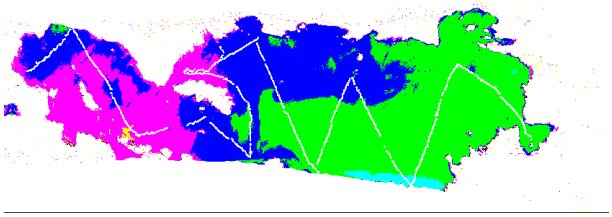
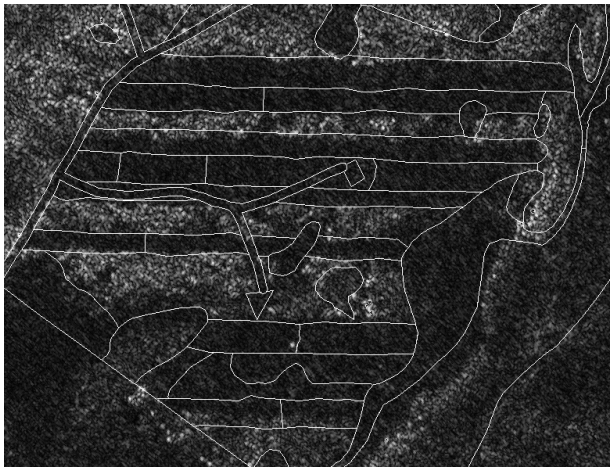
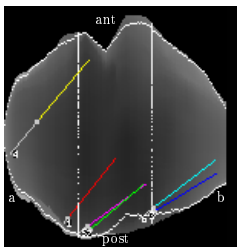
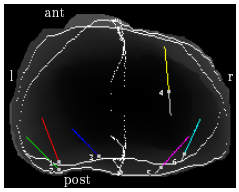
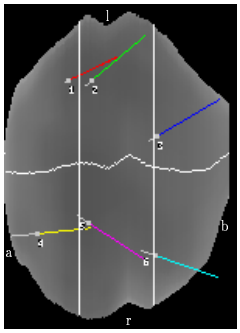
Annual Report 1999

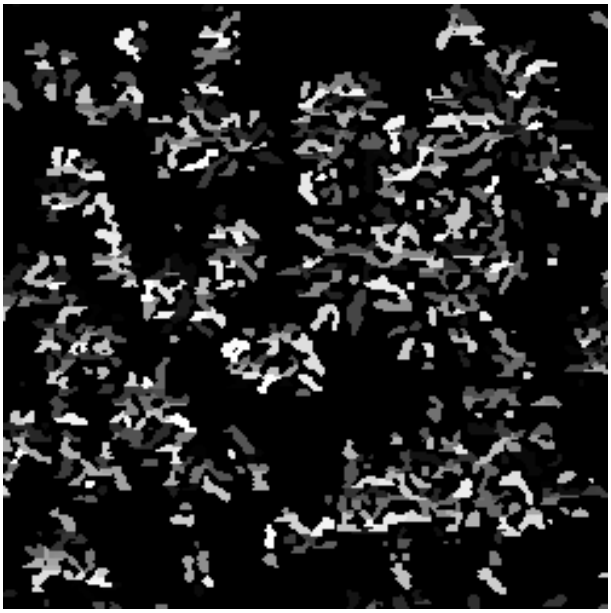












Annual Report 1999

Centre for Image Analysis

Centrum för bildanalys

Cover:
Illustrations from the four PhD theses presented at CBA during 1999.
Top-left: Catherine Östlund. Top-right: Fredrik Walter.
Bottom-left: Hans Frimmel. Bottom-right: Tomas Brandtberg.

Edited by:
Mattias Aronsson, Gunilla Borgefors, Ingela Nyström
Centre for Image Analysis
Uppsala, Sweden
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Contents

1 Introduction

1.1 General background

Each year, a research Centre such as ours are required to give more and more and different summaries of our activities in more and more detail. Since 1993/94 Centre for Image Analysis assembles extensive annual reports, that we hope can fulfil all these needs. However, more important is that the annual reports are intended for anyone interested in our work, not only sponsors but users of image analysis in society and industry, co-operation partners, and research colleagues.

The Centre for Image Analysis (CBA) is a joint university entity between Uppsala University (UU) and the Swedish University for Agricultural Sciences (SLU). The employees are formally employed at either university, and the Ph.D. students are admitted at any of the three faculties where we have a Ph.D. program — Science and Technology (TN) at UU, Forestry (S) and Agriculture, Landscape planning and Horticulture (JLT) at SLU. The whole of CBA is administrated through UU. From 19990101 UU have collected their IT related activities in one new large department called Dept. of Information Technology. CBA co-operates with this department in undergraduate courses at UU. An undergraduate course at SLU, which will be held the first time in the Spring of 2000, will be administered by ourselves directly.

At the end of 1999, there were 24 persons at CBA, of which 12 are Ph.D. students. At the end of 1998, we had 20 Ph.D. students. The reason for this large discrepancy is that during 1999 we had an unprecedented number of exams: four Ph.D. dissertations, two at each university, and three Licentiate exams, two at SLU and one at UU. Catherine Östlunds thesis "Analysis of Imaging Spectrometer Data with Lake Environment Applications" won the prestigious Linné price, awarded for Best Ph.D. thesis by the Royal Society of Sciences at Uppsala. The two exams at SLU were the first in "Image analysis and Remote sensing" ever given at SLU. Most of the new Doctors and Licentiates are now working outside the universities. In addition, we for the first time awarded the Docent degree in image analysis to Lennart Thurfjell. This year has thus truly been a "harvest" year, which reflects the rapid growth of CBA after both universities got permanent chairs at CBA, in 1993 (SLU) and 1996 (UU). Naturally, we now have something of a generation shift and will, during 2000, become a little smaller than the most recent previous years. However, we aim to stay at about the same level as we have since 1998.

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; Sections 3 and 4 our undergraduate and graduate education, respectively; Section 6 lists our publications for 1999, with abstracts; and Section 7, finally, all the various activities that takes place at CBA. Note that each Section starts with a short summary printed in a larger font than the following detailed material.

This annual report is also available on internet, see
http://www.cb.uu.se/verksamhet/annual_report/AR99html/

1.2 Summary of research

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, forestry, agriculture and medicine." The research work is organised in three groups: The image analysis group at UU, headed by Ewert Bengtsson, which works mainly with medical applications; 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 on forestry and agricultural applications. Naturally, all groups also conduct some basic research. The order of groups and projects below is arbitrary.

The general objective of the 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, distribution of plumes, and algae blooms in lakes and seas to planning and management of tropical coasts and sea bottoms.

One important area of research is the continued development of image analysis techniques and environmental applications using imaging spectrometry. Much effort has been put into the procedures for pre-processing of remote sensing data and the development of bio-optical modelling for more operational monitoring of water quality from space. This work produced one Ph.D. and one Licentiate during 1999.

Tommy Lindell has since 1996 been responsible for a big grant from the EU. The project, called SALMON, had partners in Italy, Finland, and JRC and concerned monitoring of water quality in European lakes. The project was focused on the use of remote sensing measurements in different regions of the electromagnetic spectrum, with the support of limnological observations and bio-optical modelling. The project was completed during 1999 with many interesting results and international publications.

Another big, national, project called RESE (REmote Sensing for the Environment) deals with methods for detecting changes in aquatic ecosystems and monitoring of algae blooms. This project has built on and continued the work in the successful SALMON project. The long-term goals here are using satellite, together with airborne hyperspectral data, for algae bloom detection, eutrophication, and pollution in Nordic waters. The bio-optical modelling continues to be an important part of the work

By the end of 1999 a new project was initiated, that will investigate detection of coral bleaching from remote sources.

The UU image analysis group has always had its main focus on medical applications of image analysis and visualisation, where tomographic volume images from different sensors and light microscopic images of tissues and cells have been analysed.

Lennart Thurfjell heads a group that continues the development of a 3D computerised brain atlas, partially funded by NUTEK. The basic brain atlas is used clinically and in research in approximately 20 centres world-wide. Now, several new algorithms that will extend its usefulness are being developed, specifically methods for multi-modality registration and segmentation. Thurfjell also worked on multimodality registration during his stay in Sydney, Australia, using similarity measures based on mutual information. During a stay as visiting researcher at CBA Vassili Kovavlev from Minsk, Belarus, developed a method for computer assisted diagnosis of

Alzheimer's disease based on texture symmetry measures in SPECT images.

Closely related to this work is a project within the VISIT programme: "Fusion of 3D medical images," where the purpose is to relate, extract, and present information from medical images of the same patient acquired by different sensors. The UU image analysis group's contribution is analysis of PET, SPECT, MR, and CT brain scans, where methods for computer aided diagnosis and volume visualisation based on data from multiple examinations presently are being developed. VISIT also financed a Master thesis project on segmentation of structures in MR images using deformable surface models. As a continuation of this work problems of how to apply model based segmentation in scale-space to brain images are being studied.

Another project within the VISIT programme, headed by Ewert Bengtsson, is segmentation and analysis of biological 3D shapes. We focus on analysing shape and distribution of sub-cellular structures by immunostaining and in situ-hybridisation of fluorescent markers, followed by fluorescence microscopy in three dimensions. The aim is to measure differences in DNA replication times between normal and cancerous (or pre-cancerous) cells.

Several years ago we became involved in 3D analysis of electron microscopy images of HIV, but that work was then discontinued. It has been revived this year. The goal is to analyse and compare the 3D distribution of biochemical substances in the viral core structure.

In a practical use of volume image skeletonization, where the basic research is performed in close co-operation with the SLU group, we have applied curve skeletonization to MR angiography images. The blood vessels are well suited for this type of data reduction, to extract their tree structure and thickness. The latter can hopefully help the detection of stenoses.

When a cancer of the prostate is suspected needle biopsies are taken to diagnose the tumour. These biopsies are painful, so it is important to minimise the number and optimise the placements of the needles. In co-operation with the Department of Pathology we have developed a 3D model of the probability distribution of cancer in the prostate based on 81 excised, sliced, and diagnosed prostates. Based on this model various biopsy taking strategies have been simulated, evaluated and optimised. This work lead to a Ph.D. thesis during 1999.

The work on computer assisted analysis of absorption light microscopic cell images has a long tradition in our group, dating back to 1973. We are presently involved in discussing computer support for screening specimens from various clinical applications in co-operation with the Chicago based company AccuMed International, Inc.

This year we have also taken up work on fluorescent light microscopy images in a pilot study together with the company Amersham Pharmacia Biotech. In that project we developed automatic cell segmentation algorithms, including automatic splitting and merging to handle overlapping cells.

In support of the different projects at CBA, 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. A new fully object oriented version based on the C++ programming language was released at the end of 1999.

The SLU Image Analysis and Remote Sensing group has the aim to be a central SLU source for image analysis knowledge. This means that we conduct some basic image research, but mostly are involved with a large number of — seemingly rather disparate — applications, from forest inventory to MR angiography. The main problem in the group has been the lack of seniors, which means that the number of Ph.D. students will decrease somewhat, now that the first generation students have passed their exams.

A major endeavour has been the study of forest inventory from airborne sensors, resulting in two Ph.D. theses this year. One project, that uses the Swedish VHF SAR radar CARABAS II,

has been run in close co-operation with the Dept. of Forest Resource Management and Geomatics in Umeå and the National Defence Research Establishment in Linköping. We have shown that there is a strong correlation between CARABAS II images and forest stand volume, stem diameter and tree height, in stands on fairly level ground. We have also showed that it is possible to automatically geocode CARABAS II data. This project got a fairly extensive media coverage after the thesis was released, as the potential for practical use in forestry in the near future is large. The other project uses higher resolution data, and aims at forest inventory at the individual tree level. We use high resolution colour infrared aerial images and LIDAR (laser scanning) data. Identification of individual trees, with position and tree crown area, has been developed earlier for colour images. This year, the same was done for laser data. We have also developed a fuzzy set algorithm for tree species identification. We will continue this line of research, by trying to fuse data from the different sensors.

There are also two forestry projects at a completely different scale. An automatic system for measuring soft-wood tracheid dimensions in cross-sections of wood has been developed and tested on a large number of images. The doctoral student Mattias Moëll spent eight months during 1998 and 1999 at Forest Research Ltd, New Zealand. Some of the work there was concentrated on segmentation methods for confocal microscopy images of wood cross-sections. A VISIT project, led by Gunilla Borgefors, that is a co-operation with Linköping university and StoraEnso in Falun, is aimed at analysing the internal structure of paper, by building volume images of the fibre structure to understand the relations between this structure and mechanical and optical properties. A series of paper sections depicted by an SEM camera has been semi-automatically converted into a volume image. This volume image has then been visualised, as a preparation for further studies.

We have, since 1997, been responsible for one of the technical projects within the national RESE project. This year, we worked on classification, analysis, and display of hyperspectral remote sensed data, and have developed and tested a new way of automatically selecting a few spectral bands for display among the up to several hundred in such an image. The project was terminated with a Licentiate thesis this year.

In agriculture, in addition to some feasibility studies of using satellite and aerial remote sensing for data collection, we have basic ongoing research, which currently aims at automatic field border extraction, which is important for mapping and for improving classification. This year we also finished a three-year EU financed study for predicting crop production (as averages over whole districts) using existing European models but adapting them to Swedish conditions. The results are largely negative, due to the short growing season and the relatively small fields in Sweden.

We participate in the MISTRA financed FOOD21 programme, with a Post-Doc. position. The general aim is food quality analysis using image processing. This year, we have concentrated of images of meat to measure fat and connective tissue content and distribution. We have used both normal colour images and the — for this application — novel NMR images, that give 3D data on chemical contents of the meat.

In addition to the paper project, we participate in another VISIT project: "Fusion of 3D medical images." This is originally a spin-off of the theoretical volume image analysis that has been going on for a long time (see below). So far, the main work has been on developing grey-level morphology methods (fuzzy connectedness) to improve the visualisation and analysis of MR angiography images. This has led to good separation of arteries an veins, even when they are running closely parallel to each other.

The theoretical work in the group is concentrated on various aspects of digital shape, especially in volume (3D) images. We have had co-operation since the mid-1980s with Istituto di Cibernetica, Italy in these areas, a co-operations that was intensified this year when Ph.D. stu-

dent Stina Svensson spent four months there. Shape decomposition into, simpler, basic shapes is an important area where we have achieved new results, but the main work has been on various methods for and aspects of skeletonization (or thinning). Skeletonization denotes the process where objects are reduced to structures of lower dimension, that is from volumes to surfaces to curves. In both approaches multiresolution structures are useful. A completely different approach to shape in volume images is taken in the co-operation with Dept. of Mathematics, UU, were we aim at global volume shape descriptors using polynomial expansions, or, most recently, implicit polynomials.

Finally, we have investigated how useful standard MIMD parallel computers are for image analysis. The conclusion must be that unless the memory is shared, any operation that collects information from the whole image is unsuited for this type of parallelism. This, originally NUTEK-funded, project was concluded with Licentiate thesis this year.

1.3 Sammanfattning på svenska (Summary in Swedish)

Denna sammanfattning motsvarar ungefär avsnitten 1.1 och 1.2.

För varje år måste en forskningsenhet som Centrum för bildanalys producera fler och fler olika summeringar av arbetet i större och större detalj. Sedan läsåret 93/94 producerar vi en årsrapport, som vi hoppas ska kunna fylla de flesta av dessa funktioner. Men givetvis är årsrapportens viktigaste funktion att sprida information om Centrum för bildanalys till alla med intresse för vårt arbete, t.ex. huvudmän, finansiärer, sponsorer, användare av bildanalys i praktiken, samarbetspartner och kollegor.

Centrum för bildanalys (CBA) är en för Uppsala universitet (UU) och Sveriges Lantbruksuniversitet (SLU) gemensam "inrättning", som bedriver forskarutbildning och forskning inom datoriserad bildanalys och ett antal tillämpningar av denna. Personalen är anställd vid resp. universitet och doktoranderna antas vid någon av de tre fakulteter där vi har doktorandprogram — Teknisk/Naturvetenskaplig (TN) vid UU, Skogsfakulteten (S) och (JLT) vid SLU. CBA administreras i sin helhet av UU, men administrationen blir ändå med nödvändighet komplicerad, pga vår nära relation till två universitet. Internt är verksamheten mycket väl integrerad. Från 19990101 sammanslog UU sin IT-relaterade verksamhet i en storinstitution, Inst. för informationsteknologi. CBA kommer att samverka med denna institution vad gäller undervising på grundnivå på UU. Undervisning på grundnivå på SLU, vilken startar våren 2000 kommer vi att ansvara för själva.

I slutet av 1999 fanns 24 anställda på CBA (projektarbetare och examensarbetare oräknade), varav 12 doktorander. I slutet av 1998 hade vi 20 doktorander. Orsaken till denna stora skillnad är att vi under 1999 hade hela fyra disputationer, två vid varje universitet, och tre licentiatexamina, två vid SLU och en vid UU. Catherine Östlunds avhandling "Analysis of Imaging Spectrometer Data with Lake Environment Applications" vann det prestigefyllda Linnépriset för bästa Uppsala-avhandling inom naturvetenskaperna, som utdelas av Kungliga vetenskapssociteten. De två anhandlingarna vid SLU var de första någonsin där i ämnet Bild- och fjärranlys. De flesta nya doktorerna och licentiaterna arbetar nu utanför universiteten. Dessutom fick vi i år den första docenten i bildanalys vid UU, Lennart Thurfjell. 1999 var således ett verkligt "skördeår". Naturligtvis leder detta delvis till ett generationsskifte och vi kommer under år 2000 att vara lite färre än under de senaste åren. Långsiktigt siktar vid dock på den nivå vi haft sedan 1998.

Den kvantitativa omfattningen av verksamheten vid CBA framgår av de olika listorna över undervisning, publikationer, seminarier, konferensdeltagande, studiebesök, etc. i denna årsrapport. Vi skall här inte tynga texten med ytterligare statistik. Lägg märke till att varje avsnitt startar med en kort sammanfattning i större stil.

Denna årsrapport finns även tillgänglig via www — se
http://www.cb.uu.se/verksamhet/annual_report/AR99html/

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 skogsbruk samt medicin". Vid CBA skall bedrivas forskning, dels inom bild- och fjärranalys som sådan, med målet att utveckla bättre algoritmer, generella metoder och system för dessa typer av tillämpningar, och med direkta tillämpningar och projekt inom de angivna områdena. CBA skall medverka till att bildanalystekniken sprids och tillämpas även inom andra institutioner vid de båda universiteten. CBA skall dessutom vara ett kompetenscentrum med internationell kompetensnivå. Forskningen vid CBA organiseras i tre grupper: bildanalys vid UU, som leds av Ewert Bengtsson; akvatisk fjärranalys vid UU, som leds av Tommy Lindell; och bild- och fjärranalys vid SLU, som leds av Gunilla Borgefors. Samtliga grupper bedriver förutom tillämpningsorienterad forskning även grundläggande bildanalysforskning. Ordningen i vilken projekten nämns är godtycklig.

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 och algblomning i hav och sjöar till planering och hantering av kustzonsresurser och havsbottnar i tropikerna.

Ett viktigt forskningsområde är utvecklingen av bildanalysteknik för och miljötillämpningar av avbildande spektrometri. Mycket arbete har lagts ner på förbehandling av fjärranalysdata och utvecklingen av bio-optiska modeller för operationell övervakning av vattenkvalité från rymden. Detta arbete resulterade i en doktors- och en licentiatavhandling under 1999.

Tommy Lindell har sedan 1996 varit en av ledarna för ett stort EU-projekt. Projektet, med deltagare från Sverige, Italien och Finland, har som mål övervakning av vattenkvalité i europeiska insjöar. Fokus är på användning av fjärranalysmätningar i olika delar av det elektromagnetiska spektrat, tillsammans med limnologiska mätningar och bio-optiska modeller. Projektet avslutades under 1999 coh gav upphov till många interessanta resultat och internationella publikationer.

Ett annat stort nationellt program där vi medverkar är RESE, med medverkan i projektet "Detektion av förändringar i akvatiska ekosystem och övervakning av algblomning". Detta projekt har byggt vidare på de metoder som utvecklades i ovanstående EU-projekt. Det långsiktiga målet är här att använda satellitdata tillsammans med flygburen avbildande spektrometri för att upptäcka algblomning, eutrofikation och föroreningar i nordiska vatten. De bio-optiska modellerna är viktiga även här.

I slutet av 1999 initierades ett nytt projekt, som kommer att handla om detektion av blekning av korall i tropiska vatten med fjärranalys.

UU-gruppens huvudtema är och har alltid varit medicinska tillämpningar av bildanalys och visualisering, där tomografiska bilder från olika sensorer samt mikroskopiska bilder av vävnader och celler har analyserats.

Lennart Thurfjell leder en grupp som fortsätter arbetet med en datoriserad hjärnatlas i 3D, som delvis finansieras av NUTEK. Den ursprungliga hjärnatlasen används idag på cirka

20 platser världen runt. Nu tas nya metoder fram, som gör den ännu mer användbar. Dessa inriktas framför allt på multimodal registrering till samma koordinatsystem och segmentering av olika strukturer i hjärnan. Thurfjell arbetade med multimodal registrering även under sin tid i Sydney, Australien, där han använde likhetsmått baserade på ömsesidig information. Under året besöktes bruppen av gästforskaren Vassili Kovavlev från Minsk, Vitryssland. Han utvecklade en metod för datorstödd diagnos av Alzheimer, baserad på mätningar av textursymmetri i SPECT-bilder.

Ovanstående projekt är nära kopplat till ett projekt inom VISIT med namnet "Fusion av medicinska 3D-bilder" som leds av Ewert Bengtsson. Målet är att relatera, extrahera och presentera information från bilder från olika medicinska sensorer på samma patient. UU-gruppens bidrag är fusion av PET-, SPECT-, MR- och CT-bilder av hjärnan. För närvarande utvecklas metoder för datorstödd diagnos och visualisering baserad på multipla undersökningar. VISIT finansierade även ett examensarbete inom segmentering av strukturer i MR-bilder med hjälp av deformerbara ytmodeller. En fortsättning på detta kommer att vara modellbaserad segmentering av hjärnan i skalrumsbilder.

Ett annat projekt inom VISIT-programmet som också leds av Ewert Bengtsson är segmentering och analys av biologiska volymer. Vi inriktar oss på form och fördelning av sub-cellulära strukturer, som görs synliga genom immunfärgning och in situ hybridisering av fluoriserande markörer. Dessa avbildas med fluorescensmikroskopi i tre dimensioner. Målet är att mäta skillnader i tiden för DNA-kopiering i normala och maligna (eller premaligna) celler.

För ett antal år sedan var CBA involverat i ett projekt för att rekonstruera volymsbilder av HIV från serier av elektronmikroskopibilder. I år har detta projekt återuppstått. Målet är att analysera och jämföra rymdfördelningen av biokemiska substanser i viruskärnan.

En tillämpning av den forskning om skelett i volymsbilder som sker i samarbete med SLU-gruppen är kurvskelettering av blodådror i MR-angiografibilder. Ådrorna passar bra för denna typ av förenkling, där trädstrukturen och åderns tjocklek tas fram. Det senare kan hjälpa till att upptäcka blodkärlsförträngningar.

När man misstänker cancer i prostata gör man nålbiopsier för att diagnosticera den eventulla tumören. Biopsierna är smärtsamma, så det är viktigt att minimera antalet nödvändiga stick genom rätt placering av dem. I samarbete med institutionen för patologi har vi utvecklat en virtuell digital tredimensionell modell av cancerfördelning i prostata. Modellen baseras på 81 verkliga prostator med cancer, som skivats och diagnosicerats. Baserat på denna modell har olika strategier för biopsitagning simulerats och optimerats. Arbetet resulterade i en doktorsavhanfling under året.

Arbetet med datorstödd analys av ljusmikroskopiska cellbilder har en lång tradition i gruppen; det startade redan 1973. Vi diskuterar för närvarande samarbete med det Chicago-baserade företaget AccuMed International, Inc. för att utveckla datorstöd för granskning av cellprover från gynekologisk hälsokontroll.

Under året har vi startat arbete med flouroscensmikroskopibilder i en pilotstudie tillsammans med Amersham Pharmacia Biotech. Inom denna studie har vi utvecklat automatiska segmenteringsalgoritmer för cellbilder, som inkluderar hantering av överlappande celler.

För att stödja alla dessa olika projekt och för att tillhandahålla ett bra verktyg för utbildning i bildanalys har arbetet med den generella bildanalysprogramvaran IMP fortsatt. En nu helt objektorienterad version baserad på programmeringsspråket C++ lanserades i slutet av 1999.

Bild- och fjärranalysgruppen vid SLU har som mål att vara en kunskapsresurs i bildanalys för hela SLU. Detta betyder att vi bedriver en del grundläggande forskning, men framför allt arbetar med ett stort antal — till synes mycket disparata — tillämpningsprojekt, från skogsinventering till visualisering av MR-angiografi. Gruppens huvudproblem har varit och är bristen på seniorer, vilket betyder att antalet doktorander kommer att minska, nu när första generationen tagit sina doktors- och licentiatexamina.

Ett omfattande arbete har bedrivits inom skogsuppskattning mad hjälp av flygburna sensorer. Detta arbete ledde till två doktorsavhandlingar under 1999. Ett projekt, som använder den svenska VHF SAR radarn CARABAS II, har bedrivits i nära samarabte med inst. för skoglig resurshushållning och geomatik i Umeå och Försvarets forskningsanstalt i Linköping. Vi har visat att korrelationen är stor mellan CARABAS-bilden och virkesvolym, stamdiameter och trädhöjd, allt på beståndsnivå och på någorlunda plan mark. Vi har även visat att det är möjligt med automatisk geokodning av CARABAS II data. Detta projekt fick ganska stor uppmärksamhet i media, eftersom det har stor potential för praktisk användning i skogsbruket inom en nära framtid. Det andra projektet anväder data med högre upplösning, och är inriktat mot inventering av enskilda träd. Vi använder infraröda färgbilder och LIDAR-data (skannande laser). Automatisk identifikation av enskilda träd, med position och kronarea har tidigare utvecklats för färgbilder. I år har vi gjort detsamma för LIDAR-data. Vi har dessutom utvecklat en algoritm för trädslagsbestämning som utnyttjar oskarp logik. Vi kommer att fortsätta denna forskningsinriktning främst genom att försöka sammaväga alla dessa datatyper.

Vi bedriver ytterligare två skogsprojekt, men i en helt annan skala. Vi har utvecklat och förbättrat ett automatiskt system för att mäta fibrer i tvärsnittsbilder av barrträd och har provat det på ett stort bildmaterial. Doktoranden Mattias Moëll tillbringade åtta månader under 1998 och 1999 Forest Research Ltd, New Zealand. En del av arbetet där gällde segmentering av konfokala tvärsnittsbilder av trä. Inom VISIT leder Gunilla Borgefors ett projekt som har som mål att analysera pappers inre strukturer. Projektet är ett samarbete mellan CBA, Linköpings universitet och StoraEnso, Falun. Idén är att skapa volymsbilder av fiberstrukturen för att öka förståelsen för hur strukturen påverkar papperets optiska och mekaniska egenskaper. En serie snittbilder av mjölkkartong har avbildats med en SEM-kamera och nästan automatiskt omvandlats till en volymsbild. Denna har sedan visualiserats, som förberedelse för fortsatt arbete.

Gunilla Borgefors har sedan 1997 varit ansvarig för ett av de s k tekniska projekten inom nationella RESE-programmet. Under året har vi arbetat med klassificering, analys och visualisering av data från avbildande spektrometer. Vi har bl a utvecklat ett nytt sätt att välja ut några av de kanske hundratals spektralbanden på ett sätt som gör att mesta möjliga information finns kvar när endast dessa band analyseras eller visas. Arbetet inom RESE avslutades under våren med en licentiatavhandling.

Inom jordbrukstillämpningar, där vi använt satellitdata, har vi dels genomfört några tillämpningsnära pilotstudier, dels arbetat med grundläggade metoder för automatisk detektion av fältkanter. Dessa behövs för att underlätta kartering och förbättra klassning. Under året avslutades också ett EU-finansierat projekt, där målet var skördeprognos för hela distrikt med användning av satellitbilder och europeiska modeller för tolkning, men anpassade till svenska förhållanden. Resultaten var ganska nedslående, främst beroende på den korta odlingssäsongen och den dåliga tillgången på satellitbilder över Sverige, tillsammans med det faktum att fälten i Sverige är små, med europeiska mått mätt.

Vi deltar i det MISTRA-finansierade MAT21-programmet, med en gästforskare från Italien som tillbringar en två-årig "post-doc"-period hos oss. Det generella målet är analys av matkvalité med hjälp av bildanalys. I år har vi mest arbetat med bilder av biff, för att mäta andel och fördelningar av fett och bindväv. Vi har använt både vanliga färgbilder och den — i detta

sammanhang — nya NMR-sensorn, som avbildar fördelningen av olika kemiska substanser i köttet.

