Centrum för bildanalys

Centre for Image Analysis

Annual Report 1995/96

Edited by: Lennart Thurfjell, Gunilla Borgefors

Centre for image analysis, 1997

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1. Introduction and summaries

1.1 Background

The CBA was founded in 1988 based on three small research groups, from Uppsala University (UU), the Swedish University for Agricultural Sciences (SLU) and the Swedish National Environmental Protection Agency (SNV). In 1995 a re-organisation of CBA took place, to reflect the actual situation of that time, and from 1 July, 1995, we are a pure university entity. The employees are employed at either university, and the Ph.D. students are admitted at any of the three faculties where we have a Ph.D. program (NT at UU, S and JLT at SLU), but CBA is administered by UU. A valuable consequence of the new constitution is the formation of the CBA reference group, consisting of (at present) seven organisations with an interest in the applications of image analysis.

The present fiscal year has been one of strong expansion, both because we have been successful in getting research grants of various types and because the SLU group, where Prof. Borgefors arrived only in the Fall of 1993, has become fully operational. However, the expansion will be even greater during the next fiscal year, through grants that were rewarded during this year but will not be really started until the next. Ewert Bengtsson was co-ordinator for the National image analysis research programme application VISIT (VISual Information Technology) which was granted by The Swedish Foundation for Strategic Research. VISIT will be administered by CBA and will finance projects at both universities (as well in at least five other universities). Tommy Lindell became co-ordinator for a big EU project on lake quality. Gunilla Borgefors and Tommy Lindell were heavily involved in the formation of the environmental surveillance programme RESE (REmote Sensing for the Environment) granted by the Foundation for Strategic Environmental Research, which will also finance projects at both universities.

CBA assembles an annual report describing the various activities that have taken place during the year. This annual report is intended for anyone interested in our work, e.g., the founding bodies, sponsors, co-operation partners and our research colleagues.

In the next two subsections the research at CBA is briefly summarised in English and Swedish, respectively. A more detailed description of each research project can be found in section 5. Section 2 describes the organisational and financial aspects of CBA. The other aspects of our work are briefly summarised in the introduction to each section which is printed in a larger font than the following detailed material.

1.2 Summary

According to the founding documents, the objective of the Centre for Image Analysis is "to create the know-how needed for an operative and sensible use of digital image analysis in society, particularly in the fields of environment and medicine." The research work is organised in three groups: The image analysis group at UU, which works mainly with medical applications and is headed by Ewert Bengtsson; the aquatic remote sensing group at UU, headed by Tommy Lindell; and the image analysis and remote sensing group at SLU headed by Gunilla Borgefors, which concentrates forestry and environmental applications.

The UU image analysis group has had its main focus on the medical application field where tomographic volume images from different sensors, particularly PET (Positron emission To-

mography) images and light microscopic images of cancerous tissues and cells have been analysed.

Our NUTEK-sponsored work on bladder cancer has continued and reached a conclusion in two doctoral theses presented this year by Heung-Kook Choi and Torsten Jarkrans. The principle is to put information from texture, object oriented analysis, and minimal-spanning-tree analysis together into a unified grading algorithm which was tested on a new clinical material. I was shown that automatic analysis can be as accurate as a pathologist.

New methods for applying colour classification algorithms to the analysis of histological tissues has been developed further and is currently being tested on routine clinical material. Similar colour analysis algorithms have also been applied to the detection of eyes and mouth in portraits. This work was financed by the company ID-kort AB.

The work on computer assisted analysis of light microscopic cell images has a long tradition in our group, dating back to 1973. Work on our first application, the automated prescreening of routine specimens from gynaecological health control, was restarted this year after a pause since 1987. This new project is financed by the Chicago based company Accumed which is developing commercial products in the field.

Lennart Thurfjell has continued his work on the 3D computerised brain atlas. Funding has been received from NUTEK for Thurfjell and a new graduate student that stared during the year.

In collaboration with other groups, we have a project to develop methods for evaluating biopsy strategies in prostate cancer diagnosis, based on 3D modelling.

Methods for quantitatively evaluating and describing structures in 3D volume images has also been studied in another more basic methodological project supported by TFR. This project involves both universities.

In support of these different projects, as well as in order to provide an improved platform for the education in image analysis, we have continued work on our general platform for image analysis, the IMP system.

The general objective of Aquatic remote sensing research is to strengthen digital remote sensing in general, focused on the fields of bio- and geosciences. The coupling to the geosciences creates a natural connection between remote sensing and Geographic Information Systems (GIS). The present activities vary from mapping and monitoring of waste water discharge and distribution of plumes in lakes and seas to the mapping of subsurface ridges in tropical and subtropic seas.

The use of satellite and airborne sensors for water quality surveillance is a long term project in co-operation with, among others, NIVA, Norway. One important area of research is the development of image analysis techniques and environmental applications in imaging spectrometry.

During the year a big grant, for which Tommy Lindell is responsible, was given by EU. It concerns monitoring of the water quality of European lakes and includes participants from many European countries.

The GIS work is concentrated on environmental impact assessments and deals with the planning of new infrastructure and industrial establishment. Our main projects today deal with coastal zone mapping and planning. An ongoing large scale project in Jamaica is an example of this.

The SLU Image Analysis and Remote Sensing group is headed by Professor Gunilla Borgefors. The group and its activities has steadily grown since 1993 when she arrived, adding a new major project and accompanying Ph.D. student approximately every six months. The aim of the group is three-fold: to do applied image analysis research in co-operation with groups outside CBA; to do basic image analysis research; and to be a central SLU source for image analysis knowledge.

Several projects are aimed at forestry applications. SJFR finances a project were high resolution colour infrared images are used for forest inventory. Image variables to be extracted are, for example, horizontal tree crown area, tree species, and tree positions in the image. Another project has essentially the same goal, but using a radically different sensor, the new CARABAS radar, developed at the National Defence Research Establishment in Linköping. This sensor should, in contrast to conventional SAR radar, be well adapted to vegetation analysis. Its potential is so far largely unknown, but preliminary results are promising.

The graduate school in Wood and Fiber Science finances a forestry project at a completely different scale. The aim is to develop objective and, as far as possible, automatic methods for description and analysis of wood fibre morphology, where the fibre is modelled in all its dimensions.

One project is aimed at analysis of remote sensed images for agricultural uses, in particular methods using pixel neighbourhoods rather than single pixels. So, far, this has been concentrated on extraction of field borders. A Ph.D. student from Belarus spent 6 months with us on this, and now a full time Ph.D. student continues the work. A more application oriented project in the same area is financed by EU though Statistics Sweden (SCB). The aim of that is crop prediction using existing European models but adapting them to Swedish conditions.

NUTEK finances a project on low and medium level image analysis on general SIMD and MIMD parallel machines, to see who much these kinds of architectures can speed up the heavy computations. In contrast to other similar projects we have concentrated on operations that need global rather than local image information, these being a much harder to speed up.

Since the mid 1980s Gunilla Borgefors has co-operated with Dr. Gabriella Sanniti di Baja at Istituto di Cibernetica, Napoli, Italy, on various aspects of digital shape in two and higher dimensions. Skeletonization (or thinning) denotes the process where objects are reduced to structures of lower dimension. Together with Ingela Nyström from the UU group, we have developed skeletonization methods for 3D images. We also worked on shape preservation and skeletonizing in 2D binary resolution pyramids, together with Dr. Giuliana Ramella.

In the future we will continue our research in the areas outlined above, with a focus on methods for analysis of multi-dimensional and multi-spectral images coming from various sensors.

1.3 Sammanfattning på svenska (Summary in Swedish)

Centrum för bildanalys, CBA, är ett forskningscentrum som grundades 1988, baserat på tre små forskningsgrupper från Uppsala universitet, (UU), Sveriges Lantbruksuniversitet, (SLU), och Naturvårdsverket (SNV). Den första juli 1995 ändrades konstitutionen i enlighet med hur CBA hade utvecklats sig, så att vi blev en ren universitetsorganisation. Personalen är anställd vid resp. universitet och doktoranderna antas vid någon av de tre fakulteter där vi har doktorandprogram (NT vid UU, S och JLT vid SLU), men CBA administreras i sin hel-

het av UU. En värdefull följd av den nya konstitutionen är bildandet av CBA referensgrupp, som för närvarande består av sju organisationer med intresse för tillämpningar av bildanalys. Dessa är: Fiskeriverket, Försvarets forskningsanstalt, Riksantikvarieämbetet, SkogForsk, Naturvårdsverket, STFi, och Uppsala akademiska sjukhus. I juni 1996 tillsattes dessutom en permanent professor i bildanalys vid UU, med Ewert Bengtsson som innehavare.

Det budgetår som täcks av denna årsrapport omfattar 18-månadersperioden juli 1995 till dec. 1996. Det har varit en tid av stark expansion, dels därför att CBA har varit framgångsrikt i att få in nya forskningsmedel, dels därför att SLU-gruppen, där Prof. Borgefors startade hösten 1993, har kommit igång på allvar. Expansionen kommer att bli ännu större under nästa budgetår, eftersom många av de projekt som beslutats under innevarande budgetår inte startar förrän under nästa. Ewert Bengtsson var koordinator för VISIT (VISual Information Technology) det nationella forskningsprogram inom bildanalys som Stiftelsen för strategisk forskning (SFF) beviljat. VISIT kommer att administreras av CBA och finansiera projekt vid båda universiteten (samt vid de flesta andra svenska universitet). Tommy Lindell blev koordinator för ett stort EU-projekt om vattenkvalitén i Europas stora insjöar, som innefattar deltagare från många länder. Gunilla Borgefors och Tommy Lindell har varit djupt engagerade i planeringen av miljöövervakingsprogrammet RESE (REmote Sensing for the Environment) som finansieras av Miljöstrategiska fonden (MISTRA). Borgefors är projektledare och RESE kommer även det att finansiera projekt vid båda universiteten.

Enligt vår konstitution gäller följande: "Huvudinriktningen för CBA skall vara digital bildanalys inom bio- och geovetenskaperna. Forskningen skall syfta till tillämpning inom främst miljö och vatten, jord- och skogsbruket samt medicin. ... Vid CBA skall bedrivas forskning, dels inom bild- och fjärranalysen som sådan, med målet att utveckla bättre algoritmer, metoder och system för dessa typer av tillämpningar, dels inom de angivna områdena med direkta tillämpningar och projekt. CBA skall medverka till att bildanalystekniken sprids och tillämpas även inom andra institutioner. ... CBA skall vara ett kompetenscentrum med internationell kompetensnivå."

Forskningen organiseras i tre grupper: bildanalys vid UU, akvatisk fjärranalys vid UU, och bild- och fjärranalys vid SLU. Centrum för bildanalys hade 961230 tio doktorander, sju disputerade, två projektanställda, och två administrativ personal. Två doktorander disputerade under höstterminen 1996. Under början av 1997 kommer åtta nya doktorander att rekryteras. Fördelningen på doktorandnivå är jämn mellan universiteten, medan endast en disputerad finns vid SLU. I praktiken är verksamheten mycket väl integrerad.

Det mesta av CBA aktivitet liknar den vid vilken universitetsinstitution som helst, men administrationen blir med nödvändighet något mer komplicerad, p g a av vår nära relation till två universitet. Årets budget omfattade omkring 13.5 millioner kr, varav 45% kommer från de två universiteten och de övriga 55% från forskningsråd, NUTEK, EU, och många mindre källor. Dessutom deltar vi i undervisningen på grundnivå via andra institutioner vid UU till ett belopp av c:a 2 millioner kr.

UU-gruppens huvudtema är medicinska tillämpningar där tomografiska bilder från olika sensorer samt mikroskopiska bilder av cancerogena vävnader och celler har analyserats.

Vårt NUTEK-stödda projekt angående cancer i urinblåsan har fortsatt och under året resulterat i två doktorsavhandlingar, av Heung-Kook Choi och Torsten Jarkrans. Principen är att kombinera information från textur, objektanalys och MST-analys till ett enhetligt graderingssystem vilket testades på ett omfattande kliniskt material. De visade att automatisk analys kan vara lika bra som den som utförs av en patolog.

Nya metoder för att använda färgbaserade klassificeringsalgoritmer på histologiska preparat har vidareutvecklats och testas för närvarande på kliniskt material. Liknande färganalysalgoritmer har också använts för att lokalisera ögon och mun i fotografier för körkort o. dyl. Det senare arbetet har stötts ekonomiskt av företaget ID-kort AB.

Arbetet med datorstödd analys av ljusmikroskopiska cellbilder har en lång tradition i gruppen, det startade redan 1973. Arbetet med vår första tillämpning, den automatiska förgranskningen av rutinpreparat från gynekologisk hälsokontroll återupptogs under 1994 efter ett uppehåll sedan 1987. Detta projekt finansieras av det i Chicago baserade företaget Accumed International Inc. som utvecklar kommersiella produkter inom området.

Lennart Thurfjell har fortsatt sitt arbete med sin 3D datoriserade hjärnatlas. Ekonomiskt stöd har kommit från NUTEK för Thurfjell och för en doktorand som startat sitt arbete under året.

I ett annat projekt utvecklar vi metoder för att utvärdera strategier för nålbiopsier vid prostatacancerdiagos baserade på 3D modeller.

Metoder för att kvantitativt utvärdera och beskriva strukturer i 3D volymbilder har också studerats i ett grundforskningsprojekt med ekonomiskt stöd från TFR. Detta projekt bedrivs inom båda universiteten.

Såväl för att stödja dessa olika projekt som för att tillhandahålla ett förbättrat verktyg för utbildning i bildanalys har arbetet med den generella bildanalysprogramvaran IMP fortsatt.

Huvudmålet för den Akvatiska fjärranalysgruppen är att stärka digital fjärranalys i allmänhet, fokuserat på områdena bio- och geovetenskap. Kopplingen till geovetenskap skapar en naturlig koppling mellan fjärranalys och geografiska informationssystem (GIS). Nuvarande aktiviteter spänner från kartering och övervakning av utsläpp av avloppsvatten, fördelning av plymer i hav och sjöar till kartering av undervattensryggar i tropiska och subtropiska hav.

Användningen av satelliter och flygburna sensorer för vattenkvaliteövervakning är ett långsiktigt projekt som bedrivs i samarbete med bland andra NIVA i Norge. Ett viktigt tillämpningsområde är utvecklingen av bildanalysteknik och miljötillämpningar inom avbildande spektrometri.

Under året har ett stort anslag, med Tommy Lindell som ansvarig, beviljats av EU. Det avser övervakning av vattenkvalite i europeiska insjöar och bedrivs i samarbete med ett antal EU-länder.

Arbetet med GIS är koncentrerat till mätningar av miljöpåverkan och handlar om att planera ny infrastruktur och industriella etableringar. Vårt huvudprojekt för närvarande är kartering och planering av kustnära zoner. Ett storskaligt projekt på Jamaica rör detta område.

Bild och fjärranalysgruppen vid SLU leds av professor Gunilla Borgefors. Gruppens mål är trefaldigt: att bedriva tillämpad bildanalysforskning i samarbete med grupper utanför centrum; att bedriva grundforskning i bildanalys; att vara en kunskapsresurs i bildanalys för SLU.

Arbete inom ett flertal skogstillämningsprojekt bedrivs. SJFR finansierar ett projekt där högupplösta infraröda färgbilder används för skogsinventering. Bildegenskaper som tas fram är t. ex. horisontell yta för trädkronorna, trädarter samt trädens läge. Ett annat projekt har huvudsakligen samma mål, men en helt annan sensor används, den nya CARABAS radarn, utvecklad vid FOA i Linköping. Denna sensor tycks, i motsats till traditionell SAR-radar, vara

väl anpassad till analys av vegetation. Dess möjligheter är än så länge till stora delar okända men preliminära resultat är lovande.

Forskarskolan Trä och träfiber finansierar ett skogsprojekt i helt annan skala där syftet är att utveckla en objektiv, och så långt som möjligt, automatisk metod för karakterisering och analys av träfibrers form, där fibern modelleras i alla sina dimensioner.

Ett annat projekts mål är att analysera fjärranalysbilder för jordbrukstillämpningar, speciellt metoder baserade på lokala pixelomgivningar snarare än enstaka pixel. Hittills har detta koncentrerats på detektion av av åkrarnas kanter. En doktorand från Vitryssland tillbringade sex månader hos oss och arbetade inom detta projekt, nu arbetar en ny heltidsdoktorand inom projektet. Ett mer tillämpningsorienterat projekt inom samma område är finansierat av EU genom Statistiska Centralbyrån (SCB). Syftet är skördeprognos med användning av europeiska modeller, men anpassade till svenska förhållanden.

NUTEK finansierar ett projekt inom bildanalys på låg- och medelnivå på generella SIMD- och MIMD-parallella datorer. Syftet är att studera hur mycket denna typ av arkitekturer kan öka hastigheten hos tunga beräkningar. I motsats till andra liknande projekt har vi koncentrerat oss på operationer som behöver global snarare än lokal information, eftersom dessa är mycket svårare att effektivisera hastighetsmässigt.

Gunilla Borgefors har sedan mitten av 1980-talet samarbetat med Dr Gabriella Sanniti di Baja vid Instituto di Cibernetica, Neapel, Italien. Samarbetet rör olika aspekter av digital form i två och fler dimensioner. Skelettering beskriver en process där ett objekt reduceras till strukturer av lägre dimensionalitet. Tillsammans med Ingela Nyström från UU-gruppen har en metod för skelettering av volymsbilder utvecklats. Forskning inom området form och skelettering i tvådimensionella binära upplösningspyramider, bedrivs i samarbete med Dr Giuliana Ramella.

Den kvantitativa omfattningen av verksamheten vid CBA framgår av de olika listorna över publikationer, seminarier, konferensdeltagande, studiebesök etc i denna årsrapport. Vi skall här inte tynga texten med ytterligare statistik.

I framtiden avser vi att följa på den inslagna vägen, där forskning runt volymsbilder och multi- och hyperspektrala bilder kommer att ges särskilt utrymme. Efter den ytterligare ökning som nu beslutade stora projekt innebär har vi däremot inte ambitionen att växa särskilt mycket ytterligare.

