Final Report: Computational Colour Processing

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1 Overview

The project helped to start up research and teaching in color related problems in the Media Technology group at ITN. The focus has mainly been on research but an undergraduate course on advanced computational color processing and an introduction to basic color science was also developed.

2 Scientific Results

The research related to the CENIIT project can basically be divided into three categories:

1. Color based search in large image databases

2. Basic research in multispectral color processing

3. Paper and graphic arts technology

2.1 Color based search

This was a part of the SSF-funded VISIT program. Here we investigated tools for color based image retrieval. In order to be able to test these tools we developed a simple Matlab-based webserver. Using this webserver the user can search for similar images in a database of over 126 000 images. The server is now ported to Linköping University Electronic Press where it will be available in the near future. This project will be followed up in a new Vinnova project in which we will investigate scaling problems (extending the search engine to an even larger database with more than 300 000 images of greater size) and establish a connection to a conventional, keyword-based search engine.

2.2 Basic research

Here we developed a completely new, group theory based, approach to multispectral color processing. We showed how to describe multispectral color distributions with the help of Lorentz groups, how to construct invariants and developed new methods for data compression and color adaptation. Recently we found that the basic methods developed in the color processing framework are similar to approaches used in fMRI and we want to explore this connection further.

2.3 Paper and graphic arts

The other major research field in our group (lead by B. Kruse) is research in paper and printing technology. One of the most important problems here is to understand the interaction between the illumination, the paper and the print colors. This is done by investigating models that describe the scattering and absorption properties of the light during its interaction with paper and print colors.

3 Exams

I was advisor for the following Licentiate and PhD theses:

- L. V. Tran: Statistical Tools for Color Based Image Retrieval LIU-Tek-Lic-2001:41

- L. V. Tran: Efficient Image Retrieval with Statistical Color Descriptors, Dissertation 810, 2003

- T. H. Bui: Non-Euclidian structures in PCA-based descriptions of multispectral databases, LIU-Tek-Lic-2003:49

I was also substantially involved in the following theses:

- A. Fayyazi: Texture Based Duplex-Board Layer Segmentation, LIU-Tek-Lic-2002:05

- L. Yang: Ink-Paper Interaction, Dissertation 806, 2003

Currently I am main supervisor for T. H. Bui. I am also assistant supervisor for B. Olsson (main adviser A. Ynnerman) who is working on visualization of weather data (also in co-operation with SMHI) and assistant supervisor for D. Nyström (main advisor B. Kruse). D. Nyström works on research topics within the graphic arts.

4 Diploma Works

Media technology is new and therefore we had no diploma workers in the first few years of the project. In recent years I was responsible for the following diploma theses:

- Patrik Stark and Daniel Westling, (SSAB) LITH-ITN-MT-EX–02/08–SE

- Maria Asplund, (Alstom) LITH-ITN-MT-EX–02/37–SE

- Hans Boija, (Nymölla Bruk) (ongoing)

- Christina Heide (Chiba University, Japan) (ongoing)

I was also involved as second adviser in: Daniel Nyström, LITH-ITN-MT-EX–02/25–SE.

5 Finance

My salary was mainly financed by the CENIIT grant, the remaining part was paid in part by grants from TFR and now VR and to a minor part by teaching (around 12%).

6 Industrial Contacts

Industrial contacts can mainly be divided in three groups:

Research projects: The color based search engine was developed in cooperation with MATTON AB, a leading supplier of images in Scandinavia. This cooperation will continue within the Vinnova project. The Lic-thesis of A. Fayyazi was a cooperation with Uppsala University and Stora Enso in Falun. Within the basic research project in multispectral data processing we cooperate with SMHI in Norrköping who provided us with a large database of daylight spectra and a simulation program that generates daylight spectra depending on atmospheric parameters such as particle distribution, time, position etc..

Diploma Works: Here we investigated multispectral signal processing methods in industrial inspection problems (temperature measurements of turbines, Alstom) and new display technologies (SAAB). The diploma work at Nymölla bruk investigates the influence of optical whiteners and other colorants on the color reproduction properties of the paper.

Other contacts: B. Kruse is one of the coordinators within the T2F and S2P2 programs on paper and graphic arts. In connection with my involvements in the PhD project of L. Yang I am also in contact with major paper manufacturers.