I tillägg till pappersprojektet medverkar vi ett ett annat VISIT-ptojekt: "Fusion av medicinska 3D-bilder". Denna medverkan är ursprungligen en följd av vårt mångåriga arbete med teoretisk analys av volymsbilder (se nedan). Hittills har vi mestadels ägnat oss åt att utveckla metoder för att förbättra visualiseringen och analysen MR-angiografibilder. Vi använder gråskalemorfologi och oskarp logik i detta sammanhang. Det är nu möjligt att säskilja t ex artärer och vener i bilderna, även när de löper pallellt tätt intill varandra.

Det teoretiska arbetet i gruppen har under senare år varit koncentrerat på olika aspekter av digital form, speciellt i volymsbilder (3D). Vi har här samarbetat sedan mitten av 1980-talet med Istituto di Cibernetica, Neapel, Italien. Samarbetet intensifierades detta år, när vår doktorand Stina Svensson tillbringade fyra månader där. Uppdelning av objekten i enkla former är ett viktigt område där vi uppnått nya resultat, men viktigast har varit utvecklingen av nya skeletteringsmetoder i volymsbilder. Skelettering, eller tunning, beskriver en process där ett objekt reduceras till strukturer av lägre dimensionalitet, från volymer till ytor till kurvor. Både för uppdelning av former och vid skelettering är upplösningspyramider användbara. Ett helt annat sätt att betrakta tredimensionell form utvecklas inom ett samarbetsprojekt med institutionen för matematik vid UU, där målet är global formbeskrivning med polynom (motsvarigheten i tre dimensioner till Fourier-deskriptorer i två) eller, under senaste tiden, med implicita polynom.

Till slut har vi undersökt hur användbara generella MIMD-parallella datorer är för bildanalys. Slutsatsen är att om analysen kräver samverkande data från hela bilden och minnet inte är gemensamt för alla processorer så är dessa datorer olämpliga. Detta, från början NUTEK-finansierade, projekt avslutades med en licentiatavhandling under 1999.

I framtiden avser vi att följa på den inslagna vägen, där forskning kring volymsbilder och multi- och hyperspektrala bilder kommer vara huvudtemata. För trots alla våra till synes disparata tillämpningar är det dessa baskunskaper vi framför allt bygger på.

1.4 How to contact CBA

CBA maintains a home-page on the *World Wide Web* (WWW) both in English and in Swedish. We have tried to make it easy to navigate by giving it a simple structure and layout. The main structure, containing such information as a presentation of CBA, information about the staff, vacant positions, current activities, etc., is continuously updated by the web master, Carolina Linnman. Web pages containing information about research projects, courses, seminars, this annual report, etc., are managed by other persons at CBA. By having different persons responsible for different parts of the home page and keeping everything together by the main pages, the aim is to keep it informative and up-to-date.

CBA home-page: http://www.cb.uu.se/

In addition to the CBA home page, all personnel have their own home pages, that are linked to the CBA one. On these, you can usually find detailed project information and other interesting things.

In co-operation with The Forestry Research Institute of Sweden (SkogForsk) and the Swedish Space Corporation (SSC) we also maintain a WWW-document titled "Remote Sensing for Forest Management Planning." The aim is to provide information about the remote sensing sensors and methods that can be used in forestry and to create a site for presentation of new such methods. The web master for this document is Fredrik Walter.

Remote Sensing for Forestry home-page: http://www.cb.uu.se/~fredrik/fjarr/

CBA can be contacted in the following ways:

Address:	Lägerhyddvägen 17 SE-752 37 Uppsala Sweden
Telephone:	+46 18 471 3460
Fax:	+46 18 553447
E-mail:	cb@cb.uu.se

2 Organization

The CBA consists of three research groups. We were at 1999-12-31 a total of 24 persons, 10 of which are PhDs and 12 graduate students. About half the graduate students belong to each university, but only one senior is employed by SLU. 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. Less than half of the research income of about 12 million SEK was covered by funds from the two universities. The rest came from many different outside sources.

2.1 Constitution

The CBA was founded in 1988. In 1995 a re-organization of CBA took place to give it its present constitution. We are a joint University entity (due to administrative rules, we can not be denoted "department") between Uppsala University (UU) and the Swedish University for Agricultural Sciences (SLU). 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 — Science and Technology (TN) at UU, Forestry (S) and Agriculture, Landscape planning and Horticulture (JLT) at SLU. The whole of CBA is administered through UU. In late 1998 UU re-organized its activities in the information technique fields into the large new Dept. of Information Technology (IT). CBA is now "associated" with this department for undergraduate education. All personnel (from both universities) is employed directly at CBA, except Lecturers at UU. These are employed by IT, and teach there. Their research activities, however, are carried out at CBA to a degree (usually 25%-75%) which is regulated by individual five year contracts.

The CBA is thus an independent entity within the TN faculty at UU and the S faculty at SLU, respectively. It is directed by a board with representatives from the universities (three each) and the unions (two). 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 economy. 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 Prof. Gunilla Borgefors has served as director, with Olle Eriksson as deputy director. The other board members have been: Ewert Bengtsson UU, Nils-Einar Eriksson TCO, Bengt Gustavsson UU, Anders Hemmingsson UU, Christer Kiselman UU (suppl), Tommy Lindell SACO, Thomas Nybrandt SLU, Kerstin Lundström 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 image analysis and remote sensing group at SLU headed by Gunilla Borgefors, which works with various applications in forestry, agriculture, industry, as well as in basic research, and the group in aquatic remote sensing at UU, headed by Tommy Lindell.

2.2 Finances

The CBA is financed through the two universities, through research grants and contracts and through co-operation projects with other organizations. The summary in Table 1 describes our overall economy for the year 1999, 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. The numbers are rounded to the nearest 1000 SEK. The same numbers are also given as pie charts in Figure 1. Which projects that are financed by whom can be ascertained in Section 5, where each project is listed. We had around 1 MSEK in personnel costs covered through undergraduate teaching administrated through the Departments of Scientific Computing and of Geoscience at UU. 1999 was a year of consolidation where we stayed at roughly the same level as the previous fiscal year, with a turnover

Table 1: CBA income and costs for 1999.

Income		**Costs**	
UU	2800	Personnel	7658
SLU	2666	Equipment	346
UU undergraduate education	1028	UU undergraduate education	251
Governmental grants[1]	1880	Operating exp.[3]	2421
Non-governmental grants[2]	2927	Rent	882
Contracts	630	University overhead	1328
Financial netto	105		
Total income	**12036**	**Total cost**	**12886**

1) NUTEK, SJFR, TFR, Sw. National Space Board
2) MISTRA, SSF, etc.
3) Including travel and conferences

of about 13 MSEK. Of our own (research) activities more than half is financed by outside funding, but the percentage is less than 1998. The deficit of this year is covered by accumulated funds from the previous year.

2.3 Reference group

To increase the interaction with the world outside the universities, the constitution of CBA 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 seminars annually.

In 1999 the reference group consisted of the following organisations:

- Forestry Research Institute of Sweden
- National Board of Fisheries
- National Defence Research Establishment
- Swedish National Environmental Protection Agency
- Swedish Pulp and Paper Research Institute
- Uppsala University Hospital

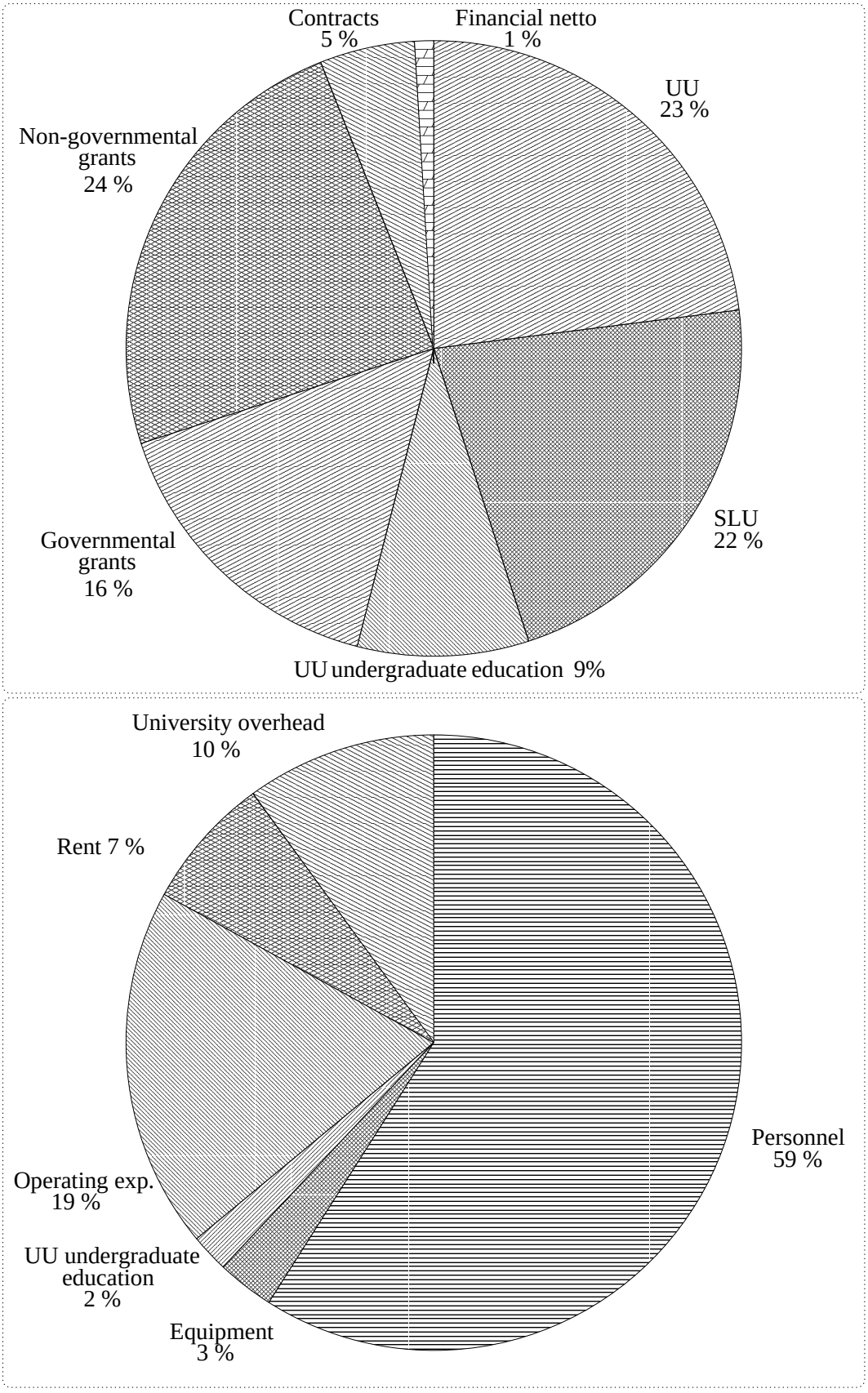

Figure 1: CBA income and costs for 1999.

2.4 Staff

Gunilla Borgefors, Professor, PhD, director, SLU
Olle Eriksson, Lecturer, PhD, deputy director, (part time) UU

Petra Ammenberg, Graduate Student, UU
Mattias Aronsson, Graduate Student, SLU
Lucia Ballerini, Researcher, PhD, 9908–, SLU
Ewert Bengtsson, Professor, PhD, UU
Tomas Brandtberg, Graduate Student/PhD, SLU
Peter Flink, Graduate Student, –9908, UU
Anders Forsmoo, Graduate Student, –9909, SLU
Hans Frimmel, Graduate Student, –9906, UU
Roger Hult, Graduate Student, UU
Joakim Lindblad, Graduate Student, UU
Petter Lindborg, Graduate Student, –9903, SLU
Tommy Lindell, Docent, PhD, UU
Emma Lindqvist, Graduate Student, –9905, SLU
Carolina Linnman, Graduate Student, UU
Roger Lundqvist, Graduate Student, UU
Tomas Löfstrand, Graduate Student, –9901, SLU
Mattias Moëll, Graduate Student, SLU
Jakob Nisell, Graduate Student, –9901, SLU
Bo Nordin, Researcher/Lecturer, PhD, (part time) UU
Ingela Nyström, Researcher/Lecturer, PhD, UU
Anna Rydberg, Graduate Student, SLU
Örjan Smedby, Professor, MD, LiU, (part time)
Stina Svensson, Graduate Student, SLU
Lennart Thurfjell, Docent, PhD, UU
Xavier Tizon, Graduate Student, 9905–, SLU
Mikael Vondrus, Graduate Student, UU
Fredrik Walter, Graduate Student/PhD, SLU
Felix Wehrmann, Graduate Student, UU
Catherine Östlund, Graduate Student/PhD, –9911, UU/SLU

Lena (Nordström) Wadelius, Administration
Marcelo Toledo, Administration

Benjamin Björknäs, master thesis
Mattias Jacobsson, master thesis
Poul Thygesen, project work

In addition to the above Graduate Students we are assistant supervisors to
Hannes Edvardsson, Dept. of Mathematics, –9910, UU (G. Borgefors),
Anders Engqvist, Dept. of Agricultural Engineering, SLU (G. Borgefors)
Anders Hast, Dept. of Mathematics, Natural Sciences, and Computing,
University College of Gävle, 9909–, UU (E. Bengtsson)
Kenneth Wester, Dept. of Genetics and Pathology, –9910, UU (E. Bengtsson)

The letters after the name indicate the employer for each person: UU - Uppsala University, SLU - Swedish University of Agricultural Sciences. The staff can in addition to regular mail, telephone, and fax to CBA be reached by e-mail at the address Firstname.Lastname@cb.uu.se

3 Undergraduate education

CBA does not (yet) have responsibility for organizing undergraduate education at any of the two universities. The staff at CBA is, however, involved in teaching courses organized by other departments at UU. From the academic year 99/00 CBA will give an undergraduate course at SLU in basic image analysis. We also offer a number of Master thesis projects (examensarbeten) each year. One was completed during 1999.

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 languages such as C++. There are also courses at Dept. of Geosciences.

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

1. **Internet programming, TDB, 5p**
   Bo Nordin *Period:* 9812–9906
   Topic: HTML, Java programming including Java graphics and Java networking, etc. 25% (with KTH)
2. **Computer Graphics MN2, TDB, 5p**
   Hans Frimmel, Mark Ollila, Daniel Okunbor, Anders Ynnerman, Niclas Andersson
   Period: 9901–9903
   Topic: Raytracing, radiosity, visualisation.
3. **Software Tools, TDB, 5p**
   Olle Eriksson *Period:* 9901–9903
4. **Mathematics and Statistics with computer aided learning MN1, 10p**
   Anna Rydberg *Period:* 9901–9903
   Comment: Computer exercises
5. **Computers and Programming, TDB1**
   Torsten Jarkrans, Roger Hult, Stina Svensson *Period:* 9901–9903
   Comment: Introduction to computer programming techniques using C++
6. **Technical calculations and mathematical programming languages, TDB1, 5p**
   Henrik Brandén, Mattias Aronsson *Period:* 9902–9904
   Topic: Evening course with computer exercises, introducing MapleV and MATLAB.
7. **Programming techniques 1, K1, TDB, 4p**
   Roger Lundqvist *Period:* 9902-9905
8. **Object oriented programming in C++ TDB3 , 5p**
   Bo Nordin, Hannes Edvardson *Period:* 9902–9906
   Topic: Object oriented programming in C++, object oriented analysis and design, data structures.
9. **Computer assisted image analysis, TF1, 3p**
   Carolina Linnman, Lennart Thurfjell *Period:* 9903–9905
   Comment: At the end of the course, the students visited CBA. Anna Rydberg, Joakim Lindblad, Stina Svennson, Felix Wehrmann and Carolina Linnman presented their research projects. Carolina Linnman, Felix Wehrmann and Petra Ammenberg supervised the computer exercises.
10. **Programming MN2, TDB, 5p**
    Olle Eriksson *Period:* 9903–9905
11. **Programming techniques, MI1, 5p**
    Mattias Aronsson *Period:* 9903–9906
    Topic: Introduction to the C++ computer language for Machine Engineers.

12. **Computer Graphics MN1/DV1, TDB, 5p**
Joakim Lindblad, Bo Nordin *Period:* 9903–9905

13. **Computer Programming I (chemistry), 5p**
Hans Frimmel *Period:* 9903–9906
Comment: Lectures and exercises

14. **Hyperspectral Remote Sensing**
Tommy Lindell *Period:* 990503–990515
Comment: Remote sensing applications for water quality monitoring in lakes. Norr Malma field station, Norrtälje

15. **Remote sensing applications for water quality monitoring in lakes**
Tommy Lindell *Period:* 990519
Comment: Remote sensing applications for water quality monitoring in lakes. Stockholm Water Company, Stockholm.Course designed for County and community officers

16. **Programming techniques MN1, TDB, 5p**
Mikael Vondrus, Felix Wehrmann *Period:* 9909–9912
Topic: Programmeringsteknik, C++
Comment: Vondrus and Wehrmann responsible for separate classes.

17. **Introduction to programming, TDB, 5p**
Olle Eriksson *Period:* 9909–9912

18. **Remote Sensing for Geoscientists, 5p**
Tommy Lindell *Period:* 991006
Comment: One lecture in a course at the Dept. of Geosciences

19. **Computer Graphics MN1/DV1, TDB, 5p**
Joakim Lindblad, Bo Nordin, Mark Ollila *Period:* 9910–9912

20. **Computerized Image Analysis MN2**
Ewert Bengtsson, Tomas Brandtberg, Ingela Nyström, Lennart Thurfjell *Period:* 9910–9912
Comment: Given for the first time. A number of CBA graduate students also attended.

21. **Internet programming, TDB, 5p**
Bo Nordin *Period:* 9910–0003
Topic: Distance course. HTML, Java programming including Java graphics, Java networking, etc.

22. **Digital Remote Sensing, 5p**
Tommy Lindell, Petra Ammenberg *Period:* 9911–0001
Comment: Through Dept. of Geosciences

3.2 Master thesis project

CBA has been responsible for the following master thesis project.

1. **Methods and Algorithms in Real-time 3D Computer Graphics**
   Student: Johan Mattsson
   Advisors: Hans Frimmel, Ewert Bengtsson
   Period: 9811–9904 *Pages:* 57
   Abstract: The challenge of real-time 3D computer graphics lies within designing as fast as possible algorithms, and systems that still can generate interesting visual effects. We are not concerned with the physical correctness, rather the spatial perception of the animation composed by the sequence of generated images. This document describes a selection of software methods and a set of algorithms that can be used to create such an animation. The primal focus on the content is to simplify and modify known general algorithms and systems for speed tradeoff.

4 Graduate education

At the end of 1999, there were at CBA six graduate students in computerised image processing at UU, one in remote sensing at UU and five in image analysis and remote sensing at SLU, i.e., a total of twelve. This is considerably less than last year, the reason being that there has been no less than seven exams this year. We have had four PhD dissertations, two at each university. The two at SLU were the first ones ever in image analysis and remote sensing at that university. In addition there were three licentiate degrees awarded, two at SLU and one at UU. Finally, for the first time, a Docent degree was awarded at CBA. Formally, you can apply for this degree when you have published an amount comparable to a thesis after your dissertation and proven your pedagogic abilities. Thus, the year 1999 can truly be said to have been a great "harvest" as regards graduate education.

4.1 Courses

Every autumn CBA organizes a graduate course in *Application Oriented Image Analysis*. The course is intended for researchers and research students in other fields who wish to learn digital image analysis for use in their own research. Therefore, the focus is more on practical issues than on theory. The course usually has students from both universities, together with some from industry. We have also given two other graduate courses.

During 1999 the following graduate courses were given:

1. **Modern Imaging Systems**
   Period: 9901-9903 *Credits:* 5
   Examiner: Ewert Bengtsson
   Lecturers: About a dozen invited experts from various imaging fields
   Topic: A comparative description of various modern imaging techniques and how they can be applied discussing aspects such as resolution in space, spectrum and time, signal to noise etc.

2. **High-dimensional Data and Image Analysis**
   Organiser: Dietrich von Rosen, Lennart Thurfjell
   Address: TDB
   Date: 990805–990806
   Attendees: 45 graduate students participated
   Topics:
   "Multivariate Analysis in large Number of variables", Kai-Tang Fang, Hong Kong Baptist Univ.
   "Orthogonal Image Transformations", Allan Aasbjerg Nielsen, Tech. Univ. of Denmark
   "Independent Component Analysis (ICA)", Aapo Hyvärinen, Helsinki Univ. of Technology
   "Image Analysis for the Biological Sciences", Chris Glasbey, Univ. of Edinburg
   Comment: The course was a joint event between VISIT and NTM. Apart from the scientific program, a Boule contest was arranged.

3. **Application Oriented Image Analysis**
   Period: 9910-9912 *Credits:* 5
   Examiner: Gunilla Borgefors
   Lecturers: Petra Ammenberg, Ewert Bengtsson, Gunilla Borgefors, Bo Nordin, Ingela Nyström, Lennart Thurfjell
   Computer Exercises: Mattias Aronsson, Carolina Linnman, Roger Lundqvist, Mattias Moëll, Anna Rydberg, Felix Wehrmann
   Topic: Introduction to Image Analysis concepts. In addition to the lectures there are three half-day computer exercises.

4.2 Licentiates

1. **The Distance Transform Algorithm on General Parallel Computers**
   Anders Forsmoo
   Date: 990506
   Pages: 15 *Year:* 1999; CBA Licentiate Thesis No. 1
   Committee: Ewert Bengtsson, Mikael Thuné, Thomas Wester
   Abstract: Parallelization of image analysis algorithms is often suggested when faster execution is asked for. Algorithms that use local information in the image, e.g. filtering, is easy to parallelize. This thesis is about attempts to parallelize the distance transform algorithm, which needs global information from the image and thus cannot easily be parallelized. This property is common with other algorithms and therefore the distance transform is a model algorithm and the results may be applicable to other algorithms. Modest improvements of speed is found. The presented methods can be used to parallelize more time-consuming algorithms in which the distance transform is used.

2. **Automatic and Interactive Information Extraction from Hyperspectral Imagery**
   Emma Lindqvist
   Date: 990903
   Pages: 19 *Year:* 1999; CBA Licentiate Thesis No. 2
   Committee: Sören Molander, Petter Ranefall, Catherine Östlund
   Abstract: The purpose of the thesis was to combine relevant parts of classical image analysis with remote sensing and add multivariate statistics and other modern mathematical image analysis tools. The work has been concentrated on the data from imaging spectrometers, which deliver data of high dimensionality, yielding more measurements per pixel than previous sensors. Spectral signatures are acquired from hyperspectral imagery. Some problems that may occur when analyzing them are discussed, as are a method of finding targets in the imagery. In order to increase the spatial resolution of the data, a fusion with image data of higher spatial resolution may be performed. Some methods to reduce the amount of data are discussed: the common PCA (principal component analysis) and the new SDR (standard deviation ratio) method. A feature selection method is included in order to give a brief overview of yet another reduction method. Two methods of classification are described, the supervised Bayes classifying method and the unsupervised k–means clustering method. Classification is an important application within both image analysis and remote sensing and therefore mentioned. The art of edge detection is treated, and it is discussed how it may be done in multiple band images, e.g., hyperspectral images. Two different sets of hyperspectral data have been used: GER–63 data and 48 bands of data by AVIRIS.

3. **Aspects of the Chain of Processing and the Application of Multi- and Hyper-Spectral Data from Lakes**
   Peter Flink
   Date: 991119
   Pages: 46 *Year:* 1999; CBA Licentiate Thesis No. 3
   Opponent: Bertil Håkansson, SMHI, Norrköping
   Abstract: This thesis deals with the use of imaging spectrometry data in the science of remote sensing. The focus is on remote sensing of lakes. The overall objective is to assess lake water quality by means of remote sensing, which indeed is a very complicated task. To fulfil this objective an interdisciplinary approach is necessary. Disciplines involved are limnology, optics in general and, specifically, optical properties of lake water environments and of the atmosphere, electronics to understand the instruments, signal and image processing methods. Fragments from all these disciplines are mentioned in this work. More focused objectives with this work have been to evaluate

the importance of different preprocessing steps in remote sensing, to provide tools to handle remote sensing data and to develop a tool for monitoring lake water quality based on bio-optical modelling. One challenge of remote sensing of lakes is their low reflectance, which gives low signals that are hard to accurately measure. Several disturbances that are present, but which are negligible in other applications, become important in lake applications. Common problems with hyperspectral datasets are addressed and the influence of the atmosphere on the data is exemplified. Methods of preliminary data analysis are given as well as application-oriented methods connected with lake water quality assessment.

4.3 Dissertations

1. **Analysis of Imaging Spectrometer Data with Lake Environment Applications**
   Catherine Östlund
   Dissertation date: 990312
   Pages: 123 *Year:* 1999; Uppsala Dissertations from the Faculty of Science and Technology, No. 17
   ISBN: 91-554-4384-2
   Opponent: Stein Bie, ISNAR, The Hague, The Netherlands
   Committee: Bengt Lundén, Håkan Olsson, Jussi Parkkinen
   Abstract: In this thesis the image processing and analysis aspects of imaging spectrometer (IS) data have been investigated for water and wetland applications. The Compact Airborne Spectrographic Imager (CASI) has been the main instrument in the evaluations. To fully benefit from the high spectral and spatial resolution data in the analysis phase, the pre-processing of data, is important and has been a focus of this thesis. To restore, improve and evaluate the data, the radiometric calibration, wavelength band positioning, noise and other radiometric anomalies, geometric calibration and atmospheric calibration have been studied. Existing methods have been evaluated, and new ones proposed, and the most appropriate methods applied to the data. On the image analysis aspects of hyperspectral data sets, spatial true physical structures in the images were studied using data compression and segmentation methods, and a new technique combining compression and colour transformation. The latter was shown to be a fast and objective method to visualise the spatial structures in a large data set. The usefulness of IS data in water quality applications was evaluated developing statistical relationships between image data and data collected in the field. A comprehensive *in situ* data set, collected along a transect in Lake Erken, Sweden, during a bloom of the cyanobacteria Gloeotrichia echinulata was used. It was found that a correlation of the image data to chlorophyll a and phaeophytine a could be established, but also that the pre-processing of images is important, and that the dynamic character of water is a complicating factor. Aquatic macrophytes in Lake Mälaren, Sweden, were classified. IS data was found to be powerful for these kinds of applications, but the analysis suffered from poor data.

2. **Extraction of Forest Stand Parameters from CARABAS VHF SAR Images**
   Fredrik Walter
   Dissertation date: 991008
   Pages: 49 *Year:* 1999; Acta Universitatis Agriculturae Sueciae, subserie Silvestria, No. 115
   ISBN: 91-576-5649-5
   Opponent: George Nagy, Rensselaer Polytechnic Institute, Troy, NY, USA
   Committee: Josef Bigün, Hans Hellsten, Göran Ståhl
   Abstract: Methods for extracting stand-wise forest parameters from CARABAS VHF SAR images have been developed and evaluated. CARABAS is a unique airborne synthetic aperture radar (SAR), developed by the Swedish Defence Research Establishment. It differs a lot from ordinary microwave radars by using wavelengths between 3.3 and 15 m, making the image intensity highly correlated to stem volume. Furthermore, by providing its own illumination source, the sensor operates independently of daylight and weather conditions. Empirical regression models have been developed for relating backscattering amplitude to stem volume, stem diameter, and tree height. To compare between CARABAS image data and forest parameters effective, a fully automatic geocoding algorithm was developed. Image texture features have also been investigated. By using the variogram as a discriminating feature, CARABAS images and aerial images were segmented into homogeneous regions. Furthermore, a method for discriminating recently clear felled areas from forested areas, combining information from Almaz-1 SAR images and SPOT panchromatic data has also been developed, serving as a comparison to the main work of this thesis. For forest stands at near-horizontal ground, the results for estimating stem volume, stem diameter, and tree height

from CARABAS image data are very satisfactory. The root mean square errors for the estimates are comparable to subjective ground-based inventories for dense forest stands. The methods and algorithms described in this thesis have been developed towards an operational remote sensing tool. Altogether, significant potential for mapping of forest characteristics exists using the CARABAS VHF SAR sensor.

3. **Positioning Biopsy Needles in the Prostate Gland Using 3D Computer Modelling**

Hans Frimmel

Dissertation date: 991015

Pages: 52 *Year:* 1999; Uppsala Dissertations from the Faculty of Science and Technology, No. 465

ISBN: 91-554-4516-0

Opponent: Björn Gudmundson, Linköping University

Committee: Tomas Gustavsson, Örjan Smedby, Björn Stenkvist

Abstract: In the world of medicine, image diagnostics have, until recently, been based merely on two dimensional information sources. The understanding of three dimensional structures has been limited to creating mental images in the mind of the physician, to wax models and to autopsy. In the last few years, computers have made it possible to model and reconstruct real three dimensional objects and thus give the physician a new tool not only to describe localisation and distribution patterns of diseases, above all cancer, but also as an aid in the understanding of the human body. This thesis contributes in the development of such tools, based on a specific application.