2. Organization

The CBA consists of three research groups. We were at 19961231 a total of 22 persons, seven of which are PhD:s. Most of the activity at CBA is similar to a department within any university but the administration becomes somewhat more complicated due to our close relation to two different universities. Only about 45% of the budget of about 13.5 million SEK was covered by funds from the two universities. The rest came from various outside sources.

2.1 Constitution

The CBA was founded in 1988 based on three small research groups, from Uppsala University (UU), the Swedish University for Agricultural Sciences (SLU) and the Swedish National Environmental Protection Agency (SNV). In 1995 a re-organization of CBA took place to reflect the actual situation of that time, and from 1 July, 1995, we are a pure university entity. The employees are employed at either university, and the Ph.D. students are admitted at any of the three faculties where we have a Ph.D. program (NT at UU and S or JLT at SLU), but CBA is administered by UU.

The CBA is directed by a board with representatives from the universities and the personnel organizations. The board meets about four times per year to draw up the overall policies for the work at CBA and to take responsibility for the budget. In between board meetings CBA is headed by a director who is appointed by UU and who also serves as chairman of the board. During this year Gunilla Borgefors has served as director with Olle Eriksson as deputy. The other board members have been: Ewert Bengtsson UU, Nils-Einar Eriksson TCO, Bengt Gustafsson UU, Anders Hemmingsson UU, Christer Kiselman UU (suppl), Tommy Lindell SACO, Thomas Nybrandt SLU, Håkan Olsson SLU, and Magne Tuvesson SLU (suppl).

According to the founding documents the objective of the CBA is "to create the know-how needed for an operative and sensible use of digital image analysis in society, particularly in the fields of environment and medicine". The research work is organized in three groups: The image analysis group at UU which works mainly with medical applications and is headed by Ewert Bengtsson, the group in aquatic remote sensing, headed by Tommy Lindell and the image analysis and remote sensing group at SLU headed by Gunilla Borgefors.

2.2 Finances

The CBA is financed through the two universities, through research contracts and grants and through cooperation projects with other organizations. The brief listing below describes our overall economy for the 18 month fiscal year 1995/96 including both internal and external incomes and expenditures. Since part of our economy is handled at UU and part at SLU, this summary is based on joining the two accounts and clearing internal transactions. Additionally we have around 2 MSEK in personnel costs covered through teaching administrated through the Departments of Scientific Computing and of Geoscience at UU. The numbers are rounded to the nearest 1000 SEK. The total sum increased about 30% since the previous fiscal year (per 12 mnths). Below the same numbers are also given as pie charts. It is worth noting that of our own activities (teaching excluded) 55% are financed through outside funding.

2.3 Reference group

To increase the interaction with the world outside the universities, the new constitution of CBA (see Section 2.1) defines a reference group of official bodies that makes a small annual contribution to CBA in exchange for a monthly information letter, consulting possibilities, and several informative meetings annually. Two meetings were held this period. The first was a preliminary meeting 960422 to which a large number of organisations had been invited. At this meeting the plans for, and motivation behind, the reference group were presented. The first "real" meeting of the reference group was held 961126 were *General image analysis methods* from the theses of Choi and Jarkrans were presented.

At present the reference group consists of the following organisations:

National Board of Fisheries

National Defence Research Establishment

The National Board of Antiquitys

The Forestry Research Institute of Sweden

Swedish National Environmental Protection Agency

Swedish Pulp and Paper Research Institute

Uppsala University Hospital

2.4 Staff

Gunilla Borgefors, Professor, PhD, director, SLU
Olle Eriksson, Lecturer, PhD, deputy director, UU
Ewert W Bengtsson, Professor, PhD, UU
Tommy Lindell, Docent, PhD, UU

Tomas Brandtberg, Doctoral Student, SLU, UU
Heung-Kook Choi, Doctoral Student, -960930, UU
Anders Forsmoo, Doctoral Student, 951101-, SLU
Hans Frimmel, Doctoral Student, UU
Roger Hult, Doctoral Student, 960101-, UU
Torsten Jarkrans, Adjunct, PhD, UU
Mattias Moëll, Doctoral Student, 960701-, SLU
Jakob Nisell, Research engineer, part time (~50%), SLU
Bo Nordin, Researcher, PhD, UU
Ingela Nyström, Doctoral Student, UU
Petter Ranefall, Doctoral Student, UU
Anna Pettersson, Doctoral Student, 960208-, SLU
Lennart Thurfjell, Researcher, PhD, part time (80%), UU
Fredrik Walter, Doctoral Student, SLU
Daniel Wedjesjö, Doctoral Student, -951031, SLU
Catherine Östlund, Doctoral Student, UU

Helena Olsson, Administration
Marcelo Toledo, Administration, 950918-

Hua Guo, project work, 9609-, SLU
Yueqin Sun, project work, 9603-, UU

The letters after the name indicate the employer for each person. The interpretation is as follows: UU - Uppsala University, SLU - Swedish University of Agricultural Sciences. The staff can in addition to regular mail, telephone and fax to the CBA be reached through email at an address which usually is their first name followed by @cb.uu.se.

3. Undergraduate education

CBA does not have responsibility for organizing undergraduate education at any of the two universities. The staff at CBA is, however, involved in teaching several courses organized by other departments. We also offer several Master thesis projects (examensarbeten) each year.

3.1 Courses

The undergraduate courses which staff from CBA have taught have mainly been organized through the Department of Scientific Computing at UU. These courses have dealt with subjects closely related to our research i.e. Computerized image analysis and Computer graphics. We have also taught courses in programming in C and C++.

At SLU we have not yet given any undergraduate courses but plans are in progress for offering courses in our field also at that university.

During the period covered by this report, we have been involved in the following courses:

1. **Introduction to scientific programming**
   Name: Olle Eriksson, *Period:* Sep-Nov 1995
   Topic: Introduction to computer programming using C++ .
2. **Computers and Programming**
   Name: Torsten Jarkrans, *Period:* Sep-Nov 1995
   Topic: Distance course in programming using C++ (18h lectures).
3. **Satellite image interpretation**
   Name: Tommy Lindell, *Period:* Oct 1995
   Topic: Part of a basic level remote sensing course, Geosciences
4. **Satellite remote sensing**
   Name: Tommy Lindell, *Period:* Nov 1995
   Topic: General review of techniques in remote sensing for the image analysis course
5. **Object-oriented programming**
   Name: Olle Eriksson, Hans Frimmel, *Period:* Nov-Dec 1995
   Topic: Introduction to C++.
   Comment: A course given for Sandviken AB
6. **Computers and Programming**
   Name: Petter Ranefall, *Period:* Oct-Dec 1995
   Topic: Programming using C++
7. **Computerized Image Analysis**
   Name: Ewert Bengtsson, *Period:* Nov-Dec 1995
   Topic: a full 5 credit course on image analysis, including lab excercises and examination
   Comment: given at Umeå University.
8. **Digital remote sensing**
   Name: Tommy Lindell, *Period:* Nov 1995 - Jan 1996
   Topic: Course on basic level Geosciences
9. **Introduction to scientific programming**
   Name: Fredrik Walter, *Period:* Jan 1996.
   Topic: Introduction to computer programming using C++ .
10. **Computer Assisted Image Analysis**
    Name: Torsten Jarkrans *Period:* Jan-March 1996
    Topic: Lectures and laborations in image analysis for 15 students.
11. **Scientific programming**
    Name: Olle Eriksson, *Period:* Mar-May 1996
    Topic: Programming using C++ .

12. **Computer Assisted Image Analysis**
Name: Petter Ranefall, Ewert Bengtsson, Ingela Nyström, *Period:* March-May 1996
Topic: Lectures and laborations in image analysis for 15 students.

13. **Computer Graphics**
Name: Torsten Jarkrans, Hans Frimmel, *Period:* March-May 1996
Topic: Lectures and laborations in computer graphics.

14. **Introduction to scientific programming**
Name: Olle Eriksson, *Period:* Sep-Nov 1996
Topic: Introduction to computer programming using C++ .

15. **Object-oriented programming using C++**
Name: Bo Nordin, *Period:* Oct-Dec 1996
Topic: Introduction to C++.
Comment: A national distance course - most contacts between students and teachers via email

16. **Computer Graphics**
Name: Bo Nordin, *Period:* Oct-Dec 1996
Topic: Introduction to computer graphics (40h lectures and 10h laborations).

17. **Software Tools**
Name: Olle Eriksson, *Period:* Jan-March 1996
Topic: Object oriented design and and analysis, softwre tools.

18. **Object-oriented programming using C++ (TDB3)**
Name: Bo Nordin, *Period:* Jun-Aug 1996
Topic: Introduction to C++.
Comment: A national distance course

19. **Satellite image interpretation**
Name: Tommy Lindell, *Period:* Oct 1996
Topic: Part of a basic level remote sensing course, Geosciences

20. **Digital remote sensing**
Name: Tommy Lindell, *Period:* Dec-Jan 1996-1997
Topic: Course on basic level Geosciences

21. **Introduction to scientific programming**
Name: Torsten Jarkrans, *Period:* Oct-Mar 1996-1997
Topic: Introduction to computer programming using C++ .

3.2 Master thesis projects

The center has organized the following master thesis projects which have been carried out this year:

1. ***Topic:*** **Reconstruction of insects' ganglion**
Student: Roger Hult
Advisor: Ewert Bengtsson
Period: 9507-9512
Abstract: The purpose of this undergraduate thesis work is to reconstruct insects' ganglion from consecutive slices made by a microtome. The project itself was initiated several years ago by Professor Christine Dahl at the Department of Entomology at Uppsala University. The main difficulty when reconstructing the 3D structure from this type of data is that the slices normally are misaligned In this thesis two algorithms for alignment have been tried out, besides doing the alignment manually. These two algorithms are Hierarchical Chamfer Matching Algorithm and an intensity based correlation technique. These are referred to as HCMA and Grey-match throughout this thesis. HCMA uses information from the edges of the images to create a distance image and tries to minimise the sum of the values in the distance map that the contour hit. Grey-match uses grey-level intensities and tries to maximise the correlation between adjacent slices by altering translation in x- and y-direction and also the rotation about the z-axis. Because of the nature of biological data and that the samples used in this thesis were originally not intended for this purpose, both of the algorithms have difficulties in some cases. What is decided to be a good matching is rather subjective, although bad correlation values give a hint of if the matching is totally wrong.

2. ***Topic:*** **Development of a windows based system for evaluation of mottle in full tone printed paper surfaces**
Student: Anna Svärd
Advisor: Ewert Bengtsson
Period: 9507-9512
Abstract: A windows program has been developed, for evaluation of mottle in full tone printed paper surfaces, with help of image analysis. Earlier visual judgment has been used for evaluating the degree of unevenness in the printed samples. This is a very time consuming method, and it doesn't always give reliable results. The development if a new PC based system is an important step in making an equipment available for the paper mills. It will make it easier to perform a larger number of mottle evaluations, which in turn will give a better knowledge of the reasons for mottle in printed paper. The images are read from a line scanner. there has also been some tests done to change the imaging equipment into a smaller CCD-camera. The images are evaluated with frequency analysis. The degree of mottle is given as the variance of the grayscale in the image. A separation of the frequency domain is done into a number of wavelength areas. The variance is then summed for the different areas, and given as result. The wavelength can here be seen as a measurement of the size of the unevenness. A large variance in one of the wavelength areas means that the unevenness in the sample has this characteristic size.

3. ***Topic:*** **Image Analysis algorithms for inspecting of the superconducting LHC-cable**
Student: Tobias Öhman
Advisor: Ewert Bengtsson
Period: 9601-9606
Abstract: This paper concerns the idea of using image analysis to inspect a superconducting cable, which is to be used in high field magnets within the LHC-project at CERN. The methods described here, are based on direct extraction of data from images. This data is then used to reconstruct a simplified, structural representation of the image. Features from this model makes the foundation of a classifier which classifies images into the two possible classes 'fault' or 'normal'.

4. ***Topic:*** **Targe detection in IR (Infra Red) video**
Student: Tomas Holm
Advisor: Ewert Bengtsson
Period: 9601-9607
Abstract: Research about point target detection systems for IR-cameras. Following subjects have been penetrated: how noise affect point targets in IR-camera. Classification of backgrounds in IR-images. Test of different point target detection methods, The results are following: noise and point targets can not be separated by looking at the form of the signal in the spatial plane. IR-image background classification is difficult due to the different adjustment that can be done on the IR-camera. Several different point target detection methods were tested and four of them were easy to implement and showed food result, they were: Target detection system developed by EMW (Ericsson Microwave Systems AB) in Mölndal, Robinson filter, Top-Hat transform and Motion detection. Data fusion between Motion detection and other target detection methods showed food result.

5. ***Topic:*** **Digital image analysis of clumps and clusters of cells in cervical cancer screening**
Student: Kenneth Jonsson
Advisor: Ewert Bengtsson
Period: 9603-9609
Abstract: Despite over 40 years of active research, automated cervical cancer screening is still an unsolved problem. However, as a result of the increasing computational power of modern digital computers in conjunction with new sophisticated methods for specimen preparation, image acquisition and image analysis significant progress is now being made. The principal objective of this thesis was to investigate whether it is possible to extract discriminatory information from clumps and clusters of cells in standard PAP-smears. In many specimens, the majority of the cells are part of aggregates and the successful classification of these could increase the reliability of the PAP-smear analysis. the methods consider stem from several different areas within digital image analysis and mathematical statistics. These include image enhancement and segmentation, feature extraction, cluster analysis and statistical classification. Emphasis was placed on the improvement of existing enhancement techniques, the development of new segmentation algorithms and the application of known methods within cluster analysis. The results indicate that it is quite feasible to extract valuable information from different types of cell aggregates.

6. ***Topic:*** **Detection of small airborne targets in visual and infrared images**
Student: Fredrik Lingvall
Advisor: Gunilla Borgefors, Thomas Andersson*, Bengt Andersson*
Funding: CelsiusTech Electronics AB, Järfälla (*)
Period: 9606-9611
Comment: The work was done at Celsius Tech AB, Järfälla.
Abstract: A crucial component in infrared and visual search and track systems is the detection of targets. The subsequent tracking problem in largely solved. Several techniques that are useful for the problem of detecting small air-

borne targets in images from such systems were investigated. These include: a number of filtering techniques for enhancing the signal-to-clutter ratio, especially matched filters in 2D and 3D (sequences); segmentation methods, especially 2D histogram methods based on the co-occurrence matrix; object measuring in the segmented images, especially basic form measures; and finally classification of objects based on these measures.

7. **Topic: Using texture of remote sensed images for classification of agricultural scenes**
   Student: Lars Bergqvist
   Advisor: Gunilla Borgefors
   Funding: TFR
   Period: 9608-9701
   Abstract: Texture data and spectral information from remote sensed agricultural scenes (SPOT-images) were used for distinguishing between different crop types in agricultural fields. The co-occurrence method was used for the texture analysis. The classification results, using several classification methods, were compared to experiments where only spectral data was used. The comparison unfortunately showed that no significant improvement is achieved when texture data is introduced. Even though the fields do contain texture, this texture is not related to the crop, at least not in the low resolution possible in satellite images. An overview of alternative methods and related work have also been performed as an introduction to future work in this area.

4. Graduate education

At CBA during the period covered by this report, there have been six doctoral students in computerized image analysis at UU, one in remote sensing at UU and five in image analysis and remote sensing at SLU, i.e., a total of 12. Four of these started their studies during the period and two students defended their PhD theses.

4.1 Courses

CBA has for several years organized graduate courses in "Application oriented image analysis". These courses have been intended for researchers and research students in other fields who wish to learn digital image analysis for use in their own research and have therefore had their focus more on practical issues than on theory. These courses usually have students from both universities, together with some from industry. We have also given a number of other graduate courses. During the period covered by this report the following graduate courses were given:

1. **Application oriented image analysis**
   Period: Oct-Dec, 1995
   Credits: 5
   Examiner: Gunilla Borgefors
   Lecturers: Ewert Bengtsson, Tommy Lindell, Torsten Jarkrans, Bo Nordin, Lennart Thurfjell
   Topic: A course in Application oriented image analysis for PhD students.

2. **Application oriented image analysis**
   Period: Oct-Dec, 1996
   Credits: 5
   Examiner: Gunilla Borgefors
   Lecturers: Ewert Bengtsson, Tommy Lindell, Bo Nordin, Ingela Nyström, Lennart Thurfjell
   Topic: A course in Application oriented image analysis for PhD students.

3. **Visual Form**
   Period 9601-9603
   Credits: 3
   Examiner: Gunilla Borgefors
   Topic: Selected papers from the 2nd International Conference on Visual Form, Capri, Italy, where presented by the students.

4. **Classification and Decision Theory**
   Period 9603-9606
   Credits: 5
   Examiner: Lennart Bondesson, Mathematical Statistics, UU
   Lecturers: Gunilla Borgefors, Tomas Brandtberg, Mats Gustafsson, Lennart Norell, Finn Pedersen, Dietrich von Rosen
   Topic: The course was partly based on "Duda & Hart: Pattern Classification and Scene Analysis." In addition to classical statistics, several "modern" classification methods were covered. The main lecturers were Bondesson and Norell.

