The Norwegian Colour and Visual Computing Laboratory

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The Norwegian Colour and Visual Computing Laboratory

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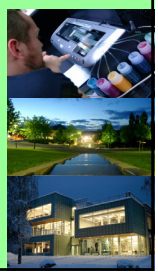

The Norwegian Colour and Visual Computing Laboratory

NTNU

Norwegian University of Science and Technology

- 39000 students
- 6700 person years employees
- Specialization in technology and the natural sciences.
- About 380 doctoral degrees awarded annually
- More than 100 laboratories
- Trondheim, Gjøvik, Ålesund

Photo:Mentz Indergaard/NTNU Info

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Faculty of Computer Science and Media Technology (AIMT)

- The activity at AIMT in Gjøvik is concentrated around modern computer, communication and media technology.
- Undergraduate programmes in information technology, computer science, information security, digital media technology, media design, and media management.
- Graduate programmes in applied computer science, color in informatics and media technology, and information security.
- PhD programmes in computer science and information security.

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Research labs

- The Norwegian Biometrics Laboratory
  - Human characteristics as a form for identification and access control.
  - 18 members
- Testimon Forensic Laboratory
  - Digital and Computational Forensics.
  - 15 members
- Game Technology Lab
  - Focused on technology related to games and the development of serious games.
  - 4 members
- The Norwegian Colour and Visual Computing Laboratory

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On the same campus

- Faculty of Technology, Economy and Management
- NTNU Additive Manufacturing Laboratory
- http://www.addlab.no

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The Norwegian Colour and Visual Computing Laboratory

- Established at Gjøvik University College (GUC) in 2001 to serve the graphic arts industry's need for colour management
- In 2012 the name changed from The Norwegian Color Research Laboratory to The Norwegian Colour and Visual Computing Laboratory.
- From 2016 a part of NTNU
- Well equipped laboratory facilites
  - Colour and spectral measurement, Colour management software, viewing booths, image acquisition and reproduction devices, etc.
  - >200m2
- Research group at Faculty of Computer Science and Media Technology at GUC
- 35 members
  - 6 permanent faculty members
  - 12 temporary, post doc, visiting, and adjunct faculty
  - 17 PhD students
- Fundamental and applied research within colour science and image/video processing
- Education
  - Courses and projects to media bachelors and Master of Applied Computer Science
  - Erasmus+ Joint Master's Degree COSI (Color in Science & Industry)
  - International Erasmus Mundus master CIMET (Color in Informatics and Media Technology)
  - French-Norwegian master programme: 3D Multimedia Technology
  - Master programme with South China University of Technology in printing.
- International, national, and regional collaboration with industry and academia
- Website: http://www.colourlab.no

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Colourlab.no

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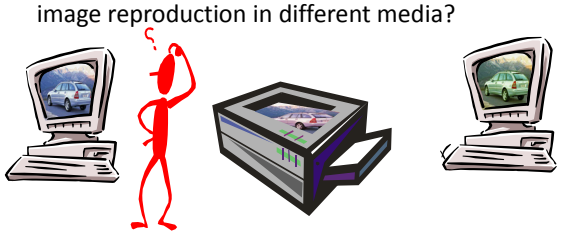
The existential research question:

- How can we achieve consistent colour image reproduction in different media?



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STAFF OVERVIEW

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Permanent faculty

- Professor Jon Y. Hardeberg
  - Multispectral color imaging
  - Image difference metrics

- Professor Ivar Farup
  - Colorimetry
  - Spatial gamut mapping
  - Colour image processing

- Associate Professor Peter Nussbaum
  - Colour management
  - Print quality

- Associate professor Faouzi Alaya Cheikh
  - Video and image processing
  - Compression
  - Quality

- Associate Professor Marius Pedersen (lab director)
  - Image quality/difference metrics
  - Print Quality

- Professor Phil Green
  - Colour management

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Adjunct and temporary faculty

- Senior Lecturer Frode Volden
  - Psychology
  - Psychophysical experiments

- Assistant Prof. Eivind Johansen
  - colour management in design

- Associate Professor Ali Imran
  - Image processing, video processing

- Assoc. professor Ali Alsam
  - image processing, color science

- Prof. Azeddine Beghdadi
  - image quality, image enhancement

- Assoc. Prof. Reiner Eschbach
  - Printing, security, image processing

- Assoc. Prof. Casper Find Andersen
  - Vision science, color science

- Post doc. Sony George
  - Cultural heritage, multispectral imaging

- Post doc. Steven Le Moan
  - Multispectral imaging

- Post doc. Tomas Majtner
  - Medical imaging, image processing, image enhancement