Prostate cancer is for men the most common form of cancer. Improvement in diagnostics for this form of cancer would facilitate planning of treatment and hence save, and preserve the quality of, life. One way to diagnose and quantify prostate cancer is to assess its presence and malignancy grade in cylindrical tissue samples taken with a needle biopsy device. Today, two to six such samples are generally taken, with poorly standardised rules for the positioning of the needle, thus interindividual variation exists.

In this thesis, 3D models to analyse the problem with the positioning of biopsy needles have been developed. By using information from physical prostates removed from patients by surgery, a 3D cancer probability distribution has been built. Using this information, a standardised biopsy needle protocol has been created that is efficient, stable and easy to use. In this process new methods for morphing images, registrating slices and optimising positions for use with computer modelling have been developed.

Many physicians were involved in the study. Thus, an important part of the work has been to make every part of the work understandable for people without special computer programming knowledge. Also, efforts have been made to make it possible to easily examine every piece of information created in order to verify the correctness of the methods used.

4. **Automatic Individual Tree-Based Analysis of High Spatial Resolution Remotely Sensed Data**

Tomas Brandtberg

Dissertation date: 991119

Pages: 46 *Year:* 1999; Acta Universitatis Agriculturae Sueciae, subserie Silvestria, No. 118

ISBN: 91-576-5852-8

Opponent: Axel Pinz, Graz University of Technology, Austria

Committee: Sten Nyberg, Håkan Olsson, Gunnar Sparr

Abstract: The thesis presents automatic and computer-based methods for analysing near-nadir high spatial resolution remotely sensed data on forests, and the objective of the thesis is to further investigate this relatively young research area. The data are acquired from low altitude (below 1000 m) on Swedish forests, at the Huljen test site 40 km west of Sundsvall (62°27′ N, 16°55′ E), and at the Tönnersjöheden Experimental Forest in the vicinity of Halmstad (56°41′ N, 13°6′ E). The remotely sensed data consist of digital colour infrared aerial photographs (CIR) and laser

scanning data (LIDAR). Collections of individual tree-based ground truth data are available on each test site. The presented approaches are based on individual trees, i.e., the visible individual tree crowns in the data are delineated and in the subsequent analysis treated as single objects. The reflectance values in the CIR images, the general pattern, and tree crown dimensions in 3D, are measured. Predictions of stem and crown diameters, stem number per hectare, and tree stem position are evaluated. Internal structures of the tree crowns, i.e., regions similar to branches or part of branches, are defined and extracted. Several applications of these regions-of-interest are shown. In this thesis they are mainly used for tree species classification. A complete system to classify the species of each individual image object was developed using measured features of each tree crown. The classification system is based on fuzzy set theory and its accuracy is evaluated and discussed. A scale-space and fuzzy set-based method to identify the extent of individual tree crowns in high spatial resolution laser scanning data was developed. The technique might be capable of estimating a stable height value of an individual tree crown.

4.4 Docent degree

Registration of Medical Images

Lennart Thurfjell

Date: 991001

Abstract: Different imaging modalities enhance complementary information. Single photon emission computed tomography (SPECT) and positron emission tomography (PET) provide functional information whereas x-ray computed tomography (CT) and magnetic resonance imaging (MRI) supply anatomical information. Comparison of images from different examinations is important for improving diagnosis and for planning and evaluation of treatment. However, direct comparison of different images voxel by voxel requires that the images are brought into a form in which each voxel corresponds to a predetermined anatomical entity. This process is known as image registration.

Registration of images from the same individual is known as intra-subject registration. Furthermore, intra-subject registration can be subdivided into intra-modality registration (the images are obtained using the same modality) and inter-modality registration (images are from different modalities).

Comparison of scans between individuals is also important for example to allow for a patient's scan to be compared to an average image obtained from a control group thereby providing new diagnostic information to the physician. This requires inter-subject registration that brings all images into a standard anatomy.
At the lecture, previous work in the field of intra- and inter-modality as well as intra- and inter-subject image registration will be reviewed and some of the problems with current methods and challenges for future developments will be discussed.

Comment: Sten Kaijser was present as representative of "Docenturnämnden".

5 Research

The CBA is conducting a whole range of projects ranging 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 CBA we have given priority to applications in the fields of biomedicine and the environmental sciences. We have also some 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. We start with applications, loosely grouped by subject, and continue with basic research.

For each project we list who at CBA is involved, where the funding comes from, when the project started and finished, and who our cooperation partners outside CBA are.

5.1 Current research projects

1. **Automated analysis of forest using high resolution CIR aerial images**
   Tomas Brandtberg, Gunilla Borgefors
   Funding: SJFR
   Period: 9508–0006
   Abstract: The main goal of the project is to develop methods for computerized analysis of high spatial resolution remotely sensed data, i.e., digitized aerial photographs and laser scanning data. A set of 50 research aerial images (digitized colour-IR film), with resolution approximately 10 cm (flight height 600 m, focal length 300 mm) to make the individual tree crowns clearly visible is used. Interesting image features are (e.g.) horizontal tree crown area, features related to the individual tree species, such as (R,G,B)-data, and tree height and position. A fuzzy set-based system for tree species classification has been developed during 1999. An automatic system for individual tree-based analysis of laser scanning data has also been developed and will be evaluated next year (2000). See some image examples in Figure 2. Two papers (a conference and a journal paper) were published during 1999. Dissertation was held November 19, 1999 in Uppsala.

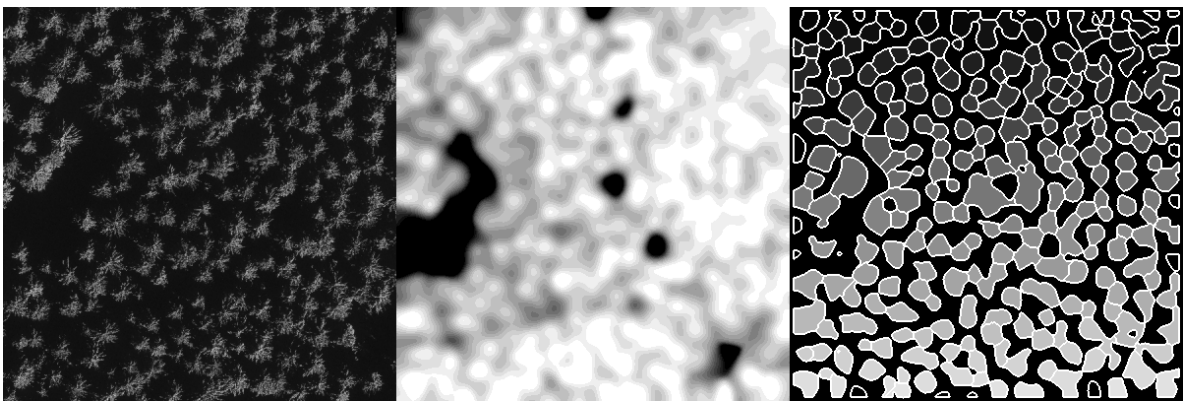

Figure 2: The leftmost image shows a high spatial resolution aerial image, the middle image shows the corresponding smoothed laser height (above ground) image with tree crowns visible as bright blobs, and the rightmost image shows individual tree crowns found by the system in the laser scanning data set. (Each image is 100x100 meter and the forest is dominated by Norway spruce.)

2. **Automatic geocoding of CARABAS VHF SAR data**
Fredrik Walter
Funding: SLU S-faculty, SJFR
Period: 9806–9907
Partners: Johan Fransson, Dept. of forest resource management and geomatics, SLU, Umeå; Per-Olov Frölind, Sensor technology division, National Defence Research Establishment (FOA)
Abstract: Fully automatic geocoding algorithms of CARABAS VHF data have been developed. The CARABAS flight parameters and a 50×50 m resolution digital elevation model has served as input data for the algorithms. Algorithms for both Slant-Range projection (SAR image plane) to Ground-Range projection (orthogonal map projection) and vice versa have been developed. The maximum deviation from true position on the ground is in the order of 10 m, which is satisfactory for most forestry applications. The main source of error in the geocoding is caused by the coarse scale digital elevation model, which does not take small scale variations into account. The results of this project have been presented at IGARSS'99 in Hamburg, 28 June - 2 July, 1999.

3. **Extraction of forest parameters from CARABAS VHF SAR data**
Fredrik Walter, Gunilla Borgefors
Funding: SLU S-faculty
Period: 9407–
Partners: Dept. of Surveillance Radar, Swedish Defence Research Establishment (FOA), Linköping Dept. of Forest resource management and geomatics, SLU, Umeå
Abstract: CARABAS is a VHF SAR sensor, developed at the Swedish Defence Research Establishment (FOA) in Linköping. By using frequencies in the range of 20–90 MHz, the sensor is in sharp contrast to conventional microwave SARs well adapted to the larger objects constituting the forest, i.e. trunks and other larger objects. The goal of this project has been to develop methods for automatic extraction of forest parameters from CARABAS image data. Forest stand volume, stem diameter, and tree height have been compared to CARABAS I and II backscattering amplitude. In the first study in 1994, and in studies performed by other research groups, it was shown that there is correlation between the backscattered signal and forest biomass. In late 1997 the CARABAS II sensor registered images over the forest research park Tönnersjöheden in Halland. These images have been analysed during 1998 and 1999. In the main study on these data it has been shown that there is a very strong correlation between CARABAS II images and forest stand volume, stem diameter and tree height in forest stands situated on near-horizontal ground. See Figure 3. During year 2000, investigations over other forested areas will be performed, to validate the obtained results and to develop methods for compensation of ground slope induced backscattering variation.

4. **Automatic geographical correlation of LIDAR data and CARABAS images**
Mattias Jacobsson, Tomas Brandtberg, Fredrik Walter
Funding: SLU
Period: 9909-0003
Abstract: The LIDAR (SAAB TopEye) system and the CARABAS VHF SAR are two different airborne sensors used for acquisition of high and moderately high, respectively, spatial resolution images of forests. Very accurate individual tree-based parameters about the forest can be extracted, especially the tree height and position, after processing of the LIDAR data. In order to judge the usefulness of the CARABAS image for individual tree-based forest parameters extraction, a correlation of the two different images are performed. See Figure 4.

5. **Automated segmentation of remotely sensed images over agricultural fields**
Anna Rydberg, Gunilla Borgefors
Funding: SLU JLT-faculty
Period: 9602–
Abstract: Crop species identification, crop area, and yield prediction and estimation are important measurements, that can be facilitated by remote sensing. 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 remotely 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.
As a first step, a multispectral segmentation method for automated delineation of agricultural field

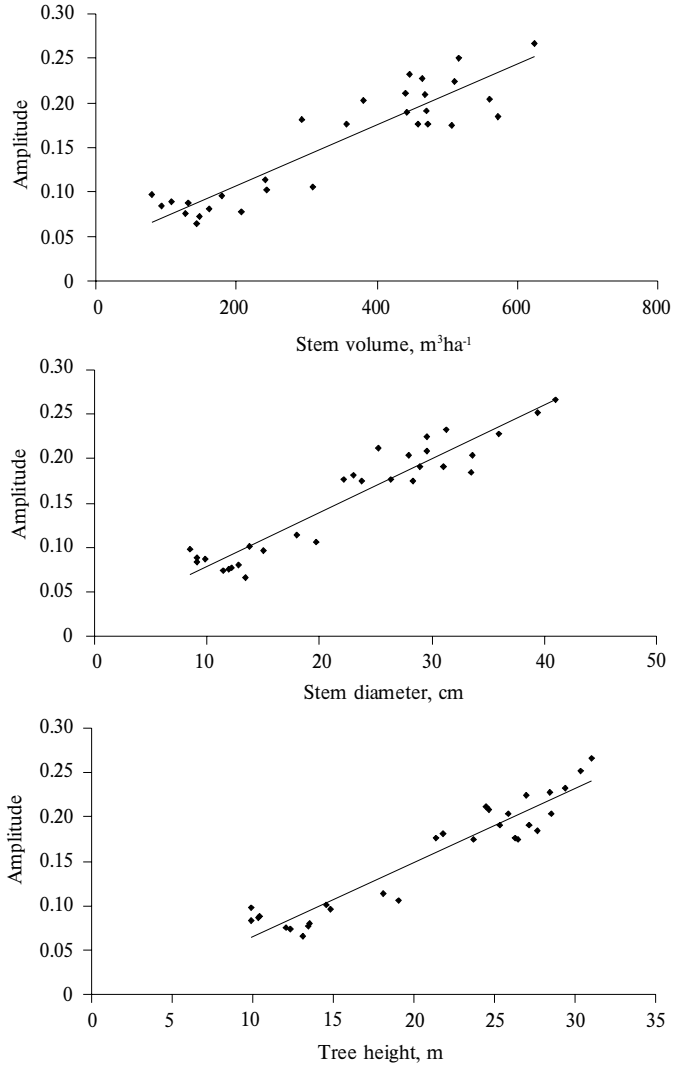

Figure 3: CARABAS-II backscattering amplitude plotted against forest stand volume, stem diameter, and tree height.

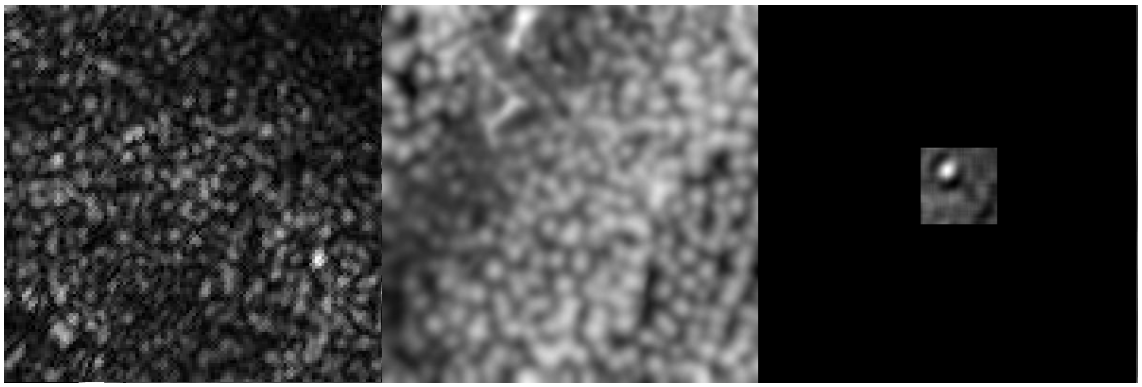

Figure 4: A CARABAS image (left) and an artificial image based on the LIDAR data (middle) with the corresponding correlation image (right).

Figure 5: A SPOT scene with multispectraly detected edges in white.

borders is under development. Information from several spectral bands (and/or different dates) can be used for delineating field borders with different characteristics. Multispectral and multi-temporal edge detection in remotely sensed scenes is a challenging but increasingly important task. Agricultural statistics are often obtained per-field and for instance crop classification procedures obtain better results from a per-field classification than from a per-pixel classification.
There is a very large number of edge detectors available in the literature, but few are able to combine information from many spectral bands in an optimal way. Also, general edge detectors tend to perform badly for some object classes, e.g., sharp corners are often rounded. Apriori knowledge about field shape and size should be taken into account if possible. Some results were presented on the ICIAP'99 conference in Venice.

6. **Application of remote sensing for agricultural crop production in Sweden**
Jakob Nisell, Catherine Östlund, Gunilla Borgefors
Funding: European Commission through Statistics Sweden (SCB)
Period: 9611–
Partners: Statistic Sweden (SCB), Örebro; 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 has partly been adopted to Swedish conditions. We have used time series of NOAA AVHRR images to follow spectral and vegetation index changes during the crop season growth over large areas in the Skåne and Skaraborg counties. Because of the low spatial resolution of NOAA AVHRR the index changes for a single crop can not be followed. However, by using high resolution images from Landsat TM and/or SPOT relative crop areas within the large pixels can be determined. Unfortunately, the methods does not seem to work very well for Swedish conditions. There is a close cooperation with Dept. of Crop Production, SLU, where a crop growth model based on the CGMS model is being developed. A preliminary version of the final report has been sent to IRSA.

7. **Environmental applications of Imaging Spectrometry**
Catherine Östlund, Tommy Lindell
Funding: Swedish Space Board, EU
Period: 9207–9903
Partners: K. Sörensen, NIVA, Oslo, Norway; F.L. Berta Andersson, Dept. of Environmental Assessment, SLU, Uppsala
Abstract: Data with high spatial and spectral resolution collected by imaging spectrometers (ISs) has been analysed in lake applications. The aim was to study the processing steps from raw image data to a final processed thematic image. Pre-processing problems originating from sensor, atmosphere, and target, were studied for evaluating the data quality, and different techniques were studied and applied for improving the data. High resolution gives large data sets, and several methods of compressing and segmenting data were studied. For water quality purposes, the correlation between spectral data and separate water quality variables were studied partly using ordinary statistics techniques, and partly using image-based techniques, such as colour transformations. The results of the project were presented in the PhD thesis "Imaging Spectrometer Data with Lake Environment Applications". See cover page (top-left) for a pseudo-coloured image of Lake Erken from the thesis.

8. **Satellite remote sensing for lake monitoring (SALMON)**
Tommy Lindell, Peter Flink, Catherine Östlund
Funding: EU
Period: 9601–9911
Partners: CNR-IRRS, Milano, Italy; CNR-ISDG, Venezia, Italy; Joint Research Centre-Environment Institute, Water Research Management, Ispra, Italy; Dept. of Biology, Universit degli Studi, Milano, Italy; Laboratory of Space Technology, Helsinki Technical University, Finland; Finnish Environment Agency, Finland; Dept. of Limnology, UU
Abstract: The main objectives with the project have been:

   - the exploration of new correlations between biological, chemical, physical parameters with the remotely sensed data
   - the optimization and actual limits in the use of existing and near-future EO data in this field of application
   - the definition of future space sensor needs for monitoring of European lakes
   - the definition of new protocols for standards in the acquisition of remotely sensed data of limnological interest
   - a procedure for integration of EO data information in a suitable GIS in order to design, in the near future, an automated model of lake surveillance

   The most important advances are judged as:

   - the identification of the most suitable methodologies to correlate remotely sensed data to limnological parameters with the aid of bio-optical modelling
   - the definition of a reliable surveilling tool for the lake water quality analysis, that is expected to be less dependent on *in-situ* calibration measurements than the usual routine applications and much less site and time-dependent than the existing analysis techniques
   - the direct implication of either public or private water management agencies and enterprises at different levels of territorial competence. Major industrial implications concern the design and creation of new cost-effective tools for monitoring environmental emergencies for European lakes

   The project was finished in 1999 with a final report to EC and more than 35 papers published or under publication in international media of which 18 from the Uppsala group.

9. **Remote sensing for change detection and monitoring of Case II and lake waters**
Tommy Lindell, Petra Ammenberg
Funding: Foundation for Strategic Environmental Research (MISTRA), RESE programme
Period: 9701–
Partners: Swedish Meteorological and Hydrological Institute (SMHI), Norrköping; et al.
Abstract: The ability to map and monitor water quality parameters in Case II and lake waters is of great environmental interest. Images from spectrographic sensors constitute an important part of such a mapping and monitoring system and the evaluation of these images/sensors is of major interest.
Images from the Compact Airborne Spectrographic Imager (CASI), collected over the inner parts of the archipelago of Stockholm in August 1997 have been evaluated in combination with simultaneously collected field data. The work in the archipelago has been concentrated on finding relations between the water quality variables and the reflectance measurements from the field and correlation analysis between field and scanned data (CASI).
The correlation between the reflectance measurements and the water quality variables is high, which indicates possibilities to use optical data for mapping. However, subsequent regression analysis between CASI data and field data did not show the same promising tendency in small areas. This is mainly a result of the poor quality of the CASI data caused by turbulent and cloudy weather conditions, small water quality gradients and unsatisfactory pre-processing. However, the correlation is obvious considering the whole data set.
It is unlikely that the resulting algorithms from these kind of empirical relationships will be sufficiently general to be used in a variety of contexts. The algorithms derived in this manner are often very site and/or instrument specific. In recent years, the focus of lake water monitoring by remote sensing, has shifted towards coupling remotely sensed data to semi-analytical modeling of the sub-water optics. A semi-analytical model has been used to construct algorithms independently of the image data. The algorithms were applied to atmospherically corrected CASI data from Lake Malaren collected in August 1997.
Distribution maps (Figure 6) for three retrieved parameters were constructed and the continuous field measurements have been used for validation of the retrieved variables. The results from the validation of the CASI algorithms are very satisfying, and the modelled concentrations and absorption coefficients corresponds very well to the ground truth measurements, which is very encouraging for the future work.

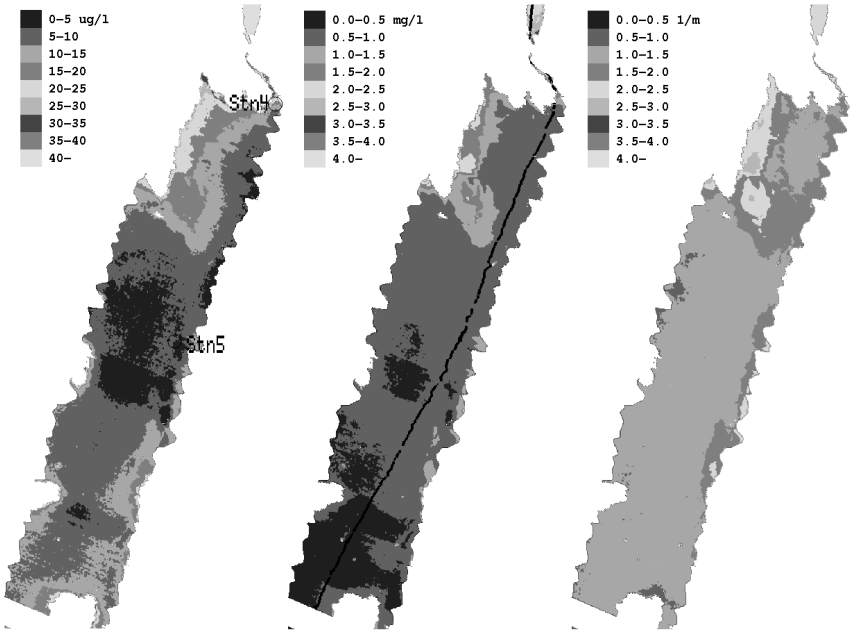

Figure 6: Distribution maps for Chl (left), SPIM (middle), and $a_g(420)$ (right).

10. **Analysis and display of high dimensional remote sensed data**
Emma Lindqvist, Gunilla Borgefors
Funding: Foundation for Strategic Environmental Research (MISTRA), RESE program
Period: 9702–9909
Partners: The "thematic" projects within the RESE program
Abstract: New kinds of sensors for remote sensing, e. g. imaging spectrometers, will deliver data of great dimensionality, up to 100–200 spectral bands, compared to "normal" multispectral images with only 5–10 spectral bands. Each hyperspectral pixel thus yields an almost continuous spectrum. The spatial resolution, on the other hand, is not equally high. The amount of data in hyperspectral images and multisensor data is enormous, and makes human interpretation impractical. That is why methods to select the most important information for display and analysis are needed. A method for automatic selection of bands to use for these purposes has therefore been developed, and a paper on this method has been submitted for publication. The method is called the Standard deviation ratio method and uses different mathematical measures like standard deviation and correlation in order to find the most useful bands. The method does not transform the data as the commonly used Principle components analysis (PCA) does. Experiments were made in order to evaluate the advantages between selecting data by the SDR method and PCA. In images with bands selected by SDR, it was found that e.g. edges were more easily detected than in images composed by principal components.

11. **3D image reconstruction and analysis of HIV-1**
Ingela Nyström
Funding: UU
Period: 9906-
Partners: Stefan Höglund, HIV structure group, Dept. of Biochemistry, UU
Abstract: Sample specimens of HIV-1 are studied in series of different tilt angles between +60° to -60° with a goniometer in transmission electron microscopy (TEM). Typically a tilt series consists of 25 to 40 electron micrograph projections. Each of these is digitised. Thereafter, the digital images are aligned, using the coordinates of (some of) the gold particles (10 nm) as reference points. The 3D reconstruction is made as a series of 2D reconstructions, each a combination of the radius-weighted Fourier transform of one pixel line of each micrograph. The 3D reconstructions are typically of size $256 \times 256 \times 80$ voxels (appr. 5 Mbyte).
The goal of the project is to achieve 3D reconstructions of single HIV particles. The reconstructions must be of as good quality as possible so these can then be quantitatively analysed through, e.g., convex hull computations, as well as qualitatively analysed through visualization methods. The 3D reconstructions are prepared both for structural analysis and evaluation of optical density of the micrographs. This would reflect the distribution and packing of biochemical substances in the viral core structure.
Comments: The former project between CBA and the HIV structure group has been revived.

12. **Segmentation and analysis of biological 3D shapes**
Carolina Linnman, Ewert Bengtsson
Funding: Swedish Foundation for Strategic Research, VISIT program
Period: 9806–
Partners: S. Ekholm-Jensen, F. Erlandsson, and A. Zetterberg, Dept. of Oncology/Pathology, CCK, KI
Abstract: Shape and distribution of various subcellular structures and components can be observed by immunostaining and insitu-hybridization of fluorescent markers followed by fluorescence microscopy in three dimensions. The 3D images are aquired by making noninvasive serial optical sections of the object. Studies of the distribution of signaling-factors involved in the cell cycle control indicate that minor changes in the signaling systems are the first signs of cancer transformation and tumor formation. Understanding the 3D organisation of normal and transformed cell-nuclei is therefore of great interest as a new approach to understanding the pathways of cancer. The aim of this project is to measure the differences in DNA-replication-time between normal and transformed cell-lines. A large number of test images have been supplied by a close cooperation with the Dept. of Oncology/Pathology, Div. of Tumor Cytology, CCK, Karolinska Hospital and Institute. A 3D segmentation method that finds local intensity maxima is used together with a

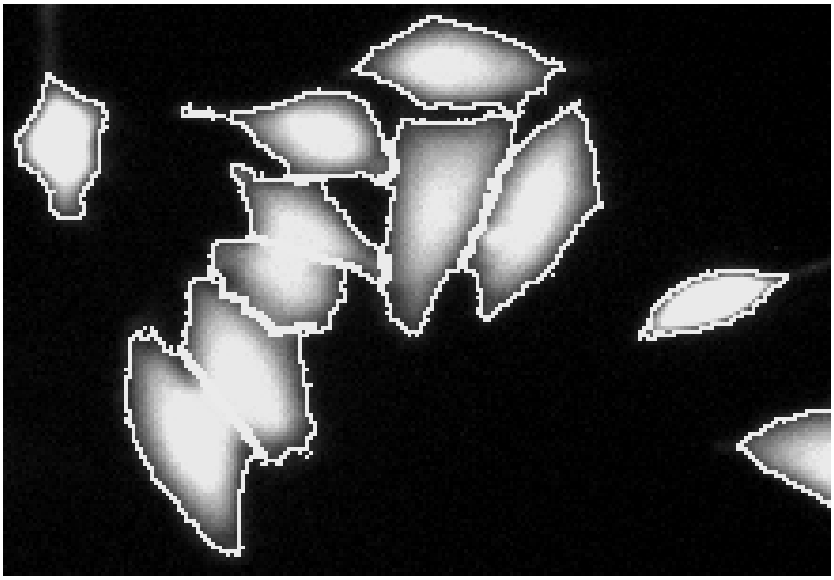

Figure 7: Fluorescence microscopy image of cells growing on a surface and the result of the segmentation algorithm.

3D distance transforms and the possibilities of extracting information about colocalisation and pairing of replication complexes and newly synthesized DNA is presently being explored. Simple methods for semi-automated measurements of fluorescent signals from labeled proteins involved in the cell-cycle have also been developed.

13. **Algorithms for segmentation of fluorescence labelled cells**
Carolina Linnman, Joakim Lindblad, Mikael Vondrus, Torsten Jarkrans, Ewert Bengtsson
Period: 9902–
Partners: Lennart Björkesten, Amersham Pharmacia Biotech, Uppsala
Abstract: The interaction with and effect of potential drugs on living cells can be observed by fluorescence microscopy. Automated methods for feature extraction from fluorescence microscopy images of cells can be used as a tool in the drug discovery process. The cell nucleus has a well-defined shape and is relatively easy to detect. The cytoplasm is however more complex. The first goal of this project was to develop a fully automatic method for cytoplasm segmentation. The present algorithm, inspired by literature and previous experience, consists of an image pre-processing step, a general segmentation and merging step followed by a quality measure and a splitting step. By training the algorithm on one image, it is made fully automatic for subsequent images created under similar conditions. The method was presented at an internal Amersham Pharmacia Biotech R&D conference December 2, 1999 in Uppsala.

14. **Computer assisted cervical cytology**
Ewert Bengtsson, Bo Nordin, Mikael Vondrus, Joakim Lindblad
Funding: AccuMed International, Inc., Chicago, USA
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. Since the summer of 1994 we have had a cooperation project with the Chicago based company AccuMed International, Inc. A number of student projects and some investigations by the senior researchers at CBA have been carried out within this cooperation. During the last couple of years the activity has been limited to some technical discussions and feasibility studies of alternative approaches that Ewert Bengtsson has carried out for AccuMed and discussed during a visit in Chicago in March 1999. A more ambitious cooperation is currently being discussed.