4.2 Dissertations

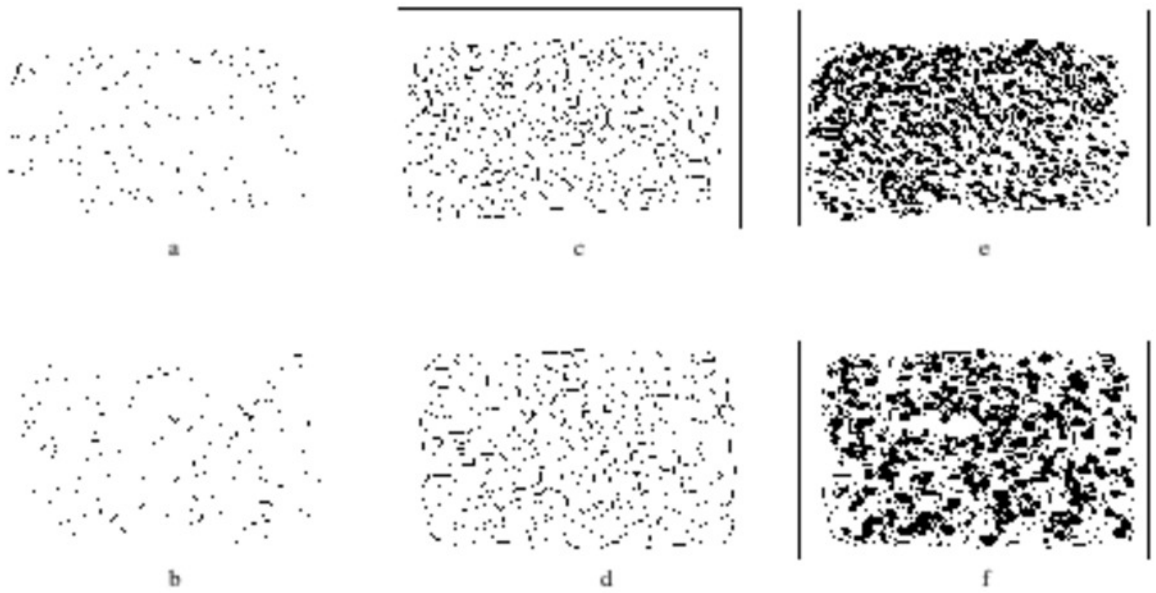
New Methods for Image Analysis of Tissue Section

Name: Heung-Kook Choi
Dissertation date: 960920
Publisher: Uppsala University, Sweden ISBN: 91-554-3829-X
Abstract: Computerized image analyses using new and highly developed methods have the potential of increasing the reproducibility of the grading of malignant bladder carcinoma compared to the conventional subjective grading made by pathologists. In an effort to develop such methods texture analysis, morphology analysis and graph based analysis were carried out from Feulgen stained histological tissue sections. A correct segmentation of regions of interest is a prerequisite for further studies. A histogram based global thresholding segmentation and texture based local segmentation using 3X3 masks on images were developed for this purpose. The textural features were based on the spatial gray-tone co-occurrence probability matrices. The morphological features were extracted from gray scale images, binary images obtained by threshold-

ing the nuclei and several other images derived through image processing operations. The graph based features were extracted from the minimum spanning trees connecting all nuclei. The large numbers of extracted features were evaluated in relation to subjective grading and other factors related to prognosis using multivariate statistical methods and multilayer backpropagation neural networks. All the methods were originally developed and tested on one set of patient material and then tested for reproducibility on an entirely different set of patient material. The results indicate reasonably good reproducibility for the best sets of features. It should thus be possible to use this kind of image analysis as a prognostic tool for bladder carcinoma patients.

Algorithms for Cell Image Analysis in Cytology and Pathology

Name: Torsten Jarkrans
Dissertation date: 961031
Publisher: Uppsala University, Sweden ISBN: 91-554-3844-X
Abstract: Scene segmentation and feature extraction are essential components of automatic computerized cell image analysis. Algorithms have been developed for the analysis of cell images in a project whose aim was to construct an automated prescreener for cervical cytology specimens. For the segmentation, two methods were developed, both of which assume knowledge of a point inside each nucleus. The first method traces all sharp edges around the cell with the purpose of finding the best closed boundary of the cell nucleus and the cytoplasm. The other method searches for the most compact cell nuclues and cytoplasm by tracing iso-density contours at every reasonable gray-level. As the overlap of cell nuclei is one type of artefact that needs to be identified, a method for overlap detection was tested. In another study, this method was compared with an alternative approach. In a pathology project, the aim was to develop a method for an objective grading of histological tissue sections from malignant bladder carcinoma. For this purpose, morphologic analysis and graph based analysis were tested. For the morphological analysis, features were extracted from gray scale images, from binary images obtained by thresholding the nuclei and from several other images derived through image processing operations. The graph based features were extracted from the minimum spanning trees connecting all nuclei. The large numbers of extracted features were evaluated by making a comparison with the results of subjective grading and other factors related to prognosis using multivariate statistical methods. All the methods were originally developed and tested on one set of patient material and then tested for reproducibility on an entirely different set of material. The results indicate that there is reasonably good reproducibility for the most important features.



The skeleton image for the grade 1 image (a) and the grade 3 image (b). The zoi image for grade 1 (c) and grade 3 (d). The zoi image and the binary image merged for grade 1 (e) and grade 3 (f).

5. Research

The CBA is conducting a whole range of projects from basic image analysis research to direct application work. By keeping close touch both with the theoretical front line research and with real life application projects we believe we can make the best contribution to our field. In keeping with the stated goal for our center we have given priority to applications in the fields of biomedicine and the environmental sciences. Lately we have also started projects relevant for the forest industry. Most of the application projects are carried out in close cooperation with other departments.

In this section we list our current research projects and provide a short description of each. They are grouped by application and ends with basic projects.

5.1 Current research projects

1. ***Topic:*** **3D medical image analysis based on a computerized brain atlas**
   Name: Lennart Thurfjell, Ewert Bengtsson, Roger Hult, Jesper Andersson
   Funding: NUTEK
   Period: 9501--
   Partners: Departments of Neuroradiology and Clinical Neurophysiology at the Karolinska Institute and Hospital and the Department of Physics at the University of Stockholm. Cooperation also with the PET Center in Uppsala.
   Abstract: This is a long term project developing the tools for medical research and future clinical image usage. A computerized brain atlas was developed in an earlier project and documented in a thesis by Thurfjell in May 1994, as well as in several journal papers. It is used clincally and for research in around a dozen centers world wide. In the current project several new algorithms that will extend the usability of the atlas are being developed. Examples of such algorithms are improved inter-individual registration methods. The atlas will also be used as a platform for model based image segmentation methods, an important enabling technology for routine use of 3D imaging and "virtual reality" techniques in medical diagnosis and treatment planning. A new doctoral student started in the fall of 1995 and another student will start in early 1997. Jesper Andersson from Uppsala PET Center is also working part time on this project.

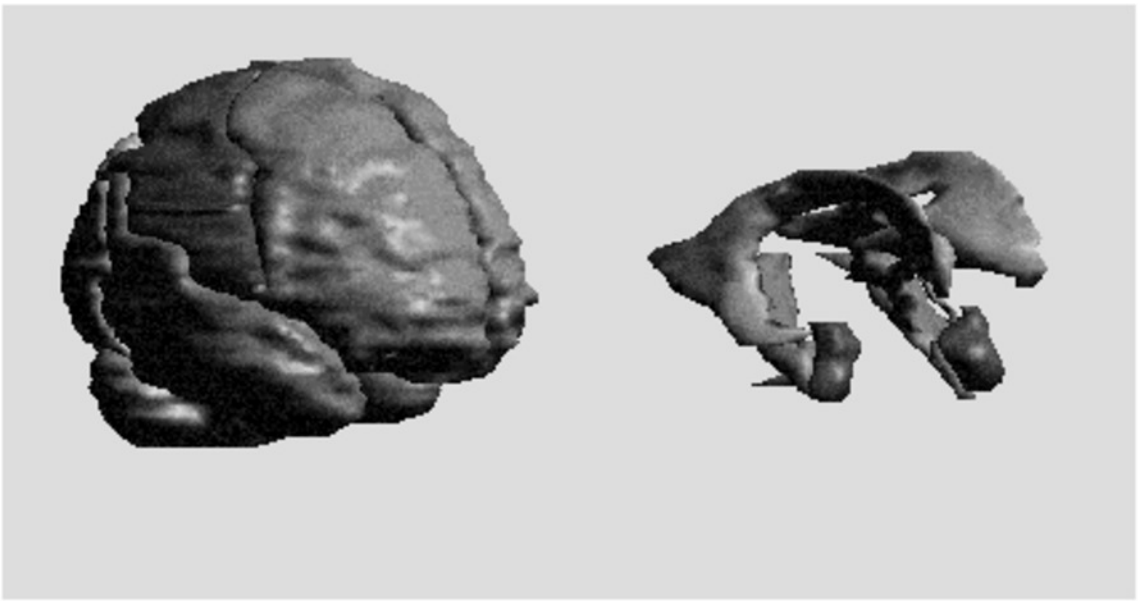


FIGURE: Surface renderrings of the brain lobes (left) and the ventricles, hippocampus and amygdala (right)

2. *Topic:* Optimizing the 3D placement of needle biopsies of the prostate

Name: Hans Frimmel, Ewert Bengtsson
Funding: UU
Period: 9505--
Partners: Christer Busch, Michael Häggman, Lars Egevad, Department of Pathology, Uppsala University Hospital, Ingrid Carlbom, Digital Equipment Corporation.
Abstract: In order to obtain a reliable diagnosis of prostate cancer in preparation for possible surgery or other therapy needle biopsies need to be taken of the prostate tissue. The placement of these biopsies is critical since too few or wrongly oriented biopsies may lead to a missed tumor and a false negative result. In this project we are studying how the biopsies should be placed based on 3D modeling of the cancer distribution obtained from the study of about 50 resected prostates which have been digitized slice by slice, registered and remapped to a common coordinate system. The resulting 3D cancer distribution is visualized through computer graphics techniques as well as used for mathematical optimizations of the needle placement strategies. The project is based on previous work at DEC research labs in Cambridge, USA and carried out in cooperation with the Department of Pathology at Uppsala University

3. *Topic:* Computerized wound image analysis

Name: Ewert Bengtsson, Bo Nordin
Funding: The industrial liason office UU, CWA Institute AB
Period: 9502--
Abstract: When an open wound is healing a necessary first step is for yellow and black inflammatory and necrotic areas to be cleared and red granulation tissue will become visible before the reepitalisation can take place. Based on this the wound healing process can be monitored through a quantitative analysis of color photographs of the wounds taken at regular time intervals. This quantitative evaluation of the healing process is of particular interest to pharmaceutical companies developing new wound treatment compounds. In 1988-90 we developed a hardware/software system for this purpose in collaboration with Pharmacia. Later this system was taken over by CWA Institute AB. Now the old hardware has become obsolete and CWA asked us to implement a new version based on modern computer technology. We decided to use IMP (see another project description) as a platform and developed a new software for this application during 1995. This software has been tested and further improved during 1996.

4. *Topic:* Standardisation of histopathological grading through digital image analysis

Name: Torsten Jarkrans, Heung-Kook Choi, Ewert Bengtsson
Funding: NUTEK, UU
Period: 9007-9512
Partners: Christer Busch, Department of Pathology, Uppsala University Hospital
Abstract: The diagnosis of cancer is mainly based on visual evaluation of histopathological specimens in a light microscope. In this evaluation the pathologist is usually very good at recognizing the type of cancer but has much more difficulty in recognizing the malignancy grade. The latter is important in the determination of an adequate treatment of the patient. In this project we are developing methods for computer assisted grading of tumors. We have concentrated the work on bladder cancer since this is a histologically well defined type of cancer. The analysis has proceeded along two different complementing lines: Evaluating the overall order/disorder of the tissue by texture analysis and evaluating the tissue architecture by identifying and measuring the relationships between the individual cells that make up the tissue. This is supplemented by graph theoretical methods for evaluating disorder in the organization of objects in histological tissues. Each line of research was presented as the core parts of two doctoral dissertations by Choi and Jarkrans resepctively during the fall of 1996 (see the section on doctoral dissertations). The developed methods were also tested and compared on a new independent patient material during 1996. The results were submitted and accepted for publication in a journal and will appear in 1997.

5. *Topic:* Quantification of immunohistochemistry using digital image analysis

Name: Petter Ranefall, Ewert Bengtsson
Funding: NUTEK
Period: 9307--
Partners: Christer Busch, Department of Pathology, Uppsala University Hospital
Abstract: Modern methods in immunohistochemistry makes it possible to create very specific stains that quantitatively shows presence of proteins, enzymes, oncogenes etc. The human visual system is good at qualitatively evaluating images but not at retrieving the quantitative information. In this project we are developing methods for quantitative analysis of color images in cytology and histopathology. These methods provide new tools for histopathological research and clinical practice with substantial potential for becoming the basis for new products. Two different approaches have been followed based on supervised and unsupervised classification/segmentation of the images respectively. In the supervised case the operator marks a few typical areas in the image and a classifier is created and applied to the rest of the image based on this. This allows good control over the segmentation but also introduces some subjectivity. In the unsupervised approach a fully automatic segmentation is achieved based on the assumption that the image contains some positive and some negative cells. This removes the subjectivity in the selection of training areas but it is still necessary to visually select relevant fields of view for the analysis. Descriptions of both meth-

ods have been accepted for publication in journals. The methods have been implemented in a user friendly software and are being used in application oriented studies at the Department of Pathology at Uppsala University Hospital.

6. *Topic:* Computer assisted cervical cytology

Name: Ewert Bengtsson, Bo Nordin, Martin Potappel, Kenneth Jonsson
Funding: AccuMed International Inc
Period: 9407--
Abstract: The computer assisted or automated analysis of cell specimens from the uterine cervix, so called PAP-smears, obtained during gynecological health control is one of the long standing problems in digital image analysis. One of the groups that formed the CBA was active in this field 1973-1987. In the spring of 1994 we were contacted by the Chicago based company AccuMed which was interested in developing products based on our old results. A research cooperation contract was signed and we have since the summer 1994 carried out a number of studies in cooperation with AccuMed. In the fall of 1995 a study concerned the possibility of analyzing clumps of cells and not only the free-lying cells was completed by a visiting student from Holland, Martin Potappel. This study was followed by more detailed clump and cluster analysis including implementation of the methods in the AccuMed software by a Master Thesis student, Kenneth Jonsson. He completed his project in the fall of 1996. The cooperation with AccuMed will continue also during 1997.

7. *Topic:* Wood Fibre Morphology

Name: Mattias Moëll, Gunilla Borgefors
Funding: Wood and Wood Fiber graduate school
Period: 9509--
Partners: Prof. Erik Ståhl, Dept. of Forest Production, SLU, Garpenberg
Abstract: The morphology of wood fibre is of great importance to the mechanical properties of pulp and paper. For the forest industry to be able to produce new products, renew processes, and to maximise the use of the Swedish wood fibre potential, more knowledge of the fibre morphology is needed. The aim of this project is to develop an objective and, as far as possible, automatic method for description and analysis of wood fibre morphology, where the fibre is modelled in all its dimensions. The method is based on the use of a zoom microscope and digital image analysis. Methods for correctly identifying and linking the parts of crossing fibres must be developed, as must methods for measurement of length, width and cell wall width along the whole fibre.
The project is a part of the graduate school "Wood and Wood fiber" established by SJFR and SLU.

8. *Topic:* Root length measurement using digital image analysis

Name: Tomas Brandtberg, Gunilla Borgefors
Funding: Dept. of Ecology and Environmental Research (EMC), SLU
Period: 9410-9509
Partners: Helena Elmqvist, EMC, SLU, Uppsala; Johan Wiklund, Computer Vision Laboratory, Dept. of EE, Linköping University.
Abstract: The main goal of the project is to automate the extraction of root lengths from images depicting growing roots in soil. The project is run in close co-operation with EMC and is split into two parts. The first part included thresholding, distance transformation and skeletonizing of the roots. The second part involved constructing three convolution kernel pairs, able to extract lines and edges, i.e. root surfaces and root edges, in the digital images. The kernels were optimised by Johan Wiklund.

9. *Topic:* Digital image classification of compression wood in Norway spruce discs

Name: Fredrik Walter, Gunilla Borgefors
Funding: S faculty, SLU
Period: 9401--
Partners: Mats Warensjö, Dept. of forestry products, SLU, Uppsala
Abstract: Compression wood is an important defect in wood products. To understand the relationships between compression wood and warpage in the sawn wood product, the Dept. of forestry products studies thin discs cut from Norway spruce. Our part of the project has been to develop an interactive system that automatically identifies normal wood and two degrees of compression wood in colour images of these discs. The areas of the three wood types and the approximate location of the compression wood were extracted. The extracted data from the analysis has been compared to the real sawn wood products.

10. *Topic:* Analysis of forests using high resolution CIR aerial images

Name: Tomas Brandtberg, Gunilla Borgefors
Funding: SJFR
Period: 9402--
Abstract: The main goal of the project is to develop methods for automating forest inventory. using high spatial resolution colour infrared aerial images (CIR). The resolution of the 50 aerial images used as the test set of the project is high enough to make the individual tree crowns visible and accessible for analysis. Image variables to be extracted are horizontal tree crown area, tree species and tree positions. Automation of the image analysis is emphasized. We have

showed that it is possible to distinguish between spruce on one hand, and pine and birch on the other, using a structure-based algorithm.
The two-dimensional aerial image information could, in the future, be integrated with a tree height profile, e.g. from a laser system, to make three-dimensional measurements possible. Flight height for the photographs and the laser profile meter is 600 m.

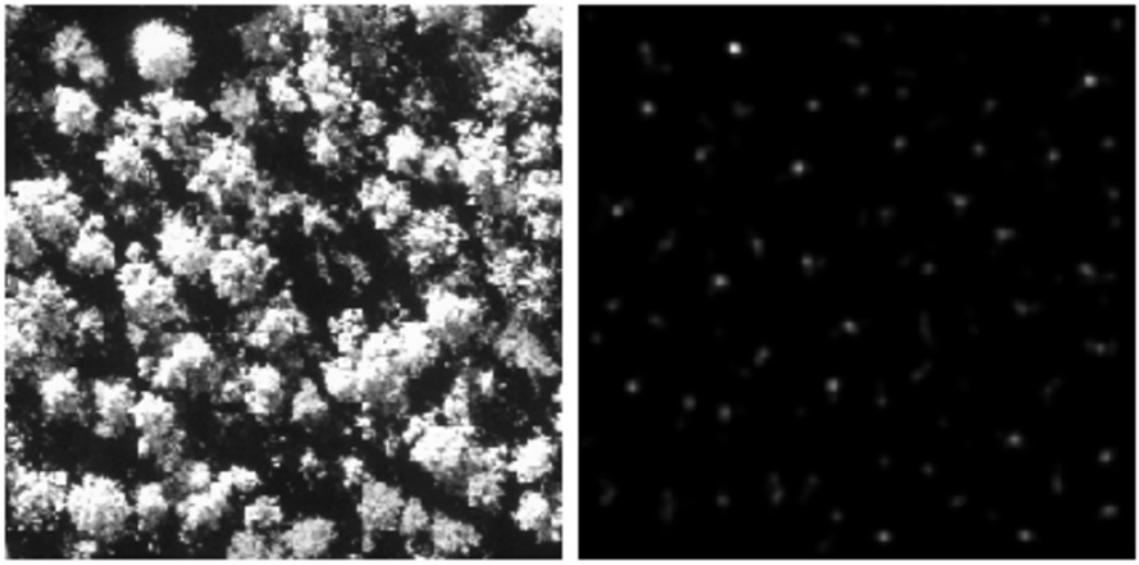


FIGURE: Aerial image with automatically identified tree crowns.

