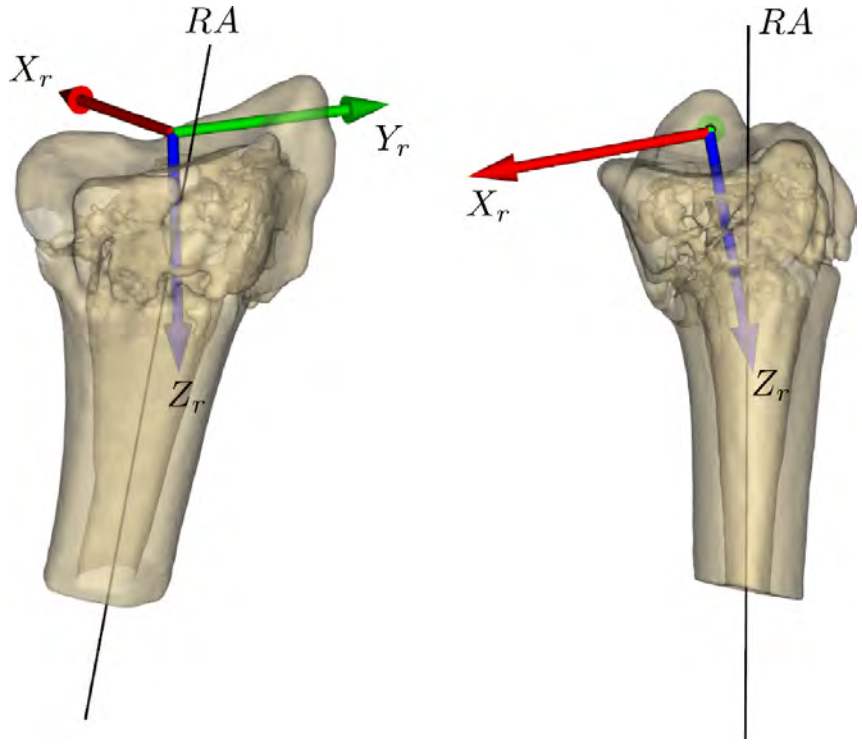

Figure 28: Project 32, Precise 3D Angle Measurements in CT Wrist Images

33. **Statistical Considerations in Whole-Body MR Analyses**
Eva Breznik, Robin Strand, Filip Malmberg
Partners: Joel Kullberg, Håkan Ahlström, Division of Radiology, Dept. of Surgical Sciences, UU
Funding: Centre for Interdisciplinary Mathematics, CIM, UU; TN-faculty, UU
Period: 201609–Current
Abstract: In this project, the focus is on testing and developing methods for Imiomics, to facilitate utilization of whole-body MR images for medical purposes. For inference about activated areas, present in the image, statistical tests are done on series of images at every voxel. This introduces accuracy and reliability problems when drawing conclusions concerning the images or multi-voxel areas as a whole, due to the multiplicity of tests that are considered at the same time. The solution to this problem is a proper multiple testing correction method. Therefore we need to test the existing ones on our specific datasets, examine the effect they have in terms of power to detect activation as well as to which extent they can increase the reliability of subsequent inferences, and explore possibilities of new ones, specifically tailored to our problem. To be able to do the statistical analysis on a set of images from different subjects in the first place, a well-performing registration method is required. For this reason, the second part of the project aims at improving the existing method by including more prior anatomy information to guide the procedure. More specifically, we will try to include the segmentation of the organs in the abdominal cavity. Another important question within the method is the choice of the reference coordinate system, to which the subjects are registered. This can affect the performance of the registration method itself, as well as interpretation of results from statistical analyses that follow it, so in addition attention will be put on resolving this issue and finding the optimal properties of a reference subject.

34. **Interactive Bone Segmentation**
Johan Nysjö, Filip Malmberg, Ida-Maria Sintorn, Ingela Nyström
Funding: TN-faculty, UU
Period: 201501–Current
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 this project, we are developing a fast interactive tool for segmenting individual bones and bone fragments in CT images. This tool, called BoneSplit, combines intuitive 3D texture painting with efficient graph-based segmentation algorithms and makes it easy for the user to mark bones of interest and edit the segmentation result. It has been evaluated on complex trauma and tumor cases (provided by the UU hospital) and been used internally in the HASP project. During the spring 2016, we installed BoneSplit at two hospitals for further testing and evaluation. A paper about BoneSplit was presented at SSBA 2016 and received the Best Industry Related Paper award.

35. **Coverage Model and its Application to High Precision Medical Image Processing**
Nataša Sladoje, Joakim Lindblad
Partners: Slobodan Dražić, Vladimir Ilić, Faculty of Technical Sciences, University of Novi Sad, Serbia
Funding: Swedish Governmental Agency for Innovation Systems (VINNOVA); TN-faculty, UU
Period: 201409–Current
Abstract: The coverage model, which we have been developing for several years now, provides a framework for representing objects in digital images as spatial fuzzy sets. Membership values indicate to what extent image elements are covered by the imaged components. The model is useful for improving information extraction from digital images and reducing problems originating from limited spatial resolution. During 2016, we analyzed and further developed a method for estimation of Feret's diameter from a pixel coverage representation. We improved the accuracy of the method by introducing a correction term that minimizes the absolute estimation error. The improved method, published in the Pattern Recognition Letters journal, demonstrates increased precision and accuracy and provides state-of-the-art performance on synthetic and real images. We also developed an iterative method for computing the signature of a shape based on its coverage representation. A statistical study indicates considerable improvements in both accuracy and precision, compared to crisp approaches and an existing approach based on averaging signatures over alpha-cuts of a fuzzy representation. We observe improved performance of the proposed descriptor in the presence of noise, and reduced variation under translation and rotation. The method was presented at the DGCI conference in Nantes.

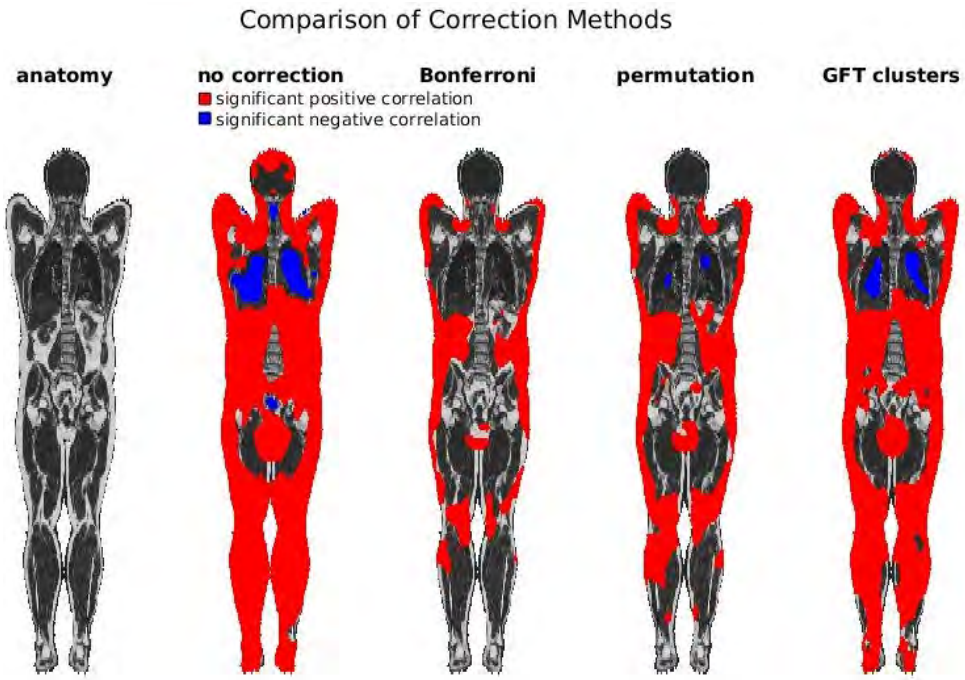

Figure 29: Project 33, Statistical Considerations in Whole-Body MR Analyses

Figure 30: Project 34, Interactive Bone Segmentation

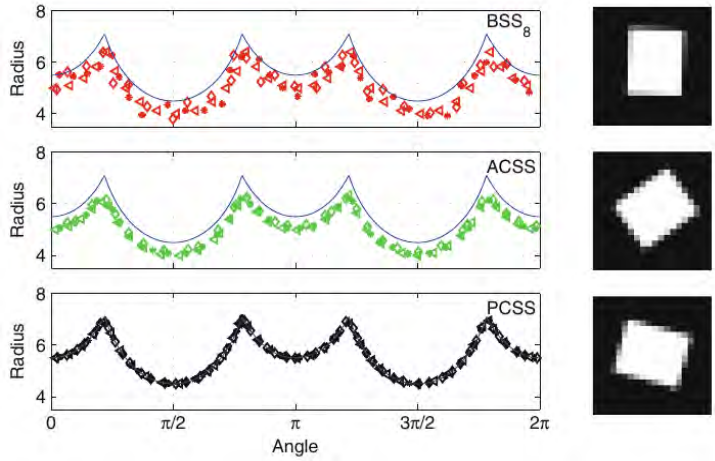

Figure 31: Project 35, Coverage Model and its Application to High Precision Medical Image Processing

36. **Methods for Combined MR and Radiation Therapy Equipment**
Robin Strand
Partner: Tufve Nyholm, Dept. of Immunology, Genetics and Pathology, UU
Funding: Vinnova; Barncancerfonden; TN-faculty, UU
Period: 20160601–Current
Abstract: Uppsala University and Hospital are current investing in image guided radiotherapy. An important component in the strategy is a combined MR scanner and treatment unit, enabeling MR imaging right before and during treatment making it possible to adjust for internal motion. In this project, we develop methods for fast detection and quantification of motion for real-time adjustment of the radiation therapy in the combined MR scanner and treatment unit.

37. **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, Hospital Necker Enfants-Malades, Paris, France; Jonathan Britto, Great Ormond Street Hospital, London, UK
Funding: TN-faculty, MF-faculty, UU
Period: 200912–Current
Abstract: In this project, we are developing semi-automatic methods for segmenting and analysing the size and shape of the orbit (eye socket) in computed tomography (CT) images - a task that is of great interest for surgery planning. A prototype segmentation tool combining deformable surface models with haptic 3D interaction was implemented in 2010 using WISH, an open-source software package for interactive visualization and segmentation that has been developed at CBA since 2003 and is available for download at http://www.cb.uu.se/research/haptics. This tool has been shown to yield accurate and precise segmentation results while only requiring a few minutes of user interaction time. It has been used in several medical research studies for segmenting intact as well as injured (fractured or malformed) orbits. We have also developed automatic registration-based techniques for comparing and analysing the shape of segmented orbits. During 2016, we developed an alternative 3D painting-based orbit segmentation technique that aims to offer tighter control over the segmentation result and produce a more accurate and consistent delineation of the anterior (frontal) boundary of the orbit. The segmentation is performed with a user-steered volumetric brush that uses distance and gradient information to fill out and find the exact boundaries of the orbit.

38. **HASP: Haptics-Assisted Surgery Planning**
Ingrid Carlbom, Pontus Olsson, Fredrik Nysjö, Johan Nysjö, Ingela Nyström
Partners: Daniel Buchbinder, Icahn School of Medicine at Mount Sinai, New York, NY, USA; Jan-Michael Hirsch, 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; TN-faculty, MF-faculty, UU
Period: 20150101–Current
Abstract: The goal of HASP, our haptics assisted surgery planning system, is to put the planning process for complex head and neck surgery into the hands of the surgeon. During 2016, we completed the 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, and installed HASP and the BoneSplit segmentation software both at the Uppsala University Hospital and at Mount Sinai Beth Israel in NYC for validation. At the UU Hospital, the focus has been on testing HASP on incoming oncological cases, and a study on trauma cases is also being prepared. At Mount Sinai Beth Israel the focus has been validation of the accuracy of HASP with 12 retrospective cases and eight prospective cases. For each case, we produce a neomandible from resin models generated by a 3D printer of the mandible, cutting guides, fibula, and case-specific plates, that are cut and glued together. We will then compare a CT model of the reconstructed resin neomandible with the HASP neomandible, and verify their correspondence. We expect to complete the study in the spring of 2017.

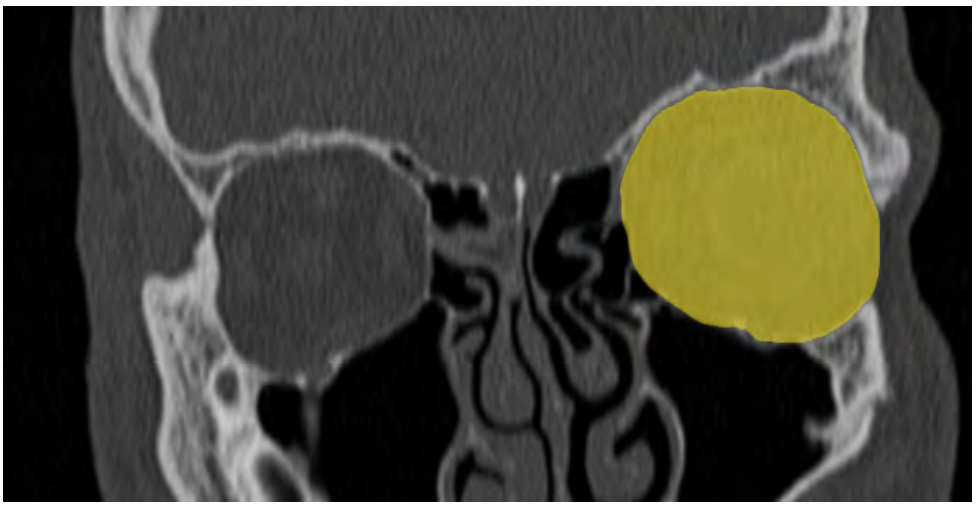

Figure 32: Project 37, Orbit Segmentation for Cranio-Maxillofacial Surgery Planning

Figure 33: Project 38, HASP: Haptics-Assisted Surgery Planning

5.4 Light microscopy, cell biology

39. **Automated Quantification of Axonal Growth**
Petter Ranefall, Carolina Wählby
Partners: Sarah Pan, Nils Hailer, Nikos Schizas - Dept. of Surgical Sciences, Uppsala University.
Funding: SciLifeLab
Period: 20161004–Current
Abstract: The aim of this project is to establish a standardised method for measuring axonal growth from spinal cord slice cultures using ImageJ and CellProfiler softwares. To measure the area of axons outside the explant body, pictures of spinal cord slice cultures are captured through a light microscope and then analysed in ImageJ and CellProfiler. Our plan is to use this method in future experiments on axonal regeneration and growth from the spinal cord.

40. **Assessing Bacterial Growth Kinetics and Morphology Using Time-lapse Microscopy Data**
Petter Ranefall, Carolina Wählby
Partners: Elisabet Nielsen - Dept. of Pharmaceutical Biosciences, UU, Pikkei Yuen, Pernilla Lagerbäck, Thomas Tängdén Otto Cars - Dept. of Medical Sciences, UU
Funding: SciLifeLab
Period: 20160603–Current
Abstract: In vitro methods are often used to study the concentration-effect relationship for antimicrobial agents. Time-kill curve experiments have long been the standard methodology, with bacterial counts followed over time using viable count assessments on agar plates. This method is labor-intensive and recently digital time-lapse microscopy methods have become available which might allow a more rapid assessment of antibiotic activity. Additionally, these methods could add information related to drug-induced morphological changes. The aim of this project is to integrate information obtained from time-lapse microscopy in the characterization of antibiotic effect on bacterial growth and morphology.

41. **Amyotrophic Lateral Sclerosis**
Petter Ranefall, Carolina Wählby
Partners: Jordi Carreras Puigvert, Oskar Fernandez-Capetillo - Division of Translational Medicine and Chemical Biology, Dept. of Medical Biochemistry and Biophysics Karolinska Institutet, SciLifeLab, Stockholm
Funding: SciLifeLab
Period: 20160113–Current
Abstract: Amyotrophic lateral sclerosis is a neurodegenerative disease characterized by the loss of motor neurons in the cortex brain stem and spinal chord. The incidence is 1 in 50 000 combining US and EU populations. The disease is fatal in approximately 5 years and there is currently no cure for AL. Morover, given the low incidence of case, finding new treatments for ALS is not a priority of the Pharma industry. At SciLifeLab, we are developing several image based assays to discover strategies that can alleviate the death of ALS-motor neurons.

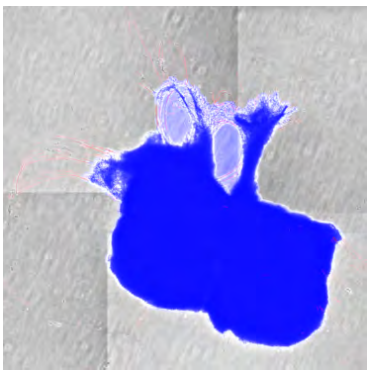

Figure 34: Project 39, Automated quantification of axonal growth

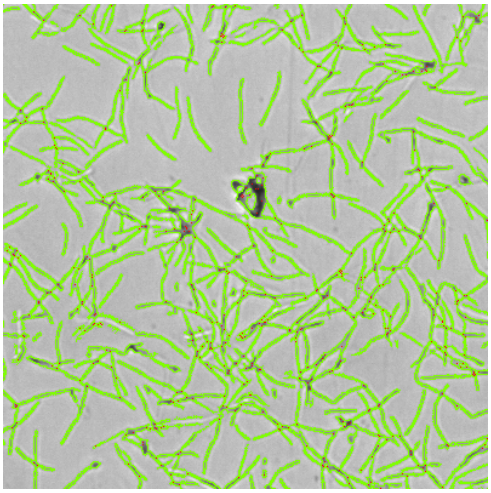

Figure 35: Project 40, Assessing Bacterial Growth Kinetics and Morphology Using Time-lapse Microscopy Data

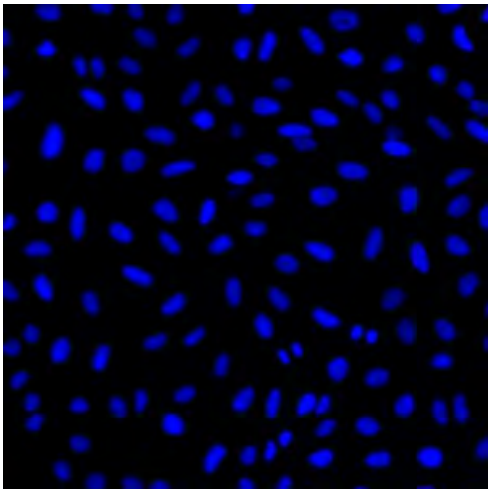

Figure 36: Project 41, Amyotrophic lateral sclerosis

42. **Quantification of Lipid Droplets in Human Pre-Adipocyte**
Maxime Bombrun, Petter Ranefall, Carolina Wählby
Partners: Hui Gao, Niklas Mejhert, Mikael Ryden, Peter Arner - Dept. of Medicine (H7) Karolinska Institute
Funding: SciLifeLab
Period: 20160311–Current
Abstract: Adipocytes store lipids, predominantly triglycerides (TGs), in lipid droplets (LDs). Upon energy shortage, TGs are hydrolyzed into non-esterified fatty acids and glycerol in an enzymatic process termed lipolysis. LDs are highly dynamic and undergo fragmentation or fusion under lipolytic and lipogenic conditions, respectively. The aim of this project is to unravel the molecular mechanisms governing LD formation and investigate connections between LD morphology and lipolysis rate. We will perform a high throughput image analysis of TG (BODIPY)-stained adipocytes treated with siRNAs that target lipolysis regulating genes. Images will be acquired by an automated microphotography pipeline. Using the proposed image analysis, we aim to quantitatively measure the effects on LD morphology and lipolysis rate for each gene. The results from this screen are compared with clinical measures in our cross-sectional and prospective cohorts. This will constitute an invaluable resource for in-depth and hypothesis-driven analyses, which will improve our understanding of the mechanisms controlling human adipocyte lipolysis.

43. **Segmentation of Neurons**
Petter Ranefall, Carolina Wählby
Partners: Niklas Dahl, Loora Laan, Jens Schuster - Dept. of Immunology, Genetics and Pathology, UU
Funding: SciLifeLab
Period: 20140201–Current
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.

44. **Ubiquitin Screen**
Carolina Wählby, Petter Ranefall
Partners: Johan Boström, Jordi Carreras Puigvert, Mikael Altun, Molecular Biochemistry and Biophysics, KI
Funding: Science for Life Laboratory
Period: 201502–Current
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.

45. **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: 201510–Current
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.

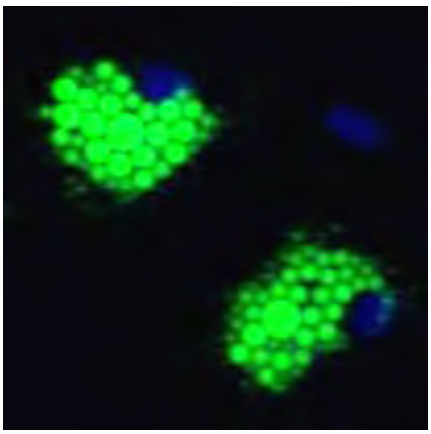

Figure 37: Project 42, Quantification of lipid droplets in human pre-adipocyte

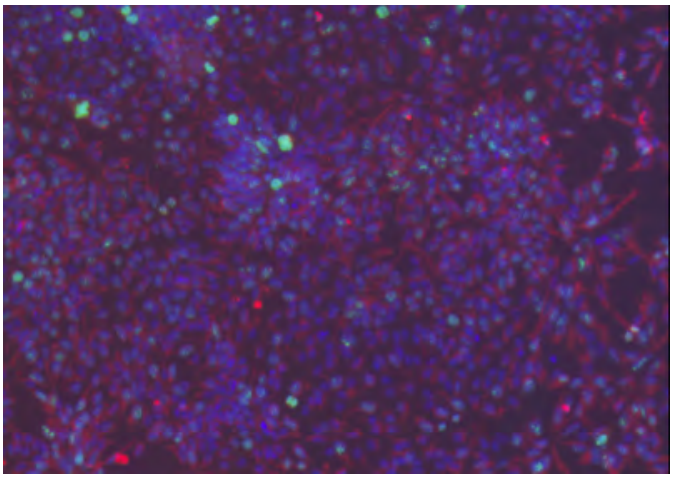

Figure 38: Project 43, Segmentation of Neurons

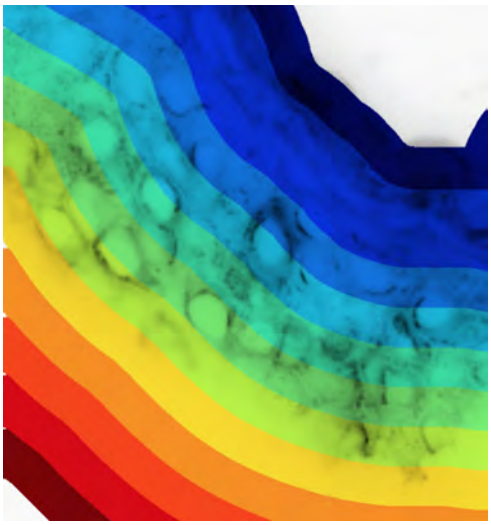

Figure 39: Project 45, Analysis of Keratin Aggregates

46. **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: 201410–Current
Abstract: he 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.

47. **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: 201406–Current
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.

48. **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 Jalden, ACCESS Linnaeus Centre, KTH.
Funding: Science for Life Laboratory, eSSENCE, VR junior researcher grant to CW
Period: 201210–Current
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. We developed a novel method for the E.coli cell segmentation using deep neural networks. This new method was able to detect irregular and unusually large cells present in the sample. The methods and results were published in a paper in the Bioimaging workshop as part of European Conference on Computer Vision 2016.

49. **PopulationProfiler**
Damian J. Matuszewski, Carolina Wählby, Ida-Maria Sintorn
Partners: Jordi Carreras Puigvert - SciLifeLab and Helleday Laboratory, Karolinska Institutet, Stockholm
Funding: Science for Life Laboratory
Period: 20160715–20160715
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 paper introducing this tool was published in PLoS ONE 11(3) (doi:10.1371/journal.pone.0151554). The source code, sample dataset and an executable program (for Windows only) are freely available at http://www.cb.uu.se/˜damian/PopulationProfiler.html. PopulationProfiler was used in a comparison of cell cycle disruption measurements from commonly used flow cytometry and image-based screening. The results were presented at the International Conference on Image Analysis and Recognition (ICIAR 2016) and published in Lecture Notes in Computer Science, vol 9730 (doi: 10.1007/978-3-319-41501-7_70).