15. **Quantification of microvessels in the prostate**
Mikael Vondrus, Ewert Bengtsson
Funding: UU
Period: 9901–
Partners: Christer Busch, Dept. of Pathology, University Hospital, Tromsø
Abstract: Quantification of microvessel density in prostatic carcinoma is often done by calculating the number of and/or the area outlined by the endothelial cells. The result is expressed in relation to the quantified tumour area. Automized image analysis quantification of microvessel density has proven to correlate well with manual quantification done by a pathologist. We have observed that the microvessel-pattern is highly dependent on the tissue architecture, which in turn depends on the distribution and size of the prostate glands. This indicates that, besides microvessel density, also microvessel pattern may be of prognostic importance in prostate cancer diagnostics. In this project, a new approach to microvessel quantification is tested and evaluated in comparison to malignancy grading and classical microvessel density.

16. **Optimizing the 3D placement of needle biopsies of the prostate**
Hans Frimmel, Ewert Bengtsson
Funding: UU
Period: 9505–9906
Partners: Christer Busch, Dept. of Pathology, UU, Lars Egevad, Dept. of Pathology and Cytology, Karolinska Hospital
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 81 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. During 1999 the project was documented in a PhD thesis by Hans Frimmel and several manuscripts were submitted to international journals covering various aspects of the obtained results.

17. **Fusion of 3D medical images**
Roger Lundqvist, Xavier Tizon, Lennart Thurfjell, Ewert Bengtsson, Gunilla Borgefors, Örjan Smedby
Funding: Swedish Foundation for Strategic Research, VISIT program
Period: 9707–
Partners: Uppsala University Hospital, Context Vision, EPIX Medical, Inc., Nycomed Amersham
Abstract: This is a long-term project where the overall objective is to develop methods to support diagnosis based on medical volume images. The data sets provided by the latest imaging techniques are often confusing to interpret for the physicians, mainly because of the complexity of the 3D structures visualized and the lack of visualization techniques. The images need to be presented to the physicains in such a way that they can be easily and correctly interpreted, but without removing essential information. In particular, we concentrate on the development of new methods for registration, visualization, and segmentation of medical images.

One part of the project is focused on analysis of PET, SPECT, MR, and CT brain images. We have developed voxel-based registration methods, both for rigid registration of data from different examinations of the same patient but also for non-rigid registration of data from different individuals. Furthermore, we have used a brain atlas to define volumes of interest and we have studied various texture features for classification of, e.g., Alhzheimer's disease.
Another part of the project has been to develop methods for measuring volumes of malformed blood vessels from X-ray angiography images. The subproject also involves fusion of the angiography information with anatomical MRI data, to better localize the position of the malformation.
As part of all subprojects there is also development on methods for 3D visualization of volume images. A goal is to construct new methods to visualize information from different image modalities

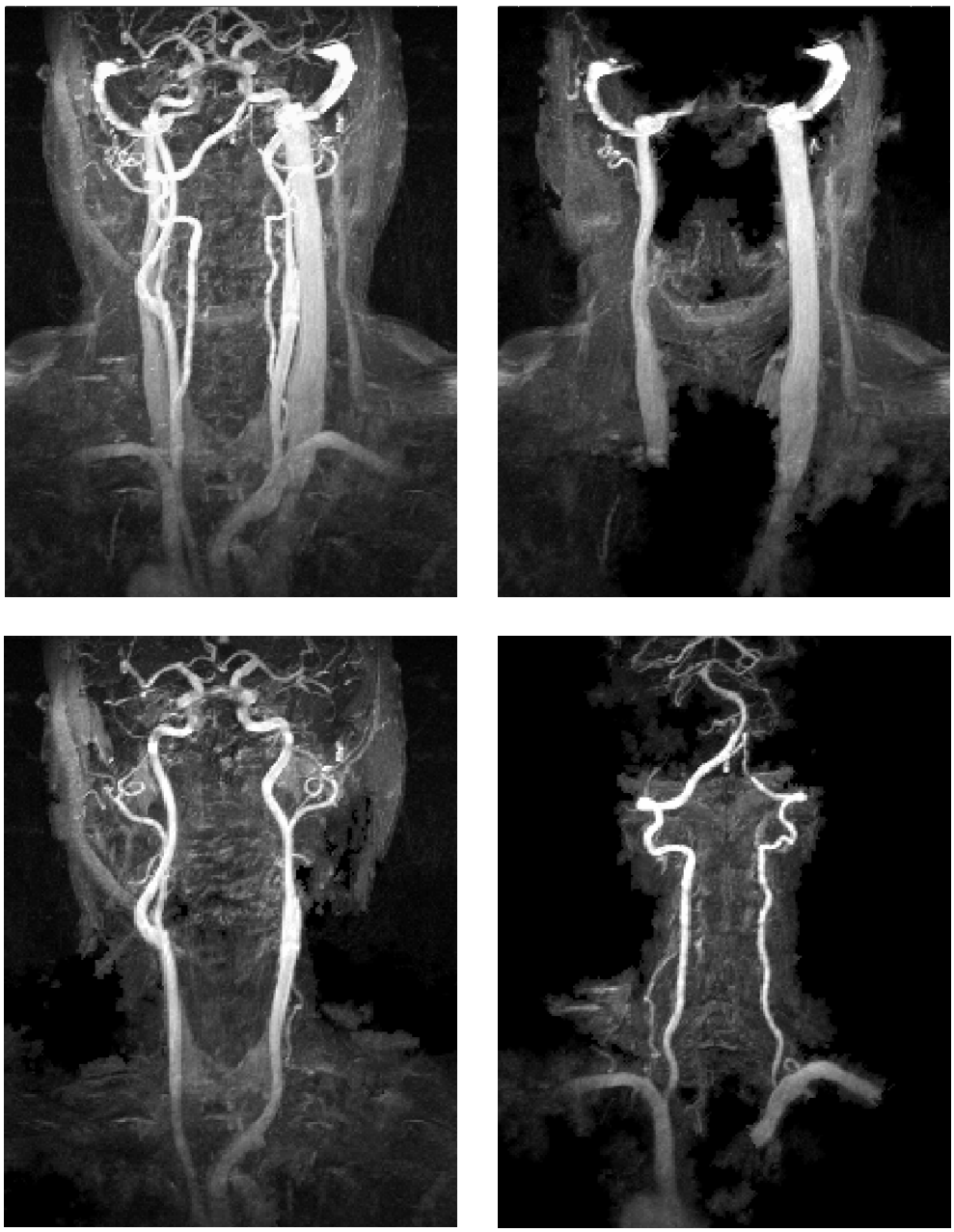

Figure 8: MIP projections of a contrast-enhanced MRA volume of the neck and head. Top-left: the original MIP. Top-right: the veins as retrieved by SeparaSeed. Bottom-left: the carotid arteries. Bttom-right: the vertebral arteries.

together, to enhance the complementary information contained in the images.

Arteries-veins separation in magnetic resonance angiography images
Yet another part of the project aims at selecting a subset of the volumetric data, and to present it in order to make the diagnosis easier. As an example, in magnetic resonance angiography (MRA), to be able to separate arteries from veins is of great interest. This problem is not trivial, because the vessels can lie in close parallel troughout the image. Our algorithm extends the concept of binary connectedness by using a fuzzy sets approach. We join together voxels that have high "hanging-togetherness", i.e., which form a coherent set in terms of gray-level variation. The results are then displayed as 2D projections using the common maximum intensity projection (MIP). See Figure 8.

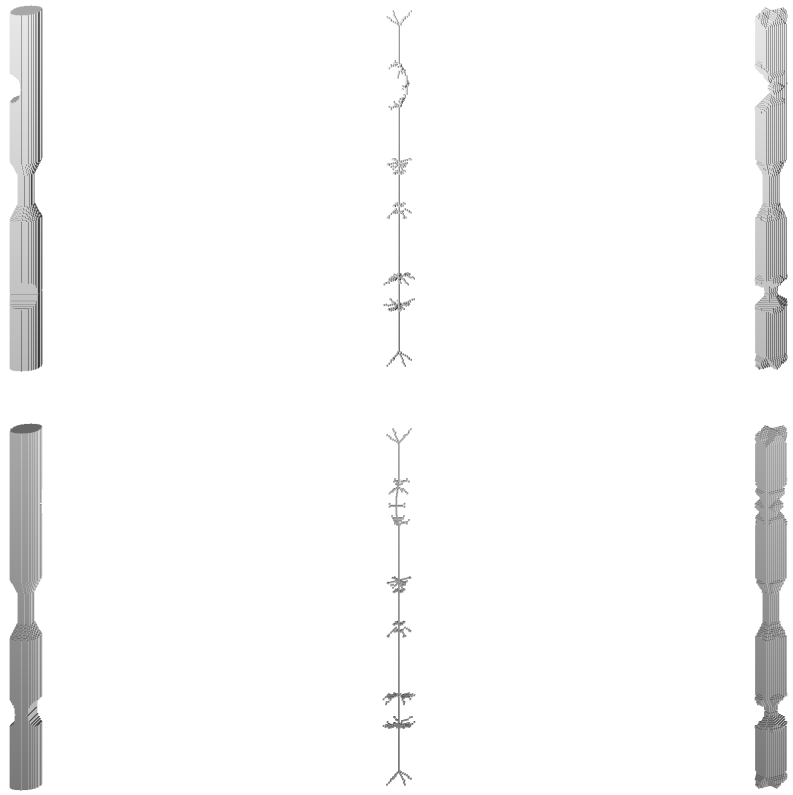

Figure 9: A synthetic image where three artificial "stenoses" have been introduced. Left: rendered 2D projections of the object for two different viewing directions. Middle: the corresponding curve skeleton. Right: reconstruction from the curve skeleton, showing that the choice of viewing direction is no longer crucial for detection of the "stenoses".

18. **Skeletonization applied to magnetic resonance angiography images**
Ingela Nyström
Funding: UU
Period: 9703–
Partners: Örjan Smedby, Dept. of Diagnostic Radiology, UU/ Div. of Medical Radiology, Linköping University Hospital
Abstract: When interpreting and analysing magnetic resonance angiography (MRA) images, the 3D overall tree structure and the thickness of the blood vessels are of interest. This shape information may be easier by utilizing the skeleton of the blood vessels. Skeletonization of digital volume objects denotes either reduction to a 2D structure consisting of 3D surfaces and curves, or reduction to a 1D structure consisting of 3D curves only. Thin elongated objects, such as blood vessels, are well suited for reduction to curve skeletons. There are indices that the tree structure of the vascular system is well represented by the skeleton. Positions for possible artery stenoses may be identified by locating local minima in curve skeletons, where the skeletal voxels are labelled with the distance to the original background.
MRA images are usually presented as maximum intensity projections (MIP), and the choice of viewing direction is then critical for the detection of stenoses. We propose a new presentation method which visualizes variations in vessel width independent of viewing direction. The idea is to surround each voxel in the curve skeleton with a sphere of radius corresponding to the distance value. This is done by the reverse distance transformation on the distance-labelled curve skeleton. See Figure 9. The distance values correspond to the minimum radius of the object at that point, i.e., half the minimum diameter of the blood vessel at that level. The reconstructed vessels may be visualized with any projection method.

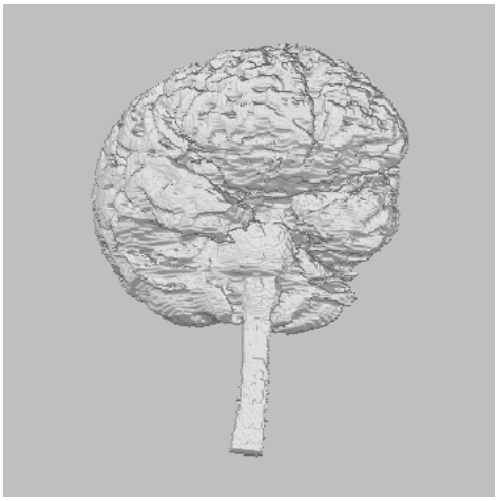

Figure 10: Visualisation of a segmented brain and spinal cord.

19. **3D medical image analysis based on a computerised brain atlas**
Lennart Thurfjell, Ewert Bengtsson, Roger Hult
Funding: NUTEK
Period: 9501–
Partners: Depts. of Neuroradiology and Clinical Neurophysiology, Karolinska Institute and Hospital; Dept. of Physics, Stockholm University; PET Centre, UU
Abstract: The objective of this project is to develop new tools for analysis and visualisation of neuroimaging data. These tools are partly integrated in a computerised brain atlas. The work during the last years has been focused on segmentation of MR images. A segmentation method based on connectivity analysis and morphology has been developed. The goal is to have a robust three dimensional method for segmentation of the brain in MRI data. A new atlas based on MRI data is under development and the segmentation method developed will be one of the tools used in this work. The present student Roger Hult started on this project in the end of 1995. The project is closely related to project 17. The medical cooperation partners are very important for this project. Due to an injury that Roger Hult suffered from, the rate of progress in the project has been slower than planned. A segmentation algorithm was presented at SCIA'99 on Greenland.

20. **Asymmetry of SPECT perfusion image patterns as a diagnostic feature for Alzheimer's Disease**
Lennart Thurfjell
Funding: Swedish Foundation for Strategic Research through the VISIT program and the Swedish Institute
Period: 9902-9905
Partners: Vassili Kovalev, Institute of Engineering Cybernetics, Belarus National Academy of Sciences, Minsk
Abstract: Diagnosis of Alzheimer's Disease is often based on blood flow images obtained using Single Photon Emission Tomography (SPECT). The objective of the project was to study the usefulness of different texture features derived from SPECT perfusion scans for discrimination of patients with Alzheimer?s Disease and normal controls. Asymmetry features were computed by considering different combinations of intensity and gradient information within pairs of three-dimensional anatomical regions defined by a brain atlas registered to the SPECT data. A K-means clustering algorithm was used to classify SPECT scans from 46 patients with Alzheimer's disease and 34 normal controls. The results showed that asymmetry features based on five-dimensional co-occurrence matrices, which combined intensity and gradient information, were very useful for discrimination of patients with Alzheimer's Disease and normal controls.
Comment: The project was carried out while Vassili Kovalev was appointed as a visiting researcher at the Centre for Image Analysis.

21. **Validation of fully automatic multi-modality registration**
Lennart Thurfjell
Funding: The project was jointly funded by Westmead Hospital, Sydney, Australia, and the Swedish Foundation for Strategic Research through the VISIT program
Period: 9811-9905
Partners: Westmead Hospital, Sydney, The Queen Elizabeth Hospital, Adelaide, Australia
Abstract: The purpose of the current work was divided into two parts. The first part was to implement a multi-modality registration method based on mutual information (MI) of voxel intensities and to investigate if the registration process could be accelerated through subsampling, i.e., by using only a subset of all voxels for the calculations. In the second part of the work, the implemented method was compared to several other previously published multi-modality registration methods. We evaluated 99mTc HMPAO SPECT to MR co-registration for 5 fully automatic methods. We attached 6 small fiducial markers, visible in both SPECT and MR, to the skin of 13 subjects. The location of each fiducial marker was determined in each modality to sub-pixel precision and the inter-modality distance was averaged over all markers to give a fiducial registration error (FRE). From the component of FRE we computed the error at a representative set of locations within the brain thus giving us an intrinsic registration error (IRE).
Comment: The first part of the project work was carried out while Lennart Thurfjell was appointed as a visiting researcher at Westmead Hospital in Sydney, Australia.

22. **Computerized wound image analysis**
Ewert Bengtsson, Bo Nordin
Funding: The industrial liason office, UU; CWA Institute AB, Västra Frööolunda
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 colour 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 cooperation with Pharmacia. Later this system was taken over by CWA Institute AB, and in 1995–96 we developed a new version based on a modern computer platform and our IMP software.
The exisiting versions of the system require the images to be delivered as paper photo copies. With the increased popularity of the Internet it would be a great advantage to be able to accept images and deliver results over the network. In addition to the straightforward communication aspects this involves the development of robust calibration procedures that can be based on calibration images scanned at the customer sites to ensure that we have full control over the photometric properties of the digital images that are analyzed. This new functionality was delivered to CWA Institute in 1999.

23. **Image analysis methods for food quality measurements**
Lucia Ballerini, Gunilla Borgefors
Funding: Foundation for Strategic Environmental Research (MISTRA), FOOD21 programme
Period: 9908–
Partners: Dept. of Food Science, SLU, Uppsala
Abstract: FOOD 21 is a broad scientific project, aimed to develop sustainable food production methods. To evaluate the results of the various experiments, the food quality project within FOOD21 requires quantitative analysis of a large amounts of microscopic and macroscopic pictures of fish, meat, cereal kernels, etc. This makes automatic or almost automatic image analysis methods necessary. These range from basic segmentation methods, where the percentage of various colours (substances) within the sample are determined developing both measures and measuring methods that can characterise net-like structures in biological samples. Sample preparation methods will be developed in close co-operation with image analysis methods, to get stable and objective results, and that colour images will be used thorough. Specifically, in the microscopical images of cereal kernels the net-like cell-wall structure will be studied. Of interest is how macro-properties of the cereal relates to extracted global measures of the microscopic structure. In the meat images

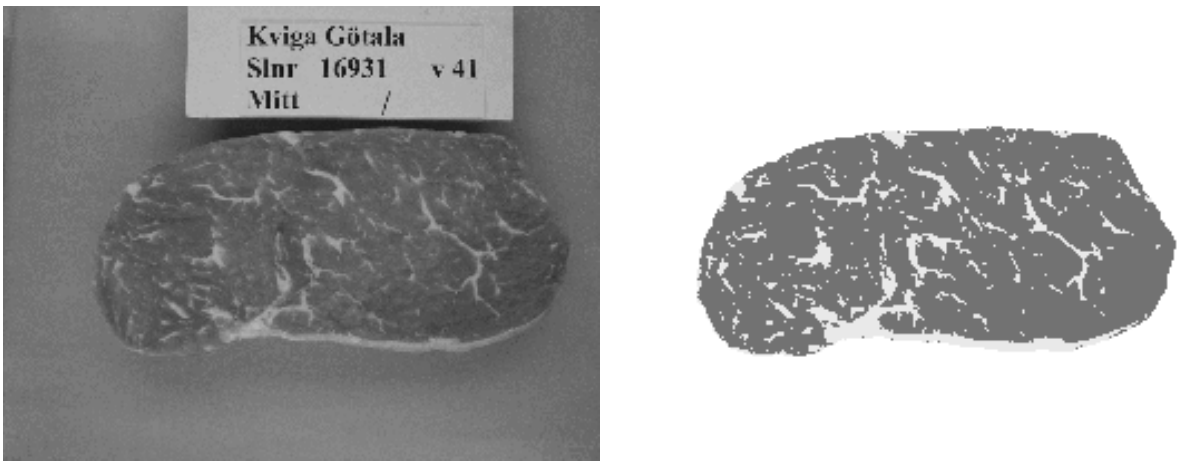

Figure 11: Left: An example of a meat image (digital camera photograph). Right: Segmented image.

the distribution of different tissues is of interest. Here, the digital image analysis involves colour segmentation and extraction of objective distribution measures. See Figure 11 for original and segmented image.

We are also investigating the use of a new technology to control food quality: NMR imaging. The NMR technique has been developed and greatly improved for medical imaging and it is in common clinical use. We believe in a great future for NMR application in the field of food science, which, in combination with image processing techniques, can lead to automatic and quantitative methods to assess meat quality. The inherent advantages of NMR images are many. Chief among these are unprecedented contrasts between the various structures present in meat as muscle, fat and connective tissue; in particular connective tissue and fat, that are almost indistinguishable in color images, but in NMR images fat areas appear lighter than other structures, while connective tissue is darker. Moreover, the three-dimensional nature of the NMR method allows to analyse isolated cross-sectional slices of the meat and to measure the volumetric contents of fat, not only the superficially visible one. The aim of this part of the project is to develop image analysis methods to evaluate fat content and distribution and to correlate these measurements with chemical properties.

24. **Wood Fibre Morphology**
Mattias Moëll, Gunilla Borgefors
Funding: Wood and Wood Fiber graduate school
Period: 9509–
Partners: Forest Research New Zealand Ltd.
Abstract: The morphology of wood fibres 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 fiber potential, more knowledge of the fiber morphology is needed. The aim of this project is to develop objective and, as far as possible, automatic methods for description and analysis of wood fiber morphology, where the fiber is modelled in all its dimensions.

Currently the project consists of two parts: analysis of "free" fibres in light microscopy images; and analysis of fibre cross-sections in confocal microscopy images of transverse sections of wood. In the light microscopy images, methods for indetifying individual fibres and correctly measuring lenght, width and cell wall width along the whole fibre must be developed. The analysis of the confocal microscopy images is mainly concerned with measurement of cell wall width, lumen width and determination of the fraction of cell wall area. The confocal microscopy part of the project was started out as a collaboration between CBA, Dept. of Forest Genetics, Dept. of Forest Management and Products SLU, and CITU for obtaining radial/tangential lumen width and radial cell wall width from confocal microscopy images. As a final step of that collaboration the method was used in two studies conducted by the Dept. of Forest Genetics and the Dept. of Forest Management and

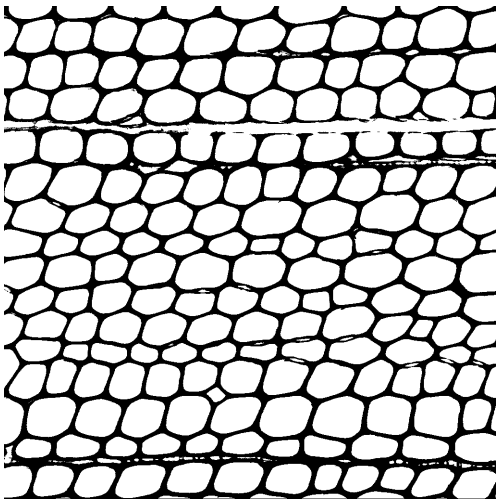

Figure 12: Example of automatic segmentation method applied to confocal microscopy image of wood fibres.

Products, and two papers were submitted during 1999.
Starting in the fall of 1998 a collaboration with Forest Reserach New Zealand Ltd. was introduced to study and compare segmentation methods of confocal images of transverse sections of wood. See image example in Figure 12.
The first half of 1999 was spent at Forest Research New Zealand Ltd. and the main research areas was automatic, and semi-automatic, segmentation for confocal microscope images of wood. The collaboration with Forest Research New Zealand Ltd. continues and one of the new areas will be shading-correction for confocal wood images.

25. **3D tracking of fibers in paper**
Mattias Aronsson, Gunilla Borgefors
Funding: Swedish Foundation for Strategic Research, VISIT programme
Period: 9710–
Partners: Björn Kruse, Arash Fayyazi, Dept. of Science and Engineering, Linköping University, Campus Norrköping; Stora Corporate Research, Falun; Institute of Optical Research (IOF), Kista
Abstract: Using image analysis on paper samples, can increase the understanding of how individual fibres build up the paper and what effect different networks have on the paper properties. This network of fibres is a very complicated structure and creating images of it is a challenging problem. Fibres are thin, so the resolution must be in the micrometer range to enable accurate measurements. Also, not distorting the fibres during the imaging process is very hard. With a supporting fibre embedding of a resin, it seems possible to get very good views of the internal structures using a standard slicing approach.
It is essential to use 3D volume images, since 2D images cannot capture enough information of the fibre network. Our main concern is developing the necessary image analysis tools to enable a practical process method for creating volume images of paper samples, and then use this image to measure various properties of the fibre network.
Our first dataset provided by STFI/IOF was assembled into a small 3D volume of paper, and an oral presentation was made at STFI in June. We noticed that the large distortions in this data set make it unsuitable, or at least very hard, for accurate measurements. We received a new data set from StoraEnso, and a preliminary registration and visualization was made. The data set is based on microtoming and uses a SEM camera for the imaging. See Figure 13.
We continue to work with this new data set, as it has several appealing properties. E.g., very low distortion and reference threads making the registration more accurate. Primarily concentrating on segmentation of individual fibres, registration, developing measurements and increasing the computer assistance during the process of assembling a digital volume model of paper.

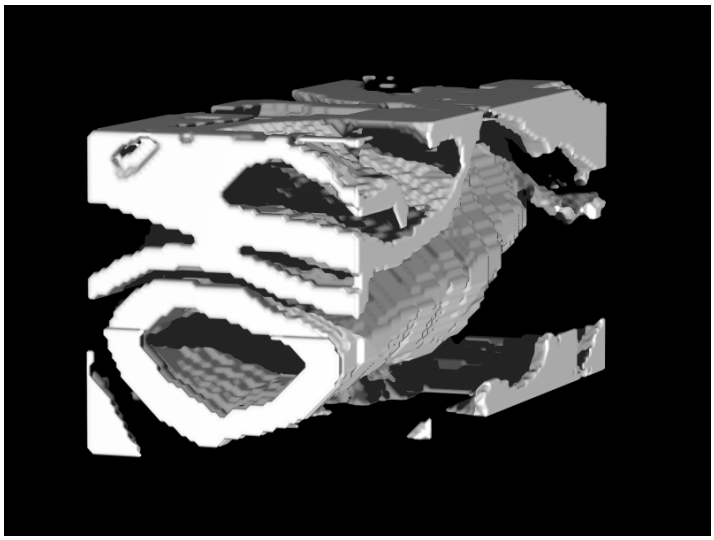

Figure 13: Reconstruction into a digital volume from slices of paper creates opportunities for both visualization and 3D measurements. This small piece of the volume (dimensions around $75 \times 75 \times 150$ μm) shows a single fibre that is a tiny fraction of the material building up an ordinary milk carton at your breakfast table.

26. **DANS: Digital image analysis of dance sequences**
Anders Forsmoo
Funding: SLU
Period: 9905–08
Partners: Gertrud Ericson, Dept. of Psychology, UU
Abstract: At the Dept. of Psychology at UU research is carried out on how people experience the expression of emotions in dance performances. As a complement to more subjective methods a more objective analysis of the patterns of motion was desired. In this pilot study it was investigated if computerized image analysis could provide a tool for such an objective assesment of the motion patterns in dance sequences. Two videotaped sequences of dance performances were digitized, one with a slow dance with limited expressions and another more rapid highly expressive dance. The length of each sequence was about 10 seconds. After format conversions the images were semiautomatically segmented so that the dancer was isolated in a sequence of binary images. A number of shape measures were then extracted from these silhouettes. Finally, these shape measures were correlated to the power envelope of the music accompaning the dance. The results showed clear correlations although the material was too limited for any far reaching conclusions. The study also experienced many the difficulties due to the technical format conversions of the video sequences, the panning camera and the textured background. If dance sequences were recorded with automated comuter analysis in mind the recording circumstances could be arranged so that automated analysis became far simpler and thus a larger material could be analyzed more effectively. The conclusion thus was that it should be possible to extract motion parameters from dance sequences using automated image analysis.

27. **Global shape description in 2D and 3D by polynomial expansion**
Gunilla Borgefors, Örjan Smedby
Funding: (TFR)
Period: 9701–
Partners: Hannes Edvarson, Christer Kiselman, Dept. of Mathematics, UU
Abstract: Shape description derived from volume images is usually local, e.g., finite elements, surface facets, spline functions. This can be a severe limitation on usefulness, as comparison between different shapes becomes very difficult. In 2D, the Fourier descriptors is a successful and often used global shape descriptor with adaptable accuracy. The aim of this project is to develop

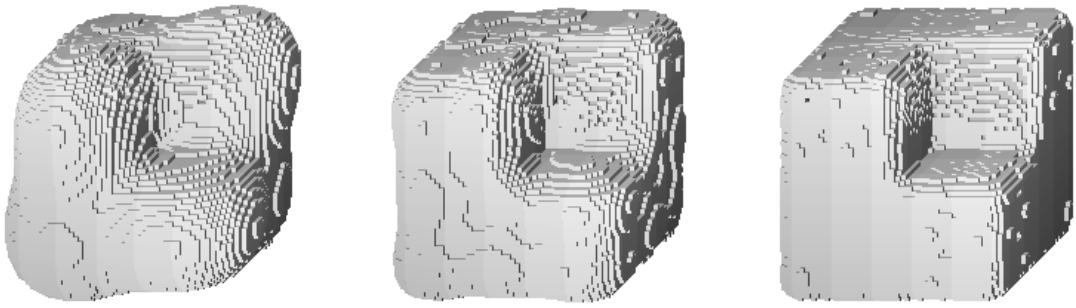

Figure 14: Approximations of a cube with a cubic concavity. The degrees of the spherical harmonics used are 5, 10, and 20, respectively.

something similar in 3D. The basic idea is to study the distance from the "object centre" to the object boundary as a function of the direction vector. This function is approximated by Fourier methods in the basis of the spherical harmonics, a complete orthonormal set of functions on the unit sphere. Depending on the degree of the spherical harmonics used, the shape can described with variable accuracy, see Figure 14. A limitation is that the objects must be star-shaped.
A simple way of comparing the shapes of two objects is to form the normalised inner product between their shape functions. This measure, the likeness measure, is 1 if the functions are identical except for scaling. The likeness is dependent on translational and rotational differences between the objects. The approximating expansions will differ for two expansions describing identical objects using different origins. Thus, it is crucial that the two origins are placed in approximately identical positions inside their objects. Sometimes, this requirement collides with the wish to place the origin so that the object appears star-shaped. At the moment, there is no good solution to this problem. When an approximating expansion has been calculated, it is possible to rotate the object in the space of the Fourier coefficients. That is, to apply to the coefficients operations which represents rotation in the image space. This way, it is possible to rapidly rotate the object until a maximum likeness is obtained. The theory may thus be used for rigid-body registration of 3D objects.