11. *Topic:* Extraction of forest parameters from CARABAS radar data

Name: Fredrik Walter, Gunilla Borgefors
Funding: S faculty, SLU
Period: 9407--
Partners: Division of Surveillance and Seeker Systems, National Defence Research Establishment, Linköping
Abstract: CARABAS in a completely new type of radar, developed at the National Defence Research Establishment. It is, in sharp contrast to conventional SAR radar, well adapted to the interesting scatterers in the forest, i.e. trunks and other large objects. The goal of the project is to develop methods for extracting forest parameters from the radar data. Forest tree volume have been compared to CARABAS imagery. The study shows that there is a strong correlation between forest biomass and CARABAS radar data. A method for relative correction of CARABAS data had to be developed. The correction is needed due to large variation in incidence angle over the image. In the end of 1996, test flights were made with the new generation sensor, CARABAS II. Due to its improved sensor technology, the data will have higher spatial quality than before.
The project will continue with studies regarding the possibility of extracting information from individual trees in the imagery. Studies regarding other interesting parameters, like tree species composition and tree height, will also be performed. Other sources of information, such as other types of images, ground truth data and geological data, will be used in combination with the radar data.

12. *Topic:* Automated Analysis of Agricultural Remote Sensed Images

Name: Anna Pettersson, Dimitry Lagunovsky, Gunilla Borgefors
Funding: JLT faculty, SLU
Period: 9602--
Abstract: Information of agricultural activities are increasingly collected using remote sensing, especially within the European Union. Crop species identification, crop area, and yield prediction and estimation are important measurements, that can be facilitated by remote sensing. Today the image analysis is mostly manual, or at least is using heavy human interaction. As an increasing number of satellites and other sensors provide more and more information, there is a need for interactive or even automated analysis of the remote sensed images. The goal of this project is to develop better and more automated methods for the analysis of agricultural images than those available today. The focus will be on neighbourhood operations, rather than "classical" spectral analysis. As a first step, a method for automated field boarder extraction is under development. A priori knowledge of the field boarders will probably greatly improve the results of subsequent classification.

13. *Topic:* Application of remote sensing for agricultural crop production in Sweden

Name: Jakob Nisell, Gunilla Borgefors
Funding: European Commission through Statistics Sweden (SCB)
Period: 9611--
Partners: Statistic Sweden (SCB); Dept. of Crop Production Sciences, SLU, Uppsala; Swedish Meteorological and Hydrological Institute (SMHI), Norrköping; Joint Research Centre (JRC), Ispra, Italy
Abstract: The main goal of the project is to find new objective and less expensive methods for crop yield estimation for Sweden. The Institute for Remote Sensing Application, IRSA, has been conducting and implementing a crop yield information system for mid European conditions, within the MARS project. Their methods will be adopted to Swedish conditions. We will use NOAA AVHRR images to follow vegetation growth over large areas in Skåne and Skaraborgs län. Homogeneous areas of 5 km x 5 km will be defined and followed during the vegetation season. High resolution images from Landsat TM and/or SPOT will be used for calibration of the crop relationship to the AVHRR data and for the definition of the homogeneous areas. There will be a close collaboration with Department of Crop Production, SLU where a crop growth model based on CGMS model is being developed.

14. *Topic:* Environmental applications of Imaging Spectrometry

Name: Tommy Lindell, Catherine Östlund
Funding: Swedish Space Board
Period: 9207--
Partners: K. Sörensen, NIVA, OSLO, Norway, F.L. Berta Andersson, Dept of Environmental Assessment, SLU
Abstract: To develop our own algorithms for data visualization and analysis based on SIPS and EASI/PACE. The system will contain a displaying function for spectral data and the connection to the recovery image. It should also contain the unpacking of the spectral data for displaying it in "signature" form and present it together with the recovery image for the detection and analysis of different features. There should also be a routine for calculating different types of statistics from the spectral data, including routines for atmospheric corrections and calibrations. The system should also display the spatial data together with the recovery image for the detection and analysis of different features. New ways of presenting and analyzing the data based on PCA and PLS will be developed. The knowledge will be applied to environmental mapping and monitoring in water and wetland sites, concentrating on detecting of different types of phytoplankton and other types of suspended matter and the classification of periphyton.

15. *Topic:* Coastal dynamics research in the wider Caribbean

Name: Tommy Lindell
Funding: SAREC
Period: 9107-9612
Partners: John Norrman, Dept of Geosciences, Uppsala
Abstract: The project has been based on, or supported by, remote sensing information, and included the following items:
- Identification of some specific ooid generating areas and estimation of the status of surrounding shores.
- Identification of transport forms.
- Identification of erosion, transport and accumulation areas associated with oolitic and non-oolitic areas.
- Determination of transport directions and intensity.
- Evaluation of the estimations within the coastal zone based on remote sensing.
- Evaluation of the usefulness of available remote sensing data for land-use and land-cover mapping, particularly with respect to agriculture and forestry.

16. *Topic:* Land-use mapping of the Vilsandi National Park, Estonia

Name: Tommy Lindell, Jakob Nisell
Funding: Swedish Space Corporation
Period: 1995
Partners: Arvo Kullapere, Vilsandi National Park, Estonia
Abstract: The Vilsandi National Park is a located on the western coast of Saaremaa island along the Baltic coast of Estonia. The park lies within the Saaremaa Biosphere reserve. The area is important for bird breading and bird resting place and has long been of utmost importance as a protected area of the Baltic coast.
The present project reports a land-use/land-cover satellite imagery classification and a coastal type classification of the Vilsandi National Park. The classification is based on a LANDSAT scene from May, 1993.
Field ground truth reconnaissance studies were carried out in June of 1994 and served as a basis for improved classification. Both supervised, unsupervised and manual classification, as well as semi-manual interpretation methods were used to separate 21 classes. The classification results gave the following generalised land-use/land-cover composition:
- 24 % agricultural lands and pastures
- 33 % forests
- 32 % coastal alvar, plains and wetlands
- 10 % other land-use
The results are presented in map form and statistics. The automatic coastal classification was made using a method,

develeoped at CBA. The field work made in 1994, served as a calibration for the classification. The results show that most of the coastline consists of morainic deposits with some exceptions for rocks and sand.
The project has provided the following benefits:
- A land-use/land-cover map of the national park that can be used for environmental planning inside the park monitoring of the land-use/land-cover changes
- Mapping and monitoring forests and agricultural land
The project has also contained educational items in the field of remote sensing for the Estonian environment monitoring group of EEIC and personnel at Vilsandi National Park.

17. *Topic:* Integrated Coastal Planning - Jamaica

Name: Tommy Lindell
Funding: Sida
Period: 1994--
Partners: John Norrman, Dept of Geosciences, Uppsala , Chiefs of County planning Lars-Ulrik Bergström and Örjan Molund, Chif of City Planning Kaj Wejander and the Staff of Natural Resources Conservation Authority, Kingston, Jamaica
Abstract: The initial phase of the project was concentrated on collection of basic background information, field inventories, initial training/exchange of experiences between our counterparts and ourselves and attempts to build up a network of contact persons, engaged in coastal planning and management issues. The Coastal Zone Management (GZM) branch of the Natural Resources Conservation Authority (NRCA) has the operational responsibility for the project. The project organization comprises a Steering Committee, a Reference Group, a Project Group and ourselves as advising consultants.
A number of conscious and well organized NGOs are engaged in coastal environmental issues. They have good relations to NRCA. There are some sensitive areas along the coast with already occurring environmental disturbances, risks for natural hazards but also because of an expected tourism expansion.
Training in remote sensing and GIS and mapping of coastal morphology have taken place in Uppsala and Kingston. The adjacent inventory program was been carried out for most of the coast, the rest estimated to be completed during 1997. The legislative basis for coastal planning/management is in transition. Obsolete parts of some laws are updated and some new regulations like the Local Improvement Act or the Marecultural Act are being prepared. It is also urgent to continue the training program, and a second workshop in Integrated Coastal Management and planning was held in Kingston in August of 1996.
A basic policy of the project is to aim at a harmonization between economic development and environmental considerations, with the emphasis on strengthening the legal basis as well as on implementation means and realization of plans and decisions. Up till now the assumptions and proposed suggestions in the working plan have proved to be relevant for the project. The work during this first two phases have on the whole proceeded in line with the preliminary schedule. During the last phase, we have to strengthen and intensify the network of contact persons, try to attain an effective extrovert information and establish an active public participation in the planning process.

18. *Topic:* Construction of a GIS applied for physical planning.

Name: Tommy Lindell, Tomas Brandtberg
Funding: The Swedish Council for Building Research
Period: --96
Partner: Chief City Planning Kaj Wejander
Abstract: A GIS has been constructed for physical planning activities. The system is based on MAPINFO, focusing on the localization of environment disturbing activities. Map data in digital form has been supplied by the county authority and routines for calculating different buffering zones, logical operations on the zones and specially designed output has been developed. The program has been implemented on a PC system at the office of the city architect in Söderhamn, Northern Sweden.

19. *Topic:* Satellite Remote Sensing for Lake Monitoring (SALMON)

Name: Tommy Lindell
Funding: EU
Period: 1996--
Partners: The project has the following participating partners:
- CNR-IRRS CNR-IRRS, Milano, ItalyCNR-ISDGM CNR-ISDG Venezia, Italy
- JRC-EI Joint Research Centre-Environment Institute Water Research Management
- UMI-DB Universit degli Studi, Dip.to Biologia
- HUT-LST Helsinki Technical University - Laboratory of Space Technology
- FEA-IRD Finnish Environment Agency
- UUP-CBA Centre for Image Analysis (CBA), Uppsala University
- UUP-IL Department of Limnology, Uppsala University
Abstract: Objectives
The overall objective of the project is the evaluation of the capabilities of current and forthcoming spaceborne remote

sensing for the monitoring of European lake water quality.
To this end, the following specific objectives will be targeted:
- interaction with end-users to define their needs for the monitoring of water quality (parameters, accuracy, frequency);
- evaluation of the capabilities of current instruments and methods to fill these needs;
- improvement of the processing methods for remote sensing data including calibration, atmospheric correction, and correction for solar zenith angle;
- acquisition of airborne and in-situ data during campaigns involving instruments similar to the next generation of spaceborne instruments (e.g. hyperspectral passive observation, fluorescence lidar);
- evaluation of the capabilities of these airborne instruments to fill these needs;
- definition of an optimal spaceborne sensor for the purpose of lake water quality monitoring.
The project is focused on the use of remote sensing measurements, in different regions of the electromagnetic spectrum (optical, thermal infrared, microwave), with the support of limnological observations. The combinations of these measurements will allow the development and the evaluation of techniques for remote sensing data processing.
The project is organized into five main work-packages: Introductory activities, Preliminary application of remote sensing algorithms, Synchronous remote sensing and limnological surveys, Data analysis and methodological validation and First use and dissemination of project results.
The project results and conclusions will be widely distributed. The promotion will be achieved through various communication media:
- scientific communications;
- electronic (Internet & WWW, multimedia, etc.);
- demonstrations packages designed for the local lake management agencies;
- a CD-ROM for educational purposes.ing part in the project.

20. *Topic:* Multiresolution Binary Images: Shape and Skeletons

Name: Gunilla Borgefors
Funding: SLU, CNR
Period: 9501--
Partners: Gabriella Sanniti di Baja, Giuliana Ramella; Istituto di Cibernetica, CNR, Arco Felice, Italy
Abstract: Multiresolution structures have proved very useful in image analysis. However, when the resolution of a binary image is changed, the shapes of the objects in the image is quickly seriously distorted. The reason is that "normal" averaging can not be used, as each pixel value must be either one or zero. We have developed several methods for shape preservation in binary pyramids, methods that are significant improvements of existing ones. The main approach is to implicitly or explicitly analyse large, overlapping neighbourhoods in the image to construct the lower resolution image. Skeletonization, where an object is reduced to a stick-like figure, has also been a successful approach to shape manipulation and recognition. Multiresolution skeletons can be constructed from multiresolution binary pyramids. Linking the results from different resolution levels can improve the results.

FIGURE: Standard binary pyramid, using the AND rule a), shape preserving binary pyramid b). The original image (level 0) is not shown.

21. *Topic:* Digital distance transforms

Name: Gunilla Borgefors
Funding: SLU
Period: 9309--
Abstract: This is an ongoing project where the geometry of discreet spaces is investigated. A major consideration is to measure global distances within the spaces using local operations, that is using distance transforms. Other aspects of the differences between Rn and Zn are also considered. The digital geometry in 3D is quite complex, more so than generally realised. The properties of semi-regular weighted distance transforms in 3D have been discovered and investigated. An article on 3D distance transforms was published in Computer Vision and Image Understanding, Nov. 1996. Lately, some effort has been spent on 4D problems.

22. *Topic:* Visualization of Distance Transforms in Four Dimensions

Name: Hua Guo, Gunilla Borgefors
Funding: SLU
Period: 9609-9702
Abstract: The first attempts of optimising weighted distances transforms is from 1984. However, not much has been done since, partially because visualization of the results is still a challenge. The purpose of this project is to visualize the hyper-spheres associated with different weighted distance transforms in 4D. These spheres are hyper-polyhedra with different number and shape of facets. The approach is to construct an image sequence of the 2D projections of the volume images resulting from traversing the hyper-volume with a plane.

23. *Topic:* Skeletonization of volume images

Name: Gunilla Borgefors, Ingela Nyström
Funding: TFR, SLU, UU
Period: 9501--
Partners: Gabriella Sanniti di Baja, Istituto di Cibernetica, CNR, Arco Felice, Italy
Abstract: Skeletonization (or thinning) denotes the process where objects are reduced to structures of lower dimension. Skeletonization reduces objects in 2D images to a set of planar curves and objects in volume (3D) images to a set of 3D surfaces. In volume images, skeletonization might furthermore compress the skeleton to a set of 3D curves. Unlike the surface skeletons, which are reversible, the curve skeleton would express only certain aspects of the original shape. Skeletonizing volume images is a promising approach for quantification and manipulation of volumetric shape, which is becoming more and more essential, especially in medical image analysis. We have developed a novel method for reducing a 3D object to a surface skeleton. This surface skeleton can then be reduced to a curve skeleton using another of our methods. In both cases, voxels are iteratively removed according to conditions of their local neighbourhoods. In previous papers on 3D skeletonization, the methods have mostly been exemplified using quite tiny test images, that makes it difficult to understand what the results would be in more application oriented examples. Our methods have been tested with good results on large iages.

FIGURE: The surface and curve skeletons of a pyramid.

24. *Topic:* SIMD and MIMD parallel algorithms for image analysis

Name: Anders Forsmoo, Gunilla Borgefors
Funding: NUTEK
Period: 9408-
Abstract: Images used in many practical applications contain huge amounts of data (but not necessarily much information). To be able to extract information in reasonable times, parallel architectures can be used. The purpose of this project is to develop parallel algorithms and implementations for image analysis, with a special emphasis on shape analysis, starting with distance transforms. These operations are global in the sense that information must be transferred long distances over the image. This is in sharp contrast to local filters, that are much simpler to implement in parallel. Distance transforms are used as part of many complex algorithms, such as matching of images, finding binary skeletons, path planning, and many other basic image analysis tools. The project should lead to increased understanding of the behaviour of parallel distance transforms on SIMD and MIMD architectures, which are very different and pose different problems.

25. *Topic:* The development of a general image analysis software platform

Name: Bo Nordin, Ewert Bengtsson
Funding: UU
Period: 8807--
Partners: Uppsala Bildbehandling AB, Diascan AB, Uppsala, Wallac Oy, Åbo, Finland
Abstract: In recognition of the need in image analysis research to have a good platform for interactive work with digital images we several years ago started a project with the aim of developing such a platform. This has been a very large project (about 13 man years of which CBA has put in about 4) which would have been impossible to finance by regular research money. But through a cooperation with a group of companies we have coordinated our interests of obtaining a good software platform for research with their interest in development of a new software product: a general purpose software system on which specific commercial image analysis applications easily can be implemented. The effort reached the goals of creating a platform useful both for specific applicaitons and for general purpose image analysis work called IMP. Unfortunately a change of company ownership in Wallac led to a cancellation of the marketing plans. So presently a "product" is available but no marketing organization. At CBA the IMP system is used as a software basis for most of the teaching and research in image analysis. During this year limited new developments and maintenance work has been carried out but a major revison is planned for 1997.

26. *Topic:* Inspecting the LHC superconducting cable

Name: Yueqin Sun, Ewert Bengtsson, Tobias Öhman, Joakim Lindblad
Funding: *NFR, CERN*
Period: 9603--
Partners: CERN
Abstract: In the development of the next generation elementary particle research accelerator at CERN, the Large Hydron Collider, LHC, 6000 km of superconducting cable has to be manufactured. This cable has to be "perfect" without any crossing strands or other irregularites. In order to ensure this the cable has to be inspected through computerized image analysis techniques. The CBA has been commissioned by CERN to develop such an inspection system in a three phase project. In the first phase, during the spring of 1996, a feasibility study was carried out using static images and our general image analysis platform IMP. The results were documented as a Master Thesis report by Tobias Öhman and an CBA internal report by Yueqin Sun and presented at CERN in July 1996. Based on this study a proposal for a real time inspection system was developed by Bengtsson and presented at CERN in September. This led to the second phase during which the analysis algorithms were implemented in an IVP integrated camera/parallell processor and a Pentium PC. In addition to Sun a second Master Thesis student, Joakim Lindblad carried out this work. A first working implementation became operational in the end of 1996. The analysis speed is about 2000 scanlines across the cable per second. In the third project phase the system will be equipped with a user interface for generating alarms, saving images which document the detected errors etc and installed and tested first at CERN and then at a cable manufacturing plant. This phase is expected to be completed before the summer of 1997.