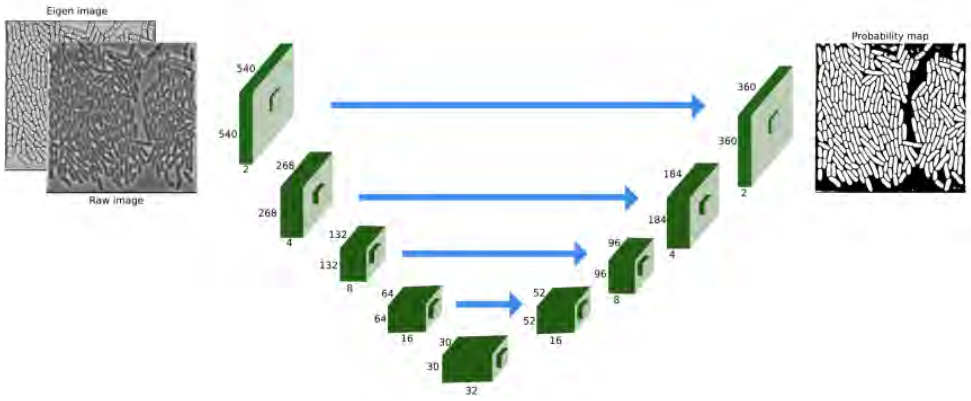

Figure 40: Project 48, Segmentation and Tracking of E.coli Bacteria in Bright-Field Microscopy Images

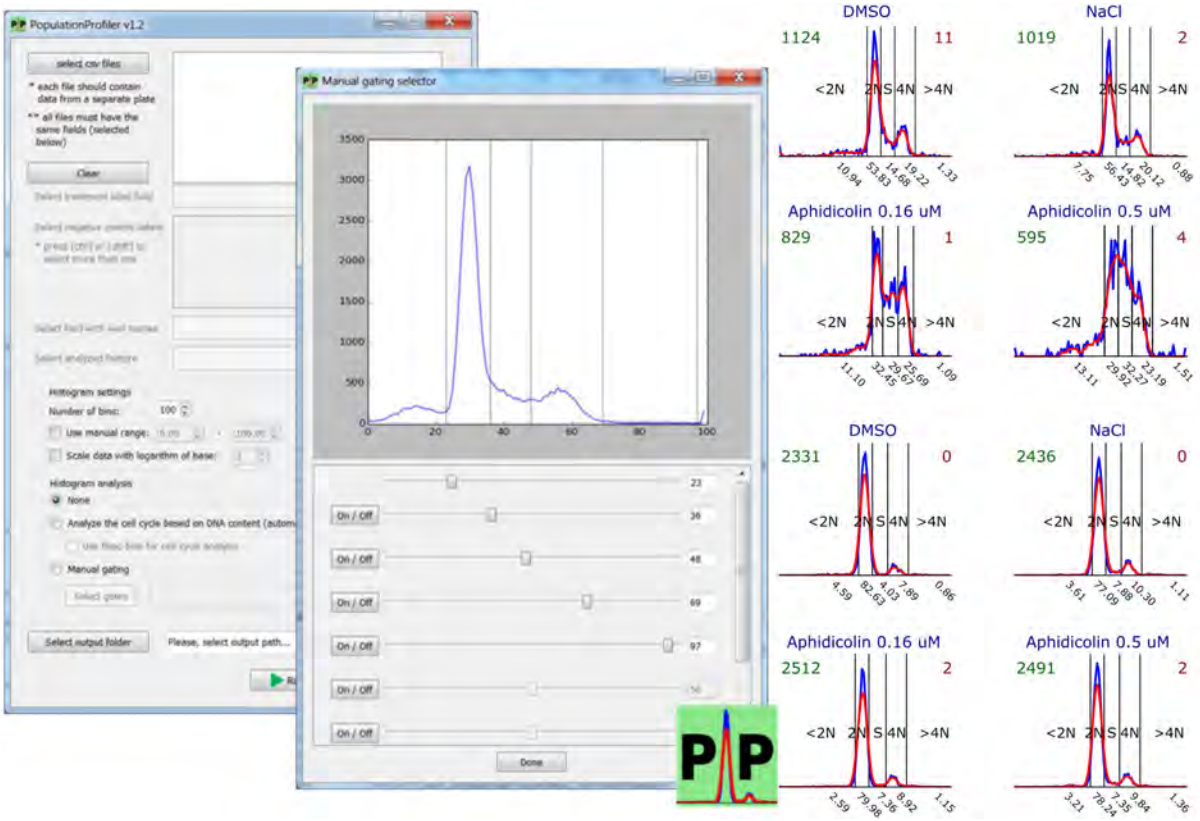

Figure 41: Project 49, PopulationProfiler

50. **SciLifeLab Cancer Stem Cell Program**
Damian Matuszewski, Petter Ranefall, Carolina Wählby, Ida-Maria Sintorn, Andre Liebscher
Partners: Sven Nelander, Ingrid Lönnstedt, Cecilia Krona, Linnéa 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 University of Technology, Gothenburg; and Göran Hesselager - UU Hospital, Uppsala
Funding: AstraZeneca-Science for Life Laboratory Joint Research Program
Period: 201303–Current
Abstract: The SciLifeLab Cancer Stem Cell Program is a cross-platform initiative to characterize cancer stem cells (CSCs). Previously, the development of drugs targeting the CSC population in solid tumors has been curbed by the lack of valid cell model systems, and the complex genetic heterogeneity across tumors, factors that make it hard to assess new targets or predict drug responses in the individual patient. To solve these problems, our aim is to develop a biobank of highly characterized CSC cultures as a valid model of cancer heterogeneity. We will combine mathematical and experimental approaches, including image-based high-throughput cell screening, to define the spectrum of therapeutically relevant regulatory differences between patients. This will help elucidate mechanisms of action and enable accurate targeting of disease subgroups. Patient data is continously 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 2016 algorithms for cell cycle analysis and automatic selection of potentially effective treatments were developed.

51. **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: 201501–Current
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 results were submitted for journal publication.

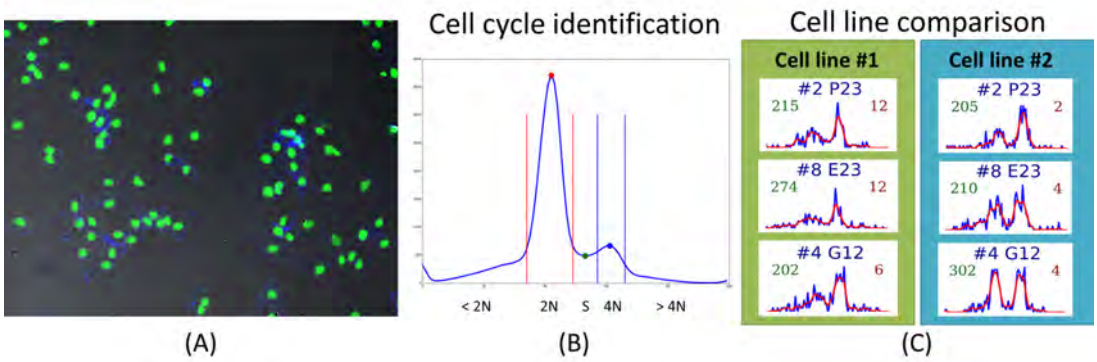

Figure 42: Project 50, SciLifeLab Cancer Stem Cell Program

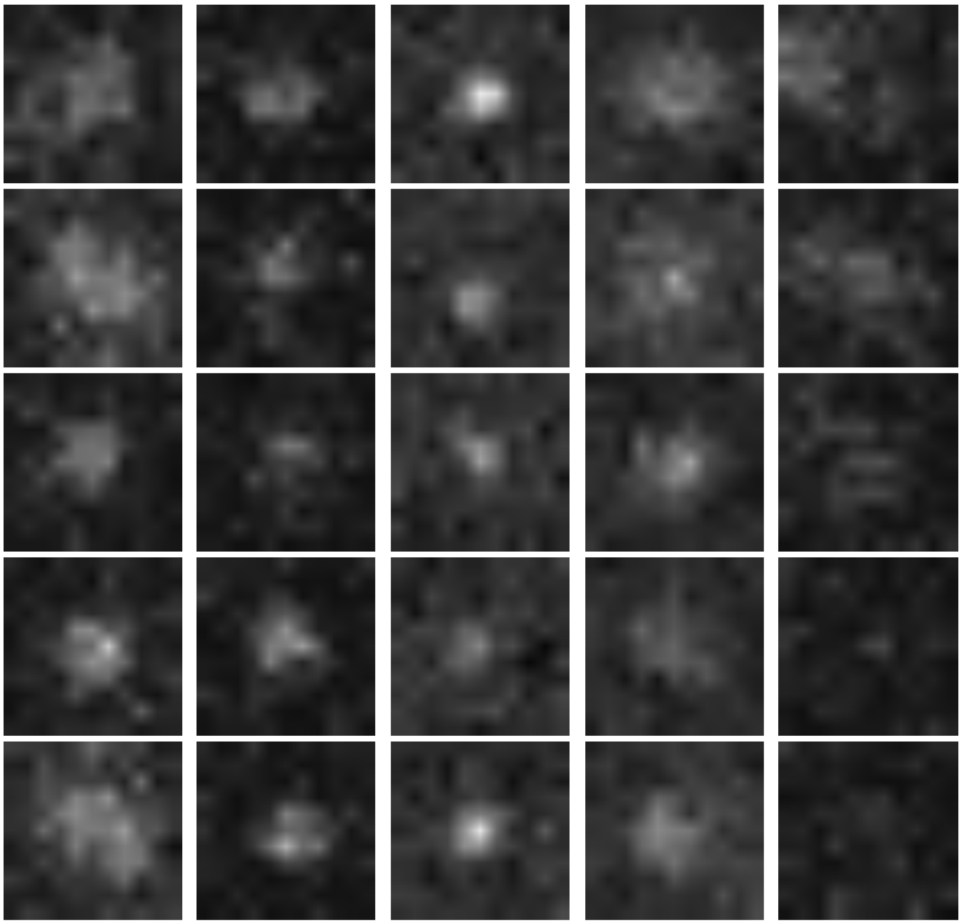

Figure 43: Project 51, Detection of Fluorescent Signals using Deep Learning Architectures

5.5 Light microscopy, model organisms and tissues

52. **Effects of Mixtures of Endocrine Disrupting Compounds (EDC) on Wnt/Beta-Catenin Signaling in Developing Zebrafish**
Petter Ranefall, Carolina Wählby
Partner: Maria Jönsson - Dept. of Organismal Biology, Environmental Toxicology, UU
Funding: SciLifeLab
Period: 20160902–Current
Abstract: Wnt/beta-catenin signaling is involved in proliferation and fate of cells thus playing fundamental roles during embryo development. The specific aims of this part of the EU project are to 1) develop methods for detection of chemically induced changes in Wnt/beta-catenin signaling and to 2) determine developmental effects of EDC mixtures on Wnt/beta-catenin signaling. EDC-induced changes in Wnt/beta-catenin signaling are visualized and studied by transgenic zebrafish carrying a beta-catenin signaling fluorescent reporter (Tcf/Lef-miniP: d2EGFP).

53. **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: SciLifeLab
Period: 20151008–Current
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.

54. **Infiltration of T Cells in Thyroid Glands**
Petter Ranefall, Carolina Wählby
Partner: Susanne Kerje - Dept. of Medical Biochemistry and Microbiology, UU
Funding: SciLifeLab
Period: 20160630–20160630
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.

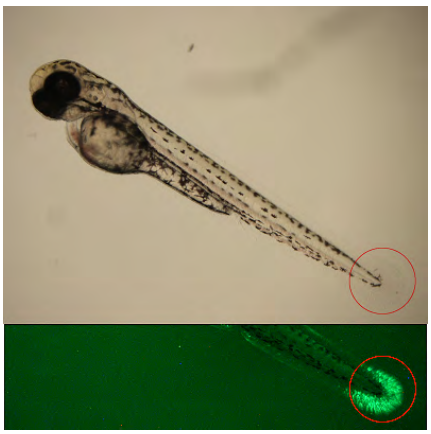

Figure 44: Project 52, Effects of mixtures of endocrine disrupting compounds (EDC) on Wnt/beta-catenin signaling in developing zebrafish

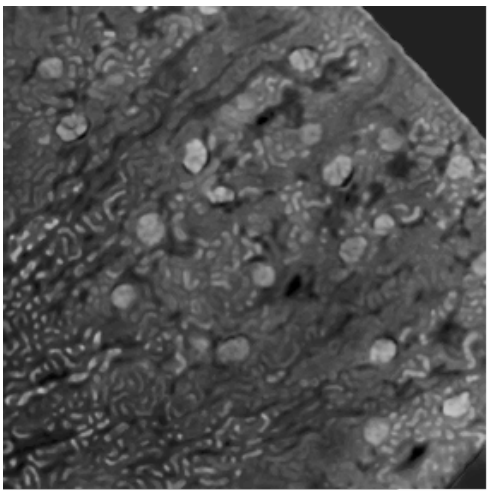

Figure 45: Project 53, Kidney Morphology and Topology of the Glomerular Filtration Barrier

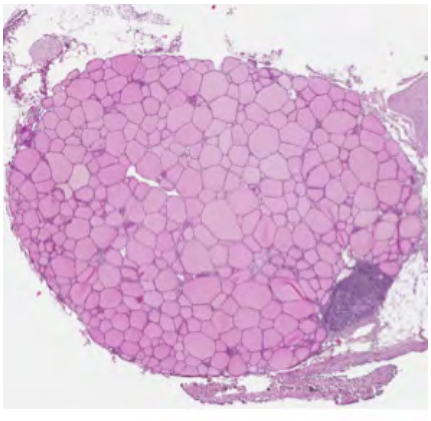

Figure 46: Project 54, Infiltration of T Cells in Thyroid Glands

55. **Cell Distribution and Protein Expression in the Ectocervix**
Petter Ranefall, Carolina Wählby
Partners: Anna Gibbs, Gabriella Edfeldt, Maria Röhl, Annelie Tjernlund - Dept. of Medicine, KI
Funding: SciLifeLab
Period: 20150401–Current
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.

56. **Quantification of Zebrafish Lipid Droplets**
Petter Ranefall, Carolina Wählby
Partners: Marcel den Hoed, Manoj Bandaru, Anastasia Emmanouilidou - Dept. of Medical Sciences and SciLifeLab, UU
Funding: SciLifeLab
Period: 20130801–Current
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.

57. **Pigment Gene Expression in the Early Developing Crow Feather**
Petter Ranefall, Carolina Wählby
Partners: Chi-Chih Wu, Axel Klaesson, Ola Söderberg, Jochen Wolf - Dept. of Immunology, Genetics and Pathology, UU
Funding: SciLifeLab
Period: 20161108–Current
Abstract: The project is to quantify and compare pigment-associated gene expressions between two closest related crow species that carrion crow has black feathers and hooded crow has gray feathers in the belly. The cooperators have adapted in situ PLA with padlock probes to label targeted mRNAs across varied developmental stages of melanocytes in feathers. We are developing a CellProfiler pipeline and scripts to recognize and quantify signals across complex tissues with strong autofluorescence.

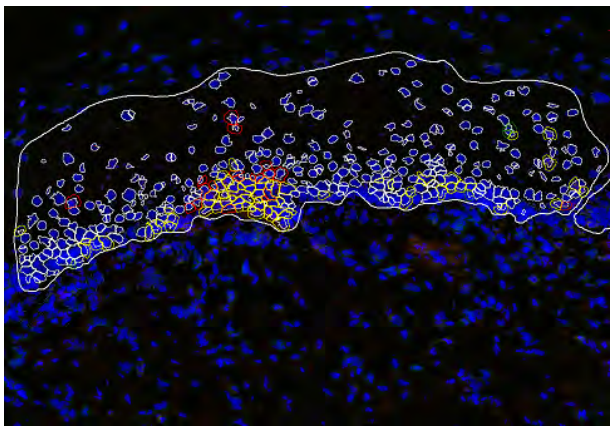

Figure 47: Project 55, Cell Distribution and Protein Expression in the Ectocervix

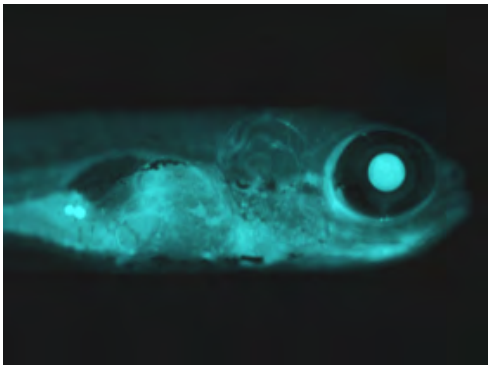

Figure 48: Project 56, Quantification of Zebrafish Lipid Droplets

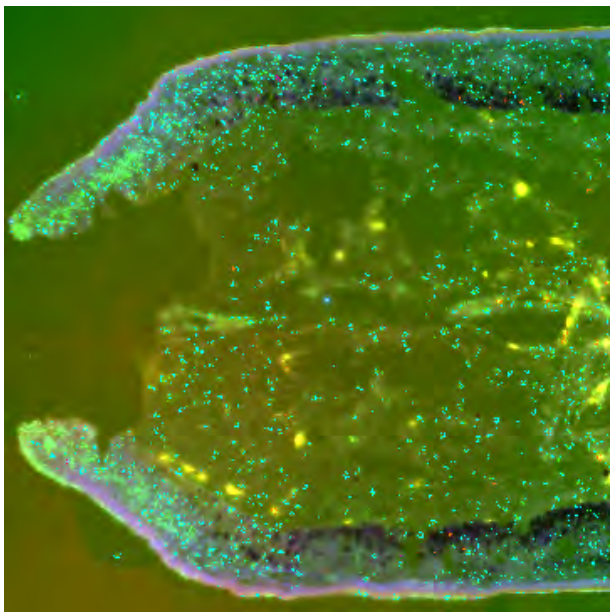

Figure 49: Project 57, Pigment gene expression in the early developing crow feather

58. **in Vivo Modeling of High Grade Glioma for Oncology Drug Developments**
Petter Ranefall, Carolina Wählby
Partners: Riasat Islam, Cecilia Krona and Sven Nelander. Dept. of Immunology, Genetics and Pathology, UU
Funding: SciLifeLab
Period: 20161007–Current
Abstract: The main goal of this study was to develop a platform for quantifying the tumor-initiating capacity of a large panel of glioma-stem cell cultures (GSCs) in adult mouse brain to define the cancer stem-cell like property of the individual cultures and to integrate the result with genomic and transcriptional profiling of the GSCs. In order to achieve this, adherently grown GFP-luciferase GSC cultures were dissociated and injected stereotactically into the brain of immunodeficient mice. Tumor growth was monitored in vivo by bioluminescence imaging for up to 40 weeks and brains were collected for histopathological and immunohistochemical stainings. Automatic quantification and growth pattern analysis of tumor cells in brain sections was set up based on human cell specific staining using NuMa antibodies and a CellProfiler Analyst machine learning classifier with a manual observer correlation of 0.86. Tumors were identified in brains from mice injected with 15/29 GSC cultures, suggesting these cells as a valuable resource for future preclinical therapeutic studies targeting predicted vulnerabilities for individual glioma patients.

59. **Effect of Perfluorononanoic Acid (PFNA) on Early Embryo Development in Vitro**
Petter Ranefall, Carolina Wählby
Partners: Ida Hallberg, Ylva Sjunnesson, Dept. of Clinical Sciences, SLU
Funding: SciLifeLab
Period: 20170119–Current
Abstract: For the last decades a concern has been raised that female fertility is declining – more than could be explained by the fact that we choose to have children later in life and possible genetic effects. Subfertility – and infertility – is a devastating experience for those who are affected and as the subject is also somewhat of a taboo – the numbers affected are most likely higher than perceived among the general public. In our environment, we are continuously exposed to a number of exogenous chemicals, originating from industries, agriculture and other. As many of these chemicals show persistence and are very bio-accumulative, they will concentrate higher up in the food-chain, in both wildlife and humans. Many of the chemicals are new – and have yet not been investigated regarding their full toxicological potential. Perfluorononanoic acid (PFNA) This project aim to further investigate perfluorononanoic acid (PFNA) and its effect on the early embryo development. This chemical is closely related to know toxic substances such as PFOS and PFOA, but is in contrary to those – little research has yet been done regarding PFNAs potential toxicological effects. We have used a bovine model, where we collect material from the slaughter-house

60. **Objective Automated Quantification of Fluorescence Labeling in Histologic Sections of Rat Lens**
Carolina Wählby
Partners: Per Söderberg and Nooshin Talebizadeh, Dept. of Neuroscience, UU
Funding: Science for Life Laboratory
Period: 20150101–Current
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. A methods paper was submitted for journal publication in late 2016.

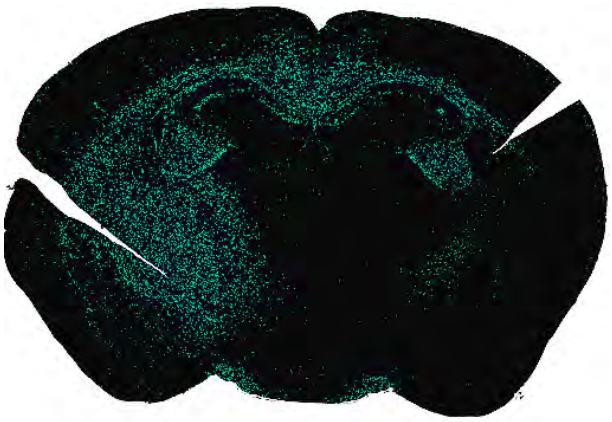

Figure 50: Project 58, In vivo modeling of high grade glioma for oncology drug developments

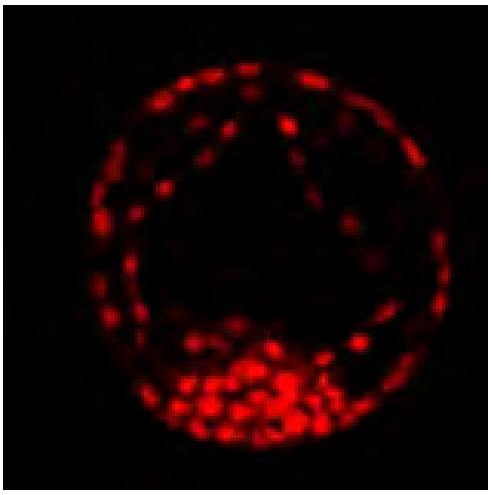

Figure 51: Project 59, Effect of perfluorononanoic acid (PFNA) on early embryo development in vitro

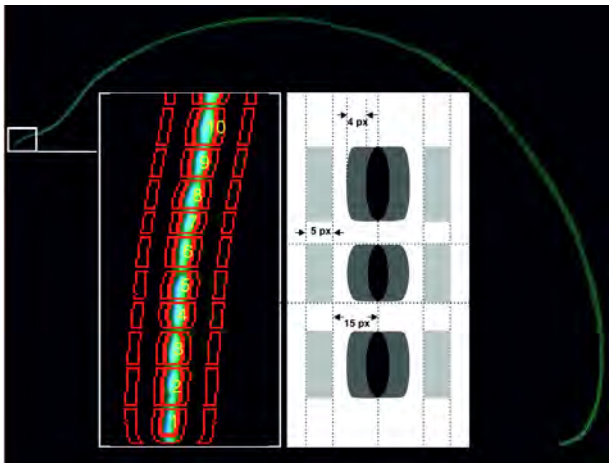

Figure 52: Project 60, Objective Automated Quantification of Fluorescence Labeling in Histologic Sections of Rat Lens

61. **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: 20150101–Current
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.

62. **Rat Spinal Cord**
Carolina Wählby, Petter Ranefall
Funding: Science for Life Laboratory
Period: 201506–Current
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.