- Rachael Gibb
  - Consultant, administrative support

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PhD students

- Arne Magnus Bakke
  - Colour gamuts, programming, movie industry

- Gabriele Simone
  - HDR imaging, contrast, image difference

- Ferdinand Deger
  - Cultural heritage
  - Multipectral imaging

- David Völgyes
  - Radiography
  - Medical imaging

- Xingbo Wang
  - Multispectral imaging
- Aditya Sole
  - Printing, soft-proofing
  - Gonioradiometry

- Ruven Pillay
  - Cultural heritage, multispectral imaging
- Jacob Bauer
  - Multispectral imaging, medical imaging

- Ahmed Mohammed
  - Medical imaging, image enhancement

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PhD students

- Anne Kristin Kvitle
  - GIS, colour management, color deficiency
- Ibrahim Arief
  - Mobile devices, mobile imaging.
- Xinwei Liu
  - Image quality
  - Biometrics
- Fan Yu
  - Video guided surgery
- Gregory High
  - Common color appearance
- Vlado Kitanovski
  - Watermarking






- Thomas Simon-Liedtke
  - Visual impairment , modelling the human visual system, quality enhancement
- Rafael Palomar
  - Video assisted surgery, image registration
- Hilda Tobing
  - Cultural heritage, multispectral imaging,mathematical morphology
- Bilel Sdiri
  - Medical imaging, video guided surgery
- Mohib Ullah
  - Video tracking





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Visiting researchers and others

- Sun Bangyong
  - Xi'An University of Technology, China

- Others
  - M.Sc and B.Sc students working on projects
  - Laboratory student assistants
  - Interns
- Jana Blahová
  - Lab assistent

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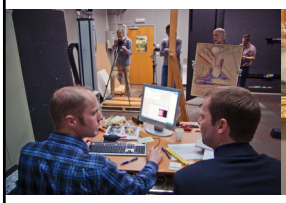


RESEARCH OVERVIEW

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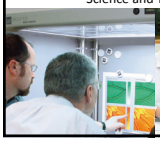
Graphic arts industry

- **Colour management**
  - Nussbaum and Hardeberg, Print Quality Evaluation and Applied Colour Management in Coldset Offset Newspaper Print. CR&A, 2012.
- **Print quality evaluation**
  - Nussbaum, Hardeberg, Skarsbø, Svein Erik. Print quality evaluation for governmental purchase decisions. Advances in Printing Science and Technology, 2006.
- **PSO colour certification**
  - Certifying the Norwegian printing industry according to the UGRA system of PSO Certification.
  - Since 2007.
  - www.colourlab.no/psoinfo

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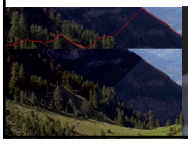
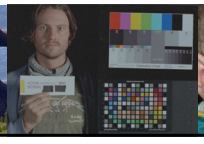
Media technology industry

- **Display technology**
  - Pedersen and Bakke. Seam carving for multi-projector displays. International conference on Pervasive Computing, Signal Processing and Applications, 2011.
- **Movie production**
  - Drylab R&D (2006-2008)
  - Bakke, Hardeberg, and Paul. Simulation of film media in motion picture production using a digital still camera. Image Quality and System Performance VI, 2009.
- **Redeye correction**
  - George, Hardeberg, George and Nampoori. Automatic Redeye Correction Algorithm with Multilevel Eye Confirmation. Journal of Imaging Science and Technology , 2010.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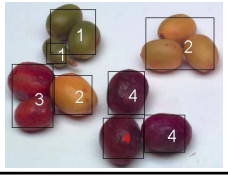
Computer vision

- **Bottle recycling automata**
  - Tomra
  - 2004, 2007-2008

TOMRA
Helping the world recycle

- **Coffee bean sorting**
  - Le Moan, Amin, Pérez, Voisin, Hardeberg. Convex Objects Recognition and Classification Using Spectral and Morphological Descriptors. CGIV 2010



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Multispectral colour imaging

- **Acquisition**
  - Connah, Alsam and Hardeberg. Multispectral Imaging: How Many Sensors Do We Need? JIST, 2006
  - Deger, Mansouri, Pedersen, Hardeberg, Voisin. A sensor-data-based denoising framework for hyperspectral images. Optics Express, 2015.
  - Shrestha and Hardeberg. Spectrogenic imaging: A novel approach to multispectral imaging in an uncontrolled environment. Optics Express, 2014.
- **Reproduction**
  - Abebe, Gerhardt and Hardeberg. Kubelka-Munk theory for efficient spectral printer modeling. Color Imaging XVI, 2011.
  - Alsam and Hardeberg. Optimal Colorant Design for Spectral Colour Reproduction. CIC, 2004.
  - Gerhardt. Spectral Color Reproduction: Model Based and Vector Error Diffusion Approaches. PhD thesis, 2007.