5.2 Cooperation partners

The CBA has an extensive cooperation with other research groups locally as well as nationally and internationally. Our research philosophy is that good application work in image analysis requires good competence both in image analysis technology and in the specific application field. We have, and are constantly building, the highest possible expertise in image analysis within our center and are seeking the expertise in the applications through close cooperations with other researchers.

We are also trying to bring our results out from the research situation into real world use. In order to achieve this we are cooperating with several companies, local and central government agencies, and hospitals. In our list of projects above and the list of publications in the next section the names and affiliations of many of these cooperation partners can be found.

6. Publications

Our research results have been published in journals, books and conference proceedings as well as in our own report series. The list covers papers with a publication date in the range 950701-961231. As can be seen from the lists in the following sections we have published five journal articles and book chapters, nine papers in refereed international conferences, six papers in workshops and other non-refereed conferences and several reports and similar publications. CBA has its own report series, that has now been complemented with a series of internal reports.

6.1 Journals and book chapters

1. **3D Segmentation of Medical Structures by Integration of Raycasting with Anatomic Knowledge**

   Authors: T de Araujo Buck (1), HH Ehricke(1), W Strasser (1) and L Thurfjell
   1) Institut fur Informatik, University of Tubingen

   Journal: Computer & Graphics

   Volume: 19 Number: 3 Pages: 441-449 Year: 1995

   Abstract: We present a graphically interactive procedure which is used to register a digital anatomic brain atlas with the tomographic patient volume. Patient structures to be segmented are outlined by local elastic deformation of corresponding objects from the anatomy model. This is performed in voxel space using a cost minimization procedure. The anatomic knowledge acquired in this manner is stored in a patient specific volume dataset and guides a raycaster with respect to the localization of object surfaces in order to control the result of the deformation process. Thus objects, which so far could not have been segmented appropriately or only after tedious manual editing efforts, become accessible by physicians. We present several results demonstrating the high quality and practicality of the method.

2. **Classification of Compression Wood using Digital Image Analysis**

   Authors: Christer Andersson (1), Fredrik Walter
   1) Dept of Forest Products, UPPSALA

   Journal: Forest Products Journal

   Volume: 45 Number: 11/12 Pages: 87-92 Year: 1995

   Keywords: Compression Wood, Image Anlysis

   Abstract: Compression Wood causes warping in sawn wood products. In order to compare the deformations in boards sawn from logs that commonly have compression wood, a distinct classification method for compression wood must be used. Visual human detection in combination with a planimeter might be used to determine the amount of compression wood in a log cross section, but this is a subjective and very time-consuming method. This paper describes a new method that uses digital image analysis techniques. Color images of wood disks that were 2 to 3 mm thich were digitized. The computer program developed uses a supervised maximum-likelihood classification to discriminate between three kinds of wood-types in the images: normal wood, mild, and severe compression wood. The most important descriptors computed by the program are the proportions of different woo-types and the angle from the pith to the center of gravity of the two kinds of compreesion wood. The advantages of this method are that it is more objective, faster, and easier to implement than other metods. The estimations of the amount of total and mild compression wood are quite good, while those of severe compression wood are not so good. The estimation of the angle are satisfactory. The use of computer tomography and ultraviolet light might be other approaches to classify compression wood.

3. **On Digital Distance Transforms in Three Dimensions**

   Author: G. Borgefors

   Journal: Computer Vision and Image Understanding

   Volume: 64, Number: 3, Pages: 368-376, Year: 1996

   Abstract: Digital distance transforms in 3D have been considered for more than ten years. However, not all of the complexities involved have been unravelled. In this paper the complete geometry and equations for 3D transforms based on a 3x3x3 neighbourhood of local distances are given. A new type of valid distance transforms have been discovered. The optimal solutions are computed, where optimality is defined as minimising the maximum difference from the true Euclidean distance, thus making the distance transforms as direction independent as possible. The well-known (3,4,5) DT is confirmed as the most practical weighted DT, where the distance is set to 3 between neighbours sharing an area, 4 between neighbours sharing an edge, and 5 between neighbours sharing a point.

4. **Discretization - problems and solutions**

Author: Gunilla Borgefors

In: Les Houches session LVIII: Progress in Picture Processing, Eds. H. Maitre, J. Zinn-Justin, Elsevier, Amsterdam

Pages: 80 Year: 1996

Abstract: The fact that digital images are discrete representations rather than functions in the continuous plane, have profound consequences. These consequences are not primarily linked to resolution, so they can not be circumvented by using high resolution imagery. Instead they are linked to the flow of data and information within the image, when various processing algorithms are performed. The data can only jump from pixel to neighbouring pixel, like the pieces on a gaming board, and not flow freely like paint over a paper. Unwanted and unexpected distortions can easily be the result, when we try to compute global properties from local operations (and local operations is usually all we CAN perform). Various ways of digitizing an image are first discussed. As hierarchical structures are necessary tools for image analysis, the suitability of the digitizing schemes in this respect are treated next. As an example of how to compute global properties from local operations, distance transforms will be covered rather extensively. The task is to compute the distance between objects far from each other in the image, using only a small "peep-hole" (neighbourhood), and not even knowing in which direction to go. Finally, some examples of applications of distance transforms will be given.

5. **Analysing non-convex 2D and 3D patterns**

Authors: G. Borgefors and G. Sanniti di Baja (1)

1) Istituto di Cibernetica, CNR, Napoli, ITALY

Journal: Computer Vision and Image Understanding

Volume: 63 Number: 1 Pages: 145-157 Year: 1996

Abstract: A non-convex pattern can be analysed by describing its concavity regions. These can be identified by computing the difference between the convex hull of the pattern and the pattern itself. A suitable approximation of the convex hull can be obtained by repeatedly filling local concavities of the pattern. Parallel and sequential algorithms are proposed, to fill concavities of 2D and 3D patterns. The resulting approximation of the convex hull is a covering polygon or polyhedron, which is either convex or nearly convex. Exact measures of worst remaining concavities and created protrusions are given. The concavity regions are extracted and different features are presented and computed. Hierarchical pattern descriptions are also suggested, based on the use of concavity trees.

6.2 Refereed conference proceedings

1. **Finding Facial Features Using an HLS Colour Space**

Authors: Petter Ranefall, Bo Nordin, Ewert Bengtsson

Conference: 8th International Conference on Image Analysis and Processing, Sanremo, Italy

Pages: 191-196 *Year:* 1995 *Publisher:* Springer Verlag

Abstract: A method for finding facial features using information from an HLS colour space is presented. This method attempts to find the face with simple single band operations and in case of failure a more advanced method is used. Using this approach the nice photos which are the majority will be handled quickly, more difficult photos will be handled with more advanced methods and only a few images will be reported as failures.

2. **Synthesising objects and scenes using the reverse distance transformation in 2D and 3D**

Authors: I. Nyström, G. Borgefors

Conference: 8th International Conference on Image Analysis and Processing, Sanremo, Italy

Pages: 441-446 *Year:* 1995 *Publisher:* Springer Verlag

Keywords: Synthetic image, Reverse distance transform, Volume image

Abstract: The reverse distance transformation has proved useful in image syntheses. This paper discribes how digital object are created from a number of seed labels in an image. The shape of the obtained objects depends on the metric used. In 2D the Euclidean and the 3-4 metrics are mentioned, and in 3D the D^6, D^26, and the 3-4-5 metric are discussed. The proposed method has no need of expensive CAD systems. It is an excellent image synthesis tool when developing image processing algorithms, i.e. shape quantification, visualisation, scene analysis and range imaging, as the obtained objects are well-defined in the image. The method is most advantageous in 3D, as there is an increasing need for volume images, but synthesising objects in 2D can also be useful.

3. **Minimum Spanning Trees (MST) as a Tool for Describing Tissue Architecture when Grading Bladder Carcinoma**

Authors: Heung-Kook Choi, Ewert Bengtsson, Torsten Jarkrans, Janos Vasko[1], Kenneth Wester[1], Per-Uno Malmström[2], Crister Busch[1]

[1)]Dep of Pathology and [3)]Urology, Uppsala University Hospital

Conference: 8th International Conference on Image Analysis and Processing, Sanremo, Italy

Pages: 615-620 *Year:* 1995 *Publisher:* Springer Verlag

Abstract: In this pilot study we have investigated the possible use of minimum spanning trees, MST,as a way of quantitatively describing the tissue architecture when developing a computer program for malignacy grading of transitional cell bladder carcinoma. The MST was created by connecting the centre points of the nuclei in the tissue section image. These nuclei were found be thresholding the image at an automatically determined threshold followed by a connected component labeling and a watershed algorithm for separation of overlapping nuclei. Clusters were defined in the MST by thresholding the edge lengths. For these clusters geometric and densiometric features were measures. These features were compared by multivariate statistical methods to the subjective grading by the pathologist and the resulting correspondence was 85 % on a material of 40 samples.

4. Mapping the Cellular Contents of Pap-Smears

Authors: Ewert Bengtsson, Bo Nordin, Peter Gombrich[1)], Richard Domanik[1)]

[1)]AccuMed International, Chicago, USA

Conference: Fourth International Conference on the Computerized Cytology and Histolog Laboratory

Year: 1996

Keywords: cell analysis, screening, segmentation, exoskeletons

Abstract: Most approaches to the automated or computer assisted analysis of cervical cytology specimens have concentrated on free- lying cells either by preparing mono-layers or by ignoring large clusters and clumps in the analysis of the conventional smears. It is, however, well known that a significant proportion of the cells are located in clumps and clusters and ignoring these may lead to missed positives. We have therefore studied this problem and developed algorithms that can segment clumps and clusters into cell nuclei and cytoplasms. The algorithms use non-linear greyscale processing and mathematical morphology operations on images aquired at selected illumination wavelengths. Based on the segmentation results the size and cellular contents of the clumps can be quantitatively described and used as part of the specimen analysis strategy. The algorithms will also detect areas so dense that they can not be penetrated by light and thus not analyzed at all. This information is used in a new concept for supporting the cytology laboratory under development at AccuMed International. In the Model 3001M Specimen Mapping Station the specimen is automatically scanned and a 3D route map showing the location of all relevant cellular material is created. This map is then used by the screening microscopes to optimize the path used for visually screening the specimens, including keeping the specimen in focus. Since on the average 30-60% of the specimen consists of white space, opaque areas or other irrelevant objects this provides a significant time saving. The route map can be used in basic screening microscope with motorized stage and focus (Model 2000/2001) where it ensures that all cellular material is assessed and viewed in an efficient way. It may also be used in an image processing enhanced screening microscope (Model 3000/3001E) where the fields to be analyzed are brought into focus, captured, normalized with relation to illumination intensity and color and displayed. The mapper can also use the information obtained in the prescreening phase for determining specimen adequacy and, if desired, sort inadequate or particularly difficult specimens into a separate work-stream. Another possibility is to give high or low priority to certain types of material. Areas mainly occupied by blood-cells can for instance be put into a separate part of the routemap.

5. Multiresolution Representation of Shape in Binary Images

Authors: G. Borgefors, G. Ramella[1)], G. Sanniti di Baja[1)]

[1)]Istituto di Cibernetica CNR, Arco Felice (Napoli), Italy

Conference: 6th Int. Workshop on Discrete Geometry for Computer Imagery, Lyon, France

Pages: 51-58 Year: 1996

Publisher: Lecture Notes in Computer Science 1176, Springer Verlag

Keywords: Binary pyramid, multiresolution representation, shape preservation

Abstract: Binary pyramids can be used for multiresolution pattern representation. The two "standard" pyramids schemes, OR- and AND-pyramids, have, however, serious drawbacks, as they distort the shape significantly. In OR-pyramids black pixels spread all over the array due to expansion and merging of close regions. The shape of the original pattern is rapidly blurred. In AND-pyramids narrow regions of the initial pattern may either completely vanish or become disconnected. In both cases, the shape of the pattern is not preserved. Here alternative approaches, aimed at improving shape and topology preservation in binary pyramids, are presented. The first approach combines the OR and AND rules, whereas the second approach uses grey-level images as an intermediate step. The algorithms are easy to implement and produce significantly better results than the ones obtained by OR/AND pyramids.

6. Detection of agricultural fields in satellite images

Authors: Anna Pettersson, Fredrik Walter, Dmitry Lagunowski[1)]

[1)]Institute of Engineering Cybernetics, Minsk, BELARUS

Conference: 96:4 Remote sensing in agriculture, NJF Seminar, Jokioinen, Finland

Pages: 63-67 Year: 1996

Publisher: Reports of the Finnish geodetic institute

Keywords: Remote sensing, agriculture, satellite, image analysis, crop, methodology, field detection

Abstract: This study describes a new automatic field extraction algorithm which integrates edge detection, i.e. detec-

tion of spectral changes, and region growing, i.e. clustering of homogeneous areas. Even though some problems remains to be solved, these initial results are promising.

7. Multiresolution Skeletonization in Binary Pyramid

Authors: G. Borgefors, G. Sanniti di Baja[1)]
[1)]Istituto di Cibernetica CNR, Arco Felice (Napoli), Italy
Conference: 13th Int. Conf. on Pattern Recognition (13ICPR), Vienna, Austria
Pages: 570-574 *Year:* 1996
Keywords: Shape analysis, Binary image
Abstract: A multiresolution skeletonization algorithm is presented. The underlying data structure is a binary AND-pyramid. Notwithstanding the fact that the AND-pyramid is likely to break pattern connectedness at lower resolution levels, the algorithm generates connected skeletons at all resolution levels. It can most conveniently be implemented on a parallel SIMD architecture, but efficient MIMD and sequential implementations are also possible. A hierarchy among skeleton branches at various resolutions levels is also introduced.

8. Surface Skeletonization of Volume Objects

Authors: Gunilla Borgefors, Ingela Nyström and Gabriella Sanniti di Baja[1)]
[1)]Istituto di Cibernetica, National Research Council of Italy, Arco Felice (Napoli), Italy
Conference: International Workshop on Structural and Syntactical Pattern Recognition (SSPR'96), Leipzig, Germany
Pages: 251-259 *Year:* 1996 *Publisher:* Springer-Verlag
Abstract: Tools for quantitative analysis of volume images are becoming more important, as volume images are becoming more common in a number of application fields, but especially in biomedical tomographic images at different scales. Here we present a method for reducing a volume (3D) object to a surface skeleton. The original object can be recovered from its skeleton. The method is based on the notion of "multiple voxels," derived from that of "multiple pixels" in the 2D case. It consists of two phases. During the first phase non-multiple voxels are iteratively removed. During the second phase, the remaining set of voxels is thinned to a set of one-voxel thick surfaces and curves. This skeletonization method requires only a small number of local (3x3x3 neighbourhood) operations per voxel, no extra memory and no look-up tables. It is suited both for sequential and parallel implementation. We exemplify the results of the method on a number of 128x128x128 images.

9. Shape Preserving Binary Pyramids

Authors: G. Borgefors, G. Sanniti di Baja[1)]
[1)]Istituto di Cibernetica CNR, Arco Felice (Napoli), Italy
Conference: Portoguese Conference on Pattern Recognition (RECPAD'96), Guimares, Portugal
Pages: 197-203 *Year:* 1996
Keywords: Shape analysis, Binary image
Abstract: Two approaches aimed at improving shape and topology preservation in binary pyramids are presented. Both are easy to implement and produce significantly better results than the ones obtained by standard OR/AND pyramids.

6.3 Non-refereed conferences and workshops

1. Comparison of two texture based methods for cell nucleus segmentation

Authors: Heung-Kook Choi, Ewert Bengtsson
Conference: Symposium on Image Analysis (SSAB '96), Lund
Pages: 86-90 Year: 1996 *Publisher:* SSAB
Keywords: Segmentation, alinear discriminant,a backpropagation neural network,textural features.
Abstract: In this paper we described two cell nucleus segmentation algorithms - a multivariate linear discriminant algorithm and a backpropagation neural network algorithm. Textural features of 3 X 3 masks on the graytone images from Feulgen stained histological tissue sections were calculated. Using a step-wise linear discriminant analysis, we selected the seven most significant features for the classifier. In the multilayer backpropagation neural networks, we used 28 texture features to the input layer, 20 nodes in hidden layers and 2 nodes in the output layer. The results indicates that these methods are comparable in their performance for our material.

2. Radiometric Calibration of CARABAS Radar Images over Forested Areas

Authors: Fredrik Walter
Conference: Symposium on Image Analysis (SSAB '96), Lund
Pages: 111-114 Year: 1996 *Publisher:* SSAB
Keywords: CARABAS, SAR, forest inventory, radiometric clibration
Abstract: CARABAS is a newly developed airborne imaging synthetic aperture radar. It differs a lot from earlier microwave radar systems, by using wavelengths of 3-15 meters. There is a strong correlation between above-ground biomass and the reflected electro-magnetic waves. The incidence angle of the radar varies a lot over the scene, which

leads to different backscattering properties for the objects on the ground. Thus, in order to make estimations of biomass from the CARABAS images possible, the images have to be radiometrically corrected. Five forest stands of approximately the same volume content were chosen in the investigated forested area. The backscattering from these stands were compared to the distance from the sensor. A linear regression equation was developed from that material and was used to calibrate the other pixels in the image.

3. **Automated tree species classification in high resolution aerial images using a Hough transform technique**

Author: Tomas Brandtberg
Address: Centre for Image Analysis Lägerhyddvagen 17 752 37 Uppsala
Conference: Symposium on Image Analysis (SSAB '96), Lund
Pages: 115-119 Year: 1996 *Publisher:* SSAB
Keywords: pattern recognition, spruce, remote sensing, aerial image, image analysis
Abstract: An automated image analysis method for tree species classification in digital high resolution aerial images is presented here. The algorithm is based on the structure of the internal pattern (also called texture) of individual tree crowns. The infrared layer of colour infrared aerial images is used and the different crown patterns are brought out by using the second order Laplace transform. Skeletonization is used as a technique for data compression and to enhance features to be used in the subsequent analysis. The resulting skeleton branches are one pixel thick but still contains the structural pattern that was identified by the Laplace transform. The skeleton is split into simple segments, with no branches. The direction of each individual segment in a tree crown is calculated and a simple Hough transform technique is used for analysing whether they collectively have a parallel or radial structural behaviour. We can clearly discriminate between Picea abies, with a typical radial pattern, and Pinus sylvestris and Betula sp., often dominated by parallel structures. The pine has, in our images, a more clearly parallel pattern, which is probaby caused by a combination of the inclination angle of the sunlight and a slight camera motion during exposure.