63. **Automated Quantification of Zebrafish Tail Deformation for High-throughput Drug Screening**
Sajith Kecheril Sadanandan, Omer Ishaq, Alexandra Pacureanu, Carolina Wählby
Partners: Joseph Negri, Mark-Anthony Bray, Randall T. Peterson, Broad Institute of Harvard and MIT, Boston, USA
Funding: SciLifeLab Uppsala
Period: 201203–201608
Abstract: Zebrafish (Danio rerio) is an important vertebrate model organism in biomedical research, especially suitable for morphological screening due to its transparent body during early development. In this project we use deep learning approach for accurate high-throughput classification of whole-body zebrafish deformations in multifish microwell plates. Deep learning uses the raw image data as an input, without the need of expert knowledge for feature design or optimization of the segmentation parameters. We trained the deep learning classifier on as few as 84 images (before data augmentation) and achieved a classification accuracy of 92.8% on an unseen test data set that is comparable to the previous state of the art (95%) based on user-specified segmentation and deformation metrics. Ablation studies by digitally removing whole fish or parts of the fish from the images revealed that the classifier learned discriminative features from the image foreground, and we observed that the deformations of the head region, rather than the visually apparent bent tail, were more important for good classification performance. A paper describing the methods and results is published in the Journal of Biomolecular screening in 2016.

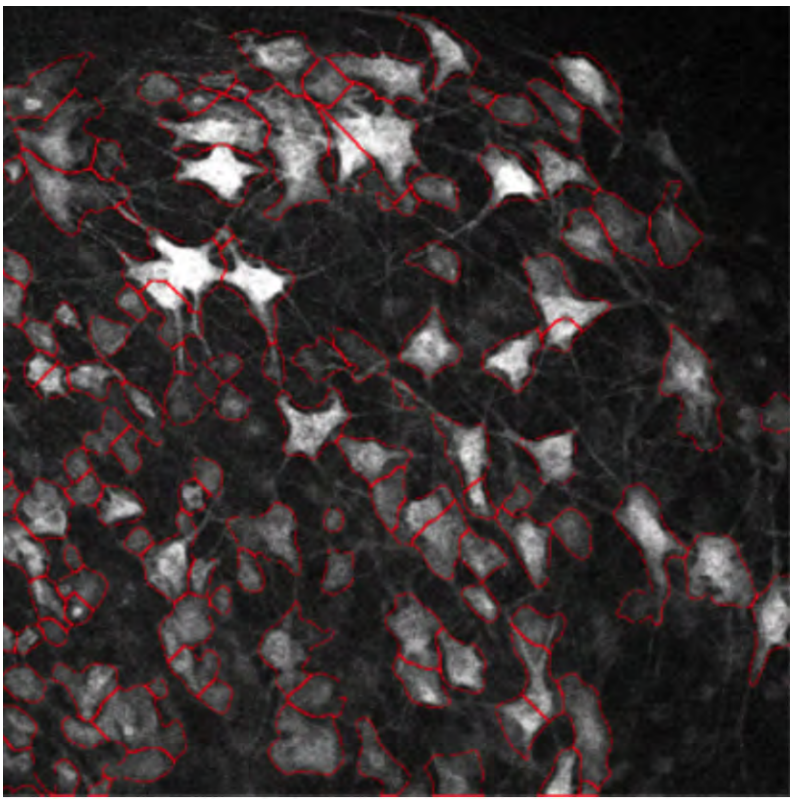

Figure 53: Project 61, A Model System for Analysis of Spinal Cord Injury

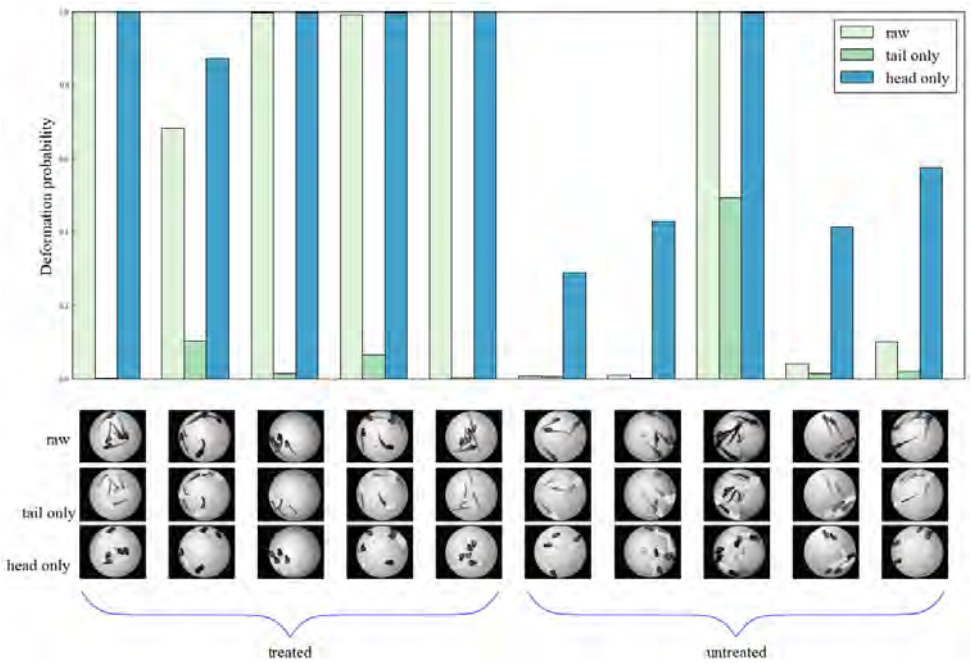

Figure 54: Project 63, Automated Quantification of Zebrafish Tail Deformation for High-throughput Drug Screening

64. **CADESS (TM), 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: Vetenskapsrådet (2009-5418 and 2012-3667); Hagstrandska fonden; Dept. of Surgical Sciences; Vinnova VFT-1; Handelsbankens Innovationsstiftelse
Period: 20160930–20160930
Abstract: CADESS is a proprietary technology combining consensus-graded tissue data and a new tissue stain with powerful AI and Machine Learning tools, such as knowledge-based systems and sophisticated classifiers, for automatic malignancy grading. During 2016 we continued to test CADESS with the help of the consensus group. They graded remotely the whole mounts from which the 650 tissue images had been selected for our consensus data base. While the pathologists claimed that context would improve the grading, we observed that this was rarely the case. We concluded that for grading variations between whole mounts and small sub-images: (1) Context did not appear to affect significantly the inter-observer variations in determining cancer vs non-cancer. (2) Intra-observer agreement between grade groups was between 20-50%; approximately the same values for inter-observer variations, but that these variations are reduced significantly when comparing only grade groups 2 and 3. All pathologists missed several cancer foci that CADESS identified; one example is shown in the figure. CADESS performs as well as or better that the pathologist. CADESS Medical AB was formed in December of 2016 and received its first funding from Uppsala University Holding AB.

65. **CerviScan**
Ewert Bengtsson, Joakim Lindblad, Bo Nordin
Partners: Rajesh Kumar, Centre for Development of Advanced Computing (CDAC), Thiruvananthapuram, Kerala, India; K. Sujathan, Regional Cancer Centre, Thiruvananthapuram, Kerala
Funding: VINNOVA; Swedish Research Council; SIDA
Period: 20080101–Current
Abstract: Cervical cancer is a disease that annually kills over a quarter of a million women world-wide. This number could be reduced by screening for signs of cancer precursors using the well-established Pap-test. However, visual screening requires highly trained cytotechnologists and is time consuming. 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, run by CDAC and RCC in Kerala and CBA in Sweden, aimed at creating a low cost, automated screening system. A prototype system has been created and used to screen over 1000 specimen. Initial classification results are promising but screening times are still about 10 times longer than what is realistic in a real screening setting. Plans for the next phase of the project, focusing on dedicated hardware, are awaiting the result of funding applications in India and Sweden. In the meantime we have funding for our collaboration from the Swedish Research Links Programme. A group of students have in the end of the year conducted a closely associated project, DeepMAC.

66. **Image Analysis in the ExDIN Digital Pathology Networks**
Ewert Bengtsson, Carolina Wählby, Petter Ranefal
Partners: RxEye, Stockholm, Groups at Karolinska Institute plus county council pathology labs.
Funding: Vinnova
Period: 20161231–20161231
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 have carried out a literature study to answer this question which was documented in a report in August. We have also taken the initiative of a special issue of the Cytometry journal addressing this question. A small pilot study demonstrating image analysis on whole immunohistochemistry stained histopathology sections in order to detect Ki67 positive cells was carried out. The work was presented at Digital pathology workshops in London in March and November and at Nordic Digital Pathology symposium in Linköping in November.

67. **Zebrafish as a Model for Cerebral Palsy and Intellectual disability**
Amin Allalou, Carolina Wählby
Partners: Marcel den Hoed, Marta Martín Martínez, Dept. of Medical Sciences and SciLifeLab, UU
Funding: Science for Life Laboratory
Period: 20161001–Current
Abstract: The zebrafish (Danio rerio) is a good model organism for vertebrate development. The organization of the embryo is simple and the body is transparent, making it easy to study with many different microscopy techniques. In this project we are using the VAST (Vertebrate Automated Screening Technology) and fluorescent imaging with OPT (Optical Tomography) to do a preliminary screen to investigate if we can detect any phenotypes for a number of candidate genes for cerebral palsy and intellectual disability. We are also performing behavioral screening to see if there are any behavioral phenotypes that can associated with the genes of interest.

68. **Heart Rate Analysis in Zebrafish**
Amin Allalou, Carolina Wählby
Partners: Marcel den Hoed, Benedikt von der Heyde, Dept. of Medical Sciences and SciLifeLab, UU
Funding: Science for Life Laboratory
Period: 20161001–Current
Abstract: Due to the transparency of the young zebrafish the heart is easily accessible for optical analysis without any invasive procedures. Video-based quantification of heart rate and rhythm is a non-invasive method that can give important information on many phenotypic changes in heart. We have developed an analysis method to quantify the heart rate and rhythm based on video recordings of zebrafish from the VAST (Vertebrate Automated Screening Technology) system.

69. **TissueMaps - Integrating spatial and genetic information via automated image analysis and interactive visualization of tissue data**
Carolina Wählby, Maxime Bombrun, Gabriele Partel, Leslie Solorzano, Petter Ranefall, Joakim Lindblad, and Amin Allalou
Partners: Mats Nilsson - Stockholm University/Science for Life Laboratory, Xiaoyan Qian - Stockholm University/Science for Life Laboratory
Funding: ERC consolidator grant to Carolina Wählby
Period: 201109–Current
Abstract: Digital imaging of tissue samples and genetic analysis by next generation sequencing are two rapidly emerging fields in pathology. Digital pathology will soon be as common as digital images in radiology, and genetic analysis is rapidly evolving thanks to the impressive development of next generation sequencing technologies. 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 (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. In 2016, the project attracted an ERC consolidator grant and led to two review-type publications in the Proceedings of the IEEE and Nature Methods.

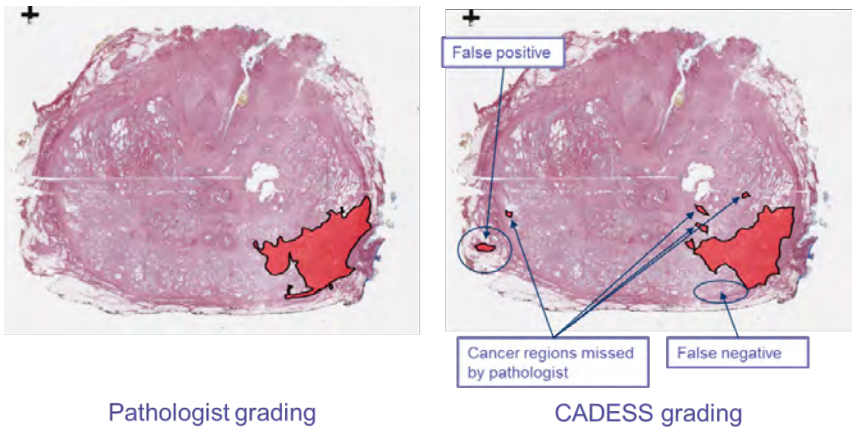

Figure 55: Project 64, CADESS (TM), A Decision Support System for the Prognostication of Prostate Cancer

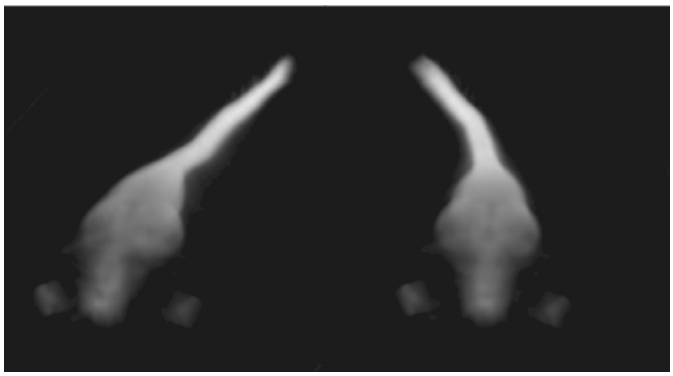

Figure 56: Project 67, Zebrafish as a Model for Cerebral Palsy and Intellectual disability

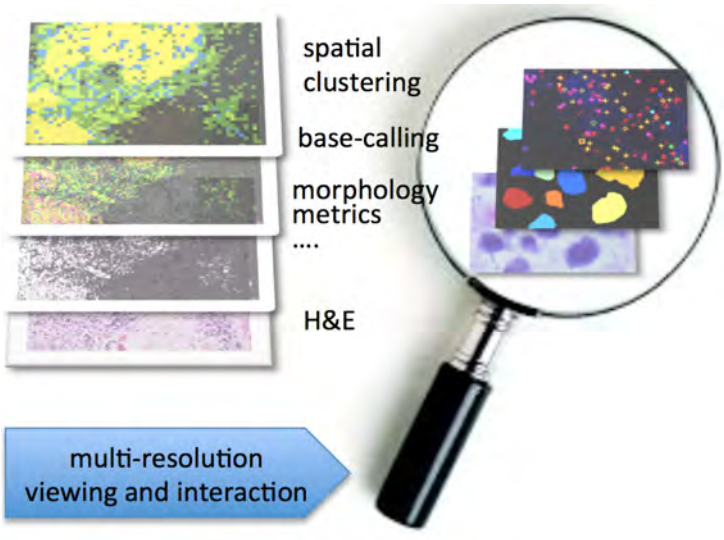

Figure 57: Project 69, TissueMaps - Integrating spatial and genetic information via automated image analysis and interactive visualization of tissue data

5.6 Electron microscopy

70. **A Smart and Easy Platform to Facilitate Ultrastructural Pathologic Diagnoses**
Amit Suveer, Nataša Sladoje, Joakim Lindblad
Partners: Ida-Maria Sintorn - Vironova AB; Anca Dragomir - Uppsala Academic Hospital; Kjell Hultenby - Karolinska Institutet
Funding: MedTech4Health, Vinnova; TN-faculty, UU
Period: 20160109–Current
Abstract: Transmission electron microscopy (TEM) is an important diagnostic tool for screening human tissues at the nanometer scale. It is the only option, or gold standard, for diagnosing several disorders e.g. cilia and renal diseases, rare cancers etc. The high resolution of TEM provides unique morphological information, significant for diagnosis and personalized care management. However, the microscope is expensive, technically complex and a special environment is required to house the bulky and sensitive machine. Interpretation of information is subjective, time consuming, and relies on a high level of expertise; unfortunately, there is a lack of trained personnel. In this project we are collaborating with microscope manufacturers, pathologists and microscopists, in order to develop the next generation of image processing and analysis tools that will significantly simplify and enhance the TEM imaging and analysis experience. The work includes steering of a TEM microscope for automated search for regions of interest, followed by multiscale imaging of objects for time efficient processing. We are developing techniques for automated detection and recognition of objects from TEM images as well as non-rigid registration techniques to align detected objects and methods to fuse information and to enhance visualization of barely visible structures.

71. **Advanced Methods for Reliable and Cost Efficient Image Processing in Life Sciences**
Nataša Sladoje, Joakim Lindblad, Ewert Bengtsson, Ida-Maria Sintorn
Partners: Marija Delić, Buda Bajić, Faculty of Technical Sciences, University of Novi Sad, Serbia
Funding: VINNOVA; UU TN-faculty; Swedish Research Council
Period: 201308–Current
Abstract: Within this project our goal is to increase reliability, efficiency, and robustness against variations in sample 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 in 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 2016, we have continued our work on robust and efficient texture descriptors. We also proposed a blind restoration method applicable to images degraded by mixed Poisson-Gaussian noise and explored its applicability in TEM; this work is summarized in a publication presented at ISBI 2016. In addition, we further developed distance measures between multi-channel representations of image objects. The latter project resulted in two submitted conference publications at the end of the year.

72. **Automated Multiscale Analysis of TEM Images for Improved Cost-Effective Diagnosis of Cilia Disorders**
Amit Suveer, Ida-Maria Sintorn, Nataša Sladoje, Joakim Lindblad,
Partners: Anca Dragomir, Anders Ahlander, Dept. of Immunology, Genetics and Pathology, UU
Funding: IT UU via Biomed SPARC Project initiative
Period: 20160831–20160831
Abstract: Dysfunctional immotile cilia are often due to genetic disorders, and result in respiratory infections, reduced female fertility and infertility in males. Transmission Electron Microscopy (TEM) is the standard technique for diagnosing cilia disorders, through a highly manual and time consuming procedure performed by an expert pathologist. In this project, we have been developing an approach for automating the TEM imaging and analysis to significantly reduce the time and efforts required by a pathologist and to enable improved and more accurate diagnosis. A specimen is systematically traversed by an automatically navigated microscope and low magnification images acquired and analyzed. This enables fast detection of regions highly populated with cilia, where high magnification images are acquired and used for the final cilia detection and super-resolution reconstruction to enhance the fine structural details used to set a diagnosis. Our results are presented at ISBI conference, as well as at SSBA symposium. The summary of the project is presented at the final SPARC workshop within BiomedIT seminar series.

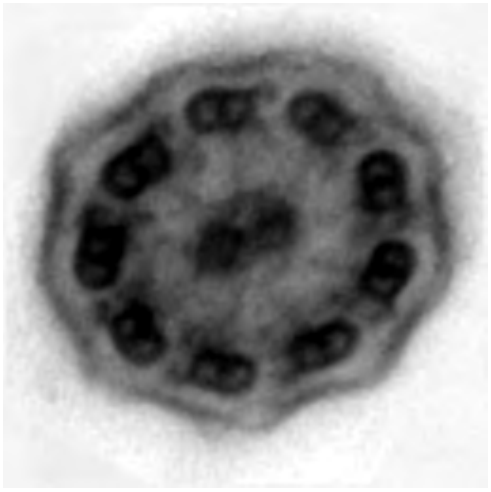

Figure 58: Project 70, A smart and easy platform to facilitate ultrastructural pathologic diagnoses

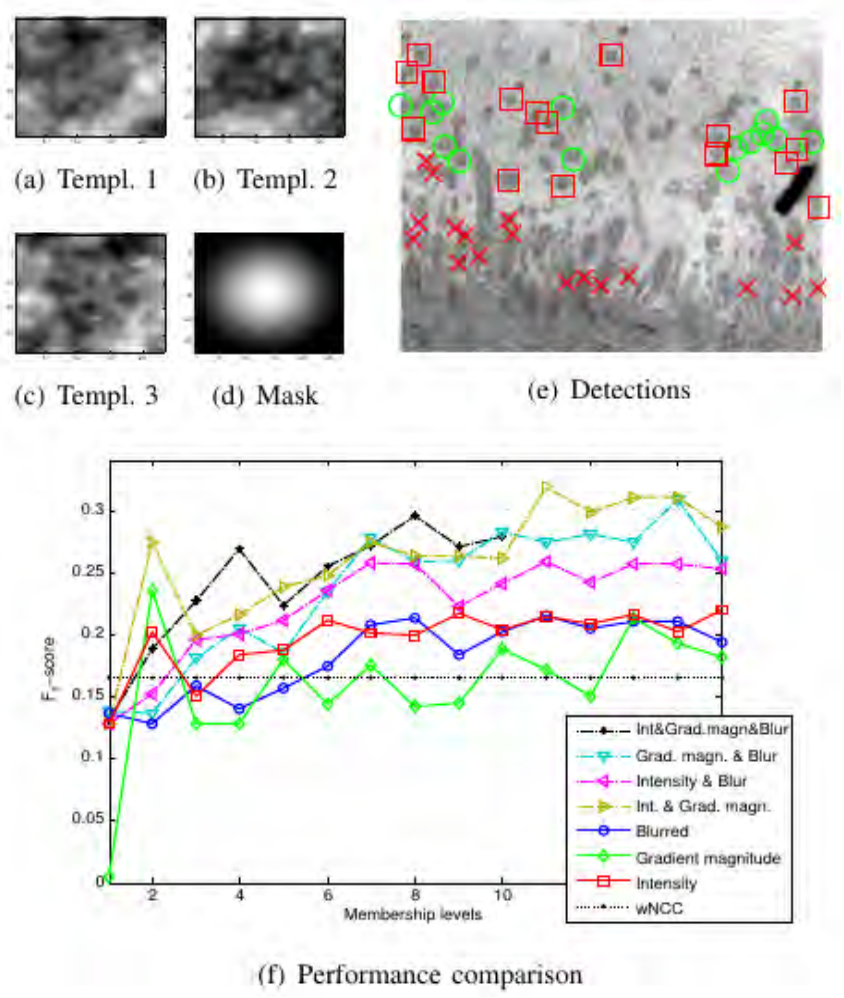

Figure 59: Project 71, Advanced Methods for Reliable and Cost Efficient Image Processing in Life Sciences

5.7 Cooperation partners

International

Dept. of Sciences, Museum Victoria, Melbourne, Australia

School of Biological Sciences, Flinders University, Adelaide, Australia

Université des Sciences, des Techniques et des Technologies de Bamako, USTTB, Bamako

Dept. of Oral and Maxillofacial Surgery, Saint-Luc University Hospital, Catholic University of Leuven, Brussels, Belgium

Visual Dimension, Belgium

Universidad de Los Andes, Bogotá, Colombia

Dept. of Dermatology and Allergy, Odense University Hospital, Odense, Denmark

Hopital Necker Enfants-Malades, Service de Chirurgie Maxillo-faciale et Plastique, Universite Paris-Descartes, Paris, France

Hopital Lariboisiore, Service de Chirurgie Orthopodique, Universite Paris-Diderot, Paris, France

IRCCyN, University of Nantes, France

University of Lyon, CREATIS, Lyon, France

University Montpellier 2, CNRS, Montpellier, France

UPMC University Paris 06, Sorbonne University, CNRS, Paris, France

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

Centre for Development of Advanced Computing (CDAC), Thiruvananthapuram, Kerala, India

Indian Institute of Science, Medical Imaging Group, Dept. of Computational and Data Sciences, Bengaluru, India

Regional Cancer Centre, Thiruvananthapuram, Kerala, India

Institute for High Performance Computing and Networking, CNR, Naples, Italy

Institute of Cybernetics ”E.Caianiello”, CNR, Naples, Italy

Istituto di Informatica e Telematica Consiglio Nazionale delle Ricerche, Pisa, Italy

Faculty of Computer Science and Media Technology, NTNU Norwegian University of Science and Technology, Gjövik, Norway

Dept. of Companion Animal Clinical Sciences, Norwegian University of Life Sciences, Norway

Dept. of Electronic Computers RSREU, Ryazan, Russia

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

Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia

Mathematical Institute, Serbian Academy of Sciences and Arts, Belgrade, Serbia

Seccion de Arqueoloxia, Concello de Ourense, Spain

Universitat Autonoma de Barcelona, Spain

Universidad de Gales Trinity Saint David, Spain

Great Ormond Street Hospital, London, UK

School of Electronics and Computer Science, University of Westminster, London, UK

School of Systems Engineering, The University of Reading, Reading, UK

The Craniofacial Unit, Great Ormond Street Hospital for Children NHS Foundation Trust, London, United Kingdom

Broad Institute of Harvard and MIT, Boston, USA

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

Dept. of Radiology, University of Iowa, Iowa City, IA, USA

Flagship Biosci Inc, Westminster, CO, USA

Israel Hospital, New York, USA

National

Dept. of Cell and Molecular Biology, UU

Dept. of Engineering Sciences, UU

Dept. of History, UU

Dept. of Immunology, UU Hospital

Dept. of Immunology, Genetics and Pathology, UU

Dept. of Linguistics and Philology, UU

Dept. of Mathematics, UU

Dept. of Medical Biochemistry and Microbiology, UU

Dept. of Medical Sciences, UU

Dept. of Neuroscience, UU

Dept. of Organismal Biology, Environmental Toxicology, UU

Dept. of Orthopaedics, UU

Dept. of Pharmaceutical Biosciences, UU

Dept. of Surgical Sciences, UU

Uppsala Clinical Research Centre, UCR Statistics, UU

Science for Life Laboratory, UU

ACCESS Linnaeus Centre, KTH, Stockholm

Akademi för Teknik och Miljö, Gävle University, Gävle

Antaros Medical AB, BioVenture Hub, Mölndal

Cell Screening Facility, SciLifeLab Stockholm

Dept. of Biochemistry and Biophysics, Stockholm University, Solna

Center for Medical Image Science and Visualization (CMIV), Link0̈ping University, Linköping

Chalmers University of Technology, Gothenburg

Comsol AB, Stockholm

Dept. for Computational Science and Technology (CST), School of Computer Science and Communication (CSC), KTH, Stockholm

Dept. of Applied Physics, KTH, Stockholm

Dept. of Biomedical Sciences and Veterinary Public Health, SLU, Uppsala

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

Dept. of Business Studies, University of Gävle, Gävle

Dept. of Clinical Sciences, SLU, Uppsala

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

Dept. of Economics, SLU, Uppsala

Dept. of Forest Genetics and Plant Physiology, Umeå Plant Science Centre, SLU, Umeå

Dept. of Human Geography, Stockholm University, Stockholm

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

Dept. of Medical and Health Sciences, Linköping University, Linköping

Dept. of Medicine (H7) Karolinska Institute, Stockholm

Dept. of Molecular Biochemistry and Biophysics, Karolinska Institute, Stockholm

Dept. of Ophthalmology, Gävle Hospital, Gävle

Dept. of Physiology and Pharmacology, Karolinska Institute, Stockholm

Dept. of Radiology, Linköping University, Linköping

Division of Translational Medicine and Chemical Biology, Dept. of Medical Biochemistry and Biophysics, Karolinska Institutet, Stockholm

Halmstad University, Halmstad

Lantmäteriet, Gävle

Protracer AB, Stockholm

RxEye Company, Stockholm

Sahlgrenska Cancer Center, Institute of Medicine, Gothenburg

School of Technology and Health, KTH, Stockholm

Science for Life Laboratory, Stockholm

SciLifeLab and Helleday Laboratory, Karolinska Institutet, Stockholm

Swedish Museum of Natural History, Stockholm

Vironova AB, Stockholm

6 Publications

"Verba volant, scripta manent"[1] is as true now as when Tito uttered it in the Roman senate about two millennia ago. Therefore, our most important (non-human) products are our published works. This year, we produced 24 articles in scientific journals and 22 in conference proceedings, all fully peer-reviewed. This is about the same as the previous three years, see Figure 60. The 24 journal papers are spread over 21 different journals and for 15 of them this was our first publication. However, three of them were published in our favourite journal Pattern Recognition Letters, where we have published 21 papers since 2001, much more than in any other journal. And Borgefors co-edited a special issue of PRL, on skeletonization. The proceedings papers where spread over 16 conferences, seven of which where we published at for the first time.