28. **Shape decomposition using multiresolution representations**
Gunilla Borgefors, Stina Svensson
Funding: SLU S-faculty, CNR
Period: 9801–
Partners: Gabriella Sanniti di Baja, Istituto di Cibernetica, CNR, Arco Felice, Italy
Abstract: Shape representation is an essential part of image analysis, especially in object recognition. One way of representing a shape is to use decomposition into significant parts. Our method uses a binary multiresolution structure of the shape. The decomposition is easy to compute and works for both 2D and 3D shapes, which is uncommon among existing methods. The cooperation has resulted in one publication at a reviewed conference during 1999.

29. **Shape decomposition using editing operators**
Stina Svensson
Funding: SLU S-faculty, CNR
Period: 9909–
Partners: Gabriella Sanniti di Baja, Istituto di Cibernetica, CNR, Arco Felice, Italy
Abstract: Another approach for decomposing a shape into its parts than the one described in Project 28, is to use editing operators. In 1989, Sanniti di Baja, together with Carlo Arcelli and Sergey Ablameyko, published an editing method for 2D images. During 1999, we have improved this method and extended it to volume images. The method simultaneously remove protrusions and cavities larger than a chosen threshold. It can also be used to remove minor noise. By considering different components of an object as "protrusions" of different sizes, the editing method can be used for decomposition purposes (Figure 15).

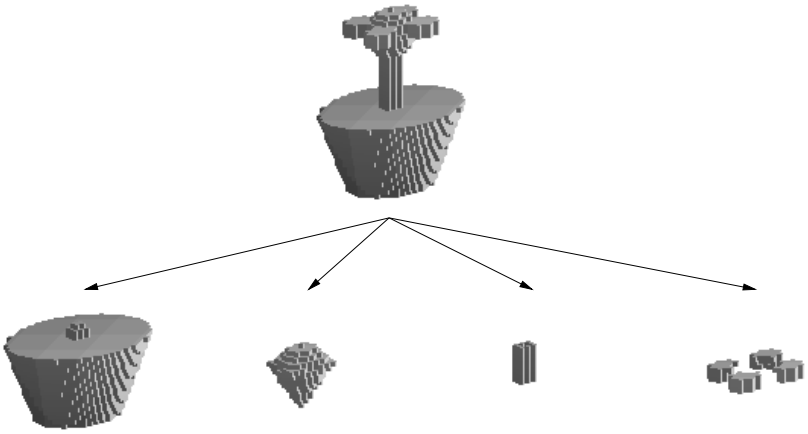

Figure 15: Decomposition of a PotPlant.

30. **Multiresolution binary images: Shape and skeletons**
Gunilla Borgefors, Stina Svensson
Funding: SLU S-faculty
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 can become seriously distorted. "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 in both 2D and 3D images, methods that are significant improvements of existing ones. This work was presented in a *Graphical Models and Image Processing* during 1999.
At present, the work concentrates on multiresolution skeletons. Multiresolution skeletons combine the advantages of skeletons and multiresolution structures. With our binary pyramids as underlying structures, multi-scale skeletons and skeleton hierarchies have been constructed. These structures can be used for hierarchical decompositions. An example is shown in Figure 16. This work was presentad at a reviewed conference.

Figure 16: Hierarchical decomposition of a rat.

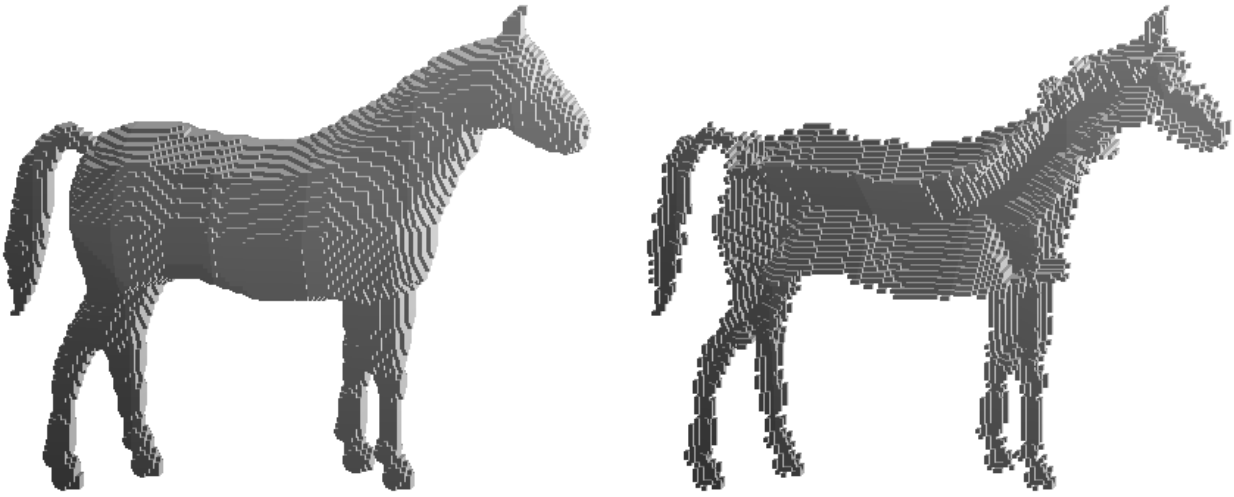

Figure 17: A "Horse" (left) and its fully reversible D^6 surface skeleton (right).

31. **Skeletonization of volume images**
Ingela Nyström, Stina Svensson, Gunilla Borgefors
Funding: SLU S-faculty, TFR, UU
Period: 9501–
Partners: Gabriella Sanniti di Baja, Istituto di Cibernetica, CNR, Arco Felice, Italy
Abstract: Skeletonization 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, if properly constructed, the curve skeleton would express only certain aspects of the original shape. We have earlier developed methods for reducing 3D objects to surface skeletons, and further reducing the surface skeletons to curve skeletons. These skeletons are based on the D^6 distance transform and voxels are iteratively removed according to conditions of their local neighbourhoods. Our methods have been tested with good results on large size synthetic and real images.
We have also worked on a skeletonization method for 2D objects aiming towards an, as simple as possible, extension to volume objects. The method is based on the idea to iteratively thin the distance transform of an object, layer by layer, until either an anchor-point is reached or the connectivity breaks.Our definition of anchor-points is a reduced set of centres of maximal discs/spheres. Any (2D or 3D) metric can be used for the distance transform. The skeletons produced fulfil the skeletal properties: they are topologically correct, centred within the object, thin, and fully reversible. The algorithm is simple to implement and is not unduly computationally heavy. During 1999, this approach has resulted in two publications, for general metrics in 2D in a journal, and for the D^{26} metric in 3D at a reviewed conference.
A new approach, for volume images, for computing the surface skeleton of an object is to use marking of skeletal voxels directly on the distance transform instead of iteratively thin the object. This method was introduced for 2D images in 1985, but has not been modified to 3D images until now. The idea is to simulate the iterative process by using the distance transform. By this approach the skeleton, for a reasonable sized object, can be found in a smaller number of scans than for an iterative method, since the number of scans is independent of the thickness of the object. During 1999, we have worked following this approach for an algorithm based on the D^6 distance transform. See Figure 17 for an example of a resulting surface skeleton.

32. **Digital distance transforms in volume images**
Gunilla Borgefors, Stina Svensson
Funding: SLU S-faculty
Period: 9309–
Abstract: This is an ongoing project where the geometry of the discrete space Z^3 is investigated. A major consideration is to measure global distances within the spaces using local operations, i.e., using distance transforms. Weighted distance transforms in 3D and even 4D have been investigated in recent years, using 3^n neighbourhoods. Now research is concentrated on $5 \times 5 \times 5$ neighbourhoods in 3D, where the complexity of the digital geometry poses a real challenge.

33. **Model-based segmentation in scale-space**
Felix Wehrmann, Lennart Thurfjell, Ewert Bengtsson
Funding: UU
Period: 9912–
Abstract: The analysis of shapes of image objects highly depends on a suitable and accurate feature space. An increased level of noise and a low sampling rate, as observed, e. g., in magnetic resonance images, often make it difficult to obtain a proper segmentation. In this project, a general 3D segmentation method is developed, comprising an initial, purely data-driven segmentation of image structures and a model-based registration of the objects found. Concepts of early vision are involved in the data-driven segmentation, providing a primal sketch in scale-space. While the primal sketch characterizes each individual object, scale-space compensates for physical effects, like resolution, size, noise, and intensity variations. In a subsequent step, a shape model extracts the objects of interest from the primal sketch, yielding a segmentation of the image. Thus, the segmentation problem becomes a design problem of models. Our desire is to develop suitable model descriptions for this purpose, generalizing image segmentation.

34. **SIMD and MIMD parallel algorithms for image analysis**
Anders Forsmoo, Gunilla Borgefors
Funding: SLU S-faculty
Period: 9408–9905
Abstract: Parallelization of image analysis algorithms is often suggested when faster execution is asked for. Algorithms that use local information in the image, e.g., filtering, is easy to parallelize. The purpose of this project is to develop parallel algorithms and implementations for image *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. 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. It can also be used as a model algorithm for methods using global information. The goal of the project is increased understanding of the behaviour of parallel distance transforms on SIMD and MIMD architectures, which are very different and pose different problems. The project was finished with a Licentiate thesis this year.

35. **The development of a general image analysis software platform**
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 applications 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 the last few years work on IMP has been carried out as a "background task" for Bo Nordin with varying intensity. The work has led to a major revision of IMP, with the core system reprogrammed in C++ to make it easier to maintain and extend. Some new functionality has also been added to the system. A preliminary version of the new program, IMP++, was released in 1999. This version of the program introduces several new features: added flexibility through the use of run-time dynamic loading of plug-in modules, a simplified programmer's interface, and a better separation of user interface modules and data handling modules are perhaps the most important ones. The work will continue during 2000 and a first version of the program will be completed.

5.2 Cooperation partners

CBA has 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 Centre 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.

The names of our cooperation partners can be found in various places in this report, but to give an overview, we list below the partners with whom we had direct project cooperation during 1999.

International

The Queen Elizabeth Hospital, Adelaide, Australia

Westmead Hospital, Sydney, Australia

Graz University of Technology, Austria

Institute of Engineering Cybernetics, Belarus National Academy of Sciences, Minsk, Belarus

Finnish Environment Agency, Helsinki, Finland

Laboratory of Space Technology, Helsinki Technical University, Finland

Wallac Oy, Åbo, Finland

Istituto di Cibernetica, National Research Council, Arco Felice (Napoli), Italy

Joint Research Centre (JRC), Ispra, Italy

Istituto per la Ricerca sul Rischio Sismico, National Research Council, Milano, Italy

Dept. of Biology, Universit degli Studi, Milano, Italy

Institute of Experimental Medicine, CNR, Rome, Italy

Istituto per lo Studio della Dinamica delle Grandi Masse, National Research Council, Venezia, Italy

Natural Resources Conservation Authority, Kingston, Jamaica

ISNAR, The Hague, The Netherlands

Forest Research Insitute (FRI), Rotorua, New Zealand

Dept. of Pathology, University Hospital, Tromsø, Norway

Navia Aviation AS, Division NOVA, Horten, Norway

Norwegian Institute for Water Research (NIVA), Oslo, Norway

AccuMed International, Inc., Chicago, IL, USA

Bell Laboratories, Lucent Technologies, Murray Hill, NJ, USA

De Witt Army Community Hospital, Fort Belvoir, VA, USA

Dept. of Genitourinary Pathology, AFIP, Washington DC, USA

Dept. of Urology, Naval Medical Center, San Diego, CA, USA

EPIX Medical, Inc., Cambridge, MA, USA

Future Tense, Inc., Acton, MA, USA

Rensselaer Polytechnic Institute, Troy, NY, USA

National

Amersham Pharmacia Biotech, Uppsala
Context Vision, Linköping
CWA Institute AB, Västra Frölunda
Diascan AB, Uppsala
Nycomed Amersham
Stora Corporate Research, Falun
Swedish Space Corporation, Solna
Uppsala Bildbehandling AB, Uppsala

Forestry Research Institute of Sweden (SkogForsk), Uppsala
Institute of Optical Research (IOF), Kista
National Board of Fisheries
Statistic Sweden (SCB), Örebro
Swedish Meteorological and Hydrological Institute (SMHI), Norrköping
Swedish National Environmental Protection Agency
Swedish Pulp and Paper Research Institute

Dept. of Biochemistry, UU
Dept. of Limnology, UU
Dept. of Mathematics, UU
Dept. of Psychology, UU
Dept. of Statistics, UU
Dept. of Diagnostic Radiology, UU Hospital
Dept. of Pathology, UU Hospital
PET Centre, UU Hospital
Dept. of Agricultural Engineering, SLU, Uppsala
Dept. of Crop Production Sciences, SLU, Uppsala
Dept. of Environmental Assessment, SLU, Uppsala
Dept. of Food Science, SLU, Uppsala
Dept. of Forest Resource Management and Geomatics, SLU, Umeå
Centre for Cancer Research Karolinska (CCK), Karolinska Institute/Hospital, Stockholm
Dept. of Clinical Cytology, Karolinska Institute/Hospital, Stockholm
Dept. of Clinical Neurophysiology, Karolinska Institute/Hospital, Stockholm
Dept. of Diagnostic Radiology, Karolinska Institute/Hospital, Stockholm
Dept. of Hospital Physics, Karolinska Institute/Hospital, Stockholm
Dept. of Neuroradiology, Karolinska Institute/Hospital, Stockholm
Section of Cognitive Neurophysiology, Karolinska Institute/Hospital, Stockholm
Dept. of Medical Radiation Physics, Stockholm University, Stockholm
Dept. of Physics, Stockholm University, Stockholm
Div. of Medical Radiology, Linköping University Hospital, Linköping

Dept. of Science and Engineering, Linköping University, Campus Norrköping
Dept. of Surveillance Radar, Swedish Defence Research Establishment (FOA), Linköping
Sensor Technology Division, Swedish Defence Research Establishment (FOA), Linköping
The Remote Sensing Group, Chalmers University of Technology, Göteborg
Dept. of Mathematics, Natural Sciences, and Computing, University College of Gävle

6 Publications

Our research results have been published in many different ways. The list covers papers with a publication date during 1999. As can be seen from the lists in the following sections we have published 15 journal articles and books, 21 papers in refereed international conference proceedings, of which 6 was presented at SCIA'99, and 9 non-refereed conference papers, of which 3 was presented at SSAB'99. CBA also has its two own report series, one external (blue) and one internal (yellow).

6.1 Journal articles and books

1. **On the Multiscale Representation of 2D and 3D Shapes**
   Authors: G. Borgefors, G. Ramella (1), G. Sanniti di Baja (1), S. Svensson
   (1) Istituto di Cibernetica, CNR, Arco Felice (Naples), Italy
   Journal: Graphical Models and Image Processing, Vol. 61, No. 1
   Pages: 44–62 *Year:* 1999
   Abstract: Binary pyramids in two and three dimensions can be used for multiresolution representation. The "standard" OR and AND pyramids have serious drawbacks, as they distort the shape significantly; therefore they can seldom be used effectively. Here, we present alternative approaches to build binary pyramids, aimed at improving shape preservation (and, as far as possible, topology preservation) in lower resolutions. The algorithms are easy to implement and produce good results.

2. **Automatic individual tree based analysis of high spatial resolution aerial images on naturally regenerated boreal forests**
   Author: T. Brandtberg
   Journal: Canadian Journal of Forest Research, Vol. 29, No. 10
   Pages: 1464–1478 *Year:* 1999
   Abstract: Individual tree based forest surveys are feasible using modern computer technology. The presented approach for analysing high spatial resolution (pixel size 10 cm) aerial images of naturally regenerated boreal forests is based on visible significant trees. Sunlight patches on the ground are suppressed, followed by optimal image smoothing. The problem with inclined illumination is handled by adapted thresholding. Each connected threshold segment (a collection of one or more trees) is further smoothed. A selection of the resulting convex edge segments is used for identifying significant tree crown circles. Six complementary image variables are estimated and used for regression analysis. An evaluation of the ground-truth data in central Sweden gives good results on the stem position estimate (a root mean square error (RMS) of 108 cm) and the stem number estimate (a relative RMS error of 11 %). The complementary variables contribute significantly to the stem diameter prediction, resulting in the following experimental values: Scots pine (Pinus sylvestris L.) (R-sq=59.5 %, s=4.9cm, N=157), Norway spruce (Picea abies (L.) Karst.) (R-sq=21.9 %, s=6.4 cm, N=398), birch (Betula pubescens Ehrh.) (R-sq=35.4 %, s=5.3 cm, N=133), and European aspen (Populus tremula L.) (R-sq=61.4 %, s=4.6 cm, N=13). The results indicate strong species dependence.

3. **A multivariate approach to registration of dissimilar tomographic images**
   Authors: J.L. Andersson (1), L. Thurfjell
   (1) PET Centre, Uppsala University Hospital, Uppsala
   Journal: European Journal of Nuclear Medicine, Vol. 26, No. 7
   Pages: 718–733 *Year:* 1999
   Abstract: We devised a method to allow for retrospective registration of tomographic images with very different information content, the main emphasis being on sets of positron emission tomography images obtained with different tracers. A multivariate cost-function based on information theory was used as an index of "goodness-of-alignment". The cost-function makes no assumptions regarding the form of the relationship between the two image sets, and is hence very general. Image volumes, with known relative spatial orientation, were simulated for tracers with different uptake patterns and the method was validated by assessing its ability to recover these known orientations.

The method was able to recover the known transformations with an accuracy of about 1 mm and 1° along and around all axes, even for tracer combinations with radically different uptake patterns and with large initial misalignment. With the suggested method it is feasible to retrospectively align examinations obtained with different tracers and/or modalities.

4. **Mapping pathological rCBF in Alzheimer disease and frontal lobe dementia using a standardised brain atlas**
   Authors: M. Pagani (1), H. Jacobsson (2), D. Salmaso, C. Ramstrom, C. Jonsson (3), P.O. Schnell, L. Thurfjell, R. Lundqvist, A. Wagner, and S.A. Larsson (3)
   Addresses: (1) Institute of Experimental Medicine, CNR, Rome, Italy
   (2) Dept. of Diagnostic Radiology, Karolinska Hospital, Stockholm
   (3) Section of Nuclear Medicine, Dept. of Hospital Physics, Karolinska Hospital and Dept. of Medical Radiation Physics, Stockholm University, Stockholm
   Journal: European Journal of Nuclear Medicine, Vol. 26, No. 9
   Pages: 973 *Year:* 1999
   Abstract: Alzheimer Disease (AD) and Frontal Lobe Dementia (FLD) are well-characterized entities with regard to cortical rCBF SPECT. The purpose of this study was to investigate the additional diagnostic information that can be given by visual and statistical evaluation comparing pathological standardised data sets to aged matched normal individuals 17 AD pts, 8 FLD pts and 20 age matched normal subjects (NOR) were studied. AD and FLD were diagnosed according to clinical presentation, EEG pattern and Mini Mental Score Examination. 99m-Tc-HMPAO SPECT was performed with a three head gamma camera. A Computerised Brain Atlas was fitted to the data and allowed for spatia normalisation. Hence it was possible to average across the subjects in the same group, compare data between groups and determine the recovered activity in all cerebral lobes, hippocampus, thalamus and basal ganglia. ANOVA resulted in a significant overall difference in all considered regions with the exception of the talamus (Table). AD differed significantly from NOR in all lobes but the frontal one. FLD did the same with the exclusion of parietal lobe. FLD and AD differed in all lobes but the insular lobe. Subtracting the AD and FLD images from the NOR resulted in highlighted caudatus, insular lobe and temporo-parietal lobes and frontal lobes, respectively. We conclude that standardising SPECT in a common space and subtracting data from a control group results in a better visual interpretation of data. Furthermore, AD and FLD rCBF decrease has to be considered parallel in insular lobe, hippocampus, caudatus and thalamus.
   Comment: Only this abstract is published

5. **Three-dimensional computer reconstruction of prostate cancer from radical prostatectomy specimens. Evaluation of the model by core biopsy simulation**
   Authors: L. Egevad (1), H. Frimmel, M. Norberg (2), S. Mattson (3), I. Carlbom (4), E. Bengtsson, C. Busch (1)
   Addresses: (1) Dept. of Pathology, Uppsala University
   (2) Dept. of Diagnostic Radiology, Uppsala University
   (3) Dept. of Statistics, Uppsala University
   (4) Bell Laboratories, Lucent Technologies, Murray Hill, NJ, USA
   Journal: Urology, Vol. 53, No. 1
   Pages: 192–197 *Year:* 1999
   Abstract: Objectives. A technique was developed for 3D modeling of prostate cancer and transrectal biopsies. To test the model, the cancer yield of a simulated 10 biopsy protocol was compared with a simulated sextant protocol and with preoperative biopsies regarding cancer detection and correlation with tumor volume.
   Methods. Transrectal ultrasound guided core biopsies were taken from 81 men according to a protocol with 10 standardized biopsy positions including sextant biopsies. The patients underwent radical prostatectomies and specimens were stepsectioned and whole-mounted. Cancer and the prostate capsule were outlined on the slides and the regions transferred to a computer software program developed by our group. A 3D volume of each prostate was reconstructed from the sections. Virtual core biopsy needles imitating the positions of the real biopsies were inserted into the prostate and the cancer yield was calculated. Only the standardized positions were considered in this study, i.e. additional biopsies from hypoechoic foci were not accounted for.
   Results. Of the cancers detected with 10 standardized virtual biopsies, 24% would have remained

undetected with sextant biopsies. The cancer yield of 10 virtual biopsies correlated with the pre-operative biopsies ($r = 0.64$) and with the tumor volume ($r = 0.56$). A multiple regression analysis showed that the cancer yield of a simulation of 10 biopsies correlated better with tumor volume than sextant biopsies ($p = 0.02$).
Conclusions. We conclude that computer assisted 3D reconstruction of prostate cancer can be used as a model for evaluation and hopefully for optimization of biopsy protocols.

6. **Biopsy Protocol Stability in a Three-Dimensional Model of Prostate Cancer: Changes in Cancer Yield after Adjustment of Biopsy Positions**
Authors: L. Egevad (1), H. Frimmel, S. Matsson (2), E. Bengtsson, and C. Busch(1)
Addresses: (1) Dept. of Pathology, Uppsala University
(2) Dept. of Statistics, Uppsala University
Journal: Urology, Vol. 54, No. 5
Pages: 862–868 *Year:* 1999
Abstract: Objectives. Transrectal ultrasound guided prostate biopsies are often taken according to a systematic, standardized schedule. The diagnostic stability of this system was evaluated by moving the biopsies in a 3D model.
Methods. A computerized 3D reconstruction was made from each of 75 radical prostatectomy specimens. Simulated core biopsies imitated a standardized 10 biopsy protocol including sextant biopsies. In total, 30.000 biopsies were generated by moving the standardized biopsies 1, 2, 3, and 4 mm (parallel needle shifts) or 5, 10, 15, and 20° (rotation of the needle tip) in a random direction.
Results. The diagnosis of the individual biopsy changed from cancer to benign or vice versa in 4.9–15.7% after 1–4 mm parallel needle shifts and 2.0–7.5% after 5–20° rotations. The corresponding figures for the final diagnosis of the 10 biopsy set were 0.8–9.6% and 0.5–3.2%, respectively. Transition zone biopsies containing cancer changed to benign more often than the other biopsies ($p < 0.001$). Parallel needle shifts of 2 mm changed the diagnosis more often than 15° rotation (9.4% and 5.9%, $p < 0.001$), although conveying the same overall needle shift.
Conclusions. The cancer yield of prostate biopsies is influenced even by small changes in needle positions. The transition zone biopsies are most likely to change from cancer to benign when moved. Changed insertion point of the needle has higher impact on cancer yield than rotation of the tip.

7. **Three-dimensional modeling of biopsy protocols for localized prostate cancer**
Authors: M. Loughlin, I. Carlbom, C. Busch, T. Douglas, L. Egevad, H. Frimmel, M. Norberg, I. Sesterhenn, J.M. Frogge
Addresses: Bell Laboratories, Lucent technologies, Murray Hill, NJ, USA
Future Tense, Inc, Acton, MA, USA
Dept. of Pathology, University of Tromsø, Norway
De Witt Army Community Hospital at Fort Belvoir, VA, USA
Dept. of Clinical Cytology, Karolinska Hospital, Stockholm
Dept. of Radiology, Uppsala University Hospital
Dept. of Genitourinary Pathology, AFIP, Washington DC, USA
Dept. of Urology, Naval Medical Center, San Diego, CA, USA
Journal: Computerized Medical Imaging and Graphics, Vol. 22
Pages: 229–238 *Year:* 1998
Abstract: Prostate cancer is the most common malignant tumor in American men, yet only a small percentage of men will develop clinically significant disease. Needle core biopsies are used to confirm the presence of cancer prior to surgery. While needle core biopsies have shown some ability to predict tumor volume and grade in prostatectomy specimens, for the indivisual patient they are neither sensitive nor specific enough to guide therapy. In this paper, we describe a system for simulating needle biopsies on three-dimensional models of cancerous prostates reconstructed from serial sections. First we segment the serial sections, delinieating tumors and landmarks. Next, we register the sections using a color-merging scheme, and reconstruct the three-dimensiona model using modified-shape-based interpolation. The resulting volume can be rendered, and simulated needle core biopsies can be taken from the reconstructed model. We use our system to simulate two different biopsy protocols on a reconstructed prostate specimen.

8. **Automatic Quantification of Microvessel Density in Urinary Bladder Carcinoma**
Authors: K. Wester, P. Ranefall, E. Bengtsson, C. Busch, and P.-U. Malmström
Addresses: Depts of Genetics and Pathology and Urology, Uppsala University
Journal: British Journal of Cancer, Vol. 81, No. 8
Pages: 1363–1370 *Year:* 1999
Abstract: Seventy-three TUR-T biopsies from bladder carcinoma were evaluated regarding microvessel density, defined as microvessels number (nMVD) and cross-section endothelial cell area (aMVD). A semi-automatic and newly developed, automatic image analysis technique were applied in immunostainings, performed according to an optimized staining protocol. In 12 cases a comparison of biopsy material and the corresponding cystectomy specimen were tested, showing a good correlation in 11 of 12 cases (92%). The techniques proved reproducible for both nMVD and aMVD quantifications related to total tumour area. However, the automatic method was dependent on high immunostaining quality. Simultaneous, semi-automatic quantification of microvessels, stroma and epithelial fraction resulted in a decreased reproducibility. Quantification in ten images, selected in a descending order of MVD by subjective visual judgement, shoved a poor observer capacity to estimate and rank MVD. Based on our results we propose quantification of MVD related to one tissue compartment. When staining quality is of high standard, automatic quantification is applicable, which facilitates quantification of multiple areas and thus, should minimize selection variabilty.

9. **Computerized wound analysis: a new method for objective asessment of healing - L'analyse informatisée des plaies: une nouvelle méthode d'évaluation objective de la cicatrisation**
Authors: E. Bengtsson, N. Engström, L. Hellgren, J. Vincent
Address: CWA Institute AB, Västra Frölunda
Journal: JPC - Journal des Plaies et Cicatrisations, Vol. 16
Pages: 31–34 *Year:* 1999
Comment: In French

10. **Fifty Years of Attempts to Automate Screening for Cervical Cancer**
Author: E. Bengtsson
Journal: Medical Imaging Technology, JAMIT, Vol. 17, No. 3
Pages: 203–210 *Year:* 1999
Abstract: Cervical cancer is one of the most deadly and common forms of cancer among women if no action is taken to prevent it, yet it is preventable through a simple screening test the so called Pap-smear. Each year at least a hundred million such samples are collected and screened and the numbers are increasing. This creates a tedious mass inspection task. Numerous attempts have been made over the last 50 years to create systems that automate this task. The author has been involved in research and development of both automated and interactive cell analysis systems during the last 25 years. Based on this experience and studies of the literature and relevant WWW-pages the developments of the field are traced through the years and some comments are made about how the different generations of systems relate to each other. In spite of all the automation efforts, still no generally accepted automated prescreening device exists on the market. The main reason for this failure is the great pattern recognition capabilities needed to distinguish between cancer cells and all other kinds of objects found in the specimens: cellular clusters, debris, degenerate cells etc. Improved algorithms, the ever-increasing processing power of computers and progress in biochemical specimen preparation techniques make it likely that eventually useful automated prescreening systems will become available.
Comment: Invited paper in reviewed journal

11. **On Reversible Skeletonization Using Anchor-Points from Distance Transforms**
Authors: S. Svensson, G. Borgefors, I. Nyström
Journal: Journal of Visual Communication and Image Representation, Vol. 10
Pages: 379–397 *Year:* 1999
Abstract: In many applications thinning of objects is of great interest. We here present a skeletonization algorithm that is based on the idea to iteratively thin the distance transform of an object, layer by layer until either an anchor-point is reached or the connectivity breaks. Our algorithm is

general in the sense that any metric and any connectivity can be used. Also, it is based on ideas that are not specific for 2D. The properties of the resulting skeletons are evaluated according to the "Lee-Lam-Suen properties".