4. **Finding "Brush Strokes" and "Spots" in Practice: Fibroblasts and Collagen**

Authors: Petter Ranefall, Morgan Gustafsson [1)], Gunilla Borgefors, Ewert Bengtsson
[1)]Medical Bio Care Sweden AB, Gothenburg
Conference: Symposium on Image Analysis (SSAB '96), Lund
Pages: 134-138 Year: 1996 *Publisher:* SSAB
Abstract: In this article we describe a method for segmenting colour images produced with uncontrolled illumination conditions and containing diffuse objects resembling brush strokes. The method is fully automatic and based on a laplace transform of the hue image. We also present a method to find spots in the image. A practical application for these methods is to segment a cell culture into fibroblasts, collagen and background.

5. **Prostate needle biopsy visualisation**

Authors: Hans Frimmel
Conference: Symposium on Image Analysis (SSAB '96), Lund
Pages: 11-13 Year: 1996 *Publisher:* SSAB
Keywords: prostate, cancer, biopsy, 3D, visualise
Abstract: Prostate cancer is for men the most common form of cancer. It is therefore important to develop reliable ways of diagnosing prostate cancer. Today the final checking whether cancer is present or not is done by inserting long thin needles which takes biopsies. The topic for this paper is how these needles should be placed. Today it is the choice of the doctor alone, which makes it rely heavily on his/her own experience. Ultrasound images normally guides the doctor and the 3D feeling is very poor. It would help a lot if there was a protocol which tells where in the prostate to put the needles to gain most information. In this paper we describe a project which is trying to find such a protocol by using the doctors experience in conjunction with 3D computer models of prostates.

6. **3D reconstruction os insects' ganglion**

Authors: Roger Hult
Conference: Symposium on Image Analysis (SSAB '96), Lund
Pages: 91-95 Year: 1996 *Publisher:* SSAB
Abstract: The purpose of this paper is to reconstruct insect's ganglion from consecutive slices made by a microtome. The main difficulty when reconstructing the 3D structure from this type of data is that the slices need to be aligned. In this paper two methods for alignment are discussed, besides manual alignment. The two methods are; "Hierarchical Chamfer Matching Algorithm" and an "intensity based correlation technique". HCMA creates a distance image using information from the edges, then tries to minimise the sum of the values in the distance map that the contour hit. Grey-match uses grey-level intensities and tries to maximise the correlation between adjacent slices by altering translation in x- and y-direction and rotation about the z-axis. To improve sensitivity and processing speed only points with high gradient values are used for the matching. Because of the nature of biological data, both of the algorithms have their difficulties in some cases. What is considered to be a good matching is rather subjective, although a bad correlation value gives a hint if the matching is extremely bad.

6.4 Other Publications

1. **Användning av GIS för planeringsändamål i Söderhamns kommun**
   Authors: T. Brandtberg, T. Lindell, K. Wejander
   Publisher: Centre for image analysis Rapport 19
   Pages: 27 *Year:* 1995

2. **Annual Report 1994/95**
   Author: Lennart Thurfjell, Ewert Bengtsson
   Publisher: Centre for image analysis
   Pages: 49 *Year:* 1995

3. **Förslag till datastruktur för fiberanalys**
   Author: D. Wedjesjö
   Publisher: Centre for image analysis Rapport 20
   Pages: 25 *Year:* 1995

4. **Detection of agricultural fields in remote sensed images**
   Author: D. Lagunovsky
   Publisher: Centre for image analysis Rapport 21
   Pages: 15 *Year:* 1996

5. **A Survey of the chamfer matching algorithm**
   Author: Gunilla Borgefors
   Year: 1996

6. **Land Surveyors Background Coursework**
   Author: Vidmantas Gurklys
   Year: 1996

7. **An image analysis system for inspecting the LHC superconducting cable**
   Author: Sun Yuenqin
   Year: 1996

7. Activities

Computerized image analysis is a technology which is finding increased application in many fields. A consequence of this is an increasing interest in our work from the surrounding society. We are trying to meet this interest by preparing workshops and seminars, receiving visitors, making visits, giving presentations, participating in conferences, etc. In the following sections we have tried to list these activities for the year 1995/96. These lists do not cover all the informal contacts through which we have informed about our field of work. We have also left out all meetings within ongoing research projects and all lectures we have given or attended as part of the regular educational activities of CBA. Still the lists become quite extensive.

We have organized six seminars with invited guests in addition to the 45 internal seminars held at CBA. We have also actively participated in 21 other seminars. We have given two invited and 13 other presentations at conferences as well as presented six posters and attended another 23 conferences without making presentations. One researcher has spent an extended period as visiting researcher abroad at two occasions and we have had two longer term visitors at the CBA. We have made 38 visits to other research groups and we have received a large number of visitors at CBA at 37 different occasions. Finally we have listed 21 international and 18 national committees and similar duties in which we have served.

7.1 Seminars held outside CBA

1. *Name:* **Ewert Bengtsson**
   Date: 950821
   Address: Department of Toxicology, Uppsala University
   Title: Computerized image analysis in toxicology Comment: Invited lecture in Nordic summer school on toxicology

2. *Name:* **Petter Ranefall**
   Date: 951019
   Address: Uppsala University hospital
   Title: Segmentation of stained cells - Image analysis as a tool for pathologists
   Comment: A seminar for a small group of researchers, followed by a discussion about their possible use of image analysis in their research.

3. *Name:* **Tommy Lindell**
   Date: 951023
   Address: Terracom, Uppsala
   Title: Course in Differential GPS

4. *Name:* **Ewert Bengtsson**
   Date: 951110
   Address: Department of Technology, UU
   Title: Overview of computerized image analysis Comment: Two hour lecture for last year students of material science program

5. *Name:* **Gunilla Borgefors**
   Date: 951123
   Address: SLU, Garpenberg
   Title: Digital Image Analysis
   Comment: Within the Nordic postgraduate course in Robotics with application to forestry operations

6. *Name:* **Gunilla Borgefors**
   Date: 951128
   Address: Dept. of Physical Geography, Stockholm University
   Title: Research at the Centre for Image Analysis

7. ***Name:*** **Gunilla Borgefors**
   Date: 951207
   Address: Faculty of Physics, Delft University of Technology, The Netherlands
   Title: The strange behaviour of seemingly innocent distance transforms in 3D

8. ***Name:*** **Gunilla Borgefors**
   Date: 960110
   Address: CBD, Högskolan i Halmstad
   Title: Ongoing research at CBA

9. ***Name:*** **Ewert Bengtsson**
   Date: 960126
   Address: Department of Zoology, UU
   Title: Computerized image analysis
   Comment: Introductory lecture as part of a graduate course i zoology

10. ***Name:*** **Gunilla Borgefors**
    Date: 960216
    Address: Swedish Pulp and Paper Research Institute, Stockholm
    Title: Generating, Analysing and visualising volume images

11. ***Name:*** **Tommy Lindell**
    Date: 960315
    Address: Geosciences, UU
    Title: A survey of complicating factors in the analysis of satellite imagery

12. ***Name:*** **Ewert Bengtsson**
    Date: 960402
    Address: Teknikum, UU
    Title: Computerized Image Analysis
    Comment: Two hour introductory lecture for undergraduate students

13. ***Name:*** **Gunilla Borgefors**
    Date: 960515
    Address: Dept. of Food Science, Swedish University of Agricultural Sciences, Ultuna, Uppsala
    Title: Image anlysis for quantitative measurements of food quality
    Comment: Starting point for cooperation in the Food 21 MISTRA application

14. ***Name:*** **Ewert Bengtsson, Fredrik Walter**
    Date: 960819-21
    Address: Jukkasjärvi
    Title: Presentation of our research plans during the MISTRA program RESE planning conference
    Comment: Fredrik made the presentation, Ewert was supporter

15. ***Name:*** **Petter Ranefall**
    Date: 960928
    Address: Friiberghs Herrgård, Örsundsbro
    Title: Helautomatisk kvantifiering av infärgade celler
    Comment: This seminar was a part of a two-day meeting about prostate cancer and bladder cancer organized by the Department of Pathology, Uppsala University. The seminar was held in swedish.

16. ***Name:*** **Ewert Bengtsson**
    Date: 961007-08
    Address: Haga Conference Castle
    Title: Faculty Board Planning conference
    Comment: Attendee as member of the board.

17. ***Name:*** **Lennart Thurfjell**
    Date: 961010
    Address: Västerås Sjukhus
    Title: Brain atlas for SPECT
    Comment: The presentation was held at a national user group meeting for GE SPECT users sponsored by General Electric

18. ***Name:*** **Ewert Bengtsson**
    Date: 961104
    Address: Teknikum, UU

Title: Computerized Image Analysis
Comment: Two hour introductory lecture for undergraduate students

19. ***Name:*** **Ewert Bengtsson**
Date: 961108
Address: Main hall (Aula) at MIC, Uppsala
Title: Mathematics Education
Comment: Workshop as part of the strategic planning of the division chaired by EWB organized mainly by Christer Kiselman

20. ***Name:*** **Ewert Bengtsson**
Date: 961120-21
Address: Sätra Brunn Conference Center
Title: Appointment Committee Conference
Comment: Attended a two day conference for members of "tjänsteförslagsnämnder" at UU faculty of science and technology

21. ***Name:*** **Gunilla Borgefors**
Date: 961122
Address: Faculty of Medicine, Uppsala University
Title: Presentation of CBA, especially our medical imagery applications

7.2 Seminars at CBA with invited guest lecturers

1. ***Name:*** **Dr. Tomas Gustavsson**
Date: 951116
Address: CTH, Gothenburg
Title: Medical Image Analysis in Gothenburg - Present and future activities

2. ***Name:*** **Dr. Björn Kruse**
Date: 951212
Address: Dept. Electrical Engineering, Linköping University
Title: A Nonlinear Model for Reflexion of Images on Translucent Media (e.g. Paper)

3. ***Name:*** **Thomas Persson**
Date: 960424
Address: Systems and Control Group, Uppsala Univeristy
Title: Use of Digital Image Analysis for Walk Analysis

4. ***Name:*** **Dr. Tony Lindeberg**
Date: 960522
Address: Computational Vision and Active Perception Laboratory, KTH, Stockholm
Title: Feature Detection with Automatic Scale Selection

5. ***Name:*** **Prof. Mats Nylinder et al.**
Date: 961018
Address: Dept. of Forest Products, SLU, Uppsala
Title: Three image analysis related projects at the Dept. of Forest Products

6. ***Name:*** **Dr. Tim Poston**
Date: 961118
Address: Inst. of Systems Science, National University of Singapore, Singapore
Title: Dextrous Virtual Work

7.3 Seminars at CBA

These seminars were almost all held in Swedish

1. ***Name:*** **Martin Potappel**
Date: 950821
Title: Clumps and cluster analyzing in PAP-smears
Date: 950828
Title: Prostate visualization

2. *Name:* **Hans Frimmel**
   Date: 950828
   Title: Prostate visualization

3. *Name:* **Ingela Nyström, Petter Ranefall**
   Date: 950904
   Title: Pre-ICIAP Poster Session

4. *Name:* **Olle Eriksson**
   Date: 950911
   Title: News in our computer system

5. *Name:* **Ewert Bengtsson**
   Date: 950918
   Title: How to find cancer cells

6. *Name:* **Torsten Jarkrans**
   Date: 950925
   Title: The elements of cancer

7. *Name:* **Catherine Östlund**
   Date: 951002
   Title: Noise removal in IS images

8. *Name:* **Heung-Kook Choi, Petter Ranefall**
   Date: 951009
   Title: The Sanremo Conference (8th ICIAP)

9. *Name:* **Daniel Wedjesjö**
   Date: 951016
   Title: A data structure for wood fibres

10. *Name:* **Tomas Brandtberg**
    Date: 951023
    Title: Automated analysis of forest using high resolution digital images

11. *Name:* **Gunilla Borgefors**
    Date: 951030
    Title: Shape preserving binary pyramids

12. *Name:* **Lennart Thurfjell**
    Date: 951113
    Title: Automatic inter-individual registration

13. *Name:* **Roger Hult**
    Date: 951120
    Title: 3D reconstruction of insect ganglia

14. *Name:* **Tommy Lindell**
    Date: 951204
    Title: The Jamaican Project. Progress report

15. **Name: Bo Nordin**
    Date: 960108
    Title: IMP

16. *Name:* **Pette Ranefall**
    Date: 960115
    Title: Cosmetic colour analysis

17. *Name:* **Fredrik Walter**
    Date: 960122
    Title: Make your own CD

18. *Name:* **Torsten Jarkrans**
    Date: 960129
    Title: Separation of overlapping objects

19. *Name:* **Anna Svärd**
    Date: 960212
    Title: Development of a windows based system for evaluation of mottle in full tone printed paper surfaces.

20. *Name:* **Heung-Kook Choi**
    Date: 960226
    Title: Hough transform

21. *Name:* **Ewert Bengtsson**
    Date: 960304
    Title: Interactive cell analysis

22. *Name:* **Hans Frimmel, Fredrik Walter**
    Date: 960311
    Title: "Music video"

23. *Name:* **Tomas Brantberg**
    Date: 960318
    Title: Fuzzy systems

24. *Name:* **Anna Pettersson**
    Date: 960325
    Title: The project at Skogforsk

25. *Name:* **Anders Forsmoo**
    Date: 960401
    Title: Evaluation of distance transforms on a SIMD-computer

26. *Name:* **Roger Hult**
    Date: 960415
    Title: aspects on 3D visualization

27. *Name:* **Olle Eriksson**
    Date: 960429
    Title: System news

28. *Name:* **Tommy Lindell**
    Date: 960506
    Title: *The* EU projects

29. *Name:* **Finn Pedersen**
    Date: 960513
    Title: Simulation of an X-ray detector

30. *Name:* **Gunilla Borgefors**
    Date: 960520
    Title: On distance transforms in 4D

31. *Name:* **Hans Frimmel**
    Date: 960603
    Title: Scale space

32. *Name:* **Petter Ranefall**
    Date: 960902
    Title: Mixtures of Normal Distributions

33. *Name:* **Kenneth**
    Date: 960909
    Title: Extraction of discriminative information
    from clumps and clusters of cells in standard PAP-smears

34. *Name:* **Heung-Kook Choi**
    Date: 960916
    Title: General discussion of Choi's thesis

35. *Name:* **Ingela Nyström**
    Date: 960923
    Title: Surface Skeletonization of Volume Objects (SSPR Leipzig)

36. *Name:* **Thomas Holm**
    Date: 960930
    Title: Target Detection in IR Video

37. *Name:* **Fredrik Lingvall**
    Date: 960710
    Title: Detection of Samll Airborne Targets in Visual & Infrared Images

38. *Name:* **Fredrik Walter**
    Date: 961014
    Title: Intel MMX

39. *Name:* **Torsten Jarkrans**
    Date: 961021
    Title: Repetition before dissertation

40. *Name:* **Catherine Östlund**
    Date: 961028
    Title: May the chromaticity technique improve IS images?

41. *Name:* **Roger Hult**
    Date: 961111
    Title: Implemenation of a surface tracking algorithm

42. *Name:* **Mattias Moëll**
    Date: 961202
    Title: Fiber Morphology

43. *Name:* **Fredrik Walter**
    Date: 961206
    Title: Animation in Computer Graphics
    Comment: Seminar at the Computer Graphics course

44. *Name:* **Hans Frimmel**
    Date: 961209
    Title: Prostata Transforms

45. *Name:* **Tomas Brandtberg**
    Date: 961216
    Title: Automatic delineation of individual tree crowns in high spatial resolution aerial images

7.4 Conference participation

Invited speakers

1. *Name:* **Fredrik Walter**
   Date: 960328
   Conference: Map Days 96, Norrköping
   Title: Biomass estimation using CARABAS radar images
   Comment: In Swedish.

2. *Name:* **Tomas Brandtberg**
   Date: 960328
   Conference: Map Days 96, Norrköping
   Title: Automated analysis of forest using high resolution CIR aerial images

Oral presentations

1. *Name:* **Roger Hult**
   Conference: Symposium on image analysis, SSAB 96
   Date: 960307-960308
   Address: Lund
   Title: 3D reconstruction of insects' ganglion

2. ***Name:*** **Hans Frimmel**
   Conference: Symposium on image analysis, SSAB 96
   Date: 960307-960308
   Address: Lund
   Title: Prostate needle biopsy visualization

3. **Name: Petter Ranefall**
   Conference: Symposium on image analysis, SSAB 96
   Date: 960307-960308
   Address: Lund
   Title: Finding "Brush Strokes" and "Spots" in Practice: Fibroblasts and Collagen

4. ***Name:*** **Tomas Brandtberg**
   Conference: Symposium on image analysis, SSAB 96
   Date: 960307-960308
   Address: Lund
   Title: Automated tree species classification in high resolution aerial images using a Hough transform technique

5. ***Name:*** **Fredrik Walter**
   Conference: Symposium on image analysis, SSAB 96
   Date: 960307-960308
   Address: Lund
   Title: Radiometric Calibration of CARABAS Radar Images Over Forested Areas

6. ***Name:*** **Heung-Kook Choi**
   Conference: Symposium on image analysis, SSAB 96
   Date: 960307-960308
   Address: Lund
   Title: Comparison of two texture based methods for cell nucleus segmentation.