Here, it should be noted that in our field, conference proceedings often have higher importance and higher rejection rates than the journals (Google Scholar ranks conference proceedings as numbers 1, 3, and 6 among the top ten publications in Computer Vision). One other top journal is Nature Methods and this year our Carolina Wählby published an invited article there.

We also wrote four book chapters and 13 non-reviewed articles of various kinds.

Note that Authors affiliated with CBA are in bold.

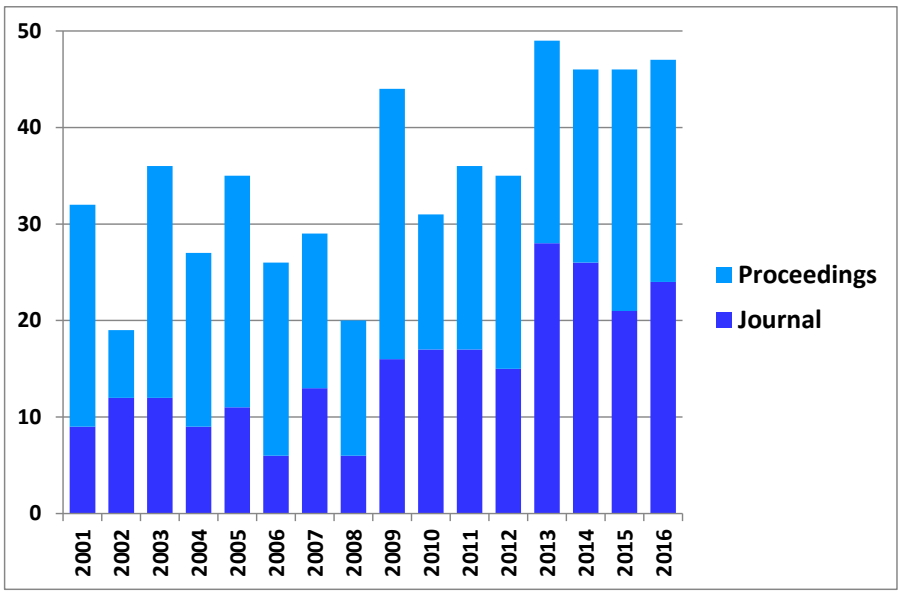

Figure 60: The number of publications from CBA 2001–2016.

6.1 Special Journal Issue

1. **Pattern Recognition Letters Vol. 76, 2016**
   Special Issue on Skeletonization and its Applications
   Editor: Punam K. Saha and **Gunilla Borgefors**
   Description: This special issue was put together in order to collect some of the best current research on this very important image analysis tool. It contains eleven research articles from all over the world, together with a Survey article of the state-of-the-art.

[1] Talk flies away, writing stays

6.2 Invited article

1. **The Quest for Multiplexed Spatially Resolved Transcriptional Profiling**
   Authors: **Carolina Wählby**
   Journal: Nature Methods, Vol. 13, No. 8, pages 623-624

6.3 Book chapters

1. **Weak Lineal Convexity**
   Author: **Christer O. Kiselman**
   Book: Constructive Approximation of Functions, pages 159-174
   Editors: Leokadia Białas-Cież, Marta Kosek
   Publisher: Polish Academy of Sciences

2. **Matematiktermer i skolan**
   Author: **Christer O. Kiselman**
   Book: Insikt och handling, pages 53-54
   Editors: Bo Hanson
   Publisher: Hans Larsson Samfundet
   Abstract: A presentation (in Swedish) of the book Matematiktermer för skolan [Mathematical terms for school use], published by Christer Kiselman and Lars Mouwitz.

3. **La jidogramatiko de Zamenhof kaj lia Lingvo universala: Mallonga versio**
   Author: **Christer O. Kiselman**
   Book: Prilingve en Nitro: politike, historie, teorie, instrue: Fakaj prelegoj prezentitaj kadre de la 101-a Universala Kongreso de Esperanto, pages 159-175
   Editors: Stanislav Kosecky
   Publisher: Universala Esperanto-Asocio
   Abstract: In this article a part of Zamehof's Yiddish grammar, elaborated during some years around 1880, is presented. A comparison of this language with his language project Universal Language is made.

4. **Lingva riĉo kaj la postuloj de la terminologio**
   Author: **Christer O. Kiselman**
   Book: Lingua, politica, cultura: Serta gratulatoria in honorem Renato Corsetti, pages 125-135
   Editors: Federico Gobbo
   Publisher: Mondial
   Abstract: Por ke lingvo taŭgu por beletra kreado, por verkado de poezio kaj fantazia prozo, necesas ke ĝi estu riĉa je vortoj kaj nuancoj, je sinonimoj por ne tedi la orelojn kaj je preskaŭ-sinonimoj por peri plej delikatajn diferencojn.

   En la teknika kaj scienca lingvaĵo, male, la idealo, formulita de Eugen Wöster, estas ke ĉiu nocio estu donita per unu kaj nur unu vorto, kaj ke, alidirekte, ĉiu vorto havu nur unu signifon. Do, ideale, nek sinonimoj, nek homonimoj ekzistu. Evidente tiuj postuloj aŭ deziroj iel kontraudiras unu la alian.

   Kiel trakti la konflikton; kiel evoluigi la lingvon esperanto tiel ke ĝi taŭgas —ne nur taŭgas, sed bone taŭgas, brile taŭgas —por ambaŭ celoj?

   Fina respondo ne estos prezentita, sed penseroj kaj cerbumado ĉirkaŭ la temo. Super ĉio, respekto al la du kulturoj necesas.

6.4 Journal articles

1. **A Faster, Unbiased Path Opening by Upper Skeletonization and Weighted Adjacency Graphs**
   Authors: **Teo Asplund, Cris Luengo(1)**
   (1) CBA and Flagship Biosci Inc, Westminster, CO, USA
   Journal: IEEE Transactions on Image Processing, Vol. 25, No. 12, pages 5589-5600
   Abstract: The path opening is a filter that preserves bright regions in the image in which a path of a certain length L fits. A path is a (not necessarily straight) line defined by a specific adjacency relation. The most efficient implementation known scales as $O(min(L, d, Q)N)$ with the length of the path, L, the maximum possible path length, d, the number of graylevels, Q, and the image size, N. An approximation exists

(parsimonious path opening) that has an execution time independent of path length. This is achieved by preselecting paths, and applying 1D openings along these paths. However, the preselected paths can miss important structures, as described by its authors. Here, we propose a different approximation, in which we preselect paths using a grayvalue skeleton. The skeleton follows all ridges in the image, meaning that no important line structures will be missed. An H-minima transform simplifies the image to reduce the number of branches in the skeleton. A graph-based version of the traditional path opening operates only on the pixels in the skeleton, yielding speedups up to one order of magnitude, depending on image size and filter parameters. The edges of the graph are weighted in order to minimize bias. Experiments show that the proposed algorithm scales linearly with image size, and that it is often slightly faster for longer paths than for shorter paths. The algorithm also yields the most accurate results- as compared with a number of path opening variants-when measuring length distributions.

2. **Solving the Table Maker's Dilemma on Current SIMD Architectures**
   Authors: **Christophe Avenel(1)**, Pierre Fortin(1), Mourad Gouicem(1,2), Samia Zaidi(1)
   (1) CBA and UPMC University Paris 06, Sorbonne University, CNRS, Paris, France
   (2) University Montpellier 2, CNRS, Montpellier, France
   Journal: Scalable Computing: Practice and Experience, Vol. 17, No. 3, pages 237-250
   Abstract: Correctly-rounded implementations of some elementary functions are recommended by the IEEE 754-2008 standard, which aims at ensuring portable and predictable floating-point computations. Such implementations require the solving of the Table Maker's Dilemma which implies a huge amount of computation time. These computations are embarrassingly and massively parallel, but present control flow divergence which limits performance at the SIMD parallelism level, whose share in the overall performance of current and forthcoming HPC architectures is increasing. In this paper, we show that efficiently solving the Table Maker's Dilemma on various multi-core and many-core SIMD architectures (CPUs, GPUs, Intel Xeon Phi) requires to jointly handle divergence at the algorithmic, programming and hardware levels in order to scale with the number of SIMD lanes. Depending on the architecture, the performance gains can reach 10.5x over divergent code, or be constrained by different limits that we detail.

3. **Restoration of Images Degraded by Signal-Dependent Noise Based on Energy Minimization: An Empirical Study**
   Authors: Buda Bajic(1), **Joakim Lindblad(2), Nataša Sladoje(2)**
   (1) Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
   (2) CBA and Mathematical Institute, Serbian Academy of Sciences and Arts, Belgrade, Serbia
   In Proceedings: Journal of Electronic Imaging (JEI), Vol. 25, No. 4, e043020, pages 11
   Abstract: Most energy minimization-based restoration methods are developed for signal-independent Gaussian noise. The assumption of Gaussian noise distribution leads to a quadratic data fidelity term, which is appealing in optimization. When an image is acquired with a photon counting device, it contains signal-dependent Poisson or mixed Poisson/Gaussian noise. We quantify the loss in performance that occurs when a restoration method suited for Gaussian noise is utilized for mixed noise. Signal-dependent noise can be treated by methods based on either classical maximum *a posteriori* (MAP) probability approach or on a variance stabilization approach (VST). We compare performances of these approaches on a large image material and observe that VST-based methods outperform those based on MAP in both quality of restoration and in computational efficiency. We quantify improvement achieved by utilizing Huber regularization instead of classical total variation regularization. The conclusion from our study is a recommendation to utilize a VST-based approach combined with regularization by Huber potential for restoration of images degraded by blur and signal-dependent noise. This combination provides a robust and flexible method with good performance and high speed.

4. **A Chronological and Mathematical Overview of Digital Circle Generation Algorithms : Introducing Efficient 4- and 8-Connected Circles**
   Authors: Tony Barrera, **Anders Hast, Ewert Bengtsson**
   Journal: International Journal of Computer Mathematics, Vol. 93, pages 1241-1253
   Abstract: Circles are one of the basic drawing primitives for computers and while the naive way of setting up an equation for drawing circles is simple, implementing it in an efficient way using integer arithmetic has resulted in quite a few different algorithms. We present a short chronological overview of the most important publications of such digital circle generation algorithms. Bresenham is often assumed to have invented the first all integer circle algorithm. However, there were other algorithms published before his

first official publication, which did not use floating point operations. Furthermore, we present both a 4- and an 8-connected all integer algorithm. Both of them proceed without any multiplication, using just one addition per iteration to compute the decision variable, which makes them more efficient than previously published algorithms.

5. **Generalized Beer-Lambert Model for Near-Infrared Light Propagation in Thick Biological Tissues**
   Authors: Manish Bhatt(1), **Kalyan R. Ayyalasomayajula**, Phaneendra K. Yalavarthy(1)
   (1) Indian Institute of Science, Medical Imaging Group, Department of Computational and Data Sciences, Bengaluru, India
   Journal: SPIE Journal of Biomedical Optics, Vol. 21, No. 7, e076012, 11 pages
   Abstract: The attenuation of near-infrared (NIR) light intensity as it propagates in a turbid medium like biological tissue is described by modified the Beer-Lambert law (MBLL). The MBLL is generally used to quantify the changes in tissue chromophore concentrations for NIR spectroscopic data analysis. Even though MBLL is effective in terms of providing qualitative comparison, it suffers from its applicability across tissue types and tissue dimensions. In this work, we introduce Lambert-W function-based modeling for light propagation in biological tissues, which is a generalized version of the Beer-Lambert model. The proposed modeling provides parametrization of tissue properties, which includes two attenuation coefficients μ_0 and η. We validated our model against the Monte Carlo simulation, which is the gold standard for modeling NIR light propagation in biological tissue. We included numerous human and animal tissues to validate the proposed empirical model, including an inhomogeneous adult human head model. The proposed model, which has a closed form (analytical), is first of its kind in providing accurate modeling of NIR light propagation in biological tissues.

6. **Preconditioning 2D Integer Data for Fast Convex Hull Computations**
   Authors: José Oswaldo Cadenas(1), Graham M. Megson(2), **Cris L. Luengo Hendriks**
   (1) School of Systems Engineering, The University of Reading, Reading, United Kingdom
   (2) School of Electronics and Computer Science, University of Westminster, London, United Kingdom
   Journal: PLoS ONE, Vol. 11, No. 3, e0149860, 11 pages
   Abstract: In order to accelerate computing the convex hull on a set of n points, a heuristic procedure is often applied to reduce the number of points to a set of s points, $s \leq n$, which also contains the same hull. We present an algorithm to precondition 2D data with integer coordinates bounded by a box of size $p \times q$ before building a 2D convex hull, with three distinct advantages. First, we prove that under the condition $min(p, q) \leq n$ the algorithm executes in time within $O(n)$; second, no explicit sorting of data is required; and third, the reduced set of s points forms a simple polygonal chain and thus can be directly pipelined into an $O(n)$ time convex hull algorithm. This paper empirically evaluates and quantifies the speed up gained by preconditioning a set of points by a method based on the proposed algorithm before using common convex hull algorithms to build the final hull. A speedup factor of at least four is consistently found from experiments on various datasets when the condition $min(p, q) \leq n$ holds; the smaller the ratio $min(p, q)/n$ is in the dataset, the greater the speedup factor achieved.

7. **Comparison of 2D Radiography and a Semi-Automatic CT-Based 3D Method for Measuring Change in Dorsal Angulation over Time in Distal Radius Fractures**
   Authors: Albert Christersson(1), **Johan Nysjö**, Lars Berglund(2), **Filip Malmberg, Ida-Maria Sintorn, Ingela Nyström**, Sune Larsson(1)
   (1) Department of Orthopaedics, UU
   (2) Uppsala Clinical Research Centre, UCR Statistics, UU
   Journal: Skeletal Radiology, Vol. 45, No.6, pages 763-769
   Abstract: Objective The aim of the present study was to compare the reliability and agreement between a computer tomography-based method (CT) and digitalised 2D radiographs (XR) when measuring change in dorsal angulation over time in distal radius fractures. Materials and methods Radiographs from 33 distal radius fractures treated with external fixation were retrospectively analysed. All fractures had been examined using both XR and CT at six times over 6 months postoperatively. The changes in dorsal angulation between the first reference images and the following examinations in every patient were calculated from 133 follow-up measurements by two assessors and repeated at two different time points. The measurements were analysed using Bland-Altman plots, comparing intra- and inter-observer agreement within and between XR and CT. Results The mean differences in intra- and inter-observer measurements for XR, CT, and between XR and CT were close to zero, implying equal validity. The average intra- and inter-observer limits

of agreement for XR, CT, and between XR and CT were +/- 4.4 degrees, +/- 1.9 degrees and +/- 6.8 degrees respectively. Conclusions For scientific purpose, the reliability of XR seems unacceptably low when measuring changes in dorsal angulation in distal radius fractures, whereas the reliability for the semi-automatic CT-based method was higher and is therefore preferable when a more precise method is requested.

8. **A New Method for Reconstructing Brain Morphology : Applying the Brain-Neurocranial Spatial Relationship in an Extant Lungfish to a Fossil Endocast**
Authors: Alice M. Clement(1,2), **Robin Strand, Johan Nysjö**, John A. Long(2,3), Per E. Ahlberg(1)
(1) Department of Organismal Biology, Evolutionary Biology Centre, Uppsala University, Uppsala, Sweden (2) Department of Sciences, Museum Victoria, Melbourne, Australia (3) School of Biological Sciences, Flinders University, Adelaide, Australia
Journal: Royal Society Open Science, Vol. 3, No. 7, e160307, 8 pages
Abstract: Lungfish first appeared in the geological record over 410 million years ago and are the closest living group of fish to the tetrapods. Palaeoneurological investigations into the group show that unlike numerous other fishes—but more similar to those in tetrapods—lungfish appear to have had a close fit between the brain and the cranial cavity that housed it. As such, researchers can use the endocast of fossil taxa (an internal cast of the cranial cavity) both as a source of morphological data but also to aid in developing functional and phylogenetic implications about the group. Using fossil endocast data from a three-dimensional-preserved Late Devonian lungfish from the Gogo Formation, Rhinodipterus, and the brain-neurocranial relationship in the extant Australian lungfish, Neoceratodus, we herein present the first virtually reconstructed brain of a fossil lungfish. Computed tomographic data and a newly developed ”brain-warping” method are used in conjunction with our own distance map software tool to both analyse and present the data. The brain reconstruction is adequate, but we envisage that its accuracy and wider application in other taxonomic groups will grow with increasing availability of tomographic datasets.

9. **Estimation of Feret's Diameter from Pixel Coverage Representation of a Shape**
Authors: Slobodan Drazic(1), **Nataša Sladoje(2), Joakim Lindblad(2)**
(1) Faculty of Engineering, University of Novi Sad, Novi Sad, Serbia
(2) CBA and Mathematical Institute, Serbian Academy of Sciences and Arts, Belgrade, Serbia
Journal: Pattern Recognition Letters, Vol. 80, pages 37-45
Abstract: Feret's diameter of a shape is a commonly used measure in shape analysis. Traditional methods for estimation of Feret's diameter are performed on binary images and are of poor precision and accuracy. We analyze and further develop a method for estimation of Feret's diameter that utilizes pixel coverage. We improve the accuracy of the method by proposing a correction term. We provide an expression for the upper bound of the absolute error of the estimation. We evaluate the improved method and compare with existing methods for Feret's diameter estimation, based on both binary and coverage representations of image objects. Tests confirm increased precision and accuracy of the new method, on synthetic as well as on real images.

10. **Precision Automation of Cell Type Classification and Sub-Cellular Fluorescence Quantification from Laser Scanning Confocal Images**
Authors: Hardy C. Hall(1), **Azadeh Fakhrzadeh, Cris L. Luengo Hendriks**, Urs Fischer(1)
(1) Department of Forest Genetics and Plant Physiology, Umeå Plant Science Centre, Swedish University of Agricultural Sciences, Umeå, Sweden
Journal: Frontiers in Plant Science, Vol. 7, e119, 13 pages
Abstract: While novel whole-plant phenotyping technologies have been successfully implemented into functional genomics and breeding programs, the potential of automated phenotyping with cellular resolution is largely unexploited. Laser scanning confocal microscopy has the potential to close this gap by providing spatially highly resolved images containing anatomic as well as chemical information on a subcellular basis. However, in the absence of automated methods, the assessment of the spatial patterns and abundance of fluorescent markers with subcellular resolution is still largely qualitative and time-consuming. Recent advances in image acquisition and analysis, coupled with improvements in microprocessor performance, have brought such automated methods within reach, so that information from thousands of cells per image for hundreds of images may be derived in an experimentally convenient time-frame. Here, we present a MATLAB-based analytical pipeline to 1) segment radial plant organs into individual cells, 2) classify cells into cell type categories based upon random forest classification, 3) divide each cell into sub-regions, and 4) quantify fluorescence intensity to a subcellular degree of precision for a separate fluorescence channel.

In this research advance, we demonstrate the precision of this analytical process for the relatively complex tissues of Arabidopsis hypocotyls at various stages of development. High speed and robustness make our approach suitable for phenotyping of large collections of stem-like material and other tissue types.

11. **Deep Fish: Deep Learning-Based Classification of Zebrafish Deformation for High-Throughput Screening**
Authors: **Omer Ishaq, Sajith Kecheril Sadanandan, Carolina Wählby**
Journal: Journal of Biomolecular Screening, Vol. 22, No. 1, pages 102-107
Abstract: Zebrafish (*Danio rerio*) is an important vertebrate model organism in biomedical research, especially suitable for morphological screening due to its transparent body during early development. Deep learning has emerged as a dominant paradigm for data analysis and found a number of applications in computer vision and image analysis. Here we demonstrate the potential of a deep learning approach for accurate high-throughput classification of whole-body zebrafish deformations in multifish microwell plates. Deep learning uses the raw image data as an input, without the need of expert knowledge for feature design or optimization of the segmentation parameters. We trained the deep learning classifier on as few as 84 images (before data augmentation) and achieved a classification accuracy of 92.8% on an unseen test data set that is comparable to the previous state of the art (95%) based on user-specified segmentation and deformation metrics. Ablation studies by digitally removing whole fish or parts of the fish from the images revealed that the classifier learned discriminative features from the image foreground, and we observed that the deformations of the head region, rather than the visually apparent bent tail, were more important for good classification performance.

12. **Segmentation and Track-Analysis in Time-Lapse Imaging of Bacteria**
Authors: **Sajith Kecheril Sadanandan**, Özden Baltekin(1), Klas E. G. Magnusson(2), Alexis Boucharin(1), **Petter Ranefall**, Joakim Jaldén(2), Johan Elf(1), **Carolina Wählby**
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(2) ACCESS Linnaeus Centre, KTH Royal Institute of Technology, Stockholm, Sweden
Journal: IEEE Journal on Selected Topics in Signal Processing, Vol. 10, No. 1, pages 174-184
Abstract: In this paper, we have developed tools to analyze prokaryotic cells growing in monolayers in a microfluidic device. Individual bacterial cells are identified using a novel curvature based approach and tracked over time for several generations. The resulting tracks are thereafter assessed and filtered based on track quality for subsequent analysis of bacterial growth rates. The proposed method performs comparable to the state-of-the-art methods for segmenting phase contrast and fluorescent images, and we show a 10-fold increase in analysis speed.