7 Research Group

The CENIIT project allowed us to build up a new research group in color related signal processing. Our activities are also internationally recognized as can be seen from the following list of activities in the year 2003:

During this year I was a program committee member for the following conferences and workshops:

1. Computer Vision and Pattern Recognition, Madison, Wisconsin, USA 2003 http://www.cs.toronto.edu/cvpr2003

2. Scandinavian Conference Image Analysis, Gothenburg, Sweden 2003 http://www.hh.se/scia2003

3. IEEE Workshop Color and Photometric Methods in Computer Vision, Nice, France, 2003 http://www.sogang.ac.kr/ cvision/cpmcv/index.htm

4. 2nd European Conf. Color in Graphics, Imaging and Vision, Germany, 2004 http://www.imaging.org/conferences/cgiv2004

5. 17th International Conference on Pattern Recognition, Cambridge, UK, 2004 http://www.ee.surrey.ac.uk/icpr2004

6. 10th Congress of the International Colour Association, Granada, 2005 http://www.ugr.es/ aic05/welcome.html

Also in 2003 I was involved in the evaluation of:

1. Mark Drew, Tenure at Simon Frazer University, Vancouver, Canada

2. Michael Felsberg, Lecturer ISY, Linköping University, Sweden

3. Jarno Mielikainen, Thesis inspector, Lappeenranta University, Finland

I was Member of the PhD committees

1. Joakim Lindblad, CB, Uppsala University, 2002

2. Qingfen Lin, ISY, Linköping University

3. Ola Friman, IMT, Linköping University

And finally I am member of the newly established CIE Technical Committee TC 8-07 Multispectral Imaging http://www.cie.co.at/doc/tcs.html

7.1 International Co-operations

This summer I visited Granada University, Spain on an Erasmus scholarship. This new cooperation has already resulted in a number of conference contributions. The Granada group organizes the Congress of the International Colour Association, held every fourth year. This is the most important color related conference. We established a cooperation with Chiba University, Japan with the help of a STINT institutional grant. This cooperation continued with a visit of Prof. Miyake who was faculty opponent at L. V. Trans disputation. Furthermore, Christina Heide did the experimental part of her diploma work in Prof. Miyakes group in Chiba and Dr. K. Miyata from the National Museum of Japanese History (a former student of Prof. Miyake) was opponent at T. H. Bui's Lic-disputation.

List of Publications (1998-2003)

[1] Thanh Hai Bui, Reiner Lenz, and Tomas Landelius. Group theoretical investigations of daylight spectra. In *2nd European Conf. Color in Graphics, Imaging and Vision*, 2004. (accepted).

[2] Reiner Lenz. Time-frequency analysis of color spectra. In *2nd European Conf. Color in Graphics, Imaging and Vision*, 2004. (accepted).

[3] Reiner Lenz and Javier Hernández-Andrés. Time-frequency analysis for multi-channel color pattern recognition. In *2nd European Conf. Color in Graphics, Imaging and Vision*, 2004. (accepted).

[4] B. Olsson, A. Ynnerman, and R. Lenz. Visualizing weather with synthetic high dynamic range images. In *Proc. SPIE-2004, Visualization and Data Analysis 2004, San Jose, USA*, 2004.

[5] B. Olsson, A. Ynnerman, and R. Lenz. Computing synthetic satellite images from weather prediction data. In *Proc. SPIE-2004, Visualization and Data Analysis 2004, San Jose, USA*, 2004.

[6] Linh Viet Tran and Reiner Lenz. Efficient descriptors of hue distributions from kernel density estimators and fourier transforms. In *2nd European Conf. Color in Graphics, Imaging and Vision*, 2004. (accepted).

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[10] Reiner Lenz, Linh Viet Tran, and Thanh Hai Bui. Group theoretical invariants in color image processing. In *Proc. Eleventh Color Imaging Conference*, pages 212–217. IS&T/SID, 2003.

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[17] A. Fayyazi and R. Lenz. Texture based duplex-board layer segmentation. In *Proceedings Swedish Society for Automated Image Analysis*, 2002.

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[21] L. V. Tran and R. Lenz. Compact colour descriptors for color based image retrieval. *Submitted to Signal Processing*, 2002.

[22] L. V. Tran and R. Lenz. Color invariant features for dielectric materials. In *Proceedings Swedish Society for Automated Image Analysis*, 2002.

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[25] Reiner Lenz. A geometric foundation of colorimetry. In *Ninth Color Imaging Conference*, pages 46–51. IS&T/SID, 2001.

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[28] P. Toivanen and R. Lenz. On the properties of gray-scale distance transforms. In *Proc. 12th Scandinavian Conference on Image Analysis*. Norwegian Society for Image Processing and Pattern Recognition, 2001.

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