7. ***Name:*** **Ewert Bengtsson**
   Conference: Fourth International Conference on the Computerized Cytology and Histology Laboratory
   Date: 960317-20
   Address: Drake Hotel, Chicago, USA
   Title: Mapping the Cellular Contents of PAP-Smears

8. ***Name:*** **Tommy Lindell**
   Conference: EMAC
   Date: 960407-08
   Address: ESA, Paris, France
   Title: Conference on Preliminary results of the ESA Campaign with the ROSIS Sensor

9. ***Name:*** **Lennart Thurfjell**
   Conference: NUTEK program conference 1996 in medical technology
   Date: 960418-19
   Address: Industrihuset, Stockholm
   Title: A brainatlas as a diagnostic tool in nuclear medicine

10. ***Name:*** **Ingela Nyström**
    Conference: International Workshop on Structural and Syntactical Pattern Recognition (SSPR'96)
    Date: 960819-960823
    Address: Leipzig, Germany
    Title: Surface Skeletonization of Volume Objects

11. ***Name:*** **Tomas Brandtberg**
    Conference: Tekniska Mässan 96
    Date: 961019
    Address: Stockholmsmässan, Älvsjö, Sweden.
    Title: Remote sensing in forestry

12. ***Name:*** **Anna Pettersson**
    Conference: Remote sensing in agriculture
    Date: 961021-961023
    Address: Finnish Agricultural Research Centre, Jokioinen, Finland
    Title: Detection of agricultural fields in satellite images

13. ***Name:*** **Gunilla Borgefors**
Conference: 6th Int. Workshop on Discrete Geometry for Computer Imagery (6DGCI)
Date: 961113-961115
Address: Lyon, France
Title: Multiresolution Representation of Shape in Binary Images

Poster presentations

1. ***Name:*** **Ewert Bengtsson**
Conference: Fourth International Conference on the Computerized Cytology and Histology Laboratory
Date: 960317-20
Address: Drake Hotel, Chicago, USA
Title: Mapping the Cellular Contents of PAP-Smears

2. ***Name:*** **Petter Ranefall**
Conference: 8th International Conference on Image Analysis and Processing
Date: 950913-950915
Address: Sanremo, Italy
Title: Finding Facial Features Using an HLS Colour Space

3. ***Name:*** **Heung-Kook Choi**
Conference: 8th International Conference on Image Analysis and Processing
Date: 950913-950915
Address: Sanremo, Italy
Title: Minimum Spanning Trees (MST) as a Tool for Describing Tissue Architecture when Grading Bladder Carcinoma

4. ***Name:*** **Ingela Nyström, Gunilla Borgefors**
Conference: 8th International Conference on Image Analysis and Processing
Date: 950913-950915
Address: Sanremo, Italy
Title: Synthesising Objects and Scenes Using the Reverse Distance Transformation in 2D and 3D

5. ***Name:*** **Tomas Brandtberg**
Conference: Tekniska Massan 96
Date: 961015-961019
Address: Stockholmsmassan, Älvsjö, Sweden.
Title: Remote sensing in forestry

6. ***Name:*** **Gunilla Borgefors**
Conference: 13th Int. Conf. on Pattern Recognition (ICPR'96)
Date: 960825-960829
Address: Vienna, Austria
Title: Multiresolution Skeletonization in Binary Pyramid

Attendee

1. ***Name:*** **Gunilla Borgefors, Petter Ranefall, Heung-Kook Choi**
Conference: 8th International Conference on Image Analysis and Processing
Date: 950913-950915
Address: San Remo, Italy

2. ***Name:*** **Ewert Bengtsson, Gunilla Borgefors**
Conference: NUTEK parallell computing conference
Date: 950928-29
Address: MIC, Uppsala

3. ***Name:*** **Ewert Bengtsson**
Conference: Nutek program conference for computations using super and parallel computers
Date: 950928-950929
Address: Uppsala

4. ***Name:*** **Gunilla Borgefors**
Conference: Garpenberg Conference 1995: Robotics i Forestry
Date: 951121

Address: SLU, Garpenberg

5. ***Name:*** **Fredrik Walter, Gunilla Borgefors**
   Conference: Workshop on low frequency SAR and forestry applications
   Date: 951201
   Address: FOA, Linköping

6. ***Name:*** **Ewert Bengtsson**
   Conference: TDB96
   Date: 960204-06
   Address: Aronsborg, Bålsta
   Comment: Participation in the biannual staff conference of the Department of Scientific Computing

7. ***Name:*** **Anders Forsmoo**
   Conference: Nordic Europort Conference
   Date: 960229
   Address: KTH, Stockholm

8. ***Name:*** **Ewert Bengtsson, Heung-Kook Choi, Gunilla Borgefors, Thomas Brandberg, Anders Forsmoo, Hans Frimmel, Roger Hult, Anna Pettersson, Petter Ranefall, Fredrik Walter**
   Conference: Symposium on image analysis, SSAB 96
   Date: 960307-960308
   Address: Lund

9. ***Name:*** **Gunilla Borgefors**
   Conference: Portoguese Conference on Pattern Recognition (RECPAD'96)
   Date: 960321-960322
   Address: Guimaraes, Portugal

10. ***Name:*** **Anders Forsmoo**
    Conference: Pedagogisk introduktion UU vt1996
    Date: 960326
    Address: Uppsala Universitet

11. ***Name:*** **Tommy Lindell**
    Conference: Teaching in Geosciences
    Date: 960413-14
    Address: Eklundshof

12. ***Name:*** **Ewert Bengtsson, Lennart Thurfjell**
    Conference: NUTEK program conference 1996 in medical technology
    Date: 960417-940419
    Address: Stockholm

13. ***Name:*** **Anders Forsmoo, Hans Frimmel**
    Conference: Conference on Classical Scale Space
    Date: 960510-960513
    Address: DIKU Copenhagen Denmark

14. ***Name:*** **Roger Hult**
    Conference: Analyze Training Course
    Date: 960523-960524
    Address: Europa Hotel, Gatwick, London

15. ***Name:*** **Roger Hult**
    Conference: Ämneslärarkonferens i numerisk analys och datalogi 1996
    Date: 960612-960614
    Address: Lund, Ven

16. ***Name:*** **Gunilla Borgefors, Ingela Nyström**
    Conference: Int. Workshop on Structural and Syntactical Pattern Recognition
    Date: 960820-960823
    Address: Leipzig, Germany

17. ***Name:*** **Ingela Nyström, Gunilla Borgefors**
    Conference: 13th International Conference on Pattern Recognition (ICPR'96)
    Date: 960825-960829
    Address: Vienna, Austria

18. *Name:* **Ewert Bengtsson, Roger Hult, Lennart Thurfjell**
Conference: VBC'96 Visualization in Biomedical Computing
Date: 960922-960925
Address: University of Hamburg, Hamburg, Germany

19. *Name:* **Mattias Moëll, Gunilla Borgefors**
Conference: Workshop Skokloster, The interface forest - industry, Graduate school: Wood and wood fiber
Date: 960923-25
Address: Skokloster

20. *Name:* **Mattias Moëll**
Conference: European Conference on Pulp and Paper Research - the present and the future
Date: 961010
Address: Foresta Hotel & Conference Lidingö

21. *Name:* **Jakob Nisell, Anna Pettersson**
Conference: Remote Sensing in Agricultural Sciences
Date: 961021-23
Address: Jokioinen, Finland

22. *Name:* **Anders Forsmoo, Roger Hult**
Conference: SIGRAD 96
Date: 961209
Address: Nacka Forum, Stockholm

23. *Name:* **Anders Forsmoo**
Conference: Software for Parallel Computing
Date: 961216-17
Address: Parallelldatorcentrum, PDC, KTH, Stockholm

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

1. *Name:* **Tommy Lindell**
Host: NRCA
Address: Kingston Jamaica
Date: 951113-951202
Topic: Coastal Planning
Comment: Workshop in Coastal Management and Planning. Preparations for field work

2. *Name:* **Tommy Lindell**
Host: NRCA
Address: Kingston Jamaica
Date: 960122-960217
Topic: Coastal Planning
Comment: Field work on submarine conditions along the coast of Jamaica

7.6 Shorter visits to other research groups

1. *Name:* **Tomas Brandtberg**
Host: SCA Skog AB
Address: Approximately at Stöde, 40 km west of Sundsvall
Date: 950713
Topic: A brief control of the test area and its quality, especially the state of the forest.
Comment: Field inventory is planned for the spring 1996.

2. *Name:* **Tommy Lindell**
Host: European Commission
Address: Bridgetown, Barbados
Date: 950802-950804
Topic: Discussions on a proposed project to map Anguillan sand resources

3. ***Name:*** **Tommy Lindell**
   Host: NRCA
   Address: Kingston, Jamaica
   Date: 950804-950817
   Topic: Work on coastal plan of Jamaica

4. ***Name:*** **Tommy Lindell**
   Host: Dr Eugenio Zilioli
   Address: CNR, Milano, Italy
   Date: 950823-950624
   Topic: Work on proposal to EU on Monitoring of lake water quality

5. ***Name:*** **Ewert Bengtsson**
   Host: Medisan Pharmaceuticals AB Jan Vincent
   Address: AR 4, 74174 Uppsala
   Date: 950908
   Topic: Discussion of possible cooperation on wound image data communication for remote computer analysis

6. ***Name:*** **Catherine Östlund**
   Host: Sam Ekstrand
   Address: IVL Hälsingegatan 43 Stockholm
   Date: 950912
   Topic: Discussions about project proposal for MISTRA. (Preliminary project name: Methods for Detection of Changes in Aquatic Ecosystems and Monitoring of Algae Blooms.)

7. ***Name:*** **Ewert Bengtsson**
   Host: Siemens Elema AB Gösta Sjöholm
   Address: Solna
   Date: 950914
   Topic: Discussion of possible cooperation

8. ***Name:*** **Ewert Bengtsson**
   Host: IVA, Royal Academy of Engineering Sciences
   Address: Stockholm
   Date: 950926
   Topic: Meeting on innovation based enterprises.

9. ***Name:*** **Gunilla Borgefors**
   Host: Gabriella Sanniti di Baja
   Address: Istituto di Cibernetica CNR, Arco Felice (Napoli), Italy
   Date: 950917-950924
   Topic: Ongoing research cooperation

10. ***Name:*** **Tomas Brandtberg, Gunilla Borgefors, Heung-Kook Choi, Fredrik Walter, Daniel Wedjesjö**
    Host: Stora Teknik
    Address: Falun
    Date: 951005
    Topic: Presentation of the image analysis going on at Stora and discussions on possible future cooperation

11. ***Name:*** **Ewert Bengtsson**
    Host: Peter Gombrich, Dick Domanik
    Address: AccuMed Inc 920 N Franklin St. Suite 402 Chicago, IL, 60610, USA
    Date: 951009-951014
    Topic: Continued discussion as part of our research cooperation on automated cell image analysis of Pap-smears

12. ***Name:*** **Ewert Bengtsson**
    Host: Gustaf Appelberg NUTEK Affärsutveckling
    Address: 117 86 Stockholm
    Date: 951025
    Topic: Discussion about possible NUTEK support for the commercialisation of the research results in our Quantitative Pathology research.

13. ***Name:*** **Ewert Bengtsson**
    Host: Dr D. Leroy
    Address: LHC-MMS Cern CH-1211 Geneva 23
    Date: 951202-04

Topic: Discussion of planned cooperation on development of image analysis based inspection of the LHC superconducting cable.

14. ***Name:*** **Gunilla Borgefors**
Host: Ian T. Young Address: Faculty of Physics, Delft University of Technology, The Netherlands
Date: 951206-951207
Topic: Research at the Pattern Recognition group in Delft

15. ***Name:*** **Most personell at CBA**
Host: LMV and Byggforsk
Address: Gävle
Date: 951220
Topic: Annual CBA excursion

16. ***Name:*** **Gunilla Borgefors**
Host: Kerstin Malmqvist
Address: CBD, Högskolan i Halmstad
Date: 960110
Topic: Common interests, especially as concerns printing and paper quality

17. ***Name:*** **Tomas Brandtberg**
Host: Kartografiska Sällskapet, Uppsala
Address: SGU, Uppsala.
Date: 960129
Topic: Seminar concerning planning of new E4 north of Uppsala.
Comment: CBA - Report no. 9 were presented and distributed.

18. ***Name:*** **Lennart Thurfjell**
Host: Ian Smith
Address: Institute for Biodiagnostics, National Research Council of Canada (IBD NRC) Winnipeg, Canada
Date: 960203-960207
Topic: Methodological aspects on functional brain imaging with MRI.
Comment: Lennart Thurfjell was invited by a group at the MR-centre, Karolinska Hospital, to join them in a visit to IBD NRC. The main purpose was to discuss areas for collaboration between the MR-centre and IBD NRC.

19. ***Name:*** **Ewert Bengtsson, Gunilla Borgefors**
Host: Foundation for strategic research
Address: World Trade Center, Stockholm
Date: 960219
Topic: Hearing on the application VISIT - VISual Information Technology with Swedish and international experts.
Comment: The hearing was prepared at two full day meetings in Stockholm on 960205 and 960214 chaired by EWB

20. ***Name:*** **Ewert Bengtsson**
Host: Peter Gombrich, Richard Domanik, Ph.D.
Address: AccuMed International Inc, Chicago
Date: 960313-20
Topic: Discussions of continued cooperation on automated cell image analysis.

21. ***Name:*** **Tommy Lindell**
Host: Gordon Jolly
Address: Godalming, England
Date: 960402
Topic: Discussion on EU Project Clean Seas
Comment: Decided to not participate in this EU project depending upon too little money available for our part and no support whatsoever from Uppsala University on the project

22. ***Name:*** **Ewert Bengtsson and several others from CBA**
Host: Post Office Mail Sorting Terminal in Uppsala
Date: 960508
Topic: Demonstration of new mail sorting equipment and discussion of the problems in automatically reading some adresses, evaluation of possible assistance in solving the problems from CBA.

23. ***Name:*** **Ewert Bengtsson**
Host: Lars Hellgren and Nils Engström
Address: Computerized Wound Analysis (CWA) Institute AB, V. Frölunda
Date: 960531
Topic: Discussion of continued cooperation in the wound image analysis field

24. ***Name:*** **Tomas Brandtberg**
Host: SCA Skog AB
Address: The forest at Huljen, near Stöde, 40 km west Sundsvall.
Date: 9606-9609
Topic: Forest inventory of the aerial photographs in the projekt SJFR-Brandtberg.
Comment: Fredrik Walter, CBA, was assisting during two weeks of the approximately six weeks. Partially paid by SCA Skog AB.

25. ***Name:*** **Ewert Bengtsson**
Host: Hans Dahlin, managing director
Address: Helax AB 10 year celebration Uppsala Castle
Date: 960608
Topic: Invited guest at the Helax company 10 year anniversary celebration

26. ***Name:*** **Ewert Bengtsson and Tobias Öhman**
Host: Dr D Leroy
Address: LHC-MMS, Cern, Geneva, Switzerland
Date: 960629-960701
Topic: Presentation of results from pilot study of LHC cable inspection project, discussion about requirements for phase 2 of the project.

27. **Name: Ewert Bengtsson Fredrik Walter**
Host: MDC "Miljödatacentrum"
Address: Kiruna
Date: 960821
Topic: Participated as invited guests in the official opening of the MDC

28. ***Name:*** **Gunilla Borgefors**
Host: International Association for Pattern Recognition (IAPR)
Address: Vienna, Austria
Date: 960827-960828
Topic: Governing Board meeting of the IAPR

29. ***Name:*** **Catherine Östlund, Tommy Lindell**
Host: Eugenio Zilioli
Address: Consiglio Nazionale delle Ricerche (CNR), Milano Italy
Date: 960902-960904
Topic: Kick-off EC SALMON project. Visit CNR.

30. ***Name:*** **Gunilla Borgefors, Tomas Brantdberg**
Host: IVL
Address: Stockholm
Date: 960903
Topic: Forest evaluation from aerial photographs

31. ***Name:*** **Gunilla Borgefors**
Host: Tor Allenius
Address: Medical Information Centre, Karolinska Institute, Stockholm
Date: 961003
Topic: The Visible Human - how can a library make it available?

32. ***Name:*** **Lennart Thurfjell**
Host: Tomas Hindmarch
Address: MR-centre, Karolinska Hospital, Stockholm
Date: 961003
Topic: Listened to a seminar presented by Gordon Scart, the Institute for Biodiagnostics (IBD), Winnipeg, Canada. Discussion about a collaboration with IBD.

33. ***Name:*** **Catherine Östlund**
Host: Yrjö Sucksdorff
Address: Finnish Environment Institute Kesäkatu 6 P.O. Box 140 FIN 00251 Helsinki Finland
Date: 961004
Topic: Talk to Tuula Hannonen about her work with the AISA imaging spectrometer. Meet people within the SALMON project.

34. *Name:* **Gunilla Borgefors, Jacob Nisell**
Address: Arlanda
Date: 961024
Topic: Application of Remote Sensing for estimation of agricultural crop production in Sweden (EU-project)
Comment: kick-off meeting

35. *Name:* **Tommy Lindell**
Host: NRCA
Address: Kingston Jamaica
Date: 961106-961122
Topic: Coastal Planning
Comment: Preparations for establishing a water quality network in Jamaica Field work on submarine conditions along the coast of Jamaica

36. *Name:* **Fredrik Walter**
Host: FOA
Address: Karlskrona
Date: 961111
Topic: Field data collection during the CARABAS II BALTASAR 96 experiment, 3 days

37. *Name:* **Ewert Bengtsson**
Host: Hans Ovesen
Address: Ericsson Telecom AB 126 25 Stockholm
Date: 961124
Topic: Discussion of planned Telepathology project in cooperation with among others Christer Busch

38. *Name:* **Gunilla Borgefors**
Host: Terry Fountain
Address: Dept. of Physics and Astronomy, University College London
Date: 961129
Topic: Celebratory lunch for the life achievement of Prof. Michael Duff. Visit to the image analysis group of University College London.

7.7 Visiting scientists (staying at least 2 weeks)

1. *Name:* **Dmitry Lagunovsky**
Address: Belarussian Academy of Sciences, Minsk, Belarus
Host: Gunilla Borgefors
Date: 950828-951127
Topic: Identifying agricultural fields in satellite imagery Comment: Part of the SLU program for exchange with the Eastern former USSR states

2. *Name:* **Vidmantas Gurklys**
Address: Lithuanian Agricultural University, Water and land management dept., Kaunas-Akademija, Lithuania
Host: Gunilla Borgefors
Date: 960506-960609
Topic: General GIS tools

7.8 Other visitors

1. *Name:* **A group from Department of Animal Physiology, SLU**
Address: SLU
Host: Lennart Thurfjell
Date: 950929
Topic: To get an overview of our research in image analysis, especially in the field of microscopy.