13. **Fronto-Facial Advancement and Bipartition in Crouzon-Pfeiffer and Apert Syndromes : Impact of Fronto-Facial Surgery upon Orbital and Airway Parameters in FGFR2 Syndromes**
Authors: Roman H. Khonsari(1,2), Benjamin Way(1), **Johan Nysjö**, Guillaume A. Odri(3), Raphael Olszewski(4), Robert D. Evans(1), David J. Dunaway(1), **Ingela Nyström**, Jonathan A. Britto(1)
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(4) Department of Oral and Maxillofacial Surgery, Saint-Luc University Hospital, Catholic University of Leuven, Brussels, Belgium
Journal: Journal of Cranio-Maxillofacial Surgery, Vol. 44, No. 10, pages 1567-1575
Abstract: A major concern in FGFR2 craniofaciosynostosis is oculo-orbital disproportion, such that orbital malformation provides poor accommodation and support for the orbital contents and peri-orbita, leading to insufficient eyelid closure, corneal exposure and eventually to functional visual impairment. Fronto-facial monobloc osteotomy followed by distraction osteogenesis aims to correct midfacial growth deficiencies in Crouzon—Pfeiffer syndrome patients. Fronto-facial bipartition osteotomy followed by distraction is a procedure of choice in Apert syndrome patients. These procedures modify the shape and volume of the orbit and tend to correct oculo-orbital disproportion. Little is known about the detailed 3D shape of the orbital phenotype in CPS and AS, and about how this is modified by fronto-facial surgery.

Twenty-eight patients with CMS, 13 patients with AS and 40 control patients were included. CT scans

were performed before and after fronto-facial surgery. Late post-operative scans were available for the Crouzon—Pfeiffer syndrome group. Orbital morphology was investigated using conventional three-dimensional cephalometry and shape analysis after mesh-based segmentation of the orbital contents.

We characterized the 3D morphology of CPS and AS orbits and showed how orbital shape is modified by surgery. We showed that monobloc-distraction in CPS and bipartition-distraction in AS specifically address the morphological characteristics of the two syndromes.

14. **On the Influence of Interpolation Method on Rotation Invariance in Texture Recognition**
Authors: Gustaf Kylberg(1), **Ida-Maria Sintorn(2)**
(1) Vironova AB, Sweden
(2) CBA and Vironova AB, Sweden
Journal: EURASIP Journal on Image and Video Processing,Vol. 2016, e17
Abstract: In this paper, rotation invariance and the influence of rotation interpolation methods on texture recognition using several local binary patterns (LBP) variants are investigated.

We show that the choice of interpolation method when rotating textures greatly influences the recognition capability. Lanczos 3 and B-spline interpolation are comparable to rotating the textures prior to image acquisition, whereas the recognition capability is significantly and increasingly lower for the frequently used third order cubic, linear and nearest neighbour interpolation. We also show that including generated rotations of the texture samples in the training data improves the classification accuracies. For many of the descriptors, this strategy compensates for the shortcomings of the poorer interpolation methods to such a degree that the choice of interpolation method only has a minor impact.

To enable an appropriate and fair comparison, a new texture dataset is introduced which contains hardware and interpolated rotations of 25 texture classes. Two new LBP variants are also presented, combining the advantages of local ternary patterns and Fourier features for rotation invariance.

15. **Fast Vascular Skeleton Extraction Algorithm**
Authors: **Kristína Lidayová**, Hans Frimmel(1), Chunliang Wang(2,3,4), **Ewert Bengtsson**, Örjan Smedby(2,3,4)
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(2) Department of Radiology and Department of Medical and Health Sciences, Linköping University, Linköping, Sweden
(3) Center for Medical Image Science and Visualization (CMIV), LinkÖping University, Linköping, Sweden
(4) School of Technology and Health, KTH Royal Institute of Technology, Stockholm, Sweden
Journal: Pattern Recognition Letters, Vol. 76, pages 67-75
Abstract: Vascular diseases are a common cause of death, particularly in developed countries. Computerized image analysis tools play a potentially important role in diagnosing and quantifying vascular pathologies. Given the size and complexity of modern angiographic data acquisition, fast, automatic and accurate vascular segmentation is a challenging task.

In this paper we introduce a fully automatic high-speed vascular skeleton extraction algorithm that is intended as a first step in a complete vascular tree segmentation program. The method takes a 3D unprocessed Computed Tomography Angiography (CTA) scan as input and produces a graph in which the nodes are centrally located artery voxels and the edges represent connections between them. The algorithm works in two passes where the first pass is designed to extract the skeleton of large arteries and the second pass focuses on smaller vascular structures. Each pass consists of three main steps. The first step sets proper parameters automatically using Gaussian curve fitting. In the second step different filters are applied to detect voxels —nodes —that are part of arteries. In the last step the nodes are connected in order to obtain a continuous centerline tree for the entire vasculature. Structures found, that do not belong to the arteries, are removed in a final anatomy-based analysis. The proposed method is computationally efficient with an average execution time of 29 s and has been tested on a set of CTA scans of the lower limbs achieving an average overlap rate of 97% and an average detection rate of 71%.

16. **Visualisation and Evaluation of Flood Uncertainties Based on Ensemble Modelling**
Authors: Nancy Joy Lim(1), Anders S. Brandt(1), **Stefan Seipel(2)**
(1) Department of Industrial Development, IT and Land Management, University of Gävle, Gävle, Sweden
(2) CBA and Department of Industrial Development, IT and Land Management, University of Gävle, Gävle, Sweden
Journal: International Journal of Geographical Information Science, Vol. 30, No. 2, pages 240-262

Abstract: This study evaluates how users incorporate visualisation of flood uncertainty information in decision-making. An experiment was conducted where participants were given the task to decide building locations, taking into account homeowners' preferences as well as dilemmas imposed by flood risks at the site. Two general types of visualisations for presenting uncertainties from ensemble modelling were evaluated: (1) uncertainty maps, which used aggregated ensemble results; and (2) *performance* bars showing all individual simulation outputs from the ensemble. Both were supplemented with either two-dimensional (2D) or three-dimensional (3D) contextual information, to give an overview of the area.The results showed that the type of uncertainty visualisation was highly influential on users' decisions, whereas the representation of the contextual information (2D or 3D) was not. Visualisation with *performance bars* was more intuitive and effective for the task performed than the uncertainty map. It clearly affected users' decisions in avoiding certain-to-be-flooded areas. Patterns to which the distances were decided from the homeowners' preferred positions and the uncertainties were similar, when the 2D and 3D map models were used side by side with the uncertainty map. On the other hand, contextual information affected the time to solve the task. With the 3D map, it took the participants longer time to decide the locations, compared with the other combinations using the 2D model.Designing the visualisation so as to provide more detailed information made respondents avoid dangerous decisions. This has also led to less variation in their overall responses.

17. **PopulationProfiler : A Tool for Population Analysis and Visualization of Image-Based Cell Screening Data**

Authors: **Damian J. Matuszewski(1), Carolina Wählby(1)**, Jordi Carreras Puigvert(2,3), **Ida-Maria Sintorn(1)**

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Journal: PLoS ONE, Vol. 11, No. 3, e0151554, 5 pages

Abstract: Image-based screening typically produces quantitative measurements of cell appearance. Large-scale screens involving tens of thousands of images, each containing hundreds of cells described by hundreds of measurements, result in overwhelming amounts of data. Reducing per-cell measurements to the averages across the image(s) for each treatment leads to loss of potentially valuable information on population variability. We present PopulationProfiler—a new software tool that reduces per-cell measurements to population statistics. The software imports measurements from a simple text file, visualizes population distributions in a compact and comprehensive way, and can create gates for subpopulation classes based on control samples. We validate the tool by showing how PopulationProfiler can be used to analyze the effect of drugs that disturb the cell cycle, and compare the results to those obtained with flow cytometry.

18. **Bridging Histology and Bioinformatics - Computational Analysis of Spatially Resolved Transcriptomics**

Authors: **Marco Mignardi, Omer Ishaq**, Xiaoyan Qian(1), **Carolina Wählby**

(1) Science for Life Laboratory, Department of Biochemistry and Biophysics, Stockholm University, Stockholm 17165, Sweden

Journal: Proceedings of the IEEE, No. 99, 12 pages

Abstract: It is well known that cells in tissue display a large heterogeneity in gene expression due to differences in cell lineage origin and variation in the local environment. Traditional methods that analyze gene expression from bulk RNA extracts fail to accurately describe this heterogeneity because of their intrinsic limitation in cellular and spatial resolution. Also, information on histology in the form of tissue architecture and organization is lost in the process. Recently, new transcriptome-wide analysis technologies have enabled the study of RNA molecules directly in tissue samples, thus maintaining spatial resolution and complementing histological information with molecular information important for the understanding of many biological processes and potentially relevant for the clinical management of cancer patients. These new methods generally comprise three levels of analysis. At the first level, biochemical techniques are used to generate signals that can be imaged by different means of fluorescence microscopy. At the second level, images are subject to digital image processing and analysis in order to detect and identify the aforementioned signals. At the third level, the collected data are analyzed and transformed into interpretable information by statistical methods and visualization techniques relating them to each other, to spatial distribution, and to tissue morphology. In this review, we describe state-of-the-art techniques used at all three levels of analysis. Finally, we discuss future perspective in this fast-growing field of spatially resolved transcriptomics.

19. **Comparison of Walking and Traveling-Wave Piezoelectric Motors as Actuators in Kinesthetic Haptic Devices**
Authors: **Pontus Olsson, Fredrik Nysjö, Ingrid B. Carlbom**, Stefan Johansson(1)
(1) Department of Engineering Sciences, UU
Journal: IEEE Transactions on Haptics, Vol. 9, No. 3, pages 427-431
Abstract: Piezoelectric motors offer an attractive alternative to electromagnetic actuators in portable haptic interfaces: they are compact, have a high force-to-volume ratio, and can operate with limited or no gearing. However, the choice of a piezoelectric motor type is not obvious due to differences in performance characteristics. We present our evaluation of two commercial, operationally different, piezoelectric motors acting as actuators in two kinesthetic haptic grippers, a walking quasi-static motor and a traveling wave ultrasonic motor. We evaluate each gripper's ability to display common virtual objects including springs, dampers, and rigid walls, and conclude that the walking quasi-static motor is superior at low velocities. However, for applications where high velocity is required, traveling wave ultrasonic motors are a better option.

20. **Global Gray-level Thresholding Based on Object Size**
Authors: **Petter Ranefall(1), Carolina Wählby(1)**
(1) CBA and Science for Life Laboratory, Uppsala University, Uppsala, Sweden
Journal: Cytometry Part A, Vol. 89A, No. 4, pages 385-390
Abstract: In this article, we propose a fast and robust global gray-level thresholding method based on object size, where the selection of threshold level is based on recall and maximum precision with regard to objects within a given size interval. The method relies on the component tree representation, which can be computed in quasi-linear time. Feature-based segmentation is especially suitable for biomedical microscopy applications where objects often vary in number, but have limited variation in size. We show that for real images of cell nuclei and synthetic data sets mimicking fluorescent spots the proposed method is more robust than all standard global thresholding methods available for microscopy applications in ImageJ and CellProfiler. The proposed method, provided as ImageJ and CellProfiler plugins, is simple to use and the only required input is an interval of the expected object sizes.

21. **A Survey on Skeletonization Algorithms and Their Applications**
Authors: Punam K. Saha(1,2), **Gunilla Borgefors**, Gabriella Sanniti di Baja(3,4)
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(3) Institute of Cybernetics "E.Caianiello", CNR, Naples, Italy
(4) Institute for High Performance Computing and Networking, CNR, Naples, Italy
Journal: Pattern Recognition Letters, Vol. 76, pages 3-12
Abstract: Skeletonization provides an effective and compact representation of objects, which is useful for object description, retrieval, manipulation, matching, registration, tracking, recognition, and compression. It also facilitates efficient assessment of local object properties, e.g., scale, orientation, topology, etc. Several computational approaches are available in literature toward extracting the skeleton of an object, some of which are widely different in terms of their principles. In this paper, we present a comprehensive and concise survey of different skeletonization algorithms and discuss their principles, challenges, and benefits. Topology preservation, parallelization, and multi-scale skeletonization approaches are discussed. Finally, various applications of skeletonization are reviewed and the fundamental challenges of assessing the performance of different skeletonization algorithms are discussed.

22. **Case-Specific Potentiation of Glioblastoma Drugs by Pterostilbene**
Authors: Linnéa Schmidt(1), Sathishkumar Baskaran(1), Patrik Johansson(1), Narendra Padhan(1), **Damian J. Matuszewski**, Lydia C. Green(2), Ludmila Elfineh(1), Shimei Wee(3), Maria Häggblad(4), Ulf Martens(4), Bengt Westermark(1), Karin Forsberg-Nilsson(1), Lene Uhrbom(1), Lena Claesson-Welsh(1), Michael Andäng(3), **Ida-Maria Sintorn**, Bo Lundgren(4), Ingrid Lönnstedt(1), Cecilia Krona(1), Sven Nelander(1)
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(2) Sahlgrenska Cancer Center, Institute of Medicine, Gothenburg, Sweden
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Journal: OncoTarget, Vol. 7, No. 45, pages 73200-73215
Abstract: Glioblastoma multiforme (GBM, astrocytoma grade IV) is the most common malignant primary

brain tumor in adults. Addressing the shortage of effective treatment options for this cancer, we explored repurposing of existing drugs into combinations with potent activity against GBM cells. We report that the phytoalexin pterostilbene is a potentiator of two drugs with previously reported anti-GBM activity, the EGFR inhibitor gefitinib and the antidepressant sertraline. Combinations of either of these two compounds with pterostilbene suppress cell growth, viability, sphere formation and inhibit migration in tumor GBM cell (GC) cultures. The potentiating effect of pterostilbene was observed to a varying degree across a panel of 41 patient-derived GCs, and correlated in a case specific manner with the presence of missense mutation of EGFR and PIK3CA and a focal deletion of the chromosomal region 1p32. We identify pterostilbene-induced cell cycle arrest, synergistic inhibition of MAPK activity and induction of Thioredoxin interacting protein (TXNIP) as possible mechanisms behind pterostilbene's effect. Our results highlight a nontoxic stilbenoid compound as a modulator of anticancer drug response, and indicate that pterostilbene might be used to modulate two anticancer compounds in well-defined sets of GBM patients.

23. **LatticeLibrary and BccFccRaycaster : Software for Processing and Viewing 3D Data on Optimal Sampling Lattices**
Authors: **Elisabeth Schold Linnér**, Max Morén(1), Karl-Oskar Smed(1), **Johan Nysjö**, **Robin Strand**
(1) Division of Visual Information and Interaction, Department of Information Technology, Uppsala University, Uppsala, Sweden
Journal: SoftwareX, Vol. 5, pages 16-24
Abstract: In this paper, we present LatticeLibrary, a C++ library for general processing of 2D and 3D images sampled on arbitrary lattices. The current implementation supports the Cartesian Cubic (CC), Body-Centered Cubic (BCC) and Face-Centered Cubic (FCC) lattices, and is designed to facilitate addition of other sampling lattices. We also introduce BccFccRaycaster, a plugin for the existing volume renderer Voreen, making it possible to view CC, BCC and FCC data, using different interpolation methods, with the same application. The plugin supports nearest neighbor and trilinear interpolation at interactive frame rates. These tools will enable further studies of the possible advantages of non-Cartesian lattices in a wide range of research areas.

24. **Quantitative Analysis of Immunofluorescence and in Situ PLA Staining Using CellProfiler Reveals Impaired Epidermal Lipid Processing Pathway in ARCI Patients with CYP4F22 Mutations**
Authors: Hanqian Zhang(1), Marie Virtanen(1), Simone Weström(1), Anette Bygum(2), **Carolina Wählby(3)**, Anders Vahlquist(1), Hans Törmä(1)
(1) Department of Medical Sciences, Dermatology and Venereology, Uppsala University, Uppsala, Sweden
(2) Department of Dermatology and Allergy, Odense University Hospital, Odense, Denmark
(3) CBA and Science for Life Laboratory, Uppsala University, Uppsala, Sweden
Journal: Journal of Investigative Dermatology, Vol. 136, No. 9, pages S180-S180
Abstract: Immunofluorescence (IF) and *in situ* proximity ligation assay (PLA) have been widely used for *in situ* protein expression and protein-protein colocalization analysis. However, there is a lack of efficient quantitative analysis methods to deal with the staining results of large amounts of image analyses of tissue sections. Therefore, we developed three CellProfiler pipelines for analysis of fluorescence intensity and protein-protein colocalization on skin sections; i.e. projection, drawing region-of-interest, stratified layer-by-layer measurement. Autosomal recessive congenital ichthyosis (ARCI) is a group of rare genetic skin disorders and caused by mutations in more than 10 genes of which many are involved in epidermal lipid processing. There is a lack of knowledge about pathogenic mechanisms in ARCI. In one of the rare causes, mutations in *CYP4F22* (encoding a very long chain fatty acid ω-hydroxylase being essential for acylceramide production), we analyzed skin section images from patients (n=3) and healthy controls (n=4) using the new CellProfiler pipelines. The IF staining showed almost complete lack of CYP4F22 in the patients' biopsies compared to healthy controls. The PLA results showed significantly reduced colocalizations of CYP4F22 with the lipid processing enzymes CERS3, ELOVL4 and FATP4 in the patient skin, indicating impaired epidermal lipid processing in ARCI patients with *CYP4F22* mutations.

6.5 Refereed conference proceedings

1. **Mathematical Morphology on Irregularly Sampled Signals**
   Authors: **Teo Asplund, Cris Luengo**, Matthew Thurley(1), **Robin Strand**
   (1) Department of Computer Science, Electrical and Space Engineering, Luleå University, Luleå, Sweden
   In Proceedings: Proceedings of Workshop on Discrete Geometry and Mathematical Morphology for Computer Vision In conjunction with ACCV 2016, Taipei, Taiwan, pages 506-520
   Abstract: This paper introduces a new operator that can be used to approximate continuous-domain mathematical morphology on irregularly sampled surfaces. We define a new way of approximating the continuous domain dilation by duplicating and shifting samples according to a flat continuous structuring element. We show that the proposed algorithm can better approximate continuous dilation, and that dilations may be sampled irregularly to achieve a smaller sampling without greatly compromising the accuracy of the result.

2. **A New Approach to Mathematical Morphology on One Dimensional Sampled Signals**
   Authors: **Teo Asplund, Cris Luengo**, Matthew Thurley(1), **Robin Strand**
   (1) Department of Computer Science, Electrical and Space Engineering, Luleå University, Luleå, Sweden
   In Proceedings: IEEE Proceedings, 23rd International Conference on Pattern Recognition (ICPR), Cancun, Mexico, 6 pages
   Abstract: We present a new approach to approximate continuous-domain mathematical morphology operators. The approach is applicable to irregularly sampled signals. We define a dilation under this new approach, where samples are duplicated and shifted according to the flat, continuous structuring element. We define the erosion by adjunction, and the opening and closing by composition. These new operators will significantly increase precision in image measurements. Experiments show that these operators indeed approximate continuous-domain operators better than the standard operators on sampled one-dimensional signals, and that they may be applied to signals using structuring elements smaller than the distance between samples. We also show that we can apply the operators to scan lines of a two-dimensional image to filter horizontal and vertical linear structures.

3. **Feature Evaluation for Handwritten Character Recognition with Regressive and Generative Hidden Markov Models**
   Authors: **Kalyan Ram Ayyalasomayajula**, Carl Nettelblad(1), **Anders Brun**
   (1)Division of Scientific Computing, Uppsala University, Uppsala, Sweden
   In Proceedings: Advances in Visual Computing: Part I, LNCS Vol. 10072, Springer, pages 278-287
   Abstract: Hidden Markov Models constitute an established approach often employed for offline handwritten character recognition in digitized documents. The current work aims at evaluating a number of procedures frequently used to define features in the character recognition literature, within a common Hidden Markov Model framework. By separating model and feature structure, this should give a more clear indication of the relative advantage of different families of visual features used for character classification. The effects of model topologies and data normalization are also studied over two different handwritten datasets. The Hidden Markov Model framework is then used to generate images of handwritten characters, to give an accessible visual illustration of the power of different features.

4. **Blind Restoration of Images Degraded with Mixed Poisson-Gaussian Noise with Application in Transmission Electron Microscopy**
   Authors: Buda Bajic(1), **Joakim Lindblad, Nataša Sladoje**
   (1) Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
   In Proceedings: IEEE Proceedings 13th International Symposium on Biomedical Imaging (ISBI), Prague, Czech Republic, pages 123-127
   Abstract: Noise and blur, present in images after acquisition, negatively affect their further analysis. For image enhancement when the Point Spread Function (PSF) is unknown, blind deblurring is suitable, where both the PSF and the original image are simultaneously reconstructed. In many realistic imaging conditions, noise is modelled as a mixture of Poisson (signal-dependent) and Gaussian (signal independent) noise. In this paper we propose a blind deconvolution method for images degraded by such mixed noise. The method is based on regularized energy minimization. We evaluate its performance on synthetic images, for different blur kernels and different levels of noise, and compare with non-blind restoration. We illustrate the performance of the method on Transmission Electron Microscopy images of cilia, used in clinical practice for diagnosis of a particular type of genetic disorders.

5. **Single Image Super-Resolution Reconstruction in Presence of Mixed Poisson-Gaussian Noise**
   Authors: Buda Bajic(1), **Joakim Lindblad(2), Nataša Sladoje(2)**
   (1) Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
   (2) CBA and Mathematical Institute, Serbian Academy of Sciences and Arts, Belgrade, Serbia
   In Proceedings: IEEE Proceedings, 6th International Conference on Image Processing Theory, Tools and Applications (IPTA), Oulu, Finland, 6 pages
   Abstract: Single image super-resolution (SR) reconstruction aims to estimate a noise-free and blur-free high resolution image from a single blurred and noisy lower resolution observation. Most existing SR reconstruction methods assume that noise in the image is white Gaussian. Noise resulting from photon counting devices, as commonly used in image acquisition, is, however, better modelled with a mixed Poisson-Gaussian distribution. In this study we propose a single image SR reconstruction method based on energy minimization for images degraded by mixed Poisson-Gaussian noise. We evaluate performance of the proposed method on synthetic images, for different levels of blur and noise, and compare it with recent methods for non-Gaussian noise. Analysis shows that the appropriate treatment of signal dependent noise, provided by our proposed method, leads to significant improvement in reconstruction performance.

6. **Stereo Visualisation of Historical Aerial Photos : A Useful and Important Aerial Archeology Research Tool**
   Authors: **Anders Hast**, Carlotta Capurro(1), Dries Nollet(1), Daniel Pletinckx(1), Benito Vilas Estevez(2), Miguel Carrero Pazos(2), Jose Maria Eguileta Franco(3), Andrea Marchetti(4)
   (1) Visual Dimension, Belgium
   (2) Universidad de Gales Trinity Saint David, Spain
   (3) Seccion de Arqueoloxia, Concello de Ourense, Spain
   (4) Istituto di Informatica e Telematica Consiglio Nazionale delle Ricerche, Pisa, Italy
   In Proceedings: 2nd International Conference of Aerial Archaeology, Roma, Italy, 9 pages
   Abstract: In this article we present some case studies in which historical aerial photos are central elements in the research process and we demonstrate how the investigation benefits from a stereo visualisation of these images, resulting in a useful tool for Aerial Archaeology. These examples include photographs from both WWI and WWII as well as images from the post war era, showing a landscape that is now transformed or not even accessible due to human constructions.

   Stereo images are useful as they give a much better understanding of what is actually seen on the ground than single photos ever can, thanks to the depth cue that helps understanding the content and adds the ability to distinguish each element on the ground. Hence, stereo helps in estimating heights of single objects, just as well as the relative height of all objects on the ground that form a site. Nonetheless, it is also important to stress that stereo also helps in understanding the surrounding landscape.

   This paper will discuss the challenges that still have to be faced in order to create stereo images useful for archaeologists and will reflect on the many possibilities and advantages that stereo visualisation of aerial photos offers

7. **A Segmentation-Free Handwritten Word Spotting Approach by Relaxed Feature Matching**
   Authors: **Anders Hast**, Alicia Fornés
   In Proceedings: IEEE proceedings, 12th IAPR Workshop on Document Analysis Systems, Santorini, Greece, pages 150-155
   Abstract: The automatic recognition of historical handwritten documents is still considered a challenging task. For this reason, word spotting emerges as a good alternative for making the information contained in these documents available to the user. Word spotting is defined as the task of retrieving all instances of the query word in a document collection, becoming a useful tool for information retrieval. In this paper we propose a segmentation-free word spotting approach able to deal with large document collections. Our method is inspired on feature matching algorithms that have been applied to image matching and retrieval. Since handwritten words have different shape, there is no exact transformation to be obtained. However, the sufficient degree of relaxation is achieved by using a Fourier based descriptor and an alternative approach to RANSAC called PUMA. The proposed approach is evaluated on historical marriage records, achieving promising results.