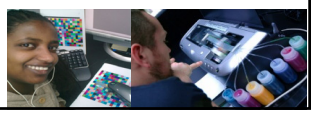

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Image quality and image difference

- **Metrics**
  - Imran and Cheikh. Blind Image Quality Metric For Blackboard Lecture Images. EUSIPCO, 2010.
  - Pedersen. Image quality metrics for the evaluation of printing workflows. PhD thesis, 2011
  - Simone, Caracciolo, Pedersen, and Cheikh. Evaluation of a Difference of Gaussians Based Image Difference Metric in Relation to Perceived Compression Artifacts. Advances in Visual Computing, 2010.
- **Psychophysical experiments**
  - Anderson, Gupta and Hardeberg. Subjective evaluations of example-based, total variation, and joint regularization for image processing. Computational Imaging X: Enhancement, Denoising, and Restoration II, 2012
  - Dugay, Farup and Hardeberg. Perceptual Evaluation of Color Gamut Mapping Algorithms. CR&A, 2008.

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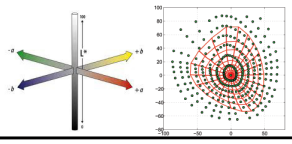
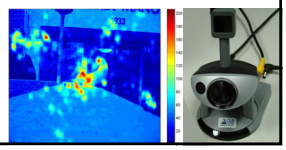
Colour and perception

- **Colour difference equations**
  - Pant. Line Element and Variational Methods for Color Difference Metrics. PhD thesis, 2012.
  - Pant and Farup. Geodesic calculation of color difference formulas and comparison with the munsell color order system. CR&A, 2012.
- **Visual saliency**
  - Cao, Pedersen and Baranczuk. Saliency Models as Gamut-Mapping Artifact Detectors. CGIV, 2010.
  - Sharma, Cheikh and Hardeberg. Saliency Map for Human Gaze Prediction in Images. CIC, 2008

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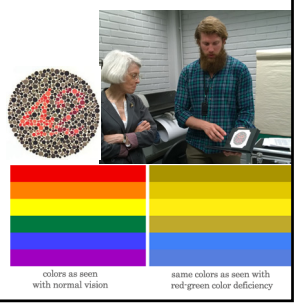
Colour deficiency

- Improving maps for color deficient users
- Daltonization
  - Simon-Liedtke and Hardeberg. Task-Based Accessibility Measurement of Daltonization Algorithms for Information Graphics. 12th Congress of the International Colour Association (AIC), 2013.



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Device modeling

- **Printers**
  - Abebe, Gerhardt and Hardeberg. Kubelka-Munk theory for efficient spectral printer modeling. Color Imaging XVI, 2011
  - Alsam, Gerhardt and Hardeberg. Inversion of the Spectral Neugebauer Printer model. AIC, 2005
- **Display**
  - Thomas, Colantoni, Hardeberg, Foucherot and Gouton. An inverse display color characterization model based on an optimized geometrical structure. Color Imaging XIII, 2008.

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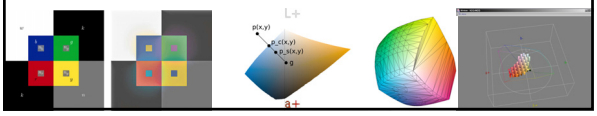
Colour gamut mapping

- **Spatial algorithms**
  - Farup, Gatta, and Rizzi. A Multiscale Framework for Spatial Gamut Mapping. IEEE TIP, 2007.
  - Alsam and Farup. Spatial colour gamut mapping by orthogonal projection of gradients onto constant hue lines. ISVC, 2012.
- **Variational methods**
  - Alsam and Farup. Colour Gamut Mapping as a Constrained Variational Problem. SCIA, 2009.
- **Gamut boundary**
  - Bakke and Farup. Simplified Gamut Boundary Representation Using Mesh Decimation. CGIV, 2010.
  - Bakke, Farup and Hardeberg. Improved gamut boundary determination for color gamut mapping. IARIGAI, 2008.
- **Gamut visualization**
  - ICC3D http://www.colorlab.no/icc3d
  - Funded by PROKOM/Morgenlandet AS
  - Farup, Hardeberg, Bakke, Kopperud, and Rindal. Visualization and Interactive Manipulation of Color Gamuts. CIC, 2002.