12. **Computing Skeletons in Three Dimensions**
Authors: G. Borgefors, I. Nyström, G. Sanniti di Baja (1)
(1) Istituto di Cibernetica, CNR, Arco Felice (Naples), Italy
Journal: Pattern Recognition, Vol. 32, No. 7
Pages: 1225–1236 *Year:* 1999
Abstract: Skeletonization will probably become as valuable a tool for shape analysis in 3D, as it is in 2D. We present a topology preserving 3D skeletonization method, which computes both surface and curve skeletons whose voxels are labelled with the D^6 distance to the original background. The surface skeleton preserves all shape information, so that (close to) complete recovery of the object is possible. The curve skeleton preserves the general geometry of the object. No complex computations, large sets of masks, or extra memory are used, which make implementations efficient. Resulting skeletons for geometric objects in a number of 2 Mbyte images are shown as examples.

13. **Identification of clear felled areas using SPOT P and Almaz-1 SAR data**
Authors: J.E.S. Fransson (1), F. Walter, H. Olsson (1)
(1) Dept. of Forest Resource Management and Geomatics, SLU, Umeå
Journal: International Journal of Remote Sensing, Vol. 20, No. 18
Pages: 3583–3593 *Year:* 1999
Abstract: Almaz-1 S-band (3.125 GHz) satellite SAR data from two subsequent years in combination with optical data have been analysed to determine the separability between recently clear felled areas and forested areas. The test area is situated in northern Sweden within the boreal conifer belt and consists of 32 ha of recently clear felled areas and 464 ha of forested areas. The basic assumption in this study is that, in an operational case, optical data before the clear felling, and radar data from both before and after the felling, will be available. The optical image is used for segmentation of the forest landscape into homogeneous segments. For each segment statistical features based on the first and second order histogram are computed in the two radar images. The changed areas are identified by linear discriminant analysis with cross-validation. Classification based on segment mean values from the Almaz-1 images performed better than using a simple square neighbourhood mean. When using the segment mean values 61.4% of the clear felled areas were correctly classified, under the premise of equal errors of omission and commission. The textural features derived from the second order histogram did not improve the classification result.

14. **CARABAS maps the forest -**
CARABAS kartlägger skogen
Authors: J. Fransson (1), G. Smith (2), L. Ulander (3), F. Walter
Address: (1) Dept. of Forest Resource Management and Geomatics, SLU, Umeå
(2) Dept. of Surveillance Radar, Swedish Defence Research Establishment (FOA), Linköping
(3) The Remote Sensing Group, Chalmers University of Technology, Göteborg
Journal: Skog & Forskning, Nr 3
Pages: Year: 1999
Comment: Popular science article in Swedish

15. **Manual for Monitoring European Lakes using Remote Sensing Techniques**
Authors: T. Lindell, D. Pierson, and G. Premazzi
Address: Joint Research Centre, Ispra, Italy
Book Volume: EUR18665 EN
Pages: 161 *Year:* 1999
Abstract: The text book is a complete manual on lake monitoring from remote sensing, including limnological, water optics and remote sensing techniques.

6.2 Refereed conference proceedings

1. **Greyscale connectivity concept for visualizing MRA and CTA volumes**
   Authors: Ö. Smedby, S. Svensson, T. Löfstrand
   Conference: SPIE Medical Imaging 1999
   Pages: 212–219 *Year:* 1999 *Publisher:* SPIE Publications No. 3658
   Abstract: A 3D image processing algorithm for separating vessels in datasets from Magnetic Resonance Angiography (MRA) and Computed Tomography Angiography (CTA) has been developed and tested on clinical MRA data. Relevant and irrelevant vessels are marked interactively by the user. The algorithm then processes the data, ideally yielding a 3D dataset representing only vessels of interest (e.g. arteries), while removing other structures (e.g. veins). The result is projected to 2D images for visualization. In contrast to traditional segmentation methods, little greyscale information is lost in the process, and the amount of interaction required is relatively small. The classification of voxels utilizes a novel greyscale connectivity measure. A comparison based on the greyscale connectivity values with marked ("seed") regions is made to decide whether a voxel is of interest for visualization or not. In the projection, those voxels are excluded where the connectivity value is smaller for the relevant vascular structure than for the irrelevant ones. In cases of ambiguity, morphological operations applied to unambiguously classified regions may be used as an additional criterium. In the implementation of the connectivity computation, an iterative propagation scheme is used, similar to that used in chamfer algorithms for distance transforms.

2. **Decomposing Digital 3D Shapes Using a Multiresolution Structure**
   Authors: G. Borgefors, G. Sanniti di Baja (1), S. Svensson
   (1) Istituto di Cibernetica (CNR), Arco Felice (Naples), Italy
   Conference: Discrete Geometry for Computer Imagery
   Pages: 19–30 *Year:* 1999 *Publisher:* Springer-Verlag
   Abstract: In many applications, e.g. object recognition, decomposition of a shape is of great interest. We present a decomposition algorithm for 3D shape that is based on a multiresolution structure. The shape is hierarchically decomposed according to local thickness. A merging process is introduced for merging of small components to more significant parts. As a side effect of the algorithm, we also obtain a way of smoothing noisy shapes.

3. **Structure-based classification of tree species in high spatial resolution aerial images using a fuzzy clustering technique**
   Author: T. Brandtberg
   Conference: 11th Scandinavian Conference on Image Analysis (SCIA'99)
   Pages: 165–172 *Year:* 1999 *Publisher:* Pattern Recognition Society of Denmark, Lyngby
   Abstract: This paper describes a fundamentally new approach of classifying the species of individual trees in high spatial resolution aerial images. The algorithm is based on simple, visible structures (similar to branches), identified in the tree crowns. Features like spectral slope, shape (eccentricity) and reflectance values in different wave-length bands are estimated on each structure. The objects with feature values are input data to a fuzzy clustering algorithm. The degree of membership of each object in each cluster and the area of the object are used for estimating the weighted mean degree of membership in each cluster, for the corresponding individual tree crown. The highest membership value defines the tree species. A test on an aerial image data set acquired in central Sweden, composed of four species, Scots pine (*Pinus silvestris L.*), Norway spruce (*Picea abies (L.) Karst.*), silver birch (*Betula pubescens Ehrh.*) and aspen (*Populus tremula L.*), shows that the probability for correct classification is almost 47 %. When three cases of subsets of the image data are used for evaluation, i.e. discrimination of coniferous and deciduous trees, discrimination of Scots pine and Norway spruce, and discrimination of birch and aspen, the accuracies are 73 %, 71 %, and 76 %, respectively.

4. **Segmentation of the Brain in MRI Using Grey Level Morphology and Propagation of Information**
   Authors: R. Hult, E. Bengtsson, L. Thurfjell
   Conference: 11th Scandinavian Conference on Image Analysis (SCIA'99)
   Pages: 367–373 *Year:* 1999 *Publisher:* Pattern Recognition Society of Denmark, Lyngby
   Abstract: An important step in the analysis of 3D MRI brain images is to segment the cortex

from surrounding tissue. In this paper we present an algorithm for fully automatic segmentation of the cortex from T1-weighted MRI data. The automatic segmentation starts with a histogram-based method for finding threshold values. Two initial masks are created; one by thresholding the volume and the other by thresholding a 3D grey-level eroded version of the volume, minvolume. Binary morphological operations and logical operations are first performed on the mid-slice of the minvolume to get a start mask. Then all consecutive slices are segmented with binary morphological operations and logical operations using the previous segmented slice as starting condition, i.e., information is propagated through the volume. The algorithm has been tested on a dozen 3D brain images with good results.

5. **Classification of Functional Patterns in SPECT Brain Scans Based on Partial Least Squares Analysis**
   Authors: R. Lundqvist, E. Bengtsson, H. Jacobsson (1), C. Jonsson (2), S. Larsson (2), M. Pagani (3), A. Wägner, L. Thurfjell
   Adresses: (1) Dept. of Diagnostic Radiology, Karolinska Hospital, Stockholm
   (2) Section of Nuclear Medicine, Dept. of Hospital Physics, Karolinska Hospital and Dept. of Medical Radiation Physics, Stockholm University, Stockholm
   (3) Institute of Experimental Medicine, CNR, Rome, Italy
   Conference: 11th Scandinavian Conference on Image Analysis (SCIA'99)
   Year: 1999 *Publisher:* Pattern Recognition Society of Denmark, Lyngby
   Abstract: The main purpose of this paper is to show the potential of the partial least squares (PLS) method for finding image descriptors which can be used for classification of clinical single photon emission computed tomography SPECT neuroimaging data. In this article this is demonstrated by using the PLS method for enhancing differences between healthy individuals of different age groups and patients with signs of different neurodegenerative diseases, such as Alzheimer's disease (AD) and frontal lobe dementia (FLD). The results show that the method of partial least squares supplies very useful information for classification of this kind of data and would be a valuable part of a larger analysis system for diagnostic purposes of SPECT neuroimaging data.

6. **Fully Reversible Skeletonization for Volume Images Based on Anchor-Points from the D^{26} Distance Transform**
   Authors: S. Svensson, I. Nyström, G. Borgefors
   Conference: 11th Scandinavian Conference on Image Analysis (SCIA'99)
   Pages: 601–608 *Year:* 1999 *Publisher:* Pattern Recognition Society of Denmark, Lyngby
   Abstract: This paper presents a 3D (volume) surface skeletonization algorithm. Our algorithm uses iterative, topology preserving thinning guided by the D^{26} distance transform, which is the 3D equivalent of the chessboard distance transform. The algorithm produces skeletons which fulfil the skeletal properties: they are topologically correct, centred within the object, thin, and fully reversible. The last property is rare for 3D skeletons. This skeletonization is very suitable for objects from the "block's world." The algorithm is simple to implement and is not unduly computationally heavy. We have verified the algorithm on a number of objects with different geometrical properties. Some of the results are shown in the paper.

7. **Fusion of Multimodality Brain Images**
   Authors: L. Thurfjell, G. Lindahl, R. Lundqvist
   Conference: 11th Scandinavian Conference on Image Analysis (SCIA'99)
   Pages: 359–366 *Year:* 1999 *Publisher:* Pattern Recognition Society of Denmark, Lyngby
   Abstract: Fusion of multimodal medical images refers both to the registration of and to the visualization of the images. The system presented uses registration methods that we have reported previously and the paper is mainly focused on visualization. We present a volume renderer that includes some standard methods such as gray level gradient shading and maximum intensity projection as well as several methods for combining functional and anatomical information in new ways. The different rendering methods are illustrated with several application examples.

8. **A 3D Deformable Surface Model to Segment the Brain in MR Images**
   Authors: F. Wehrmann, E. Bengtsson, L. Thurfjell
   Conference: 11th Scandinavian Conference on Image Analysis (SCIA'99)
   Pages: 289–294 *Year:* 1999 *Publisher:* Pattern Recognition Society of Denmark, Lyngby

Abstract: Our objective was to develop a three dimensional segmentation method for medical Magnetic Resonance images of the brain. The object to be segmented is spatially represented by a deformable surface model with physical-elastic behavior. The special quality of deformable models is their ability to individualize their shape. Starting from an initial shape, deformations are applied that improve the similarity between the model shape and the shape of an object in an image. These deformations are derived from image data. A multi-resolution approach compensates for the individuality of medical images and yields a robust segmentation method. In the discussion section we point out ways to complete the presented methodology, which is still a work in progress.

9. **Fully automatic geo-coding of CARABAS-II VHF SAR images**
Authors: F. Walter, J.E.S. Fransson (1), P.-O. Frölind (2)
Addresses: (1) Dept. of Forest Resource Management and Geomatics, SLU, Umeå
(2) Sensor Technology Division, Swedish Defence Research Establishment (FOA)
Conference: International Geoscience and Remote Sensing Symposium, IGARSS'99
Abstract: Fully automatic geo-coding algorithms for CARABAS-II VHF SAR images have been developed. By using recorded flight parameters and a coarse scale (50 50 m) digital elevation model (DEM), complex CARABAS-II slant range images were geo-coded to a local orthogonal map projection and vice versa. The aims of this paper are to describe the algorithms and to evaluate the geometric accuracy obtained. The SAR image processing was performed with a global back projection technique in order to minimise any geometrical distortions. The analysed images were processed by focusing to a nominal reference height close to an average altitude over the area of interest. With the assumption that the actual flight path is close to a straight line, the errors introduced by the approximate focusing can be negligible during normal flight conditions. The evaluation of the geo-coding accuracy was performed by measuring the displacement between curved line segments extracted from a map and corresponding visually detected segments in the CARABAS images. To avoid bias in measure-ments for images within single flight paths, two sets of images from different flight paths were used for the evaluation. The result shows that the image processing and the geo-coding algorithms have been successfully implemented. The mean displacements for the investigated forest stand borders, lake borders, and main stream border were found to be 3.4, 2.6, and 9.3 m respectively. This implies that the recorded flight parameters are reliable and that the system performance is stable. Hence, the algorithms can be used in both research studies and real world applications.

10. **Edge Detection in Hyperspectral Imagery**
Author: E. Lindqvist
Conference: Statistical Methods in Image Processing, Uppsala
Pages: 1–19 *Year:* 1999
Abstract: In all kinds of images, it is of great interest to automatically detect areas with different properties. One way of doing this is by applying an edge detection operator in order to find transitions in greylevel and texture in the image. How should a hyperspectral image with sometimes several hundreds of bands be processed in order to find the "true" edges? This paper examines different edge detection operators (Sobel and Kirsch) and different ways to efficiently reduce the amount of data (the statistical methods PCA and SDR). The result of the experiments shows that a reduction of the data is necessary, and from a hyperspectral point of view, the SDR method seems to be preferable.

11. **Forest Parameter Extraction from Airborne Sensors**
Authors: G. Borgefors, T. Brandtberg, F. Walter
Conference: ISPRS Conference: Automatic Extraction of GIS Objects from Digital Imagery
(Eds. H. Ebner et al., International Archives of Photogrammetry and Remote Sensing Vol. 32, Part 3-2W5)
Pages: 151–158 *Year:* 1999
Publisher: International Society for Photogrammetry and Remote Sensing, Münich, Germany
Abstract: In forestry and environment surveillance, reliable information about forest conditions are needed for both strategic and operational planning of activities. Here, we will describe results from and potentials for image processing techniques for three high resolution image data types. These are: aerial colour-infrared photos, scanning laser data, and CARABAS VHF SAR radar images.

No sensor can capture all interesting forest stand parameters, but together they can catch most them. An airborne laser scanning system combined with a multispectral digital camera captures can capture information on the individual trees, such as height, crown diameter, and species. A drawback is that such a system can never give full groung coverage, but only samples of the forest. The CARABAS-II system is, on the other hand, very suitable for large area mapping and is also independent on weather and lighting conditions. It can capture forest stand stem volume, stem diameter distribution, and tree height. The CARABAS mapping procedures can utilise the sample measurements from other sensors as a priori knowledge for local calibration purposes.
Comment: Invited paper

12. **Permanence-based shape decomposition in binary pyramids**
Authors: G. Borgefors, G. Ramella (1), G. Sanniti di Baja (1)
(1) Istituto di Cibernetica, CNR, Arco Felice (Naples), Italy
Conference: 10th International Conference on Image Analysis and Processing (ICIAP'99)
Pages: 38–43 *Year:* 1999 *Publisher:* IEEE Computer Society
Abstract: An algorithm to decompose hierarchically bidimensional patterns is introduced. The single-scale input pattern is first transformed into a multi-scale data set. The multi-resolution skeleton is then computed and its hierarchical decomposition is obtained by using the notion of permanence. A constrained reverse distance transformation is applied to the skeleton components to reconstruct the regions into which the pattern is decomposed. A merging process then reduces the number of components to the most significant ones and improves decomposition stability.

13. **The Distance Transform Algortihm on a Two-Processor Computer**
Author: A. Forsmoo
Conference: 10th International Conference on Image Analysis and Processing (ICIAP'99)
Pages: 114–118 *Year:* 1999 *Publisher:* IEEE Computer Society
Abstract: This paper contains the description of the implementation of the weighted distance transform for digital image analysis on a two processor shared memory computer. The computer is a SMP (symmetric multi processing) computer and the algorithm is implemented using POSIX threads.

14. **Extracting multispectral edges in satellite images over agricultural fields**
Authors: A. Rydberg, G. Borgefors
Conference: 10th International Conference on Image Analysis and Processing (ICIAP'99)
Pages: 786–791 *Year:* 1999 *Publisher:* IEEE Computer Society
Abstract: This article presents a multispectral edge detection method that combines the best approaches from several sources. It uses all available multispectral information, by adding the magnitudes and directions of edges derived from edge detection in single bands, instead of just taking the maximum, which is commonly done. The addition is weighted on the edge direction, to remove noise and enhance the "major direction". The resulting image is then thinned using magnitude and direction information, together with hysteresis thresholding, so that weak edges can be preserved without adding too much noise. Small gaps in the edges are filled in. All edges between areas with different spectral characteristics are detected. The same technique could also be used for edge detection in multi-temporal images, or even multi-temporal/ multispectral images. The edge image can then be used for further analysis, such as field segmentation and subsequent classification.

15. **Classification of SPECT scans of AD and FLD based on intensity and gradient information**
Authors: V. Kovalev, L. Thurfjell, R. Lundqvist, and M. Pagani
Conference: Medical Image Understanding and Analysis 99
Pages: 4 *Year:* 1999
Abstract: This paper describes a method for classification of SPECT perfusion scans of Alzheimer's disease (AD) and Frontal lobe dementia (FLD) when compared to normal controls. A brain atlas was used to define volumes of interests corresponding to the brain lobes. For these, intensity, gradient magnitude and orientation features were computed. When applied to a SPECT material containing 45 AD, 7 FLD and 34 normal scans, the suggested method yielded an accuracy of 96.2%,

97.6% and 94.2% in the separation of AD from normals, FLD from normals, and AD from FLD scans, respectively.

16. **Coastal Zone Mapping of Jamaica for Planning and Management**
Author: T. Lindell
Conference: Pecora 14 Land Satellite Information III
Year: 1999 *Publisher:* ASPRS, Denver
Abstract: All of Jamaica has been mapped for land-use/-cover, focusing on matters relevant for the coastal zone, applying remote sensing techniques and field inventories in a project aiming at coastal planning and management. Classification was based on Landsat TM, topographic maps and field data using GPS. All beaches were field-mapped in detail and other types of shores were classified from Landsat and aerial photos. The beach data was primarily evaluated and processed in Excel. The sub-water environment was classified from Landsat TM, using echo sounder and GPS. Manual field observations were added to the data flow into a laptop computer. The final database contained important information for the planners, like coastline types, maps of land and sea-bottom cover, and manually collected data from the beaches. An ARC/INFO structure was created allowing the Natural Resources Conservation Authority (NRCA) to continually update the database. All information has been published in a printed Coastal Atlas and a Manual for planning and management and onto a CD, including map data from local sources and layers from the Digital Chart of the Word together with a freeware handler for the data. Simple queries like "Map all public beaches with white sand accessible by road" could be handled. The data set is planned to be published on the web as a tutorial for coastal management and planning in the Wider Caribbean.
Comment: CD Edition only

17. **Genetic Evolution of Neural Networks Topology**
Author: L. Ballerini
Conference: AI*IA Congress of the Italian Association for Artificial Intelligence
Pages: 289–298 *Year:* 1999 *Publisher:* Pitagora, Bologna, Italy
Abstract: In this paper we present a new approach for automatic topology-optimization of back-propagation neural networks. In order to adapt the network topology to the problem at hand we propose an automatic design procedure which is based on Genetic Algorithms. The mechanism we propose allows all aspects of the network structure, including the number of nodes and their connectivity, to be controlled by evolution. Several encoding schemes have been investigated and the best results have been reached using a new kind of feed-forward neural network that we have called *sparse neural network*. The optimization approach we propose can produce a network with the minimal number of nodes, while performing feature selection at the same time. We applied our optimised network to a medical classification problem. The performance with respect to the training set and a test set of pattern samples was compared to fixed network topologies. Our results confirm that the topology optimization makes sense, because the generated networks outperform the fixed topologies and reach classification performances near the optimum.

18. **An Automatic System for the Analysis of Vascular Lesions in Retinal Images**
Author: L. Ballerini
Conference: IEEE Medical Imaging Conference
Year: 1999 *Publisher:* IEEE Computer Society
Abstract: In this work a computational approach for detecting and quantifying diabetic retinopathy is proposed. Particular attention has been paid to the study of Foveal Avascular Zone (FAZ). In fact, retinal capillary occlusion produces a FAZ enlargement. Moreover, the FAZ is characterized by qualitative changes showing an irregular contour with notchings and indentations. On this ground, our aim was the development of an automatic system for the quantitative morphological evaluation of the vascular lesions of the fundus oculi occurring in diabetic subjects. We propose an automatic segmentation procedure derived from the theory of active contour, also known as snakes, along with genetic optimization. Then we tried to extract features which can capture not only the size of the object, but also its shape and spatial orientation. We used a set of region and boundary moments to obtain a FAZ description which is complete enough for diagnostic purposes and in order to assess the effectiveness of moment descriptors we performed several classification experiments to discriminate diabetic from non-diabetic subjects.

19. **Moment Theory for FAZ Shape Description in Diabetic Retinopathy**
Author: L. Ballerini
Conference: European Medical and Biological Engineering Conference (EMBEC'99)
Pages: 1002–1003 *Year:* 1999 *Publisher:* Medical & Biological Engineering & Computing
Abstract: In this work a computational approach for detecting and quantifying diabetic retinopathy is proposed. Particular attention has been paid to the study of Foveal Avascular Zone (FAZ). Our study is mainly focused on the analysis of the FAZ and on the extraction of a proper set of features to quantify FAZ alterations in diabetic patients. The theory of moments provides an interesting and useful way for representing the shape of objects. We used a set of region and boundary moments to obtain a FAZ description which is complete enough for diagnostic purposes and in order to assess the effectiveness of moment descriptors we performed several classification experiments to discriminate diabetic from non-diabetic subjects. In this way we were able to transform the qualitative description of the FAZ used by ophthalmologists into quantitative measurements.

20. **Segmentation of Ocular Fundus Images using Genetic Snakes**
Author: L. Ballerini
Conference: European Medical and Biological Engineering Conference (EMBEC'99)
Pages: 1040–1041 *Year:* 1999 *Publisher:* Medical & Biological Engineering & Computing
Abstract: In this paper an approach is described for segmenting ocular fundus images. We use active contour model, also known as snakes, and we propose an energy minimization procedure based on Genetic Algorithms (GA). GAs operate on a coding of the parameters: the positions and the total number of snake points, and their fitness function is the total snake energy. We employ a modified version of the image energy which consider both the magnitude and the direction of the gradient and the Laplacian of Gaussian. Experimental results on synthetic images as well as on medical images are performed. Images used in this work are retinal images, snakes result very useful in the segmentation of the Foveal Avascular Zone (FAZ). The experiments performed with ocular fundus images show that the proposed method is promising in the early detection of the diabetic retinopathy.

21. **Genetic Snakes for Radar Images Segmentation**
Authors: L. Ballerini, E. Piazza (1)
(1) Navia Aviation AS, Division NOVA, Horten, Norway
Conference: IEEE International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS'99)
Pages: 621–624 *Year:* 1999 *Publisher:* IEEE Computer Society
Abstract: In the present work it is presented a simple method to detect target moving along runways and taxiways of an airport from images provided by a Surface Movement Radar, even with a very noisy image. The aim of the application is to determine the shape and the dimension of aircraft in Advanced Surface Movement Guidance and Control Systems (A-SMGCS). In this paper a new approach for segmenting images is proposed. This approach uses active contour model, also known as snakes, and we propose an energy minimization procedure based on Genetic Algorithms (GA). Particularly, an improving way of coding the parameters in the Genetic Algorithm (the positions of the snake) and their fitness function is proposed. We use a total snake energy which consider both the magnitude and the direction of the gradient and the Laplacian of Gaussian. Images used in this work are radar images provided by a Surface Movement Radar, genetic snakes result very useful in the segmentation of the aircraft and in the extraction of its size and shape, even with a very noise image.
The radar sensor is a prototype operating in the millimeter band (95 GHz) and conceived for the surveillance function, developed by Oerlikon Contraves Italiana SpA in the framework of the research project on transportation with a grant awarded by the Italian National Research Council. It was not possible to test the system in real time, with the computer directly connected to the radar but, on playback data, the overhead of seeking for target with the proposed filter was found to be negligible over the time needed to display the graphic raw video.

6.3 Non-refereed conferences and workshops

1. **Detection of algae in lake water by imaging spectrometers**
   Authors: P. Flink, T. Lindell, C. Östlund
   Conference: Symposium on Image Analysis - SSAB'99
   Pages: 13–16 *Year:* 1999 *Publisher:* Chalmers University of Technology, Gothenburg

2. **Detection of Fluorescent Foci and Evaluation of Spatial Relationships in 3D-Fluorescence Microscopy Images of Mammalian Cells**
   Authors: C. Linnman and E. Bengtsson
   Conference: Symposium on Image Analysis - SSAB'99
   Pages: 57–60 *Year:* 1999 *Publisher:* Chalmers University of Technology, Gothenburg

3. **A 3D Deformable Surface Model to Segment the Brain in MR Images**
   Authors: F. Wehrmann, E. Bengtsson, L. Thurfjell
   Conference: Symposium on Image Analysis - SSAB'99
   Pages: 53–56 *Year:* 1999 *Publisher:* Chalmers University of Technology, Gothenburg

4. **Detection of Fluorescent Foci and Evaluation of Spatial Relationships in 3D-Fluorescence Microscopy Images of Mammalian Cells**
   Authors: C. Linnman, E. Bengtsson, S. Ekholm-Jensen (1), A. Zetterberg (1)
   (1) Dept. of Oncology-Pathology, Div. of Tumorcytology, Karolinska Institute, Stockholm
   Conference: 6th ESACP Congress in Heidelberg
   Pages: 36–37 *Year:* 1999 *Publisher:* IOS Press, Amsterdam

5. **Computerized microscopy as a tool in medicine - the struggle to automated screening for cervical cancer**
   Author: E. Bengtsson
   Conference: Microscopy as a Tool in Pulp and Paper Research and Development
   Pages: 103–113 *Year:* 1999 *Publisher:* STFi, Stockholm

6. **Towards Assembling a Small Digital Volume of Paper**
   Authors: A. Fayyazi (1), M. Aronsson
   (1) Dept. of Science and Technology, Linköping University, Campus Norrköping
   Conference: Microscopy as a Tool in Pulp and Paper Research and Development
   Pages: 124–133 *Year:* 1999 *Publisher:* STFi, Stockholm

7. **An algorithm for delineation of individual tree crowns in high spatial resolution aerial images using curved edge segments at multiple scales**
   Author: T. Brandtberg and F. Walter
   Conference: International Forum: Automated Interpretation of High Spatial Resolution Digital Imagery for Forestry, 1998
   Pages: 41–54 *Year:* 1999 *Publisher:* Canadian Forest Service, Pacific Forestry Centre, Victoria BC

8. **Algorithms for structure- and contour-based tree species classification using digital image analysis**
   Author: T. Brandtberg
   Conference: International Forum: Automated Interpretation of High Spatial Resolution Digital Imagery for Forestry, 1998
   Pages: 199–207 *Year:* 1999 *Publisher:* Canadian Forest Service, Pacific Forestry Centre, Victoria BC

9. **Fully automatic geo-coding of CARABAS-II VHF SAR images**
   Author: F. Walter, J.E.S. Fransson (1), P.-O. Frölind (2)
   Addresses: (1) Dept. of Forest Resource Management and Geomatics, SLU, Umeå
   (2) Sensor Technology Division, Swedish Defence Research Establishment (FOA)
   Conference: International Geoscience and Remote Sensing Symposium
   Pages: 549–553 *Year:* 1999

6.4 CBA Reports

1. **Automatic detection of field, pasture, deoducios and coniferous forest in old shire maps for conversion to geographical information system (GIS)**
   Author: N. Malm
   Year: 1999 *Publisher:* CBA, Report No. 29
   Comment: In Swedish

2. **3D Fibre analysis of paper - a survey**
   Authors: M. Aronsson, A. Fayyazi (1)
   (1) ITN, Campus Norrköping, Linköping University
   Pages: 46 *Year:* 1999 *Publisher:* CBA, Report No. 30

3. **Annual Report 1998**
   Editors: M. Aronsson, G. Borgefors, I. Nyström
   Publisher: Centre for Image Analysis
   Pages: 79 *Year:* 1999

6.5 CBA Internal reports

1. **Program Code for Licentiate Thesis "The Distance Transform Algorithm on General Parallel Computers"**
   Author: A. Forsmoo
   Year: 1999 *Publisher:* CBA, Internal report No. 13

2. **Introduction to fuzzy sets - with application to image processing and pattern recognition**
   Author: T. Brandtberg
   Year: 1999 *Publisher:* CBA, Internal report No. 14

3. **Fast computation of the convex hull in digital 2D images**
   Author: P. Lindborg
   Year: 1999 *Publisher:* CBA, Internal report No. 15

4. **Image analysis of dance sequences using video and sound**
   Author: A. Forsmoo
   Year: 1999 *Publisher:* CBA, Internal report No. 16
   Comment: In Swedish

5. **On 3D Digital Topology and its Use in Skeletonization**
   Authors: I. Nyström, S. Svensson
   Pages: 18 *Year:* 1999 *Publisher:* CBA, Internal report No. 17

7 Activities

We have as an aim to keep in contact with our colleagues in academia, with industries based on image analysis or in need of its application, and with society in general. A consequence of these aims we organise workshops and seminars, receive visitors, make visits, both for long and short stays, give presentations, participate in conferences, and participate in many different committees, both international and national. In the following sections we have tried to list these activities for the year 1999. The list mostly covers new contact points. We have left out all meetings within ongoing research projects and all lectures we have given or attended as part of the regular educational activities of CBA (see Sections 3, 4, and 5). Still the lists become quite extensive.