8. **The Challenges and Advantages with a Parallel Implementation of Feature Matching**
   Authors: **Hast Anders**, Andrea Marchetti(1)
   (1) Istituto di Informatica e Telematica, Consiglio Nazionale delle Ricerche, Pisa, Italy
   In Proceedings: IEEE Proceedings, 11th Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP), Rome, Italy, Volume 4, pages 101-106
   Abstract: The number of cores per cpu is predicted to double every second year. Therefore, the opportunity to parallelise currently used algorithms in computer vision and image processing needs to be addressed sooner rather than later. A parallel feature matching approach is proposed and evaluated in Matlab. The key idea is to use different interest point detectors so that each core can work on its own subset independently of the others. However, since the image pairs are the same, the homography will be essentially the same and can therefore be distributed by the process that first finds a solution. Nevertheless, the speedup is not linear and reasons why is discussed.

9. **Signature of a Shape Based on its Pixel Coverage Representation**
   Authors: Vladimir Ilic(1), **Joakim Lindblad(2), Nataša Sladoje(2)**
   (1) Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
   (2) CBA and Mathematical Institute, Serbian Academy of Sciences and Arts, Belgrade, Serbia
   In Proceedings: Proceedings, 19th IAPR International Conference on Discrete Geometry for Computer Imagery (DGCI), Nantes, France, LNCS Vol. 9647, Springer, pages 181-193
   Abstract: Distance from the boundary of a shape to its centroid, a.k.a. signature of a shape, is a frequently used shape descriptor. Commonly, the observed shape results from a crisp (binary) segmentation of an image. The loss of information associated with binarization leads to a significant decrease in accuracy and precision of the signature, as well as its reduced invariance w.r.t. translation and rotation. Coverage information enables better estimation of edge position within a pixel. In this paper, we propose an iterative method for computing the signature of a shape utilizing its pixel coverage representation. The proposed method iteratively improves the accuracy of the computed signature, starting from a good initial estimate. A statistical study indicates considerable improvements in both accuracy and precision, compared to a crisp approach and a previously proposed approach based on averaging signatures over α-cuts of a fuzzy representation. We observe improved performance of the proposed descriptor in the presence of noise and reduced variation under translation and rotation.

10. **Feature Augmented Deep Neural Networks for Segmentation of Cells**
    Authors: **Sajith Kecheril Sadanandan, Petter Ranefall, Carolina Wählby**
    In Proceedings: Proceedings, Computer Vision ECCV 2016 Workshops : Part I, Amsterdam, The Netherlands, LNCS Vol. 9913, Springer, pages 231-243
    Abstract: In this work, we use a fully convolutional neural network for microscopy cell image segmentation. Rather than designing the network from scratch, we modify an existing network to suit our dataset. We show that improved cell segmentation can be obtained by augmenting the raw images with specialized feature maps such as eigen value of Hessian and wavelet filtered images, for training our network. We also show modality transfer learning, by training a network on phase contrast images and testing on fluorescent images. Finally we show that our network is able to segment irregularly shaped cells. We evaluate the performance of our methods on three datasets consisting of phase contrast, fluorescent and bright-field images.

11. **Improving Skin Lesion Segmentation in Dermoscopic Images by Thin Artefacts Removal Methods**
    Authors: Tomáš Majtner(1), **Kristína Lidayová** Sule Yildirim-Yayilgan(1), Jon Yngve Hardeberg(1)
    (1) Faculty of Computer Science and Media Technology, NTNU Norwegian University of Science and Technology, Gjövik, Norway
    In Proceedings: IEEE proceedings, 6th European Workshop on Visual Information Processing (EUVIP), Marseille, France, 6 pages
    Abstract: In dermoscopic images, various thin artefacts naturally appear, most usually in the form of hairs. While trying to find the border of the skin lesion, these artefacts affect the lesion segmentation methods and also the subsequent classification.Currently, there is a lot of research focus in this area and various methods are presented both for skin lesion segmentation and thin artefacts removal. In this paper, we investigate into three different thin artefacts removal methods and compare their results using two different skin lesion segmentation methods. The segmentation results are compared with groundtruth segmentation. In addition, we introduce our novel artefacts removal method, which combined with the ExpectationMaximization image segmentation outperforms all the tested methods.

12. **Comparison of Flow Cytometry and Image-Based Screening for Cell Cycle Analysis**
Authors: **Damian J. Matuszewski(1), Ida-Maria Sintorn(1)**, Jordi Carreras Puigvert(1,2), **Carolina Wählby(1)**
(1) CBA and Science for Life Laboratory, Uppsala University, Uppsala, Sweden
(2) Division of Translational Medicine and Chemical Biology, Department of Medical Biochemistry and Biophysics, Karolinska Institutet, Stockholm, Sweden
In Proceedings: Proceedings, 13th International Conference on Image Analysis and Recognition, LNCS Vol. 9730, Springer, pages 623-630
Abstract: Quantitative cell state measurements can provide a wealth of information about mechanism of action of chemical compounds and gene functionality. Here we present a comparison of cell cycle disruption measurements from commonly used flow cytometry (generating one- dimensional signal data) and bioimaging (producing two-dimensional image data). Our results show high correlation between the two approaches indicating that image-based screening can be used as an alternative to flow cytometry. Furthermore, we discuss the benefits of image informatics over conventional single-signal flow cytometry.

13. **Congruency Matters —How Ambiguous Gender Cues Increase a Robot's Uncanniness**
Authors: Maike Paetzel(1), Christopher Peters(1), **Ingela Nyström**, Ginevra Castellano(1)
(1) Department of Information Technology, Uppsala University, Uppsala, Sweden
In Proceedings: Proceedings, 8th International Conference on Social Robotics, Kansas City, MO, USA, LNCS Vol. 9979, Springer, 2016, pages 402-412
Abstract: Most research on the uncanny valley effect is concerned with the influence of human-likeness and realism as a trigger of an uncanny feeling in humans. There has been a lack of investigation on the effect of other dimensions, for example, gender. Back-projected robotic heads allow us to alter visual cues in the appearance of the robot in order to investigate how the perception of it changes. In this paper, we study the influence of gender on the perceived uncanniness. We conducted an experiment with 48 participants in which we used different modalities of interaction to change the strength of the gender cues in the robot. Results show that incongruence in the gender cues of the robot, and not its specific gender, influences the uncanniness of the back-projected robotic head. This finding has potential implications for both the perceptual mismatch and categorization ambiguity theory as a general explanation of the uncanny valley effect.

14. **Effects of Multimodal Cues on Children's Perception of Uncanniness in a Social Robot**
Authors: Maike Paetzel(1), Christopher Peters(2), **Ingela Nyström**, Ginevra Castellano(1)
(1) Department of Information Technology, Uppsala University, Uppsala, Sweden
(2) Department for Computational Science and Technology (CST), School of Computer Science and Communication (CSC), KTH Royal Institute of Technology, Stockholm, Sweden
In Proceedings: Proceedings, 18th ACM International Conference on Multimodal Interaction (ICMI), ACM Digital Library, Tokyo, Japan, pages 297-301
Abstract: This paper investigates the influence of multimodal incongruent gender cues on the perception of a robot's uncanniness and gender in children. The back-projected robot head Furhat was equipped with a female and male face texture and voice synthesizer and the voice and facial cues were tested in congruent and incongruent combinations. 106 children between the age of 8 and 13 participated in the study. Results show that multimodal incongruent cues do not trigger the feeling of uncanniness in children. These results are significant as they support other recent research showing that the perception of uncanniness cannot be triggered by a categorical ambiguity in the robot. In addition, we found that children rely on auditory cues much stronger than on the facial cues when assigning a gender to the robot if presented with incongruent cues. These findings have implications for the robot design, as it seems possible to change the gender of a robot by only changing its voice without creating a feeling of uncanniness in a child.

15. **Fast Adaptive Local Thresholding Based on Ellipse Fit**
Authors: **Petter Ranefall(1), Sajith Kecheril Sadanandan(1), Carolina Wählby(1)**
(1) CBA and Science for Life Laboratory, Uppsala University, Uppsala, Sweden
In Proceedings: IEEE proceedings, 13th International Symposium on Biomedical Imaging (ISBI), Prague, Czech Republic, pages 205-208
Abstract: In this paper we propose an adaptive thresholding method where each object is thresholded optimizing its shape. The method is based on a component tree representation, which can be computed in quasi-linear time. We test and evaluate the method on images of bacteria from three different live-cell analysis experiments and show that the proposed method produces segmentation results comparable to state-

of-the-art but at least an order of magnitude faster. The method can be extended to compute any feature measurements that can be calculated in a cumulative way, and holds great potential for applications where a priori information on expected object size and shape is available.

16. **3D Game Technology in Property Formation**
Authors: **Stefan Seipel**, Goran Milutinovic(1), Martin Andrée(2)
(1) Akademi för Teknik och Miljö, Gävle University, Gävle, Sweden
(2) Lantmäteriet, Gävle, Sweden
In Proceedings: SGEM Proceedings, 16th International Multidisciplinary Scientific GeoConference, Albena, Bulgaria, Book 2, Vol. 1, pages 539-546
Abstract: The process of real property formation involves the analysis and assessment of legal documents and cadastral information available in digital form. Quite frequently, however, it is necessary to visit the sites to establish relevant information from the real land parcels as well as communicating with involved stakeholders in the natural environment, entailing substantial cost in terms of time and travel expenses. The objective of the work presented here is to investigate alternative, IT-based processes for property formation which draw on existing data and have the potential to substitute time- and cost-intensive field visits. More specifically, the presented study explores how 3D game-based technology can be used to facilitate virtual site visits as an alternative to physical field surveys. We approach this problem by suggesting a framework that enables interoperability of existing 3D terrain models from the national land survey as well as vector data from cadastral databases with existing gaming environments for interactive exploration. Following an analysis of the quality of the existing digital terrain data, we describe an alternative data-extraction pathway that is suitable for rendering of 3D terrain models in the game engine. We present some visual results of our 3D demo system which indicate that salient structures in the terrain relevant for assessment and establishing of property boundaries are readily accessible in the virtual environment. Results of a quantitative comparison of the tested data models also support what visual inspection suggests, that existing terrain data can be refined for use of virtual site visits for property formation.

17. **Minimal Paths by Sum of Distance Transforms**
Authors: **Robin Strand**
In Proceedings: 19th IAPR International Conference on Discrete Geometry for Computer Imagery, Nantes, France, LNCS Vol. 9647, Springer, pages 349-358
Abstract: Minimal path extraction is a frequently used tool in image processing with applications in for example centerline extraction and edge tracking. This paper presents results and methods for (i) extracting minimal paths and for (ii) utilizing local direction in the minimal path computation. Minimal path extraction is based on sum of distance transforms resulting in a stable method, without need for local decisions, which is needed for methods based on backtracking. Local direction utilization is discrete derivative based concepts such as the structure tensor, the Hessian and the Beltrami framework. The combination of minimal path extraction and local direction utilization gives a strong framework for minimal path extraction.

18. **Automated Detection of Cilia in Low Magnification Transmission Electron Microscopy Images Using Template Matching**
Authors: **Amit Suveer, Nataša Sladoje, Joakim Lindblad**, Anca Dragomir(1), **Ida-Maria Sintorn**
(1) Surgical Pathology, Department of Immunology, UU Hospital
In Proceedings: IEEE proceedings, 13th International Symposium on Biomedical Imaging (ISBI), Prague, Czech Republic, pages 386-390
Abstract: Ultrastructural analysis using Transmission Electron Microscopy (TEM) is a common approach for diagnosing primary ciliary dyskinesia. The manually performed diagnostic procedure is time consuming and subjective, and automation of the process is highly desirable. We aim at automating the search for plausible cilia instances in images at low magnification, followed by acquisition of high magnification images of regions with detected cilia for further analysis. This paper presents a template matching based method for automated detection of cilia objects in low magnification TEM images, where object radii do not exceed 10 pixels. We evaluate the performance of a series of synthetic templates generated for this purpose by comparing automated detection with results manually created by an expert pathologist. The best template achieves a detection at equal error rate of 47% which suffices to identify densely populated cilia regions suitable for high magnification imaging.

19. **Large Scale Continuous Dating of Medieval Scribes Using a Combined Image and Language Model**
Authors: **Fredrik Wahlberg**, Lasse Mårtensson, **Anders Brun**
(1) Department of Business Studies, University of Gävle, Gävle, Sweden
In Proceedings: IEEE proceedings, 12th IAPR Workshop on Document Analysis Systems (DAS), Santorini, Greece, pages 48-53
Abstract: The dataset we have used for this paper was "Svenskt Diplo-matariums Huvudkartotek" (SDHK). Some example images are shown in figure 6. The charters (in total over 10000) are from the Swedish medieval period and most are dated on the day. However, a significant portion of the charters have for multiple reasons lost their dates sometime during the last 500+ years. The dates were lost due to degradations, damage or that a part of the parchment was cut off for an unknown reason. In [1], we developed a state-of-the-art pipeline for dating SDHK using only image based features. We draw heavily on that work in this paper for feature extraction and propose improvements to the estimators, more than halving the mean square error. We also explore and evaluate how adding a human to the estimation, by using transcriptions and rough estimates of the production dates, can improve the results. We find that the use of computer assisted dating, using our setup, can significantly lower the needed expertise and labour time of the user. The study we present here is a part of our project to return an estimation for the lost production dates in SDHK to the Swedish national archive (including expected estimation errors).

20. **Historical Manuscript Production Date Estimation using Deep Convolutional Neural Networks**
Authors: **Fredrik Wahlberg, Tomas Wilkinson, Anders Brun**
In Proceedings: 15th International Conference on Frontiers in Handwriting Recognition (ICFHR), Shenzhen, China, 6 pages
Abstract: Deep learning has thus far not been used for dating of pre-modern handwritten documents. In this paper, we propose ways of using deep convolutional neural networks (CNNs) to estimate production dates for such manuscripts. In our approach, a CNN can either be used directly for estimating the production date or as a feature learning framework for other regression techniques. We explore the feature learning approach using Gaussian Processes regression and Support Vector Regression. The evaluation is performed on a unique large dataset of over 10000 medieval charters from the Swedish collection Svenskt Diplomatariums huvudkartotek (SDHK). We show that deep learning is applicable to the task of dating documents and that the performance is on average comparable to that of a human expert.

21. **Semantic and Verbatim Word Spotting using Deep Neural Networks**
Authors: **Tomas Wilkinson, Anders Brun**
In Proceedings: 15th International Conference on Frontiers in Handwriting Recognition (ICFHR), Shenzhen, China, 6 pages
Abstract: In the last few years, deep convolutional neural networks have become ubiquitous in computer vision, achieving state-of-the-art results on problems like object detection, semantic segmentation, and image captioning. However, they have not yet been widely investigated in the document analysis community. In this paper, we present a word spotting system based on convolutional neural networks. We train a network to extract a powerful image representation, which we then embed into a word embedding space. This allows us to perform wordspotting using both query-by-string and query-by-example in a variety of word embedding spaces, both learned and handcrafted, for verbatim as well as semantic word spotting. Our novel approach is versatile and the evaluation shows that it outperforms the previous state-of-the-art for word spotting on standard datasets.

22. **Segmentation of Shadows and Water Bodies in High Resolution Images Using Ancillary Data**
Authors: Julia Åhlén(1), **Stefan Seipel**
(1) University of Gävle, Department of Building, Energy and Environmental Engineering, Gävle, Sweden
In Proceedings: SGEM Proceedings, 16th International Multidisciplinary Scientific GeoConference, Albena, Bulgaria, Book 2, Vol. 1, pages 827-834
Abstract: High spatial resolution imagery is often affected by shadows, both in urban environments with large variations in surface elevation and in vegetated areas. It is a common bias in classification when waters and shadows are registered as the same area. The radiometric response for the shadowed regions should be restored prior to classification. To enable that, separate classes of non-shadowed regions and shadowed areas should be created. Previous work on water extraction using low/medium resolution images, mainly faced two difficulties. Firstly, it is difficult to obtain accurate position of water boundary and secondly, shadows of elevated objects e.g. buildings, bridges, towers and trees are a typical source of noise when facing

water extraction in urban regions. In high resolution images the problem of separation water and shadows becomes more prominent since the small local variation of intensity values gives rise to misclassification. This paper proposes a robust method for separation of shadowed areas and water bodies in high spatial resolution imagery using hierarchical method on different scales combined with classification of PCA (Principal Component Analysis) bands, which reduces the effects of radiometric and spatial differences that is commonly associated with the pixel-based methods for multisource data fusion. The method uses ancillary data to aid in classification of shadows and waters. The proposed method includes three steps: segmentation, classification and post-processing. To achieve robust segmentation, we apply the merging region with three features (PCA bands, NSVDI (Normalized Saturation-value Difference Index) and height data). NSVDI discriminates shadows and some water. In the second step we use hierarchic region based classification to identify water regions. After that step candidates for water pixels are verified by the LiDAR DEM data. As a last step we consider shape parameters such as compactness and symmetry to completely remove shadows.

6.6 Non-refereed conferences and workshops

1. **Estimating a Structural Bottle Neck for Eye—Brain Transfer of Visual Information from 3D-Volumes of the Optic Nerve Head from a Commercial OCT Device**
   Authors: **Filip Malmberg**, Camilla Sandberg-Melin, Per G. Söderberg
   (1) Gullstrand lab, Ophthalmology, Dept. of Neuroscience, UU
   (2) Ophthalmology, Gävle Hospital, Gävle, Sweden
   In Proceedings: SPIE Proceedings 9693, Ophthalmic Technologies XXVI, Bellingham, e96930N, 5 pages
   Abstract: The aim of this project was to investigate the possibility of using OCT optic nerve head 3D information captured with a Topcon OCT 2000 device for detection of 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. The shortest distance between these boundaries reflects the nerve fiber layer thickness and measurement of this distance is interesting for follow-PopulationProfilerp of glaucoma.
   Comment: Abstract reviewed

2. **Analysis of the Variation in OCT Measurements of a Structural Bottle Neck for Eye—Brain Transfer of Visual Information from 3D-Volumes of the Optic Nerve Head, PIMD-Average** $[0; 2\pi]$
   Authors: Per G. Söderberg(1), **Filip Malmberg**, Camilla Sandberg-Melin(1,2)
   (1) Gullstrand lab, Ophthalmology, Department of Neuroscience, Uppsala University, University hospital, Uppsala, Sweden
   (2) Gävle regional hospital, Gävle, Sweden
   In Proceedings: SPIE proceedings, Ophthalmic Technologies XXVI, Vol. 9693, e96930O, 7 pages
   Abstract: The present study aimed to analyze the clinical usefulness of the thinnest cross section of the nerve fibers in the optic nerve head averaged over the circumference of the optic nerve head. 3D volumes of the optic nerve head of the same eye was captured at two different visits spaced in time by 1-4 weeks, in 13 subjects diagnosed with early to moderate glaucoma. At each visit 3 volumes containing the optic nerve head were captured independently with a Topcon OCT- 2000 system. In each volume, the average shortest distance between the inner surface of the retina and the central limit of the pigment epithelium around the optic nerve head circumference, PIMD-Average $[0; 2\pi]$, was determined semiautomatically. The measurements were analyzed with an analysis of variance for estimation of the variance components for subjects, visits, volumes and semi-automatic measurements of PIMD-Average $[0; 2\pi]$. It was found that the variance for subjects was on the order of five times the variance for visits, and the variance for visits was on the order of 5 times higher than the variance for volumes. The variance for semi-automatic measurements of PIMD-Average $[0; 2\pi]$ was 3 orders of magnitude lower than the variance for volumes. A 95 % confidence interval for mean PIMD-Average $[0; 2\pi]$ was estimated to 1.00 $\pm$ 0.13 mm (D.f. = 12). The variance estimates indicate that PIMD-Average $[0; 2\pi]$ is not suitable for comparison between a onetime estimate in a subject and a population reference interval. Cross-sectional independent group comparisons of PIMD-Average $[0; 2\pi]$ averaged over subjects will require inconveniently large sample sizes. However, cross-sectional independent group comparison of averages of within subject difference between baseline and follow-up can be made with reasonable sample sizes. Assuming a loss rate of 0.1 PIMD-Average $[0; 2\pi]$ per year and 4 visits per year it was found that approximately 18 months follow up is required before a significant change of PIMDAverage $[0; 2\pi]$ can be observed with a power of 0.8. This is shorter than what has been observed both for HRT measurements and automated perimetry measurements with a similar observation rate. It is concluded that PIMDAverage $[0; 2\pi]$ has the potential to detect deterioration of glaucoma quicker than currently available primary diagnostic instruments. To increase the efficiency of PIMD-Average $[0; 2\pi]$ further, the variation among visits within subject has to be reduced.
   Comment: Abstract reviewed

3. **Holistic Whole-Body MRI Image Analysis**
   Authors: **Robin Strand**, **Filip Malmberg**, Lars Johansson(1,2), Lars Lind(3), Magnus Sundbom(4), Håkan Ahlström(1,2), Joel Kullberg(1,2)
   (1) Division of Radiology, Department of Surgical Sciences, UU
   (2) Antaros Medical AB, BioVenture Hub, Mölndal, Sweden
   (3) Department of Medical Sciences, UU
   (4) Department of Surgical Sciences, UU
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Uppsala, Sweden, (SSBA)

4. **Cilia Detection using Template Matching in Low Magnification Electron Microscopy Images**
   Authors: **Amit Suveer, Nataša Sladoje, Joakim Lindblad**, Anca Dragomir,(1) **Ida-Maria Sintorn**
   (1) Surgical Pathology, Department of Immunology, UU Hospital
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Uppsala, Sweden, (SSBA)

5. **A Toolbox for Non-parametric Deformable Registration of Volume Images**
   Authors: **Filip Malmberg, Robin Strand**, Håkan Ahlström(1), Joel Kullberg(1)
   (1) Division of Radiology, Department of Surgical Sciences, UU
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Uppsala, Sweden, (SSBA)

6. **BoneSplit – A 3D Painting Tool for Interactive Bone Segmentation in CT Images**
   Authors: **Johan Nysjö, Filip Malmberg, Ida-Maria Sintorn, Ingela Nyström**
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Uppsala, Sweden, (SSBA)

7. **Word segmentation in Historical Documents using Convolutional Neural Networks**
   Authors: **Tomas Wilkinson, Anders Brun**
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Uppsala, Sweden, (SSBA)

8. **Blind deconvolution of images degraded with mixed Poisson-Gaussian noise with application in Transmission Electron Microscopy**
   Authors: Buda Bajic(1), **Joakim Lindblad, and Natasa Sladoje**
   Faculty of Technical Sciences, University of Novi Sad, Serbia
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Uppsala, Sweden, (SSBA)

9. **Global And Local Adaptive Gray-level Thresholding Based on Object Features**
   Authors: **Petter Ranefall, Sajith Kecheril Sadanandan, Carolina Wählby**
   In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Uppsala, Sweden, (SSBA)

10. **TissueMaps : A Large Multi-Scale Data Analysis Platform for Digital Image Application Built on Open-Source Software**
    Authors: **Maxime Bombrun, Petter Ranefall, Carolina Wählby**
    In Proceedings: 4th Nordic Symposium on Digital Pathology, Linköping, Sweden

11. **Signed Distance Fields for Modeling Surgical Guides and Plates from CT Images**
    Authors: **Fredrik Nysjö, Pontus Olsson, Filip Malmberg, Ingrid B. Carlbom, Ingela Nyström**
    In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Uppsala, Sweden, (SSBA)

12. **Preliminary Results from Using a Back-Projected Robot Head in Uncanny Valley Research**
    Authors: Maike Paetzel(1), Christopher Peters(2), **Ingela Nyström**, Ginevra Castellano(1)
    (1) Department of Information Technology, Division of Visual Information and Interaction, Uppsala University, Uppsala, Sweden
    (2) Department for Computational Science and Technology (CST), School of Computer Science and Communication (CSC), KTH Royal Institute of Technology, Stockholm, Sweden
    In Proceedings: IEEE Proceedings, 25th International Symposium on Robot and Human Interactive Communication, Piscataway, NJ, USA, pages 944-945

13. **Estimating Manuscript Production Dates Using Both Image and Language Data**
    Authors: **Fredrik Wahlberg**, Lasse Mårtensson(1), **Anders Brun**
    (1) Department of Business Studies, University of Gävle, Gävle, Sweden
    In Proceedings: Symposium of the Swedish Society for Automated Image Analysis, Uppsala, Sweden, (SSBA)

6.7 Other publications

See also Section 3.2 for Master theses finished during 2016.