2. *Name:* **Dr. A. Maziliauskas, Dr. Z. Dabkevicius, Prof. H. Linnér**
Address: Lithuanian Univeristy of Agriculture, Lihuanian Institute of Agriculture
Host: Jakob Nisell, Gunilla Borgefors
Date: 951024
Topic: Presentation of GIS activities at CBA

3. *Name:* **Mr. P. Vossen, Ms. V. Perdigao, and representatives from SCB, SLR, and SLU Crop Production**
   Address: IRSA, Ispra, Italy
   Host: Gunilla Borgefors, Jakob Nisell
   Date: 951115
   Topic: Presentation of CBA activities on remote sensing for agricultural applications, aiming at the planned EU co-operation project "Multi-level monitoring of agricultural land and crop yields in Sweden"

4. *Name:* **Sven Nilsson**
   Address: Dep. of diagnostic radiology, Uppsala University Hospital
   Host: Lennart Thurfjell
   Date: 951127
   Topic: Discussion about a possible cooperation in a project where the task is to define tumor volumes in from CT-images

5. *Name:* **Gabriella Sanniti di Baja**
   Address: Istituto di Cobernetica CNR, Arco Felice (Napoli), Italy
   Host: Gunilla Borgefors
   Date: 951211-951217
   Topic: Continuing cooperation in shape analysis

6. *Name:* **Olof Andrén and Helena Elmqvist**
   Address: EMC, Swedish University of Agricultural Sciences, Uppsala.
   Host: Tomas Brandtberg
   Date: 951211
   Topic: Discusion about an application of automated root image analysis and presentation of final results in the root project.
   Comment: Gunilla Borgefors and Anders Forsmoo were also on the meeting.

7. *Name:* **Lena Gustafsson, Johan Bergström**
   Address: SkogForsk, Uppsala
   Host: Gunilla Borgefors, Tomas Brandtberg
   Date: 960112
   Topic: Discussions on a GIS project to find regions for landscape planning in Sweden

8. *Name:* **David Roberts, Jonas Gårding, Jonas Larsson, Kaj Ericsson**
   Address: Darthmouth Hitchcock Medical Center, CA; ELEKTA Stockholm, Dep of Neuroradiology Karolinska Hospital
   Host: Lennart Thurfjell
   Date: 960227
   Topic: Discussion about the development of a high resolution brain atlas for planning of stereotactic surgery

9. *Name:* **Students from the course Computer Assisted Image Analysis, MN1, 5p.**
   Host: Torsten Jarkrans
   Date: 960304, 960306
   Topic: The two hour study visits waere a part of the course.
   Comment: Demonstrations: Fredrik Walter, Roger Hult, Petter Ranefall, Lennart Thurfjell, Tobias Öhman, Torsten Jarkrans

10. *Name:* **Lars-Ulrik Bergstrom**
    Host: Tommy Lindell
    Date: 960307
    Topic: Jamaican Planning

11. *Name:* **Yrjo Suckusdorff and colleagues**
    Address: Silja Line, Stockholm
    Host: Tommy Lindell
    Date: 960327
    Topic: Preliminary discussions on EU project

12. *Name:* **Invited representatives of Swedish agencies and organizations**
    Host: CBA
    Date: 960422
    Topic: Information about the work of CBA and plans for creating a Reference group in which the different organizations are invited to participate

13. ***Name:*** **Gordon Jolly, Satellite Observation Systems Ltd. England**
Host: Tommy Lindell
Date: 960423
Topic: Discussion on proposed EU project

14. ***Name:*** **Students from the course "Digital Image Analysis TF"**
Address: Dept. of Scientific Computing, Uppsala University
Host: Ingela Nyström
Date: 960503-960506
Topic: The students came in 4 groups for a two hour study visit, which was a part of the course. Comment: Demonstrators: Ewert Bengtsson, Gunilla Borgefors, Tomas Brandtberg, Hans Frimmel, Kenneth Jonsson, Petter Ranefall, Lennart Thurfjell, Fredrik Walter, Catherine Östlund and the host. Ewert, Petter and the host were also teachers for the course.

15. ***Name:*** **Eugeio Zilioli**
Address: CNR, Milan, Italy
Host: Tommy Lindell
Date: 960514
Topic: Discussions on EU project

16. ***Name:*** **Students from the course Computer Graphics**
Host: Torsten Jarkrans
Date: 960515
Topic: The two hour study visit was a part of the course.
Comment: Demonstrations: Tomas Brantberg, Petter Ranefall, Kenneth Jonsson, Tobias Öhman, Torsten Jarkrans

17. ***Name:*** **Håkan Lindström et al.**
Address: SIMS, Swedish University of Agricultural Sciences, Ultuna
Host: Gunilla Borgefors
Date: 960617
Topic: Possibilities of using image analysis for measuring wood parameters

18. ***Name:*** **Staffan Söderström**
Address: KI Innovation, Stockholm
Host: Ewert Bengtsson
Date: 960620
Topic: Discussion about the possible cooperation interest between KI Innovation and CBA

19. ***Name:*** **Eugeio Zilioli**
Address: CNR, Milan, Italy
Host: Tommy Lindell
Date: 960626-27
Topic: Final preparations for EU project SALMON

20. ***Name:*** **Curt Orbert**
Address: Allevägen 10, 746 31 Bålsta
Host: Ewert Bengtsson
Date: 960709
Topic: Consulted our former student Orbert about problems related to the CERN LHC inspection project

21. ***Name:*** **Eugeino Zilioli**
Address: CNR, Milan, Italy
Host: Tommy Lindell
Date: 960821-23
Topic: Rewriting of Final Workpackage for EU project SALMON

22. ***Name:*** **Eugenio Zilioli**
Address: CNR, Milan, Italy
Host: Tommy Lindell
Date: 960902-04
Topic: Kick off Meeting for EU project SALMON

23. ***Name:*** **Britta Fagerberg, Lars Haglad**
Address: Statistics Sweden, Dept. of Crop Production Science, SLU
Host: Gunilla Borgefors, Jacob Nisell
Date: 960918
Topic: Application of Remote Sensing for estimation of agricultural crop production in Sweden (EU-project)

24. *Name:* **Ulf Welander**
Address: Institutionen för Oral Radiologi, Karolinska Institutet, Huddinge
Host: Ewert Bengtsson
Date: 960926
Topic: Discussion about a possible joint proposal to the Foundation for Strategic Research on image analysis applications to odontology

25. *Name:* **Yvonne Ridderstråle with students**
Address: Department of Animal Physiology, SLU
Host: Anna Pettersson
Date: 961007
Topic: Study visit by PhD-course in animal physiology

26. *Name:* **Members of the 'Kartografiska sallskapet' in Uppsala**
Host: Tomas Brandtberg
Address: c/o Christian Elvhage SGU, Uppsala
Date: 961021
Topic: A visit to CBA including a presentation of CBA and of four project presentations at workstations.

27. *Name:* **Curt T. Reimann**
Address: Dept. of Radiation Sciences, Uppsala university
Host: Ewert Bengtsson, Gunilla Borgefors
Date: 961022
Topic: Analysis of Atomic Force Microscophy images

28. *Name:* **Annica Karlsson**
Address: Systems and control group, Uppsala University
Host: Ingela Nyström
Date: 961030
Topic: Walk analysis of colour images
Comment: Discussion and help with references

29. *Name:* **Örjan Smedby**
Address: Dept. of Radiology, Uppsala University Hospital
Host: Lennart Thurfjell
Date: 961113
Topic: Discuss the segmentation of organs in the thorax data from the Visible Human

30. *Name:* **Department of Agricultural Engineering, SLU.**
Host: Tomas Brandtberg
Date: 961113
Topic: Short presentation of CBA and three workstation demonstrations. Comment: Workstation demonstrations by; Anna Pettersson (Agricultural fields), Jakob Nisell (Classification) and Tomas Brandtberg (Remote sensing in forestry).

31. *Name:* **Björn Henningsson (1), Thomas Nilsson (2), Brita Swan (3)**
Address: 1, 2: SLU 3: Stora Corporate Research, Falun
Host: Gunilla Borgefors
Date: 961126
Topic: Possible future CBA involvement in the WURC project (Wood Ultrastructure Research Centre).

32. *Name:* **Reference group for CBA**
Host: CBA
Date: 961126
Topic: General image analysis methods from the theses of Choi and Jarkrans. The future of the Reference group. Comment: The first meeting of the CBA reference group.

33. *Name:* **Eugenio Zilioli**
Address: CNR, Milan, Italy
Host: Tommy Lindell
Date: 961128-29
Topic: Preparation of First Quarterly Report for EU project SALMON

34. *Name:* **Eugenio Zilioli**
Address: CNR, Milan, Italy
Host: Tommy Lindell

Date: 961202-03
Topic: Discussions on common issues of the SALMON Project. Discussions with different representatives of the CBA and demos of projects and instrumentation. Discussions with Prof. Curt Forsberg and Dr. Don Peirson and visit to Erken Laboratory

35. ***Name:*** **Group of UU department heads ("prefekter")**
Host: Ewert Bengtsson
Date: 961211
Topic: Visit to CBA and discussion about various problems encounterd as a department head.
Comment: One of several meetings with this group during 1995/96

36. ***Name:*** **Josiane Zerubia, Jean-Michel Chasseriaux, Jean-Charles Dubois**
Address: INRIA, France
Host: Ewert Bengtsson
Date: 961211
Topic: Visit to UU by official delagation from INRIA, France organized through the French Embassy. Host was EWB and the visit went to CBA and CMD

37. ***Name:*** **Dariusz Pietka**
Address: Polish academy of science Institute of biocybernetics Warszaw, Poland
Host: Ewert Bengtsson, Torsten Jarkrans, Petter Ranefall
Date: 961216-20
Topic: Visit to CBA supported by Royal Academy of Science. Presentation of our currrent work and discussion of possible future cooperation
Comment: Demonstrations: Torsten Jarkrans, Petter Ranefall, Hans Frimmel, Lennart Thurfjell. Discussions: Torsten Jarkrans, Ewert Bengtsson, Bosse Nordin and Christer Busch.

7.9 Committees

International

1. ***Name:*** **Tommy Lindell**
Committee: Affiliate Associate Professor, Univ of Washington, Seattle, USA
Date: -85--

2. ***Name:*** **Tommy Lindell**
Committee: Officer for Valle Scandinavian Exchange Program, Univ of Washington, Seattle, USA
Date: -85 --

3. ***Name:*** **Gunilla Borgefors**
Committee: Chair of the Membership Committee, International Association for Pattern Recognition
Date: 90--

4. ***Name:*** **Gunilla Borgefors**
Committee: Editor for "Pattern Recognition and Image Analysis: Advances in Mathematical Theory and Applications"
Date: 9310--
Comment: Published by Interperiodica Publishing in Cooperation with the "Cybernetics" Scientific Council, Russian Academy of Sciences

5. **Name: Gunilla Borgefors**
Committee: 1st Vice President, International Association for Pattern Recognition
Date: 94-96

6. ***Name:*** **Gunilla Borgefors**
Committee: Editorial board member, "Rivista di informatica"
Date: 9403--
Comment: Published by the Italian Association for Informatics and Automatic Computation, Milano, Italy

7. ***Name:*** **Gunilla Borgefors**
Committee: Editorial board member, "Image Processing and Communications"
Date: 9404--
Comment: Published by the Institute of Telecommunications, Bydgoszcz, Poland

8. ***Name:*** **Ewert Bengtsson**
   Committee: Editorial board member of "Computer methods and programs in biomedicine"
   Date: 94--
   Comment: Published by Elsevier.

9. ***Name:*** **Ewert Bengtsson**
   Committee: Editorial board member of "Machine Graphics & Vision"
   Date: 94--
   Comment: Published by the Polish Academy of Science

10. ***Name:*** **Ewert Bengtsson**
    Committee: International Evaluation Committee on NFR sponsored IT-research at the Medical Faculty in Bergen
    Date: 951019-20
    Comment: EB was one of four international experts appointed to evaluate this research program in preparation for the creation of a full chair in Medical IT at the University of Bergen

11. ***Name:*** **Gunilla Borgefors**
    Committee: Member of the promotion committee for the dissertation of G.W.A.M. van der Heijden, Faculty of Physics, Delft University of Technology, The Netherlands
    Date: 951207

12. ***Name:*** **Gunilla Borgefors**
    Committee: Member of the Board of Examiners for the Ph.D. dissertation of Wong Wai Him, City University of Hong Kong, Hong Kong
    Date: 961206
    Comment: Examination by group telephone call to Hong Kong

13. ***Name:*** **Ewert Bengtsson**
    Committee: Dissertation committee and opponent for dissertation of Kanagasingam Yogesan, Institutt for Informatikk, Univ., Oslo
    Date: 951207
    Comment: The title of the thesis was: Texture Analyysis as a Prognostic and Diagnostic Tool in Tumor Pathology

14. ***Name:*** **Ewert Bengtsson**
    Committee: Dissertation committee and opponent for dissertation of Ingvil Hovik, Institutt for Informatikk, Univ., Oslo
    Date: 951208
    Comment: The title of the thesis was: "Verktoy og metoder for komprimering av MR bilder I

15. ***Name:*** **Gunilla Borgefors**
    Committee: Committee member for the Ph.D. dissertation of Ashwata M. Kumar, Indian Institute of Technology, Kharagpur, India
    Date: 960401-960530

16. ***Name:*** **Gunilla Borgefors**
    Committee: Scientific Committee of 3rd Internation Conference on Visual Form, Capri, Italy, 28-30 May 1997
    Date: 960501-970530

17. ***Name:*** **Gunilla Borgefors**
    Committee: Publication Chair and Technical Programme Committee of AVBPA: Audio- and Video-based Biometric Person Authentication, Crans-Montana, Switzerland, 12-14 March 1997
    Date: 960501-970314

18. ***Name:*** **Gunilla Borgefors**
    Committee: Scientific Committee of PRIP'97: Fourth International Conference on Pattern Recognition and Information Processing, May 20-22, 1997, Minsk, Belarus
    Date: 960501-970522

19. ***Name:*** **Gunilla Borgefors**
    Committee: Independent expert for the evaluation of the European Commission Programme Agriculture and Fisheries (FAIR-3)
    Date: 960506-960510
    Comment: Evaluation took place in Brussels, Belgium

20. ***Name:*** **Gunilla Borgefors**
    Committee: Member of the program committee for International Conference on Image Processing, Lausanne, Switzerland, 1996.
    Date: 960301-960331

21. *Name:* **Gunilla Borgefors**
Committee: Expert for evalutation for the position of Full Professor in Image processing, University of Oslo, Norway
Date: 960915-961231

National

1. *Name:* **Gunilla Borgefors**
Committee: Board member, Swedish Society for Automated Image Analysis
Date: 1986--
Comment: President 1988-92

2. *Name:* **Gunilla Borgefors**
Committee: Member, Swedish Parliamentarians and Scientists
Date: 1987--
Comment: Members are elected. Only one scientist per field admitted.

3. *Name:* **Ewert Bengtsson**
Committee: Member of the electorial committee for the faculty of science and technology at Uppsala University
Date: 1993--

4. *Name:* **Ewert Bengtsson**
Committee: Steering committee of the DIXI, Digital X-ray project
Date: 95--
Comment: A joint project between departments of physics, radiation research, radiology and CBA. About six meetings during the year. Finn Pedersen, former graduate student at CBA is project manager

5. *Name:* **Ewert Bengtsson**
Committee: NUTEK Steering Committee on (styrgrupp) Minimally Invasive Medical Technology
Date: 1993-1996
Comment: Meeting about 10 times per year making decisions about funding projects for about 8 MSEK per year.

6. *Name:* **Gunilla Borgefors**
Committee: SLU review committee for SOU 1995:78 "The Swedish Space Program"
Date: 9511
Comment: SOU = Statens Offentliga Utredningar

7. *Name:* **Ewert Bengtsson**
Committee: Appointments board (Tjänsteförslagsnämnden) for the mathematics computer science division at UU
Date: 1996-1999
Comment: Regular member since 1991

8. *Name:* **Ewert Bengtsson**
Committee: Dean of the division of mathematics and computer science of the faculty of science and technology at Uppsala University
Date: 960701- (3 years)
Comment: Includes many different meetings and other responsibilites such as being a member of the board of the faculty

9. *Name:* **Tomas Brandtberg**
Committee: Kartografiska sällskapet, Uppsala.
Date: 960129
Comment: Member of the board.

10. *Name:* **Gunilla Borgefors**
Committee: Committee member for the Ph.D. dissertation of Wei Zhang, Royal Institute of Technology, Stockholm
Date: 951103

11. *Name:* **Ewert Bengtsson**
Committee: Dissertation committee for Else Nygren at CMD, UU
Date: 960328
Comment: The title of the thesis: "From paper to computer screen. Human information processing and user interface design"

12. *Name:* **Gunilla Borgefors**
Committee: Expert for evalutation for the position of Assistant Professor in Signal processing, especially neural nets, at Uppsala University
Date: 960501-960630

13. ***Name:*** **Ewert Bengtsson**
Committee: Member of the dissertation committee of Tomas Uhlin at CVAP, NADA, KTH
Date: 960503
Comment: The title of the thesis was: "Fixation and Seeing Systems"

14. ***Name:*** **Ewert Bengtsson**
Committee: Opponent for dissertation of Ulf Mattsson at the Faculty of Odontology, Göteborg University
Date: 960530
Comment: The title of the Thesis was "Computer-Assisted Image Analysis of Skin Erythemia and Oral Mucosal Lesions in Humans"

15. ***Name:*** **Gunilla Borgefors**
Committee: Opponent for the Lic. dissertation of Anders Ekman, Dept. of Computer and Information Science, Linköping University
Date: 960606

16. ***Name:*** **Ewert Bengtsson**
Committee: Strategic planning for the extended division of mathematics and computer science
Date: 9608-9612
Comment: Chaired a working group assigned with the task of creating a 10 year strategic plan for the division. The CBA hosted several meetings with this working group as well as helped administrate two workshops

17. ***Name:*** **Gunilla Borgefors**
Committee: Committee member for the Ph.D. dissertation of Heung-Kook Choi, Uppsala University
Date: 960920

18. ***Name:*** **Ewert Bengtsson**
Committee: Dissertation Committee for Jesper Andersson, Department of Radiation Sciences, Uppsala Univ. PET Centre
Date: 961006
Comment: Thesis on Functional Neuroimaging with PET, Methodological Aspects