Prof. Ewert Bengtsson has served as Vice rector for Information Technology and Chair person at the virtual faculty of information technology at UU. These two positions involved many meetings which are not listed here, as they do not directly concern CBA activities. We limit ourselves to list the various committees he has chaired as a consequence of these appointments. Doc. Lennart Thurfjell has served as Executive programme director of the National research programme VISIT.

To give some figures: We had three seminars with invited lecturers, in addition to the 31 seminars internal series. We have also given eight seminars outside CBA. We have given fours special invited presentations at scientific conferences, three of them international; five oral and eight poster presentations at international reviewed conferences and 13 other conference presentations. In addition we have attended many other international and national meetings. We have had two long term visitors, one from Minsk, Belarus and one from Bergen, Norway. Three persons from CBA have made extended visits as guest scientists in research groups in Sydney, Australia, Rotorua, New Zealand, and in Napoli, Italy. We have received a large number of visitors at (at least) 30 different occasions, and have visited others at (at least) 55 different occasions. Finally, we have listed 19 international and 41 national "committees" of the most varying types in which we have served. These figures makes 1999 a "normal" year for most of these activities.

7.1 Organised conferences and workshops

1. **Reference group seminar**
   Organiser: Ewert Bengtsson
   Address: CBA
   Date: 990519
   Attendees: 3
   Topic: Presentation of two projects using 3D medical images. The main part of the seminar was about a coming thesis by Hans Frimmel on 3D computer modeling for positioning biopsy needles in the prostate gland. The other project that was presented during the seminar dealt with separation of blood vessels in MRA images using greyscale connectivity.
   Comment: Half-day seminar organised to give information on ongoing research to our reference group.

2. **CBA internal planning workshop**
   Organiser: Anna Rydberg, Stina Svenssonm Lena Wadelius, Felix Wehrmann
   Address: Lövstabruk, Leufsta
   Date: 990901–990902
   Attendees: All personell from CBA
   Topic: As a forum of discussion this workshop addressed long-term strategic questions regarding the future of CBA. The workshop comprised four sessions, especially focusing on the major topics

"research environment", "the situation of PhD students, "meetings and activities", as well as "visions." Beside others, our discussions included questions of information sharing within CBA, national and international contacts to other research groups, quality and quantity of PhD courses, CBA's weekly Monday meetings, and social life. In addition to this, there were visits of the old brewery and the church with the unique Cahmann organ.

3. **Reference group seminar**
   Organiser: Gunilla Borgefors
   Address: CBA
   Date: 991111
   Attendees: 6
   Topic: Presentations of two thesis published during the autumn, both using aerial images for forestry applications:
   - Automatic individual tree-based analysis of high spatial resolution remotely sensed data (Tomas Brandtbeg)
   - Extraction of forest stand parameters from CARABAS VHF SAR images (Fredrik Walter)
   Comment: Half-day seminar organised to give information on ongoing research to our reference group.

7.2 Seminars held outside CBA

1. **Ewert Bengtsson**
   Address: UAS Hospital Board Room
   Date: 990121
   Title: Telemedicine in Uppsala
   Comment: Presentation of various Telemedicine projects within the SJUNET framework. Bengtsson spoke about CBA experiences as well as plans for the IT-faculty

2. **Lennart Thurfjell**
   Address: Ångströmslaboratoriet, UU
   Date: 990414
   Title: VISIT mid-term evaluation
   Comment: A total of about 20 persons from the Swedish Foundation for Strategic Research and from other image analysis groups in Sweden participated in the meeting.

3. **Catherine Östlund**
   Address: Department of Informatics, Mid Sweden University, Frösön
   Date: 990519
   Title: Remote Sensing and Imaging Spectrometry
   Comment: Seminar for students, based on the PhD thesis.

4. **Catherine Östlund**
   Address: Department of Informatics, Mid Sweden University, Frösön
   Date: 990519
   Title: Remote Sensing and Imaging Spectrometry
   Comment: Public and popular presentation of the PhD thesis.

5. **Stina Svensson**
   Address: Istituto di Cibernetica, Italian National Research Council, Arco Felice (Naples) Italy
   Date: 991026
   Title: Current status of research in 3D image analysis at the CBA

6. **Tommy Lindell**
   Address: Stockholm University, Dept of Physical Geography
   Date: 991116
   Title: Jamaican Coastal Project

7. **Ewert Bengtsson**
   Address: MIC Aula

Date: 991119
Title: The IT strategy of the virtual IT faculty
Comment: Presentation for the faculty of science and technology collegium

8. **Ewert Bengtsson**
   Address: The national agency for education (Skolverket), Stockholm
   Date: 991210
   Title: The national IT strategy for schools
   Comment: Presenting an expert study co-authored by Ewert Bengtsson

7.3 Seminars at CBA with invited guest lecturers

1. **Vassili Kovalev**
   Address: Institute of Engineering Cybernetics, Belarus National Academy of Sciences, Minsk, Belarus
   Date: 990219
   Title: Multidimensional co-occurence matrices for image analysis and recognition

2. **Jussi Parkkinen**
   Address: Dept. of Computer Science, University of Joensuu, Finland
   Date: 990311
   Title: Analysis of color images

3. **Vassili Kovalev**
   Address: Institute of Engineering Cybernetics, Belarus National Academy of Sciences, Minsk, Belarus
   Date: 990511
   Title: Analysis of 3D SPECT Perfusion Images

7.4 Seminars at CBA

Some of these seminars were held in Swedish.

1. **Johan Mattson**
   Date: 990108
   Title: Methods in algorithms in real time computer graphics
   Comment: Presentation of Master Thesis

2. **Anders Forsmoo**
   Date: 990115
   Title: The parallel distance transform algorithm on a general MIMD computer

3. **Petra Ammenberg**
   Date: 990122
   Title: CORINE land cover

4. **Fredrik Walter**
   Date: 990129
   Title: Remote Sensing for Forestry Planning
   Comment: Walter was working half-time at SkogForsk for a year. This was a presentation of what he did there.

5. **Anna Rydberg**
   Date: 990205
   Title: Multispectral edge detection in agricultural satellite images

6. **Hannes Edvardson**
   Date: 990212
   Title: Using implicit polynomials for shape desciption

7. **Petter Lindborg**
   Date: 990226
   Title: Image analysis for assessing food quality

8. **Joakim Lindblad**
   Date: 990305
   Title: Reducing the number of false alarms in the LHC cable inspection system

9. **Hans Frimmel**
   Date: 990319
   Title: Computer networks

10. **Peter Flink**
    Date: 990326
    Title: The history of mathematics

11. **Lennart Thurfjell**
    Date: 990409
    Title: Australia, mutual information and image registration
    Comment: Thurfjell was guest researcher at the Dept. of Nuclear Medicine, Westmead Hospital in Sydney for three months.

12. **Roger Lundqvist**
    Date: 990416
    Title: Discrimination of Alzheimer Brain SPECT scans from normals

13. **Stina Svensson**
    Date: 990423
    Title: Skeletonization Algorithms for 3D Objects

14. **Tomas Brandtberg**
    Date: 990507
    Title: Analysis of individual trees in high spatial resolution data

15. **Mikael Vondrus**
    Date: 990521
    Title: Quantification of microvessels in the prostate

16. **Felix Wehrmann**
    Date: 990528
    Title: A Deformable Surface Model goes Hierarchy

17. **Roger Hult**
    Date: 990604
    Title: Working with MR images

18. **Mattias Aronsson**
    Date: 990611
    Title: Volume images of fibres in paper

19. **Carolina Linnman**
    Date: 990618
    Title: The Cell Nucleus - Applying Distance Transform to Measure the Speed of DNA Replication

20. **Joakim Lindblad, Stina Svensson**
    Date: 990823
    Title: SSIP '99, Summer School in Image Processing, Szeged, Hungary

21. **Mattias Moëll**
    Date: 990906
    Title: Comparison of Segmentation Methods for Confocal Microscope Images of Wood

22. **Anna Rydberg**
Date: 990913
Title: Multispectral Edge Detection of Agricultural Fields in Satellite Images

23. **Xavier Tizon**
Date: 990920
Title: 3D registration of MRI brain images

24. **Fredrik Walter**
Date: 990927
Title: Extraction of forest parameters from CARABAS VHF SAR images
Comment: Dissertation "rehersal"

25. **Hans Frimmel**
Date: 991004
Title: Positioning Biopsy Needles in the Prostate Gland Using 3D Computer Modelling
Comment: Dissertation "rehersal"

26. **Lucia Ballerini**
Date: 991011
Title: Genetic Algorithms

27. **Petra Ammenberg**
Date: 991018
Title: Using a bio-optical model combined with remote sensing data to assess water quality

28. **Roger Lundqvist**
Date: 991101
Title: Development of a system for volume measurement of cerebral arteriovenous malformations in X-ray angiography

29. **Mattias Aronsson**
Date: 991108
Title: Paper volume #2

30. **Felix Wehrmann**
Date: 991115
Title: Basic concepts of tensors

31. **Carolina Linnman**
Date: 991206
Title: Segmentation of fluorescence labelled cells

7.5 Conference participation

7.5.1 Special invited speakers

1. **Ewert Bengtsson**
Conference: Telemedicine in vision and reality
Title: Experiences and visions in telemedicine
Date: 990518
Address: UU hospital
Comment: This is a Swedish regional telemedicine conference. In Swedish.

2. **Ewert Bengtsson**
Conference: Microscopy as a Tool in Pulp and Paper Research and Development
Title: Computerized microscopy as a tool in medicine - the struggle to automated screening for cervical cancer
Date: 990621–990622
Address: Swedish Pulp and Paper Research Institute (STFI), Stockholm

3. **Gunilla Borgefors**
   Conference: ISPRS'99: Automatic Extraction of GIS Objects from Digital Imagery
   Title: Forest Parameter Extraction from Airborne Sensors
   Date: 990908–990910
   Address: Technical University of München, Germany

4. **Ingela Nyström**
   Conference: DIMACS workshop on "Discrete Problems with Medical Applications"
   Title: Analysis of Magnetic Resonance Angiography Images using Skeletonization and Distance Transforms
   Date: 991208–991210
   Address: DIMACS Center, Rutgers University, Piscataway, NJ, USA
   Comment: In adddition to the 45 minute talk, Nyström also served as a panelist during a panel session.

7.5.2 Oral presentations - refereed conferences

1. **Stina Svensson**
   Conference: SPIE Medical Imaging
   Address: Town and Country Hotel, San Diego, California, USA
   Date: 990220–990226
   Title: Grayscale Connectivity Concept for Visualizing MRA and CTA Volumes

2. **Tomas Brandtberg**
   Conference: 11th Scand. Conf. on Image Analysis (SCIA '99)
   Address: Kangerlussuaq, Greenland
   Date: 990607–990611
   Title: Structure-based classification of tree species in high spatial resolution aerial images using a fuzzy clustering technique aerial images using a fuzzy clustering technique

3. **Roger Hult**
   Conference: 11th Scand. Conf. on Image Analysis (SCIA '99)
   Address: Kangerlussuaq, Greenland
   Date: 990607–990611
   Title: Segmentation of the Brain in MRI Using Grey Level Morphology and Propagation of Information

4. **Roger Lundqvist**
   Conference: 11th Scand. Conf. on Image Analysis (SCIA '99)
   Address: Kangerlussuaq, Greenland
   Date: 990607–990611
   Title: Classification of Functional Patterns in SPECT Brain Scans Based on Partial Least Squares Analysis

5. **Lennart Thurfjell**
   Conference: 11th Scand. Conf. on Image Analysis (SCIA '99)
   Address: Kangerlussuaq, Greenland
   Date: 990607–990611
   Title: Fusion of Multimodality Brain Images

6. **Felix Wehrmann**
   Conference: 11th Scand. Conf. on Image Analysis (SCIA '99)
   Address: Kangerlussuaq, Greenland
   Date: 990607–990611
   Title: A 3D Deformable Surface Model to Segment the Brain in MR Images

7. **Emma Lindqvist**
   Conference: Statistical Methods for Image Processing: A satellite conference of the 52nd ISI session in Helsinki

Address: MIC, Uppsala
Date: 990806–990807
Title: Edge Detection in Hyperspectral Imagery

8. **Lucia Ballerini**
Conference: AI*IA'99 Sixth Congress of the Italian Association for Artificial Intelligence
Address: Bologna, Italy
Date: 990914–990917
Title: Genetic Evolution of Neural Networks Topology

9. **Lucia Ballerini**
Conference: EMBEC'99 European Medical and Biological Engineering Conference
Address: Vienna, Austria
Date: 991104–991107
Title: Moment Theory for FAZ Shape Description in Diabetic Retinopathy

7.5.3 Poster presentations - refereed conferences

1. **Stina Svensson**
Conference: Discrete Geometry for Computer Imagery (DGCI'99)
Address: Marne-la-Vallée, France
Date: 990316–990319
Title: Decomposing Digital 3D Shapes Using a Multiresolution Structure

2. **Stina Svensson**
Conference: 11th Scand. Conf. on Image Analysis (SCIA'99)
Address: Kangerlussuaq, Greenland
Date: 990608–990610
Title: Fully Reversible Skeletonization for Volume Images Based on Anchor-Points from the D26 Distance Transform

3. **Fredrik Walter**
Conference: International Geoscience and Remote Sensing Symposium, IGARSS 99
Address: Congress centrum, Hamburg, Germany
Date: 990628–990702
Title: Fully automatic geo-coding of CARABAS-II VHF SAR images

4. **Anders Forsmoo**
Conference: 10th Int. Conf. on Image Analysis and Processing (ICIAP'99)
Address: Venice, Italy
Date: 990927–990929
Title: The Distance Transform Algorithm on a Two-Processor Computer

5. **Anna Rydberg**
Conference: 10th Int. Conf. on Image Analysis and Processing (ICIAP'99)
Address: Venice, Italy
Date: 990927–990929
Title: Extracting multispectral edges in satellite images over agricultural fields

6. **Lucia Ballerini**
Conference: IEEE Medical Imaging Conference
Address: Seattle, USA
Date: 991024–991030
Title: An Automatic System for the Analysis of Vascular Lesions in Retinal Images

7. **Lucia Ballerini**
Conference: European Medical and Biological Engineering Conference (EMBEC'99)
Address: Vienna, Austria
Date: 991104–991107
Title: Segmentation of Ocular Fundus Images using Genetic Snakes

8. **Lucia Ballerini**
   Conference: IEEE International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS'99)
   Address: Phuket, Thailand
   Date: 991208–991210
   Title: Genetic Snakes for Radar Images Segmentation

7.5.4 Oral presentations

1. **Peter Flink**
   Conference: Swedish Symposium on Image Analysis (SSAB'99)
   Address: Chalmers, Gothenburg
   Date: 990309–990310
   Title: Detection of aglae in lake water by imaging spectrometers

2. **Carolina Linnman**
   Conference: Swedish Symposium on Image Analysis (SSAB'99)
   Address: CTH, Gothenburg
   Date: 990309–990310
   Title: Detection of Fluorescent Foci and Evaluation of Spatial Relationships in 3D-Fluorescence Microscopy Images of Mammalian Cells

3. **Felix Wehrmann**
   Conference: Swedish Symposium on Image Analysis (SSAB'99)
   Address: CTH, Gothenburg
   Date: 990309–990310
   Title: A 3D Deformable Surface Model to Segment the Brain in MR Image

4. **Carolina Linnman**
   Conference: 6th ESACP Congress
   Address: DKFZ, Heidelberg, Germany
   Date: 990407–990411
   Title: Detection of Fluorescent Foci and Evaluation of Spatial Relationships in 3D-Fluorescence Microscopy Images of Mammalian Cells

5. **Lennart Thurfjell**
   Conference: Nutek Medical Technologies Conference
   Address: Industrihuset, Stockholm
   Date: 990422–990423
   Title: Segmentation and Visualization of data from MR, PET and SPECT

6. **Ewert Bengtsson**
   Conference: NGSSC National Graduate School on Scientific Computing Conference in Uppsala
   Address: MIC, Uppsala
   Date: 990510
   Title: Other applications of computing
   Comment: Welcome and introductory remarks

7. **Lennart Thurfjell**
   Conference: Mälartinget 99
   Address: City theater, Uppsala
   Date: 990520
   Title: Three dimensional map of the brain
   Comment: The presentation was one of four presentations showing examples of research at UU and SLU.

8. **Ewert Bengtsson**
   Conference: IT at School
   Address: Bolandskolan, Uppsala

Date: 990614–990615
Title: How can Uppsala university help the secondary schools in the IT field?
Comment: I was leading one of the workshops at the conference under the title above, attracting mainly IT teachers from secondary schools

9. **Mattias Aronsson**
Conference: Microscopy as a Tool in Pulp and Paper Research and Development
Address: Swedish Pulp and Paper Research Institute (STFI) Stockholm
Date: 990621–990622
Title: Towards Assembling a Small Digital Volume of Paper
Comment: Presentation together with Arash Fayyazi

10. **Tomas Brandtberg**
Conference: Nordic Workshop on Image Analysis and Spatial Statistics in Forestry
Address: The Royal Veterinary and Agricultural University, Frederiksberg, Copenhagen, Denmark
Date: 991102
Title: Individual tree-based analysis of laser scanning data
Comment: Included 40 min. talk. A proceeding of abstracts was created by the organizer Dina (Danish Informatics Network in the Agricultural sciences).

11. **Petra Ammenberg**
Conference: RESE Annual meeting
Title: Remote Sensing for monitoring of Case II and lake waters.
Date: 991111
Address: Jukkasjärvi and Satellus, Kiruna

12. **Tommy Lindell**
Conference: RESE Annual meeting
Title: Detection of Coral Bleaching from Satellites
Date: 991111
Address: Jukkasjärvi and Satellus, Kiruna

13. **Tommy Lindell**
Conference: RESE Annual meeting
Title: Remote Sensing for monitoring of Case II and lake waters
Date: 991113
Address: Jukkasjärvi and Satellus, Kiruna

7.5.5 Poster presentations

1. **Anna Rydberg**
Conference: Agriculture conference '99
Address: SLU, Uppsala
Date: 990324–990325
Title: Remote Sensing and Image Analysis for Agricultural Purposes
Comment: In Swedish

2. **Carolina Linnman, Joakim Lindblad**
Conference: Amersham Pharmacia Biotech R&D day in Uppsala
Title: Algorithms for Cytoplasm Segmentation of Fluorescence Labelled Cells Grown in Microfabricated Structures
Date: 991202
Address: Uppsala Castle, Uppsala

3. **Tommy Lindell**
Conference: Pecora 14 Land Satellite Information III
Address: Denver, Colorado, USA
Date: 991206–991210
Title: Coastal Zone Mapping of Jamaica for Planning and Management

7.5.6 Attendee

1. **Ewert Bengtsson**
   Conference: Telepresence '99
   Address: Stockholm
   Date: 990203
   Comment: National conference with presentation of various telemedicine projects

2. **Ewert Bengtsson**
   Conference: SPIE Medical Imaging Conference
   Address: San Diego, USA
   Date: 990220–990222

3. **Ewert Bengtsson**
   Conference: Computer Science in Higher Education Workshop
   Address: University of California at Berkeley, CA, USA
   Date: 990223
   Comment: Invited to represent UU at this small workshop

4. **Ewert Bengtsson**
   Conference: SUN Microsystems Worldwide Education & Research Conference 99
   Address: Francis Hotel, San Fransisco, CA, USA
   Date: 990223–990226
   Comment: Invited to represent UU at this invitational conference

5. **Tommy Lindell**
   Conference: 10 year Celebration of the Dept of Environmental Assessment
   Address: SLU Uppsala
   Date: 990304

6. **Petra Ammenberg, Mattias Aronsson, Ewert Bengtsson, Gunilla Borgefors, Tomas Brandtberg, Hans Frimmel, Roger Hult, Joakim Lindblad, Anna Rydberg, Lennart Thurfjell, Mikael Vondrus**
   Conference: Swedish Society for Automated Image Analysis Symposium (SSAB'99)
   Address: CTH, Gothenburg
   Date: 990309–990310
   Comment: Brandtberg was session chair of the "3D Shape" session

7. **Ingela Nyström**
   Conference: 8th Discrete Geometry for Computer Imagery, (DGCI'99)
   Address: ESIEE, Marne-la-Vallée (Paris), France
   Date: 990316–990319
   Comment: Presented CBA and Uppsala as host for the next conference in the series.

8. **Gunilla Borgefors**
   Conference: DGCI'99
   Address: ESIEE, Marne-la-Vallée (Paris), France
   Date: 990317–990319
   Comment: Session Chair; Poster presentation by Co-author, "Decomposing digital 3D shapes using a multiresolution structure"

9. **Ewert Bengtsson**
   Conference: 6th ESACP Congress
   Address: DKFZ, Heidelberg, Germany
   Date: 990407–990410
   Comment: Attended an ESACP board meeting and an Analytical Cellular Pathology Editorial Board Meeting during the conference

10. **Gunilla Borgefors**
    Conference: Wood and Wood Fiber towards year 2000

Address: SLU, Ultuna, Uppsala
Date: 990420

11. **Ewert Bengtsson**
Conference: Presentation of the New Research Proposition at KVA
Address: Royal Academy of Science, Stockholm
Date: 990422
Comment: The presentation was held by Tomas Östros, the Minister of education

12. **Ewert Bengtsson**
Conference: Medical Technology conference arranged by NUTEK
Address: Industrihuset, Stockholm
Date: 990422–990423

13. **Petra Ammenberg**
Conference: Remote sensing applications for water quality monitoring in lakes
Address: Norr Malma field station, Norrtälje
Date: 990503–990515

14. **Ewert Bengtsson**
Conference: The internet future
Address: Gällöfsta Conference center
Date: 990526–990527
Comment: Working seminar discussing future internet scenarios

15. **Ewert Bengtsson**
Conference: 11th Scand. Conf. on Image Analysis (SCIA '99)
Address: Kangerlussuaq, Greenland
Date: 990608–990610
Comment: Session chair. Presentation by coauthors.

16. **Gunilla Borgefors**
Conference: 11th Scand. Conf. on Image Analysis (SCIA '99)
Address: Kangerlussuaq, Greenland
Date: 990608–990610
Comment: Session Chair; Poster presentation by co-author: "Fully reversible skeletonization for volume images based on anchor-points from the D26 distance transform"

17. **Ingela Nyström**
Conference: Computational Methods in Engineering, Workshop and Celebration
Address: MIC aula
Date: 990611
Comment: Invited presentations by leading researchers in the fields of numerical analysis and scientific computing. The workshop was organized by TDB in honour of Prof. Bertil Gustafsson's 60th birthday.

18. **Joakim Lindblad, Stina Svensson**
Conference: 7th Summer School on Image Processing (SSIP'99)
Address: Szeged, Hungary
Date: 990702–990711
Comment: Neighborhood processing, Discrete Tomography, Image Segmentation Techniques, Image complexity and structure when compressing the visual information, Processing of facial laser scans, Bayesian Binary Tomography, Fuzzy Connectedness and Object Definition: Theory, Algorithms, and Applications in Image Segmentation, 3D Imaging in Medicine - what we can do!, 3D image reconstruction in Electron Microscopy, Skeletonization, Image Presentation in Nuclear Medicine, How to estimate the shape of a set of points using snakes, Picture Archiving and Communication Systems Team work

19. **Anna Rydberg**
Conference: 2nd European Conference on Precision Agriculture

Address: Odense Congress Centre, Denmark
Date: 990711–990715

20. **Roger Lundqvist**
Conference: Medical Image Understanding and Analysis
Address: Oxford, UK
Date: 990719–990720
Comment: Oral presentation by co-author: "Classification of SPECT scans of AD and FLD based on intensity and gradient information"

21. **Mattias Aronsson, Ewert Bengtsson, Gunilla Borgefors, Felix Wehrmann**
Conference: Statistical Methods for Image Processing: A satellite conference of the 52nd ISI session in Helsinki
Address: MIC, Uppsala
Date: 990806–990809
Comment: The conference was arranged in cooperation between the Dept. of Mathematical Statistics at UU and CBA. Bengtsson and Borgefors were on the program committee

22. **Felix Wehrmann**
Conference: 2nd Medical Image Computing and Computer-Assisted Intervention (MICCAI '99)
Address: Cambridge, UK
Date: 990919–990922

23. **Örjan Smedby, Xavier Tizon**
Conference: International Workshop on Magnetic Resonance Angiography
Address: Lund University Hospital
Date: 990922–990925
Comment: The theme was new aspects on visualisation of macro- and micro-circulation

24. **Gunilla Borgefors, Ingela Nyström, Stina Svensson**
Conference: 10th International Conference on Image Analysis and Processing (ICIAP'99)
Address: Venice, Italy
Date: 990927–990929
Comment: Borgefors: Session Chair; Oral presentation by co-author "Permanence-based shape decomposition in binary pyramids"; Poster presention by co-author "Extracting multispectral edges in satellite images over agricultural fields"
Nyström presented CBA and Uppsala as host for the next DGCI conference

25. **Lennart Thurfjell**
Conference: European Association Nuclear Medicine Congress, EANM'99
Address: Barcelona, Spain
Date: 991009–991013

26. **Ewert Bengtsson**
Conference: Broadband internet technology
Address: Ericsson Conference centre, Älvsjö
Date: 991105
Comment: A national conference on internet technology arranged by the National Academy of Engineering Sciences, IVA

27. **Mattias Moëll**
Conference: Swedish Forest Conference
Address: SLU, Uppsala
Date: 991130–991201
Comment: The Swedish Forest Conference (in swedish "Skogskonferensen") is a meeting place for forest, industry, and research.

28. **Torsten Jarkrans, Mikael Vondrus**
Conference: Amersham Pharmacia Biotech R&D day in Uppsala
Date: 991202
Address: Uppsala Castle, Uppsala

29. **Mattias Aronsson**
Conference: Sigrad '99, 3D Graphics on the Net Facing 2000
Address: KTH, Stockholm
Date: 991210

30. **Petra Ammenberg, Tommy Lindell**
Conference: Remote Sensing of the Littoral Marine Environment
Address: The Linnean Society, London, UK
Date: 991215–991217

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

1. **Lennart Thurfjell**
Host: Brian Hutton
Address: Dept. of Nuclear Medicine, Westmead Hospital, Sydney, Australia
Date: 9810–9901
Topic: A joint collaboration on registration of brain images.
Comment: Thurfjell was appointed visiting researcher at Westmead Hospital.

2. **Mattias Moëll**
Host: New Zealand Forest Research Institute (FRI)
Address: Rotorua, New Zealand
Date: 9810–9908
Topic: (I) Image analysis of wood fiber images. The main focus is thresholding methods for confocal microscopy images of *Radita Pine*. (II) Collaboration on automatic measurement of microscope images of wood fibers. Main focus on cross-sectional fiber dimensions.

3. **Stina Svensson**
Host: Gabriella Sanniti di Baja
Address: Istituto di Cibernetica, Italian National Research Council, Arco Felice (Naples), Italy
Date: 990922-991220
Topic: Work with common projects: Skeletonization of volume objects and Decomposition of volume objects.
The visit was possible due to grants from "SLU-grants for the internationalization of graduate education".