1. **Olle Hanner på Stockholms högskola**
   Authors: **Christer O. Kiselman**
   Journal: Svenska matematikersamfundets medlemsblad, pages 27-27
2. **Gennadi Henkin (1942-2016) : Some Memories**
   Authors: **Christer O. Kiselman**
   Journal: Bulletinen. Svenska matematikersamfundets Bulletin., pages 37-44
3. **CBA Annual Report 2015**
   Editors: **Marine Astruc, Gunilla Borgefors, Filip Malmberg, Lena Nordström, Ingela Nyström, Sajith Kecheril Sadanandan, Robin Strand**
   Publisher: Centre for Image Analysis, 120 pages

7 Activities

This year, we organized the annual symposium of the Swedish Society for Automated Image Analysis (SSBA 2016) in Uppsala. It was also the 40^{th} anniversary of the Society, which was celebrated in the afternoon and evening before the actual conference started. Most of us participated, in one way or another.

We have a longstanding tradition of having at least one seminar every Monday afternoon, where we present our own research to each other and where we get the opportunity to listen to many guest lecturers. This year, we had 42 seminars, with a record of 16 guest speakers, and an average attendance of 19 persons.

As usual, we attended many national and international meetings, where we presented our work as invited speaker or giving oral or poster presentations of reviewed papers. This is a necessary and enjoyable necessity for keeping in contact with state-of-the-art research and forming new alliances. Most remarkable this year was the number of conferences where one of us was an invited speaker.

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 reviewers for international journals (which often goes undocumented), and as members of dissertation committees, and as evaluators of projects and positions.

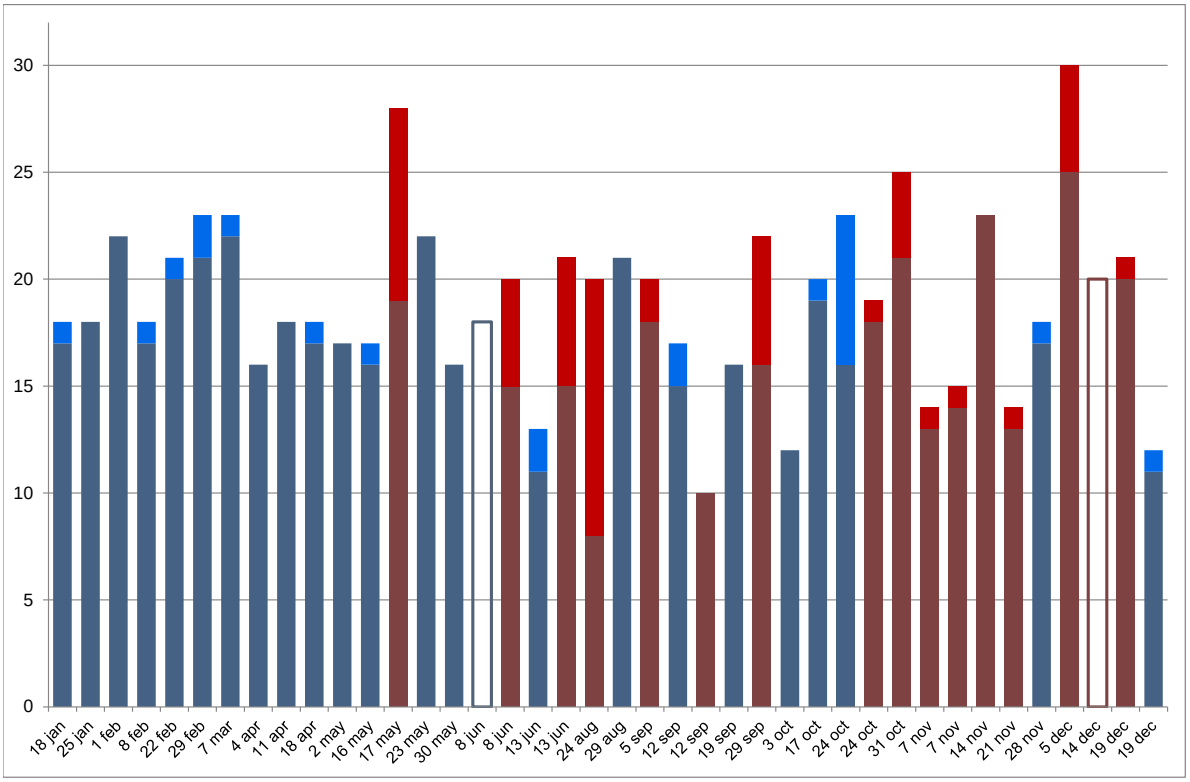

Figure 61: Our own seminar series. Blue represents seminars given by CBA people, while red represents guest lecturers. The saturated color on top represents guest attendants. For two seminars data is missing, these are shown as blank bars and represented by the median value.

7.1 SSBA Symposium 2016

An activity which should specifically be mentioned is the organization of the Swedish Symposium on Image Analysis (SSBA), held on March 14–16. We had approximately 140 participants from academia and industry who gathered for a PhD student day and two symposium days. A majority of the CBA staff were active in organization. The SSBA symposium is arranged each year by the Swedish Society for Automated Image Analysis, which during 2016 also celebrates its 40th anniversary (1976–2016). The symposium dates back to 1978 when it was arranged for the first time, then at the Royal Institute of Technology in Stockholm. For more information, see program and other details at `http://ssba2016.cb.uu.se/`.

Organizing committee

Symposium chair: Robin Strand
Program chair: Nataša Sladoje
Local chair: Ida-Maria Sintorn
Webmaster: Fredrik Nysjö
Sponsorship chair: Anders Brun
PhD student day organizers: Tomas Wilkinson and Damian Matuszewski
Advisory chair: Ingela Nyström

Figure 62: The main SSBA organizers, Ida-Maria Sintorn, Nataša Sladoje and Robin Strand at the symposium opening.

7.2 Other symposium

1. **Celsius-Linné Symposium – Winter light**
   Organisers: Gunilla Borgefors
   Address: Ångström, UU
   Date: 20160219
   Comment: Borgefors was the main organiser of the symposium and the Chair for all talks.

Figure 63: Three of the four authors of the best industry-relevant paper at SSBA 2016 at the conference dinner. Not on this picture: The first author Johan Nysjö. From left to right: Filip Malmberg, Ingela Nyström and Ida-Maria Sintorn (with Ivar Sintorn).

7.3 Seminars held outside CBA

1. **Kristína Lidayová**
   Date: 20160222
   Address: Universidad de los Andes, Cra 1 N° 18A-12, Bogotá, Colombia
   Title: Fast Centerline Extraction Algorithm for Anatomical Tree Structures

2. **Anders Brun**
   Date: 20160229
   Address: Carolina Rediviva, Uppsala, Sweden
   Title: Forum for Digital Humanities (“Forum för Digital Humaniora”)

3. **Carolina Wählby**
   Date: 20160531
   Address: Science for Life Laboratory, Solna, Sweden
   Title: Possibilities and Pitfalls in Large-Scale Image-Based Screening
   Comment: SciLifeLab Scientific Seminar: New Approaches in Cell Based Assays – Getting More Out Of Less?

4. **Ewert Bengtsson**
   Date: 20160823
   Address: Ideon, Lund
   Title: Cervical Cancer Screening through Cell Image Analysis.
   Comment: Invited to present the state of the art in cervical cancer screening to the management group of the Cellavision company

5. **Tomas Wilkinson**
   Date: 20160902
   Address: Department of Linguistics and Philology, English Park Campus, Uppsala University
   Title: Semantic and Verbatim Word Spotting using Deep Neural Networks

6. **Joakim Lindblad**
   Date: 20160913–20160916
   Address: Universitat Pompeu Fabra, Barcelona, Spain
   Title: Introduction to Matlab
   Comment: Seminars at the training school organized within NEUBIAS – A new Network of European BioImage Analysts to advance life science imaging

7. **Carolina Wählby**
   Date: 20161011
   Address: Dept. Biomedical engineering, Carnegie Mellon University, Pittsburgh, USA
   Title: Digital Image Processing and Analysis as a Tool in Life Science – From Drug Screening to In Situ Sequencing

8. **Carolina Wählby**
   Date: 20161013
   Address: Broad Institute of Harvard and MIT, Boston, USA
   Title: Deep Learning and Convolutional Neural Networks – Useful techniques in bioimage informatics?

9. **Kristína Lidayová**
   Date: 20161124
   Address: Creatis – INSA Lyon, Université Lyon 1, Lyon, France
   Title: Fast Centerline Detection and Segmentation Algorithm for Anatomical Tree Structures

10. **Sajith Kecheril Sadanandan**
    Date: 20161221
    Address: Regional Cancer Center, Thiruvananthapuram, Kerala, India
    Title: Deep Learning in Image Analysis

7.4 Seminars at CBA

1. **Robin Strand**
   Date: 20160118
   Title: Minimal Path Extraction

2. **Amit Suveer**
   Date: 20160125
   Title: Automated Detection of Cilia in Low Magnification Transmission Electron Microscopy Images Using Template Matching

3. **Maxime Bombrun**
   Date: 20160201
   Title: Anatomy of a Strombolian Plume: Inferences from Particle Data

4. **Joakim Lindblad**
   Date: 20160208
   Title: Exact Linear Time Euclidean Distance Transforms of Grid Line Sampled Shapes

5. **Damian Matuszewski**
   Date: 20160222
   Title: Log Polar Magnitude Region Descriptor

6. **Carolina Wählby**
   Date: 20160229
   Title:What Is BioImage Informatics, Today and in the Future?

7. **Fredrik Wahlberg**
   Date: 20160307
   Title: What Have We Learned about Learning?

8. **Kristina Lidayová**
   Date: 20160404
   Title: Airway Tree Segmentation in CT Images of Subjects with ARDS

9. **Johan Nysjö**
   Date: 20160411
   Title: A 3D Painting Approach to Segmenting the Orbit (Eye Socket) in CT Images

10. **Kalyan Ram Ayyalasomayajula**
    Date: 20160418
    Title: Feature Evaluation for HMM Based Character Recognition

11. **André Liebscher**
    Date: 20160502
    Title: Modelling Open Cell Foams based on 3D Image Data

12. **Christer Oscar Kiselman**
    Date: 20160516
    Title: Language Choice in Scientific Writing: The Case of Mathematics. Werner Fenchel, a Pioneer in Convexity Theory and a Migrant Scientist.

13. **Allison M. Okamura**
    Date: 20160517
    Title: Modeling, Planning, and Control for Robot-Assisted Medical Interventions
    Comment: External speaker

14. **Anders Brun**
    Date: 20160523
    Title: Ideas for Clustering of Images and Representations of Data

15. **Omer Ishaq**
    Date: 20160503
    Title: Thesis Presentation Rehearsal

16. **Tony Barrera**
    Date: 20160608
    Title: The Grand Unified Theory: From Quarks and Atoms to Galaxies

17. **Bernd Rieger**
    Date: 20160608
    Title: Super-Resolution Fluorescence Microscopy: Where to go now?
    Comment: External speaker

18. **Stefan Seipel**
    Date: 20160613
    Title: Geospatial Information Science – Current Activities and Opportunities

19. **Orcun Göksel**
    Date: 20160613
    Title: Registration: The Swiss-Army Knife of Medical Image Analysis?
    Comment: External speaker

20. **Ralf Schumacher**
    Date: 20160824
    Title: 3D Printing in Medicine: Revolution or Illusion?
    Comment: External speaker

21. **Anders Hast**
Date: 20160829
Title: An Automatic Registration Method for Non Blind Bleed-Through Restoration of Hand Written Documents

22. **Petter Ranefall**
Date: 20160831
Title: Docent Lecture: Intensity Thresholding

23. **Marco Antonio Garcia de Carvalho**
Date: 20160905
Title: Research Activities in IMAGELab (FT/UNICAMP): Work in Progress
Comment: External speaker

24. **Ingrid Carlbom**
Date: 20160912
Title: An Analysis of the Consensus-Grading of the CADESS Prostate Tissue Dataset

25. **Ramon Adrian Salinas Franco**
Date: 20160912
Title: Cytological Low-Quality Image Segmentation
Comment: External speaker

26. **Marine Astruc**
Date: 20160919
Title: Subtle Change Detection and Quantification in Magnetic Resonance Neuroimaging

27. **Johan Nysjö**
Date: 20160926
Title: Interactive 3D Image Analysis for Cranio-Maxillofacial Surgery Planning and Orthopedic Applications (Thesis presentation rehearsal)

28. **Jayaram K. Udupa**
Date: 20160929
Title: Body-wide Automatic Anatomy Recognition in Medical Imagery
Comment: External speaker

29. **Eva Breznik**
Date: 20161003
Title: Statistical Significance in Whole Body MRI Images

30. **Gabriele Partel**
Date: 20161017
Title: Gene Fusion Analysis in Cancer

31. **Sajith Kecheril Sadanandan**
Date: 20161024
Title: Cell Segmentation and Zebrafish Classification using Deep Neural Networks

32. **Antoine Vacavant**
Date: 20161024
Title: A Novel Definition of Robustness for Image Processing Algorithms
Comment: External speaker

33. **Simon Ekström**
Date: 20161031
Title: Deformable Registration of Whole-Body Fat-Water MRI Images
Comment: External speaker

34. **Alexandru Telea**
Date: 20161107
Title: Medial Descriptors: Myths, Challenges, solutions, and New Applications
Comment: External speaker

35. **Anindya Gupta**
Date: 20161107
Title: Multi-layer Perceptron for Pulmonary Nodules Detection in CT Images and Cilia Detection in Low Magnification TEM Images
Comment: External speaker

36. **Zoltan Kato**
Date: 20161114
Title: Region-Based 2D and 3D Image Registration with Medical Applications
Comment: External speaker

37. **Erik Melin**
Date: 20161121
Title: COMSOL Multiphysics – Constructing High Quality Computational Meshes
Comment: External speaker

38. **Leslie Solorzano**
Date: 20161128
Title:Visualization, Analysis and Quantification of Pulmonary Parenchyma Deformations in 3D Images in Presence ARDS

39. **Anders Eklund**
Date: 20161205
Title: Cluster Failure: Why fMRI Inferences for Spatial Extent Have Inflated False Positive Rates
Comment: External speaker

40. **Sergii Gryshkevych**
Date: 2016 1214
Title: Convolutional Neural Networks for Classification of Transmission Electron Microscopy Imagery
Comment: External speaker

41. **Jesper Molin**
Date: 20161219
Title: Using Interaction Design and Visualization to Introduce Image Analysis Tools into Clinical Routine Pathology
Comment: External speaker

42. **Amin Allalou**
Date: 20161219
Title: High-Throughput Analysis of Zebrafish Behavior and Gene Expression Pattern

7.5 Conference participation

7.5.1 Special invited speaker

1. *Conference:* Atelier de Bamako
Bamako Workshop (a mathematical conference for all of West Africa).
Christer Kiselman
Date: 20160111–20160115
Address: Université des Sciences, des Techniques et des Technologies de Bamako.
Title: Convolution discrète, la transformation de Fourier et sa correspondante tropicale : la transformation de Fenchel (Discrete Convolution, the Fourier Transformation, and Its Tropical Counterpart; The Fenchel Transformation).

2. *Conference:* SSBA Symposium 2016
Gunilla Borgefors
Date: 20160314–20160316
Address: UU
Title: SSAB/SSBA 1966-1976-2016...
Comment: Talk in Swedish about the history of SSBA

3. *Conference:* Swedish Symposium on Image Analysis (SSBA 2016)
   Ingela Nyström
   Date: 20160314–20160316
   Address: Campus ITC, Uppsala
   Title: Celebration of SSBA 40 Years on Behalf of the IAPR Executive Committee

4. *Conference:* IEEE Sweden Annual Meeting
   Ewert Bengtsson
   Date: 20160316–20160316
   Address: KTH, Stockholm
   Title: Medical Image Analysis – the Key to Personalized Medicine?
   Comment: Invited to give this lecture as a newly elevated Fellow of IEEE

5. *Conference:* 2nd Symposium on Bridging Nordic Imaging
   Carolina Wählby
   Date: 20160414–20160415
   Address: Gothenburg, Sweden
   Title: From Pretty Picture to Quantitative Data – Using Digital Image Processing and Analysis to Improve Microscopy Experiments.

6. *Conference:* 2016 International Workshop on Biomedical Image Informatics for Precision Medicine
   Carolina Wählby
   Date: 20160422–20160422
   Address: Seoul, South Korea
   Title: from Cultured Cells to Tissue Samples; Challenges and Possibilities for Digital Image Processing

7. *Conference:* DigiPath Europe
   Ewert Bengtsson
   Date: 20160518–20160519
   Address: The Tower Bridge Hilton Hotel, London
   Title: How Digital Pathology Will Impact Routine Application of Image Analysis
   Comment: My presentation was based on my work for the ExDIN project

8. *Conference:* Workshop on Discrete Geometry and Mathematical Morphology for Computer Vision, DGMM4CV
   Robin Strand
   Date: 20160615–20160617
   Address: Taipei, Taiwan
   Title: Digital Distance Functions: Recent Advances in Theory and Applications
   Comment: DGMM4CV was an ACCV 2016 workshop

9. *Conference:* ExDIN consortium meeting
   Ewert Bengtsson
   Date: 20160831–20160901
   Address: Nalen, Stockholm
   *Title:*Computerized Image Analysis in Digital Pathology Networks.
   Comment: Invited to present the result of my study of ”Computerized image analysis in digital pathology networks”

10. *Conference:* Kulturarvet som ettor och nollor
    Anders Brun
    Date: 20160912–20160912
    Address: Stockholm, Kungliga biblioteket
    Title: OCR, HTR and Data Mining for Historical Documents

11. *Conference:* Röntgenveckan (X-ray week) 2016
    Ingela Nyström
    Date: 20160914
    Address: Kistamässan, Stockholm
    Title: Virtual Facial Surgery Planning using Haptics and 3D Visualisation
    Comment: Participated in the workshop ”Advanced Post-Processing of CT Examinations”

12. *Conference:* 13th International Conference on Pattern Recognition and Information Processing (PRIP 2016)
Ingela Nyström
Date: 20161003–20161005
Address: Belarusian State University, Minsk, Belarus
Title: BoneSplit – a 3D Painting Tool for Interactive Bone Segmentation in CT Images
Comment: Celebration of Rector Sergey Ablameyko's 60th birthday. Nyström represented the International Association for Pattern Recognition in her role as President of IAPR.

13. *Conference:* Analysis Day in Memory of Mikael Passare.
Christer Kiselman
Date: 20161005–20161005
Address: Stockholm University.
Title: Gennadi Henkin (1942–2016). Some memories.

14. *Conference:* Advances in Mathematics and its Applications.
Christer Kiselman.
Date: 20161026–20161028
Address: Makerere University, Kampala.
Title: Discrete Convolution Operators, the Fourier Transformation, and Its Tropical Counterpart, the Fenchel Transformation.

15. *Conference:* XXI IberoAmerican Congress on Pattern Recognition (CIARP 2016)
Ingela Nyström
Date: 20161108–20161111
Address: Pontificia Universidad Católica del Perú, Lima, Peru
Title: The International Association for Pattern Recognition in an IberoAmerican Perspective
Comment: Nyström was also chairing the session of invited speaker Professor Yann Lecun, Director of Facebook AI Research

16. *Conference:* 5th International Symposium in Applied Bioimaging
Carolina Wählby
Date: 20161126–20161128
Address: Porto, Portugal
Title: Digital Image Analysis at Microscopy Resolution for Better Understanding of Disease

17. *Conference:* 3rd Digital Pathology Congress
Carolina Wählby
Date: 20161201–20161202
Address: London, UK
Title: Combining Image-Based in Situ RNA Sequencing with Quantitative Analysis of Cell and Tissue Morphology

7.5.2 Oral presentations – refereed conferences

1. *Conference:* CYTO Conference 2016 – Scientific Tutorial 2
Maxime Bombrun
Date: 20160611–20160615
Address: Seattle, USA
Title: Configuring Accurate Cell Detection in Images Using CellProfiler

2. *Conference:* International Conference on Frontiers in Handwriting Recognition
Tomas Wilkinson
Date: 20161023–20161026
Address: Ming Wah Conference Centre, Shenzhen, China
Title: Semantic and Verbatim Word Spotting using Deep Neural Networks

3. *Conference:* Workshop on Discrete Geometry and Mathematical Morphology for Computer Vision, DGMM4CV
   Teo Asplund
   Date: 20161120–20161124
   Address: Taipei, Taiwan
   Title: Mathematical Morphology on Irregularly Sampled Signals
   Comment: DGMM4CV was an ACCV 2016 workshop

7.5.3 Oral presentations – non-refereed conferences

1. *Conference:* Swedish Symposium on Image Analysis, SSBA 2016
   Petter Ranefall
   Date: 20160314–20160316
   Address: Uppsala University
   Title: Global And Local Adaptive Gray-level Thresholding Based on Object Features

2. *Conference:* Swedish Symposium on Image Analysis, SSBA 2016
   Fredrik Nysjö
   Date: 20160314–20160316
   Address: Uppsala University
   Title: Signed Distance Fields for Modeling Surgical Guides and Plates from CT Images

3. *Conference:* Swedish Symposium on Image Analysis, SSBA 2016
   Fredrik Wahlberg
   Date: 20160314–20160316
   Address: Uppsala University
   *Title:*Estimating Manuscript Production Dates Using Both Image and Language Data

4. *Conference:* Swedish Symposium on Image Analysis, SSBA 2016
   Johan Nysjö
   Date: 20160314–20160316
   Address: Uppsala University
   Title: BoneSplit – A 3D Painting Tool for Interactive Bone Segmentation in CT Images
   Comment: Awarded the price for "Best industrially relevant paper".

5. *Conference:* Swedish Symposium on Image Analysis, SSBA 2016
   Amit Suveer
   Date: 20160314–20160316
   Address: Uppsala University
   Title: Cilia Detection Using Template Matching in Low Magnification Electron Microscopy Images

6. *Conference:* Swedish Symposium on Image Analysis, SSBA 2016
   Robin Strand
   Date: 20160314–20160316
   Address: Uppsala University
   Title: Holistic Whole-Body MRI Image Analysis

7. *Conference:* Swedish Symposium on Image Analysis, SSBA 2016
   Filip Malmberg
   Date: 20160314–20160316
   Address: Uppsala University
   Title: A Toolbox for Non-parametric Deformable Registration of Volume Images

8. *Conference:* Swedish Symposium on Image Analysis, SSBA 2016
   Tomas Wilkinson
   Date: 20160314–20160316
   Address: Uppsala University
   Title: Word Segmentation in Historical Documents using Convolutional Neural Networks

9. *Conference:* Swedish Symposium on Image Analysis, SSBA 2016
Bettina Selig
Date: 20160314–20160316
Address: Uppsala University
Title: Analysis of Corneal Endothelium Using Fast Robust Stochastic Segmentation

10. *Conference:* ANR Convergence Labs
Ewert Bengtsson
Date: 20160704–20160706
Address: ANR Office, Paris
Title: Evaluation of Proposals to ANR Convergence Labs
Comment: A three day workshop to select propsals for interdisciplinary grants from French Research Council, ANR, I presented the evaluations of set of proposals assigned to me.

7.5.4 Poster presentations – refereed conferences

1. *Conference:* International Symposium on Biomedical Imaging (ISBI2016)
Amit Suveer
Date: 20160413–20160416
Address: Prague, Czech Republic
Title: Automated Detection of Cilia in Low Magnification Transmission Electron Microscopy Images Using Template Matching

2. *Conference:* International Symposium on Biomedical Imaging (ISBI2016)
Petter Ranefall
Date: 20160413–20160416
Address: Prague
Title: Fast Adaptive Local Thresholding Based on Ellipse Fit

3. *Conference:* 18th IAPR International Conference on Discrete Geometry for Computer Imagery (DGCI 2016)
Robin Strand
Date: 20160418–20160420
Address: Nantes, France
Title: Minimal Paths by Sum of Distance Transforms

4. *Conference:* International Conference on Image Analysis and Recognition (ICIAR 2016)
Damian Matuszewski
Date: 20160713–20160715
Address: Póvoa de Varzim, Portugal
Title: Comparison of Flow Cytometry and Image-Based Screening for Cell Cycle Analysis

5. *Conference:* European Conference on Computer Vision (ECCV 2016)
Sajith Kecheril Sadanandan
Date: 20161009–20161010
Address: The 14th European Conference on Computer Vision – Amsterdam, The Netherlands
Title: Feature Augmented Deep Neural Networks for Segmentation of Cells

6. *Conference:* International Conference on Frontiers in Handwriting Recognition (ICFHR-2016)
Fredrik Wahlberg
Date: 20161023–20161026
Address: Shenzhen, China
Title: Historical Manuscript Production Date Estimation using Deep Convolutional Neural Networks

7. *Conference:* 23rd International Conference on Pattern Recognition (ICPR 2016)
Teo Asplund
Date: 20161204–20161208
Address: Cancun International Convention Center, Cancun, Mexico
Title: A New Approach to Mathematical Morphology on One Dimensional Sampled Signals

7.5.5 Poster presentations – non-refereed conferences

1. *Conference:* Nordic Symposium on Digital Pathology
   Maxime Bombrun
   Date: 20161108–20161109
   Address: Linköping
   Title: TissueMaps: A Large Multi-Scale Data Analysis Platform for 2 Digital Image Application Built on Open-Source Software

2. *Conference:* 4th Nordic Symposium on Digital Pathology
   Petter Ranefall
   Date: 20161108–20161109
   Address: Linköping
   Title: Automatic Grading of Breast Cancer from Whole Slide Images of Ki67 Stained Tissue Sections

3. *Conference:* Digital Pathology Congress
   Petter Ranefall
   Date: 20161130–20161202
   Address: London
   Title: Automatic Grading of Breast Cancer from Whole Slide Images of Ki67 Stained Tissue Sections

4. *Conference:* Digital Pathology Congress
   Maxime Bombrun
   Date: 20161201–20161202
   Address: London, UK
   Title: a Web Application to Analyse and Visualize Digital Images at Multiple Resolutions

7.5.6 Attended conferences

1. *Conference:* Celsius-Linné symposium
   Gunilla Borgefors
   Date: 20160219
   Address: Ångström, UU
   Comment: Borgefors was Chair of the whole Symposium

2. *Conference:* BIOSTEC + BIOIMAGING
   Ewert Bengtsson
   Date: 20160221–20160223
   Address: Rome, Italy
   Comment: Served on program committee

3. *Conference:* SSBA
   Teo Asplund, Marine Astruc, Christophe Avenel, Buda Bajic, Ewert Bengtsson, Maxime Bombrun, Anders Brun, Anders Hast, Omer Ishaq, Christer Kiselman, Kristina Lidayova, Andre Liebscher, Joakim Lindblad, Damian Matuszewski, Ingela Nyström, Pontus Olsson, Kalyan Ram, Sajith Kecheril Sadanandan, Ida-Maria Sintorn, Natasa Sladoje, Carolina Wählby
   Date: 20160314–20160316
   Address: Uppsala

4. *Conference:* Deep Learning in Healthcare Summit
   Sajith Kecheril Sadanandan
   Date: 20160407–20160408
   Address: LSO St Luke's, London, UK

5. *Conference:* 19th International Conference on Discrete Geometry for Computer Imagery (DGCI 2016)
   Gunilla Borgefors, Christer Kiselman
   Date: 20160418–20160420
   Address: Nantes, France
   Comment: Borgefors participated in the DGCI Steering committee meeting

6. *Conference:* Kick-off meeting of COST Action "A new Network of European BioImage Analysts to advance life science imaging (NEUBIAS)"
   Nataša Sladoje, Joakim Lindblad
   Date: 20160503–20160504
   Address: Brussels, Belgium

7. *Conference:* Workshop on Biomedical Information Technology
   Ingela Nyström
   Date: 20160518
   Address: IT, UU
   Comment: Final presentations of the 6 SPARC projects.

8. *Conference:* Royal Society of Sciences Day
   Gunilla Borgefors
   Date: 20160830
   Address: Gustaviaum, UU
   Comment: The year's prize winners give lectures this day.

9. *Conference:* Workshop The 1st NEUBIAS Taggathon
   Nataša Sladoje, Petter Ranefall
   Date: 20160914–20160916
   Address: Universitat Pompeu Fabra, Barcelona, Spain
   Comment: Workshop is organized within NEUBIAS – A new Network of European BioImage Analysts to advance life science imaging

10. *Conference:* COSCH Final Conference
    Anders Brun
    Date: 20161010–20161011
    Address: i3mainz – Institute for Spatial Information and Surveying Technology – Mainz University of Applied Sciences

11. *Conference:* 15th International Conference on Frontiers in Handwriting Recognition (ICFHR-2016)
    Anders Brun
    Date: 20161023–20161026
    Address: Shenzhen, China

12. *Conference:* 4th Nordic Symposium on Digital Pathology
    Carolina Wählby, Maxime Bombrun, Petter Ranefall, and Ewert Bengtsson
    Date: 20161108–20161109
    Address: Linköping, Sweden

13. *Conference:* Nordic Pathology Symposium
    Ewert Bengtsson
    Date: 20161108–20161109
    Address: Linköping
    Comment: Bengtsson was chair of a session and member of the program committee

14. *Conference:* SSBA workshop
    Anders Brun, Ida-Maria Sintorn, and Thomas Wilkinsson
    Date: 20161121–20161122
    Address: Lidingö, Stockholm
    Comment: Sintorn was the chair of the industry relations work group and Brun was the chair of the research work group. Brun organized the event.

15. *Conference:* 23rd International Conference on Pattern Recognition 2016
    Ingela Nyström
    Date: 20161204–20161208
    Address: Cancun International Convention Center, Cancun, Mexico
    Comment: Participated in IAPR Executive Committee meetings. Nyström left the two-year office as President of IAPR and was appointed as Past President of the IAPR. She chaired the IAPR Governing Board meeting with 60 participants from around the World.

16. *Conference:* ICPR 2016
Ewert Bengtsson
Date: 20161205–20161208
Address: Cancun, Mexico
Comment: Bengtsson was chair of two sessions

7.6 Visiting scientists

1. **Orcun Göksel**
Address: Dept. of Information Technology and Electrical Engineering, ETH Zürich, Switzerland
Host: Ingela Nyström, Filip Malmberg
Date: 20160613–20160614
Number of visitors: 1
Topic: Common research interests in medical engineering

2. **Alicia Fornés**
Address: Universitat Autonoma de Barcelona, Spain
Host: Anders Brun
Date: 20160614–20160616, 20160831–20160930
Number of visitors: 1
Topic: Handwritten Text Recognition

3. **Marco Antonio Garcia de Carvalho, Ramon Adrian Salinas Franco**
Address: University of Campinas, Sao Paulo, Brazil
Host: Ewert Bengtsson, Carolina Wählby, Ingela Nyström
Date: 20160905–20160916
Number of visitors: 2
Topic: Common research interests in cell image analysis

4. **Anindya Gupta**
Address: Tallinn University of Technology, Estonia
Host: Carolina Wählby
Date: 20161010–
Number of visitors: 1
Topic: Guest PhD student

7.7 Visits to other research groups

1. **Kristína Lidayová**
Host: Marcela Hernández Hoyos
Address: Universidad de los Andes, Cra 1 N° 18A-12, Bogotá, Colombia
Date: 20160101–20160227
Topic: Research visit

2. **Nataša Sladoje, Joakim Lindblad**
Host: DIP group
Address: Faculty of Technical Sciences, University of Novi Sad, Serbia
Date: 20160328–20160401
Topic: Collaboration and PhD supervision
Comments: Nataša and Joakim visited their PhD students and DIP group members at UNS and organized a number of meetings.

3. **Christer Kiselman**
Host: Jean Serra, Marie-Françoise Colomé-Serra.
Address: Fontainebleau.
Date: 20160420–20160422
Topic: Mathematical morphology.

4. **Fredrik Nysjö, Pontus Olsson**
   Host: Daniel Buchbinder
   Address: Mt Sinai-Beth Israel, New York
   Date: 20160430–20160507
   Topic: Installation of the HASP surgercy planning system

5. **Nataša Sladoje, Joakim Lindblad**
   Host: DIP group
   Address: Faculty of Technical Sciences, University of Novi Sad, Serbia
   Date: 20160815–20160819
   Topic: Collaboration and PhD supervision
   Comments: Nataša and Joakim visited their PhD students and DIP group members at UNS and organized a number of meetings.

6. **Nataša Sladoje**
   Host: DIP group
   Address: Faculty of Technical Sciences, University of Novi Sad, Serbia
   Date: 20160926–20160930
   Topic: Collaboration and PhD supervision
   Comments: Nataša visited her PhD students and DIP group members at UNS and organized a number of meetings.

7. **Ingela Nyström**
   Host: Rector Sergey V. Ablameyko
   Address: Belarusian State University, Minsk, Belarus
   Date: 20161003–20161005
   Topic: Discussions on medical projects of common interest as well as University leadership and organisation
   Comments: During the conference PRIP 2016, there was a celebration of Rector Sergey Ablameyko's 60th birthday. Nyström represented the International Association for Pattern Recognition in her role as President of IAPR.

8. **Natasa Sladoje, Joakim Lindblad**
   Host: Laszlo Nyul
   Address: Department of Image Processing and Computer Graphics, Szeged University, Hungary
   Date: 20161108–20161111
   Comments: Discussions of joint research and future project collaborations

7.8 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 2016, 2123 February 2016, Rome, Italy. International Conference on Bioimaging.
- Management Committee, EU COST Action TD1201: "Colour and Space in Cultural Heritage, COSCH" November 2012–November 2016
- External examiner of the PhD thesis "Novel techniques for rapid acquisition of virtual microscopy specimens" by Yilun Fan at the School of Information Technology and Electrical Engineering, University of Queensland, Australia.
- External examiner of the PhD thesis "Identification of biomarkers for the detection of lung cancer" by VS Veena, Bharathiar University, Coimbatore, India.
- Examiner/committee member for the PhD thesis "Prognostic value of large scale genomic instability by image cytometry in selected malignancies and a premalignant condition" by Tarjei Sveinsgjerd Hveem of Department of Informatics, University of Oslo, Norway.
  Comment: The written evaluation was due in December 2016, the actual dissertation will be February 7, 2017
- Expert evaluator for Cineca, Italian Scientific Council of MIUR (the Italian Ministry for Education, University and Research) for PRIN2015 proposals
- Expert member of the Convergences jury for the ANR French Research Council.
- Programme committee, International Conference of Mass Data Analysis of Images and Signals (MDA).

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).
- Scientific board of Swedish Association for Medical Engineering and Physics, "Svensk förening för medicinsk teknik och fysik" 2013-
- Scientific board of Hillevi Fries Research Scholarship Foundation, 2006–
  Comment: A Swedish foundation that accepts applications and gives out research grants for urology research.
- Chair of UU steering group for the ALLVIS project implementing centralized storage of research data for Uppsala University
- Expert advisor to the head of the Information Technology Unit of UU administration, 2013–

- Expert evaluator of proposals for the Knut and Alice Wallenberg Foundation
- Expert for evaluating application for docent position at Linköping University by Anders Eklund

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), 2014-2016
- Fellow of the Institute of Electrical and Electronics Engineers, Inc. (IEEE), 2007–
  Comment: Member since 1997. Senior member 1998.
- Editor-in-Chief of *Pattern Recognition Letters,* 2011–
  Comment: Published by Elsevier. PRL is an official journal of the International Association of Pattern Recognition. Borgefors was Associate Editor/Area Editor 2004–2010.
- Editorial Board member of *Image Processing and Communications,* 1994–
  Comment: Published by the Institute of Telecommunications, Bydgoszcz, Poland.
- Editorial Board member of *Pattern Recognition and Image Analysis: Advances in Mathematical Theory and Applications,* 1993–
  Comment: Published by Interperiodica Publishing in cooperation with the Russian Academy of Sciences.
- Editorial Board of the book series Computational Imaging and Vision, 2003–
  Comment: Published by Springer.
- Steering committee for Discrete Geometry for Computer Imagery (DGCI) conferences, 2000–
- Steering committee for International Symposium on Mathematical Morphology (ISMM), 2011–
- Programme committee, 19th International Conference on Discrete Geometry for Computer Imagery (DGCI 2016), Nantes, France, 2016-04-18–20
- Advisory Board, 9th IAPR International Conference on Biometrics (ICB 2016), Halmstad, Sweden, June 2016-06-14–17
- Programme committee, 21st International Conference on Computer Vision and Graphics (ICCVG 2016) Warsaw, Poland, 19-21 Sep. 2016-09-19–21
- Programme committee, 13th International Conference on Pattern Recognition and Image Processing (PRIP 2016), Minsk, Belarus, 3-5 October 2016-10-03–05
- Programme committee, 21st Iberoamerican Congress on Pattern Recognition and Image Processing (CIARP 2016), Lima, Peru, 2016-11-08–11
- Programme committee, Workshop on Discrete Geometry and Mathematical Morphology for Computer Vision Pattern Recognition and Image Processing (DGMM4CV 2016) (in conjunction with ACCV '16), Taipei, Taiwan, 20-24 Nov. 2016-11-20–24
- Assessment committe for Professor in Computer Vision, Dept. of Architecture, Design and Media Technology, Aalborg University, Denmark 2016-01
  Comment: Thomas Moeslund was appointed.
- Dissertation committe for Gautam Bhattacharya, Dept. of Electronics and Telecommunication Engineering, Jadavapur University, Kolkata, India, 2016-11
  Comment: Title: A Study on Some Theoretical Variations of the k Nearest Neighbour (kNN) Algorithm

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, 2014-2017
- 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 committe for Tomas Bengtsson, Dept. of Signals and Systems, Chalmers University of Technology, Göteborg, 2016-01-29
  Comment: Title: Image Reconstruction and Optical Flow Estimation on Image Sequences with Differently Exposed Frames
- Dissertation committe for Qaiser Mahmood, Dept. of Signals and Systems, Chalmers University of Technology, Göteborg, 2016-04-01
  Comment: Title: Unsupervised Segmentation of Head Tissues from Multi-Modal Magnetic Resonance Images: with application to EEG source localization and stroke detection
- Dissertation committe for Rafael Mosberger, School of Science and Technology, Örebro University 2016-04-14
  Comment: Title: Vision-based Human Detection from Mobile Machinery in Industrial Envireonments
- Dissertation committe for Naum Rusomarov, Dept. of Physics and Astronomy, UU 2016-04-15
  Comment: Title: Magnetic Fields and Chemical Maps of Ap Stars from Four Stokes Parameter Observations
- Half-time thesis committe for Olga Dyakova, Dept. of Neuroscience, UU., 20161215
  Comment: Title: The processing of natural images in the hoverfly visual system

Anders Brun

International:

- Management Committee, EU COST Action TD1201: "Colour and Space in Cultural Heritage, COSCH" November 2012–November 2016

National:

- Board member, SSBA, 2014–
- Organizing committee member of The First Swedish Symposium on Deep Learning 2017
- Board member, Swedish Society for Automated Image Analysis, 2014–
- Sponsorship Chair, Swedish Symposium on Image Analysis (SSBA 2016) Uppsala, March 2016

Christer Kiselman
International:

- Program Committee, Discrete Geometry for Computer Imagery, DGCI 2016.
- Reference Group of the International Science Program, 2016.
- American Mathematical Society (life member)
- Société Mathématique de France
- International Academy of Sciences, San Marino
- Internacia Scienca Akademio Comenius

- Academy of Esperanto (1989 – 20151215)
- European Mathematical Society
- Polska Akademia Umiejetności (Polish Academy of Arts and Sciences)
- Associate Member, Scandinavian Society for Iranian Studies

National:

- Royal Academy of Arts and Sciences, Uppsala, 1983– .
- Royal Society of Sciences, Uppsala, 1984– .
- Royal Swedish Academy of Sciences, 1990– .
- Member of the Royal Society of Sciences in Uppsala (Kungliga Vetenskaps-Societeten)
- Evaluation of research at Linnaeus University, 20150801–20151020
- Swedish Astronomical Society (life member)
- Swedish Mathematical Society (life member)
- Royal Academy of Arts and Sciences, Uppsala
- Royal Society of Sciences, Uppsala
- Royal Swedish Academy of Sciences

Teo Asplund, Kristína Lidayová, Johan Nysjö, Fredrik Nysjö and Tomas Wilkinson

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

Joakim Lindblad
International:

- Management committe member substitute, NEUBIAS – A new Network of European BioImage Analysts to advance life science imaging, 20160503–20200502
  Comment: EU COST Action CA 15124
- Scientific committee member, International Workshop on Computational Topology in Image Context, CTIC 2016, Marseille, France
- Technical program committee member, International Conference on Image Processing Theory, Tools and Applications, IPTA 2016, Oulu, Finland
- Technical committee member, International Conference on Pattern Recognition, ICPR 2016, Cancun, Mexico
- Pre-examiner of the dissertation manuscript of Aleksandar Pejovic, Univ. of Novi Sad, 20160721
  Comment: Title: Parallel software system for counting finite models
- Pre-examiner of the dissertation manuscript of Slobodan Drazic, Univ. of Novi Sad, 20160818
  Comment: Title: Shape Based Methods for Quantification and Comparison of Object Properties from Their Digital Image Representations
- Expert evaluator for the Czech Science Foundation, 20160731
  Comment: Czech Science Foundation is the main public funding agency in the Czech Republic supporting all areas of basic scientific research

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 2016), Lima, Peru, November 2016.

Ingela Nyström
International:

- Member of the Executive Committee of International Association for Pattern Recognition (IAPR) 2014–
  Comment: 2nd Vice President 2008–2010, Secretary 2010–2014, President 2014–2016, Past President 2016–2018
- General Co-chair, XXI IberoAmerican Congress on Pattern Recognition (CIARP 2016), Peru, 20160101–20161111

National:

- Member of the Royal Society of Arts and Sciences of Uppsala (Kungliga Vetenskapssamhället i Uppsala), 2012–
  Comment: Board member 2016–
- Chair of the Advisory Board for the Centre for Image Analysis 2012–2016
  Comment: One of two representatives for UU.
- Member of a committee appointed by the Faculty of Science and Technology to propose a strategic plan for increased visibility of UU's research and education within technology at large. 201601–201606
- Member of the Council for Research Infrastructure (RFI), the Swedish Research Council, 2014–
  Comment: Vice-Chair 2015–
- Dissertation committee of Henrik Öhman, Dept. of Physics and Astronomy, High Energy Physics, UU, 20161121
  Comment: Title: Searches for Higgs bosons with hadronically decaying tao-leptons – using Grid and Cloud computing techniques

Stefan Seipel
International:

- Board of UpGIS, the network of Geographical Information Systems at UU, 2013–

National:

- Board of the Swedish Computer Graphics Association (SIGRAD), 2015

Ida-Maria Sintorn
National:

- PhD thesis evaluation committee, 20160614
  Comment: Ling Xie, Dept. Engineering Sciences, Uppsala University, title: Electron tomography analysis of 3D order and interfacial structure in nano-precipitates
- PhD thesis evaluation committee, 20161007
  Comment: Fei Liu, Dept. Information Technology, UU, title: Handheld Augmented Reality for Facility Maintenance
- PhD thesis evaluation committee, 20161028
  Comment: Matilda Landegren, Lund University, title: Analysis of Medical Images: Registration, Segmentation and Classification
- PhD thesis evaluation committee, 20161216
  Comment: Klas Magnusson, School of Electrical Engineering, KTH Royal Institute of Technology title: Segmentation and tracking of cells and particles in time-lapse microscopy

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.

- Management committe member, NEUBIAS - A new Network of European BioImage Analysts to advance life science imaging, 20160503–20200502
  Comment: COST Action CA 15124
- Scientific committee 6th International Workshop on Computational Topology in Image Context, CTIC 2016, Marseille, France, 20160615–20160617
- Reviewing committee member, International Conference on Image Processing Theory, Tools and Applications (IPTA'16), Oulu, Finland, 2016
- Program committee member, Conference on Bioimaging, BIOIMAGING 2016, Rome, Italy, 2016.
- Best Student Paper Selection Committee member at the International Symposium on Biomedical Imaging (ISBI), Prague, Czech Republic, 2016
- Pre-examiner of the dissertation manuscript of Slobodan Drazic, Univ. of Novi Sad, 20160818
  Comment: Title: Shape Based Methods for Quantification and Comparison of Object Properties from Their Digital Image Representations
- PhD Dissertation committe for Stefana Janićijević, Faculty of Technical Sciences, University of Novi Sad, Serbia, 20160929
  Comment: Title: Variable Formulation and Neighborhood Search Methods for the Maximum Clique Problem in Graph
- PhD Dissertation committee for Peter Bodnar, University of Szeged, Hungary, 20161109
  Comment: Title: Image analysis methods for localization of visual codes
- Pre-examiner of the dissertation manuscript of Buda Bajic, Univ. of Novi Sad, 20160927
  Comment: Title: Image enhancement based on energy minimization in presence of Poisson-Gaussian noise

National:

- Programme Chair, Swedish Symposium on Image Analysis (SSBA 2016) Uppsala, March 2016
- Pre-examiner of the dissertation manuscript of Elin Lundström, Uppsala University, 20161107
  Comment: Title: Magnetic resonance imaging of human brown adipose tissue

Robin Strand
International:

- Editorial Board member of *Journal of Discrete Mathematics,* 2013–201609
  Comment: Open access. Published by Hindawi Publishing Corporation.
- Editor, Frontiers topic: Spread Evaluation and Comparison of Image Analysis Algorithms (SPECIAL), 2016
- Technical Program Committee, 23nd International Conference on Pattern Recognition (ICPR 2016) Dec. 4–8 2016, Cancun, Mexico
- Program Committee, 1st Workshop on Reproducible Research in Pattern Recognition (RRPR 2016) Dec. 4 2016, Cancun, Mexico
- Program Committee, Workshop on Discrete Geometry and Mathematical Morphology for Computer Vision (DGMM4CV), held in conjunction with ACCV 2016, Nov. 20–24, 2016, Taipei, Taiwan
- Program Committee, 6th International Workshop on Computational Topology in Image Context (CTIC 2016) June 15-17 2016, Marseille, France
- Program Committee, 19th IAPR International Conference on Discrete Geometry for Computer Imagery (DGCI 2016) April 18-20 2016, Nantes, France

National:

- General Chair, Swedish Symposium on Image Analysis (SSBA 2016) Uppsala, March 2016
- Dissertation Committee of Mohammad Alipoor, Chalmers University of Technology 20160127
  Computational Diffusion MRI: Optimal Gradient Encoding Schemes

- Dissertation Committee of Johan Fredriksson, Lund University, Lund, 20161209
  Robust Rotation and Translation Estimation in Structure from Motion
- Half-time control Committee of Kenney Roy Roodakker, Dept. of Surgical Sciences, UU, 20161110
  On tumor infiltration and prognostic biomarkers in adult gliomas: toward individualized tumor treatment.
- Election committee, Dept. of IT. Deputy member
- Coordinator of biomedical information technology (biomed-IT) at the Dept. of IT

Carolina Wählby
International:

- Management Committee for NEUBIAS, 20160101
  Comment: A Network of European BioImage Analysts to advance life science imaging (NEUBIAS), fully funded by COST, a European cooperation in Science and Technology.
- Thesis opponent, 20160930
  Comment: Eero Lihavainen, Tampere University of Technology, Finland, title: Image Analysis Methods for the Characterization of Mitochondrial Morphology and Dynamics
- Scientific Advisory Board of France BioImaging, 20161201
  Comment: France BioImaging is a French national research infrastructure for biological imaging.

National:

- Member of the Electorial Board ("elektorsförsamlingen") of the Faculty of Science and Technology, UU, 2014–2016
- Board of National Microscopy Infrastructure
  Comment: A Swedish infrastructure for advanced microscopy.
- Board of Swedish Bioimaging
  Comment: A Swedish network for research infrastructures in biomedical imaging and image analysis.
- Board of Upptech, 20160906
  Comment: Upptech (Uppsala University School of Technology) has been established by the Faculty of Science and Technology at Uppsala University for raising visibility of, profiling, and enhancing the university's research and teaching within technology.
- Scientific Advisory Board of BioVis, 20160101
  Comment: BioVis is a part of Uppsala University and associated with SciLifeLab, it is a core facility belonging to the Faculty of Medicine.
- Board of Science for Life Laboratory Uppsala, 20160401
  Comment: Science for Life Laboratory, or SciLifeLab, is a national center for molecular biosciences with focus on health and environmental research.
- Thesis evaluation committee, 20160408
  Comment: Hanna Källen, Lund University, title: Applications of Machine Vision - quality control, cancer detection and traffic surveillance