7.7 Shorter visits to other research groups

1. **Carolina Linnman**
Host: Anders Zetterberg, Fredrik Erlandsson, Susanna Ekholm-Jensen
Address: Dept. of Onkology-Patology, Div. of Tumour Cytology, Karolinska Institutet, Stockholm
Date: 1999
Topic: Project collaboration
Comment: Several visits have been made during the year to discuss joint projects, install image processing programs and exchange image data.

2. **Tommy Lindell**
Host: Swedish National Space Board
Address: Solna
Date: 990112
Topic: International Evaluation of Space Projects

3. **Ewert Bengtsson**
Host: Heby Municipality
Address: Östervåla Gästgiveri
Date: 990113
Topic: How can IT be used to improve the development of the municipality of Heby

4. **Gunilla Borgefors, Mattias Aronsson**
   Host: Björn Kruse, Arash Fayyazi
   Address: Dept. of Science and Technology, Linköping University, Campus Norrköping
   Date: 990119
   Topic: Reports and planning of the VISIT project "3D Tracking of Fibres in Paper".

5. **Fredrik Walter, Gunilla Borgefors**
   Host: Lars Ulander
   Address: National Defence Research Establishment (FOA), Linköping
   Date: 990201–990202
   Topic: Workshop on CARABAS for forestry applications
   Comment: About 12 people form FOA, SLU and CTH participated

6. **Tommy Lindell, Anna Rydberg**
   Host: Gävle Technical High School
   Address: Gävle
   Date: 990204
   Topic: GIS Workshop

7. **Tommy Lindell**
   Host: Gävle Technical High School
   Address: Gävle
   Date: 990216
   Topic: GIS/Remote sensing seminar

8. **Tommy Lindell**
   Host: Gävle Technical High School, Building Sciences
   Address: Gävle
   Date: 990217
   Topic: Sven-Åke Ljungberg: Docent lecture on Thermal Remote Sensing

9. **Ewert Bengtsson**
   Host: Norman Pressman
   Address: AccuMed International Inc, Chicago, IL, USA
   Date: 990217–990219
   Topic: Discussion about how the changes at AccuMed will affect the cooperation between CBA and AccuMed; plans for future collaboration.

10. **Tommy Lindell**
    Host: EU Joint Research Centre (JRC)
    Address: Ispra, Italy
    Date: 990222–990226
    Topic: Final Joint Workshop for the SALMON Project
    Comment: Evaluation by International Reviewers

11. **Ewert Bengtsson**
    Host: Stig Hagström
    Address: Stanford Learning Lab, Palo Alto, CA, USA
    Date: 990226
    Topic: Attended a board meeting of Stanford Learning Lab and got a presentation and demonstration of the work there in preparation for our development of Uppsala Learning Lab

12. **Gunilla Borgefors**
    Host: Tomas Gustavsson
    Address: Dept. of EE, CTH, Gothenburg
    Date: 990226
    Topic: Board meeting of SSAB

13. **Ewert Bengtsson, Gunilla Borgefors**
    Host: VISIT

Address: Dept. of Electrical Engineering, CTH, Gothenburg
Date: 990308
Topic: Reference group meeting of VISIT
Comment: Bengtsson was chair of the meeting

14. **Ewert Bengtsson**
Host: Swedish National Distance Education Consortium
Address: Arlanda Sky City
Date: 990413
Topic: Annual meeting of representatives of the universities forming the consortium
Comment: Bengtsson was elected chair of the meeting

15. **Gunilla Borgefors**
Host: MISTRA
Address: SSF, Stockholm
Date: 990413
Topic: Half-time assessment of the RESE programme by a Scientific review panel

16. **Ewert Bengtsson, Gunilla Borgefors, Carolina Linnman**
Host: SSF
Address: Ångströmslaboratoriet, Uppsala
Date: 990414
Topic: Half-time assessment of the VISIT programme by an Industrial review panel

17. **Tommy Lindell**
Host: Eugenio Zilioli
Address: CNR, Milano, Italy
Date: 990419–990423
Topic: Preparation of Final Report of the SALMON Project

18. **Lennart Thurfjell**
Host: Stefan Carlsson
Address: CVAP, KTH, Stockholm
Date: 990427
Topic: VISIT board meeting followed by presentations of research projects at CVAP

19. **Ingela Nyström**
Host: Stefan Höglund
Address: Dept. of Biochemistry, HIV group, BMC, UU
Date: 990428
Topic: Discussion on continuing our earlier collaboration on structural analysis of HIV.
Comment: Dr Åsa Öhagen, Harvard University, Boston, was visiting.

20. **Carolina Linnman, Felix Wehrmann**
Host: Anders Heyden, Karl Åström
Address: Department of Mathematics, Lund University
Date: 990505–990506, 990819–990820
Topic: PhD course in computer vision, sponsored by the project VISIT. The presented material was closely related to research projects at the department.

21. **Ewert Bengtsson**
Address: UU main building
Date: 990504
Topic: Bengtsson held opening remarks and introduction to a seminar in the Speak Out (Tala Ut) project

22. **Ewert Bengtsson** *Host:* Bo Sundqvist, Rector of UU
Address: UU main building
Date: 990505
Comment: Invited to attend the official visit at Uppsala university by the Polish president

23. **Gunilla Borgefors, Fredrik Walter**
Host: SkogForsk
Address: Skogforsk, Uppsala
Date: 990517
Topic: Planning of future CARABAS activities. People from SkogForsk, CTH, CBA, FOA and SLU Umeå attended.

24. **Catherine Östlund**
Host: Ulf Persson
Address: Dept. of Informatics, Mid Sweden University, Frösön
Date: 990519
Topic: Discussions with lecturers and research students about image processing

25. **Ewert Bengtsson**
Host: InExit company
Address: Uppsala
Date: 990525
Topic: Presenting the work and plans of the IT faculty to a network group within the Uppsala is IT project

26. **Tommy Lindell**
Host: Eugenio Zilioli
Address: CNR, Milano, Italy
Date: 990609–990611
Topic: Preparation of Final Report SALMON Project and for a continuation of the SALMON project

27. **Anna Rydberg**
Host: ODAL
Address: Lidköping
Date: 990621
Topic: Remote sensing as a tool for precicion agricultural management

28. **Petra Ammenberg**
Host: Per Granström
Address: County Administrative Board of Gävleborg, Gävle
Date: 990629
Topic: Water quality measurements

29. **Tommy Lindell**
Host: Kai Sørensen
Address: NIVA, Oslo, Norge
Date: 990717–990719
Topic: Discussion and exchange of spectral sea data for calibration of models

30. **Gunilla Borgefors**
Host: Bert-Eric Tullsson
Address: CelsiusTech, Veddesta, Stockholm
Date: 990825, 991020
Topic: The Master Theses of Mattias Björkman and Andreas Lingevall

31. **Tommy Lindell**
Host: Bertil Håkansson
Address: SMHI Norrköping
Date: 990826
Topic: Application for a new Coral Bleaching Project

32. **Ewert Bengtsson**
Host: Linköping University
Address: Linköping

Date: 990830
Topic: Full day meeting with the appointment board of Linköping university for appointing a new chair in medical informatics

33. **Petra Ammenberg**
Host: Ove Forsberg
Address: County Administrative Board of Gävleborg, Gävle
Date: 990908
Topic: Water quality measurements in paper mill waste water outlets.

34. **Gunilla Borgefors**
Host: SLU
Address: Aronsborg, Bålsta
Date: 990915–990916
Topic: A two-day workshop for the department heads at SLU

35. **Lennart Thurfjell**
Host: Björn Kruse
Address: Dept. of Science and Technology, Linköping University, Campus Norrköping
Date: 990921
Topic: VISIT board meeting followed by presentations of research projects at ITN

36. **Ewert Bengtsson**
Host: Väddö development centre
Address: Väddö Folkhögskola
Date: 990930
Topic: Attended part of a one day seminar. Discussion of possible ccoperation between UU and Väddö, e.g., in offering an advanced summer school in some IT topics

37. **Roger Lundqvist**
Host: Dept. of Neuroradiology, Karolinska Hospital
Address: Stockholm
Date: 9909–9912
Topic: Research collaboration partner
Comment: Several visits, during the Autumn

38. **Lucia Ballerini**
Host: Wallenberg lab
Address: Sahlgrenska hospital, Gothenburg
Date: 991004–991006
Topic: NMR pilot experiments on food images

39. **Ewert Bengtsson**
Host: Bo Sundqvist, Rector of UU
Address: UU
Date: 991006
Topic: Official visit at UU, by the President of Slovenia, the King and Queen of Sweden, et al.

40. **Tommy Lindell**
Host: J. Gibson, Miriam Huitric, Ian Gillot Coastal Zone Management Authority
Address: Belize City, Belize
Date: 991015–991022
Topic: Work on the Coral Bleaching Project. Melanie McField, University of Southern Florida also attended

41. **Tommy Lindell**
Host: Dr. Mati Kahru
Address: University of California, Scripps dept. of Oceanography, La Jolla, CA, USA
Date: 991025–991026
Topic: Work on the Coral Bleaching Project and discussion on RESE project matters

42. **Tommy Lindell**
Host: Dr. Philip Cramer, Dr. Pamela Reid
Address: University of Miami, FL, USA
Date: 991028–991102
Topic: Work on the Coral Bleaching Project
Comment: Collection of bleaching locations and times.

43. **Gunilla Borgefors**
Host: Gabriella Sanniti di Baja
Address: Istituto di Cibernetica, CNR, Arco Felice (Napoli), Italy
Date: 991029–991109
Topic: Continued co-operation on digital shape. A joint submission to ICPR 2000 was written.

44. **Ewert Bengtsson**
Address: Grand Hotel Saltsjöbaden
Date: 991115
Conference: The Wallenberg Foundation Conference on Computer Assisted Learning

45. **Gunilla Borgefors**
Host: Björn Granström
Address: Dept. Speech, Music and Hearing, KTH, Stockholm
Date: 991115
Topic: First meeting on a proposed national programme on Multi-Modality Signal Analysis organised by Josef Bigün, HH, and Borgefors.

46. **Lennart Thurfjell**
Host: Kerstin Malmqvist
Address: CIST, Högskolan i Halmstad
Date: 991117
Topic: VISIT board meeting followed by presentations of research projects at CIST

47. **Ewert Bengtsson**
Address: Grand Hotel, Stockholm
Date: 991209
Title: The strategy of Microsoft
Comment: presented by Steve Balmer, CEO of Microsoft corporation

48. **Tommy Lindell**
Host: Prof. Alexander Goetz
Address: Colorado State University, Boulder, CO, USA
Date: 991211
Topic: Discussion on common hyperspectral issues

49. **Mattias Moëll**
Host: MoDo
Address: Örnsköldsvik
Date: 991213–991214
Topic: Automated measurements of cross-sectional tracheid dimensions using image analysis

50. **Everyhopa at CBA**
Host: Vernon Cooray, Marcus Berg
Address: Dept of High Voltage Research, UU
Date: 991213
Topic: Our hosts started by describing what lightning is, its physical background and processes. Berg showed us his equipment for studying droplet behaviour in electric fields through image analysis. Then we were shown some impressive sparks, a million volts and 100.000 amps respectively in the high voltage lab.
Comment: Lucia visit 1999

51. **Ewert Bengtsson**
Host: Bo Sundqvist, Head of UU
Address: Castle of Uppsala
Date: 991213
Topic: The lunch for Nobel laureates

52. **Ewert Bengtsson**
Host: Peter Kind
Address: EU Commission DG12, Brussels, Belgium
Date: 991214
Topic: Discussing the planned National Gerontological Institute in Uppsala and the possibility for EU to support this.

53. **Lennart Thurfjell**
Host: Arvid Morell
Address: Dept. of Nuclear medicine, Huddinge Hospital
Date: 991214
Topic: Discussion about a thesis project regarding compensation for inhomogeneities in MRI.

54. **Mattias Aronsson**
Host: Reiner Lenz
Address: Dept. of Science and Technology, Linköping University, Campus Norrköping
Date: 991214
Topic: Presentation of ICA basics. The presentation was part of the graduate course "Introduction to Statistical Pattern Recognition".

55. **Gunilla Borgefors, Lucia Ballerini**
Host: FOOD21 (MAT21)
Address: Ekeby Conference, Uppsala
Date: 991215
Topic: General meeting on ideas for phase two of FOOD21

7.8 Visiting scientists (staying at least 2 weeks)

1. **Vassili Kovalev**
Host: Lennart Thurfjell
Address: Institute of Engineering Cybernetics, Belarus National Academy of Sciences, Minsk, Belarus
Date: 990208–990512
Topic: Dr. Kovalev worked in the brain atlas group. The main topic was to use texture analysis for classification/recognition of Ahlzheimer's disease in SPECT brain scans.

2. **Lars Helge Stien**
Host: Gunilla Borgefors
Address: Bergen University, Norway
Date: 991012–991217
Comment: Following the course "Application Oriented Image Analysis" and working on salmon imagery.

7.9 Other visitors

1. **Mats Söderström, Knud Nissen**
Host: Anna Rydberg
Address: ODAL
Date: 990103
Topic: Precision Agriculture and Remote Sensing

2. **Lars Jonsson**
Host: Ewert Bengtsson

Address: Uppsala University Development Ltd. (Uppsala Universitets Utveckling AB)
Date: 990113
Topic: Possible cooperation between UUUAB and CBA or the IT-faculty

3. **Terry Caelli 1), Mark Ollila 2)**
Host: Gunilla Borgefors
Address:
1) Center for Mapping, The Ohio State University, Columbus OH, USA
2) Gävle Technical High School
Date: 990203
Topic: Presentation of CBA, esp. remote sensing applications

4. **Joshua Simons, Kent Åberg, Erik Hagersten**
Host: Ewert Bengtsson
Address: MIC
Date: 990204
Topic: Visitors from SUN Microsystems discussing possible research cooperation between UU and the company

5. **Lennart Forsberg**
Host: Ewert Bengtsson
Address: SUNET, UMDAC, Umeå
Date: 990210
Topic: Discussion about cooperation between UU and SUNET, the Swedish University Network

6. **Lars-Erik Eriksson, Mats Gökstorp, Kerstin Malmqvist, Torleiv Orhaug, Örjan Sävborg**
Host: Lennart Thurfjell
Address: Various
Date: 990215
Topic: VISIT board meeting followed by presentations of research projects at CBA

7. **Gertrud Ericson**
Host: Ewert Bengtsson
Address: Department of Psychology, UU
Date: 990331
Topic: Can image analysis be used to analyze video sequences of ballet to quantitatively describe the intensity and emotions of the dance?
Comment: The DANS project evolved from this discussion

8. **Dept. Heads and administrators from SLU**
Host: Gunilla Borgefors
Address: SLU, Uppsala
Date: 990412
Topic: On the SLU quality project

9. **Erik Ågren**
Host: Ewert Bengtsson
Address: Department of pathology, SLU
Date: 990416
Topic: Possible application of computerized image analysis on veterinary pathology specimens

10. **Lars-Ulrik Bergström and John Norrman**
Host: Tommy Lindell
Address: Uppsala
Date: 990429
Topic: Preparation for a new Caribean Planning Project

11. **Emil Sarpa 1), Kent Åberg 2), Erik Hagersten 1)**
Host: Ewert Bengtsson, Arne Andersson
Address: 1) SUN Microsystems international, Palo Alto, CA, USA.

2) SUN Microsystems international, Kista
Date: 990510–990511
Topic: Visitors from head of research cooperation, discussing plans for research cooperation between UU and the company

12. **Raimo Launonen**
Host: Lennart Thurfjell
Address: Multimedia Systems, VTT Information Technology, Finland
Date: 990521
Topic: The group from VTT came for a study visit to hear about the research at CBA, to present their own work at VTT and to discuss co-operation possibilities.

13. **Stefan Höglund, Ulf Börjesson**
Host: Ingela Nyström
Address: Dept. of Biochemistry, BMC, UU
Date: 990607
Topic: Structural analysis of HIV: generating volume images from EM tomography
Comment: We will revive some of the routines from seven years ago.

14. **Lars-Ulrik Bergström, Kjell Grip, Örjan Mohlund and John Norrman**
Host: Tommy Lindell
Address: Various
Date: 990607
Topic: Further Preparations for a Caribbean Planning Project

15. **Bertil Håkansson**
Host: Tommy Lindell
Address: SMHI, Norrköping
Date: 990608
Topic: Preparation for a new Coral Bleaching Project

16. **Indian delegation on study tour to Europe 1), Bert-Åke Näslund 2)**
Host: Gunilla Borgefors
Address: 1) Indian Research Insitutes, 2) Swedish Board of Forestry
Date: 990616
Topic: Presentation of forest reseach at CBA by Walter, Brandtberg and Aronsson

17. **Vladimir Zidek**
Host: Gunilla Borgefors, Fredrik Walter
Address: Mendel University of Agriculture and Forestry, Brno, Czech Republic
Date: 990617
Topic: Presentation of remote sensing research at CBA

18. **Harald Norin, Björn Segerholm**
Host: Gunilla Borgefors, Ewert Bengtsson
Address: Pharmacia-Upjohn, Uppsala
Date: 990618
Topic: Discussions on particle counting on filters

19. **Chris Thomsen 1), Parvati Dev 2), Anneke Eurlings 3)**
Host: Ewert Bengtsson
Address:
1) Managing Director of the Stanford Learning Lab and the Wallenberg Global Learning Center
2) Director of SUMMIT at Stanford University, School of Medicine
3) Director of the Maastricht Learning Lab
Dates: 990621, 990623
Topic: Discussion of cooperation Uppsala - Stanford, hosting an official dinner

20. **Olof Lindahl**
Host: Ewert Bengtsson

Address: Uminova, Umeå
Date: 990816
Topic: Discussion about the plans to form SIMT - a virtual research institute on medical technology

21. **Lars-Ulrik Bergström**
Host: Tommy Lindell
Address: Uppsala
Date: 990921
Topic: Updating of the digital Jamaican Coastal Atlas

22. **Fredrik Erlandsson**
Host: Carolina Linnman, Joakim Lindblad
Address: Dept. of Oncology-Patology, Div. of Tumour Cytology, Karolinska Institutet, Stockholm
Date: 990929
Topic: Unimodal thresholding of data from images of cells in different positions of the cell cycle.

23. **Karol Lacki**
Host: Ewert Bengtsson
Address: Amersham Pharmacia Biotech
Date: 990929
Topic: Possible cooperation on image analysis of Gel structures

24. **Kaj Rosén (Dean), Anki Croon, Anders Ericsson, Sune Linder**
Host: Gunilla Borgefors
Address: Faculty of Forestry, SLU
Date: 991014
Topic: Presentations of CBA to the faculty leaders and discussions of future ways of distributing faculty money.

25. **Electron microscopy course**
Host: Ewert Bengtsson
Address: SLU
Date: 991029
Topic: Lecturing for 4 hours about computerized image analysis and presenting the work at CBA

26. **Örjan Sävborg 1), Björn Kruse 2), Arash Fayyazi 2)**
Host: Gunilla Borgefors, Mattias Aronsson
Address: 1) StoraEnso, Falun, 2) Dept. of Science and Technology, Linköping University, Campus Norrköping
Date: 991112
Topic: Status of the VISIT project "3D Tracking of Fibres in Paper"

27. **Christer Björkman, Margareta Edfors**
Host: All SLU Graduate students
Address: SLU, Uppsala
Date: 991115
Topic: The situation of PhD students at SLU and CBA in general were discussed.
Comment: The visitors are directors of PhD studies at SLU

28. **Dag Molteberg, Trygve Krekling**
Host: Mattias Moëll, Gunilla Borgefors
Address: Norges landbruksh/o gskole, Institutt for Skogfag, Dept. of Wood Technology, Ås, Norge
Date: 991124
Topic: Demonstrations of the image analysis program for measuring wood fiber dimensions on cross-sections of wood, and possible future cooperation.

29. **Monika Derndarsky**
Host: Ewert Bengtsson
Address: Department of Archeology
Date: 991202

Topic: Discussing the possibility of analysing the wear of flint tools using computerized image analysis

30. **Sara Sandin**
Host: Ingela Nyström
Address: Dept. of Biochemistry, HIV group
Date: 991216
Topic: How to generate volume images from EM tomography

7.10 Committees

Ewert Bengtsson
International:

- Editorial board member of "Machine Graphics & Vision", 1994–
Comment: Published by Polish Academy of Science
- Editorial board member of "Computer Methods and Programs in Biomedicine", 1995–
Comment: Published by Elsevier
- Editorial board member of "Analytical Cellular Pathology", 1999–
Comment: Published by IOS press
- Board member of "European Society for Analytical Cellular Pathology" (ESACP), 1997–
- On the program committee of the Workshop on Statistical Methods for Image Processing, Uppsala, August 1999,

National:

- Royal Society of Sciences in Uppsala (Kungliga Vetenskaps-Societeten), 9809–
Comment: Elected member of this, the oldest scientific society in Sweden
- Vice rector for Information Technology at UU, 9802–
Comment: One of five Vice rectors appointed to lead the strategic planning of Uppsala university and give advice to the Rector. Thus member of "Rectors advisory council". Title changed to "Rector-councellor" (Rektorsråd), 9907–
- Chairperson of the virtual faculty of information technology, 980701–
Comment: The faculty is responsible for coordinating all aspects of the information technology field at UU. The faculty board has about 15 members and meets about every six weeks.
- Member of the electorial committee for the Faculty of science and technology at Uppsala University, 1993–1999
- Deputy Member of Appointments board for the Mathematics computer science division at UU, 1996–1999
- Chair of a committee to review the IT-support organization at Uppsala university, 9810–9903
- Chair of a committee to propose a policy for WWW publishing at Uppsala university, 9810–9912
- Uppsala Learning Lab, 9908–
Comment: Chairman of the board of Uppsala Learning Lab. The Swedish Learning Lab is a cooperation project for research in IT-supported higher education with KTH, KI and Stanford supported by the Wallenberg Foundation.
- Planning committee of Swedish Learning Lab, 9904–
Comment: Developed a proposal to the Wallenberg Foundation of a cooperation project between UU, KTH, KI and Stanford on research in computer assisted learning
- The regional IT organisation in Uppsala, 9908–9909
Comment: Representing UU on a committee to propose a new regional cooperation structure for IT development

- Board of the "Uppsala is IT" project, 9810–
  Comment: A project to promote cooperation in Uppsala in the IT field between companies and the universities etc.
- Planning group for Uppsala Gerontological Institute, 9903–
  Comment: A multidisciplinary group charged with the task of producing a proposal for a national gerontological institute was appointed after a meeting called by the rektor on March 22. Ewert chaired the meeting and the group which had about 10 meetings during 1999.
- The Board of UpGIS, the net for Geographical Information Systems at UU, 9904–
  Comment: Representing the virtual IT faculty, responsible for managing the economy of the network
- Chair of a planning group for a new mathematics course making it possible for students with insufficient high-school math to be accepted for computer science courses at Uppsala University, 9905–9910
- Representing UU in the project "IT penetration and sociology", 9809–9908
  Comment: This is a multi-client study with representatives from Ericsson, The National organisation of labor (LO), SEbank, The Swedish organisation of industries, the Swedish parlament, Swedish national television (SVT), Telia, The University College of Karlskrona Ronneby and UU studying the future effect of IT on Swedish society in a number of workshops during 1998–1999. The project is mainly financed by the KK -foundation.
- ARBITALL, 9904–9912.
  Comment: Chair of a working group to plan a general basic IT-course for all students at UU mainly based on the Web
- Chair of the National Reference group of the VISIT research program, 9702–
  Comment: Responsible for coordination between the various research groups and the board of the VISIT research program financed by the Foundation for Strategic Research.
- ASTEC board, 9801–9910
  Comment: Member of the board of the national Advanced Software Technology Competence Center financed by NUTEK.
- Board of the itc-project, 9810–
  Comment: Bengtsson is chairperson of this project which has the purpose of improving the IT knowledge among small companies in Uppland. The KK foundation is financing the project
- Member of the HPC High Performance Computing working group, 9803–
  Comment: The group developed a proposal for a Regional High Performance Computing Center in Uppsala during a series of meetings. The group is continuing the efforts of establishing such a center.
- The Board of Entrepreneuring High school in Heby, 990429–
  Comment: Representing IT which is to be one of the main profiles of this new high-school
- Advisory board for the Medical technology program of the foundation for Strategic Research, 9810–9902
  Comment: Proposing the distribution of about 10 MSEK per year for this National research program
- Evaluation committee for appointing a professor in medical informatics at Linköping university, 1999
- Licentiate board, Anders Forsmoo, CBA, SLU, 990506
  Comment: Thesis title: Using parallell computers for digital image analysis
- Dissertation committee, for the degree of Ph.D. of Siamak Khatibi, Dept. of Signals and Systems, CTH, Gothenburg, 991112.
  Comment: Thesis title: On multidimensional Dynamic Fluorescence Imaging and Quantitative Image Analysis in Wide-Field Microscopy. Applications to Studies of Astroglial Cells.

Gunilla Borgefors
International:

- Fellow of the "International Association for Pattern Recognition" (IAPR), 1998–
  Comment: Secretary 1990–1994, 1st Vice President 1994–1996
- Chair of the Membership Committee, International Association for Pattern Recognition (IAPR), 1990–
- Nordic correspondent for the IAPR Newsletter, 1998–
  Comment: Published by International Association for Pattern Recognition.
- Editorial board member for "Pattern Recognition and Image Analysis: Advances in Mathematical Theory and Applications", 1993–
  Comment: Published by Interperiodica Publishing in Cooperation with the "Cybernetics" Scientific Council, Russian Academy of Sciences.
- Senior member of the "Institute of Electrical and Electronics Engineers", Inc. (IEEE), 1998–
- Editorial board member, "Rivista di informatica", 1994–
  Comment: Published by the Italian Association for Informatics and Automatic Computation, Milano, Italy
- Editorial board member, "Image Processing and Communications", 1994–
  Comment: Published by the Institute of Telecommunications, Bydgoszcz, Poland
- Editorial Board member, "Pattern Recognition Letters", 1998–
  Comment: Published by Elsevier
- On the program committee of "Discrete Geometry for Computer Imagery" (DGCI'99), Noisy-le-Grand, France, March 1999
- On the program committee of "5th International Conference on Pattern Recognition and Information Processing" (PRIP'99), 1999, Minsk, Belarus, May 1999
- On the program committee of "11th Scandinavian Conference on Image Analysis" (SCIA'99), Kangerlussuaq, Greenland, June 1999
- On the program committee of the Workshop on Statistical Methods for Image Processing, Uppsala, August 1999

National:

- Board member, Swedish Society for Automated Image Analysis, 1986–
  Comment: President 1988–1992
- Member, Swedish Parliamentarians and Scientists, 1987–
  Comment: Members are elected. Only one scientist per field admitted.
- Appointments board, Faculty of forestry, SLU, 990701–020630
- The Board of UpGIS, the net for Geographical Information Systems at Uppsala University, 990413–
  Comment: Representing Faculty of Science and Technology at Uppsala University
- National Reference group of the RESE research program, 9610–9909
- National Reference group of the VISIT research program, 9702–
- Evaluation committee for Ass. Prof. in Image Processing with Computer Graphics at Dept. of EE, Linköping University, 9904
- Dissertation committee, for the degree of Ph.D. of Joakim Sorelius, Dept. of Information Technology, UU, 990205.
  Comment: Thesis title: Subspace-Based Parameter Estimation Problems in Signal Processing
- Licentiate Board, Fredrik Georgsson, Dept. of Computing Science, Umeå University, 990527
  Comment: Thesis title: Computer aided medial imaging with application in mammographic screening

- Dissertation committee, for the degree of Med. Dr. of Kenneth Wester, Dept. of Genetics and Pathology, Uppsala University, 991009.
  Comment: Thesis Title: Quantitative Immunohistochemistry in Tissue Sections
- Dissertation committee, for the degree of Ph.D. of Dan Klang, Dept. of Geodesy and Photogrammetry, KTH, Stockholm, 991209.
  Comment: Thesis Title: Recontruction of Geometric Road Data Using Remotely Sensed Imagery

Tomas Brandtberg
National:

- Board member of The Cartographic Society board (Kartografiska sällskapet), local committee in Uppsala, 9601–

Tommy Lindell
International:

- Affiliate Associate Professor and Officer for Valle Scandinavian Exchange Program, Univ. of Washington, Seattle, WA, USA, 1985–
- Steering committee for SALMON project, 1997–

Ingela Nyström
National:

- Member of the "Electorial Board" (elektorsförsamlingen) of the Faculty of Science and Technology, 9909–
- Member of the recruiting board for computer science, 9912–

Lennart Thurfjell
National:

- Executive Programme Director of the VISIT research program, 9704–

- Dissertation committee, for the degree of Ph.D. of Quan Liang, Dept. of Signal and Systems, Chalmers University of Technology, Gothenburg, 990604.
  Comment: Thesis Title: Boundary detection in Cardiovascular Ultrasonic Images based on Multiscale dynamic programming.

Catherine Östlund
National:

- Licentiate board for Emma Lindqvist, CBA, SLU, 990903.
  Comment: Thesis title: Automatic and interactive information extraction from hyperspectral imagery