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Cultural heritage

- **In-painting**
  - Oncu, Hardeberg and Deger. Evaluation of Digital Inpainting Quality in the Context of Artwork Restoration. ECCV, 2012.
- **Lost art reclamation**
  - Computer-Aided Reclamation of Lost Art. Demetriou, Hardeberg and Adelman. ECCV, 2012.
- **Film restoration**
  - Islam and Farup. Spatio-temporal colour correction of strongly degraded movies. Color Imaging XVI, 2011
- Acquisition of art
  - Hardeberg, George, Deger, Baarstad,,Palacios, Hernandez and Løk. Hyperspectral image capture and analysis of The Scream painted by Edvard Munch in 1893. MUNCH150 Conference, 2013.

Film Restoration - Before

Film Restoration - After

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Video surveillance

- **Compression**
  - Guraya, Cheikh, and Medina. A Novel Visual Saliency model for surveillance video compression. SITIS, 2011
- **Saliency**
  - Guraya and Cheikh. Visual Saliency in Video Surveillance Applications. Workshop on Visual Signal Processing and Analysis, 2008.
- **Detection and tracking of objects**
  - Cheikh, Saha, Rudakova, and Peng. Multi-people tracking across multiple cameras. IJNCAA, 2012.
  - Guraya, Bayle, Cheikh. People Tracking via a Modified CAMSHIFT Algorithm. DCABES, 2009.
- **Face recognition**
  - Boisier, Billiot, Abdessalem, Gouton, Hardeberg. Extraction and fusion of spectral parameters for face recognition. Image Processing: Machine Vision Applications, 2011.

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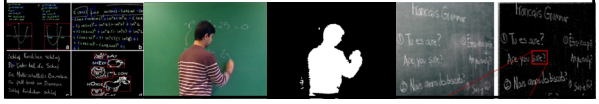
Media learning objects

- **Framework**
  - Imran and Cheikh. Multimedia Learning Objects Framework for E-Learning. ICEEE, 2012
- **Quality**
  - Imran, Guraya, and Cheikh. A visual attention based reference free perceptual quality metric. EUVIP, 2010.
- **Classification**
  - Imran and Cheikh. Blackboard content classification for lecture videos. IEEE TIP, 2011
  - Imran and Cheikh. Lecture content classification tool. ISCCSP, 2012
- **Hand written text recognition**



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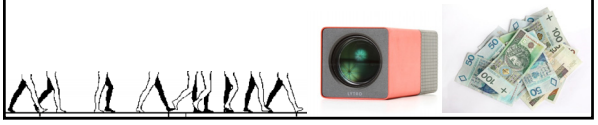
Biometrics and security

- **Video based gait recognition**
  - Derawi, Ali, and Cheikh. Gait Recognition using Time-of-Flight Sensor. BIOSIG 2011.
- **Iris recognition using light-field camera**
  - Raja, Raghavendra, Cheikh and Busch. Robust iris recognition using light-field camera. CVCS 2013.
- **Image quality in biometric systems**
- **Secure printing**
  - Masuda, Pedersen, Hardeberg. Effects of awareness to security features on the confidence in banknotes. Journal of Print and Media Technology Research. 2015



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3D and stereo

- **Image quality**
  - Hachicha, Beghdadi, Azeddine and Cheikh. Stereo image quality assessment using a binocular just noticeable difference model. International Conference on Image Processing (ICIP), 2013
- **Stereo image enhancement**
  - Hachicha, Beghdadi, and Cheikh. Combining Depth Information and Local Edge Detection for Stereo Image Enhancement. EUSIPCO, 2012

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Medical Imaging

- **Image quality in CT**
  - In collaboration with Oslo University Hospital
- **Video guided surgery**
  - In collaboration with Oslo University Hospital
  - Wang, Palomar, & Cheikh. Stereo video analysis for instrument tracking in laparoscopic surgery. EUVIP 2014.

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Recent awards

- Charles Ives Journal Award by IS&T in 2012.
  - *Farup, Kolås, Rizzi. Spatio-Temporal Retinex Inspired Envelope with Stochastic Sampling: A Framework for Spatial Color Algorithms, JIST vol. 55 #4, 040503-1--040503-10 (2011)*
- The lab received the Oppland County R&D prize in 2012.
- Best student article at Electronic Imaging 2011
  - Pedersen, Bonnier, Hardeberg, Albregtsen.
- Best paper award at CGIV 2012.
  - Simone and Farup.
- Best poster award at CIC 2014.
  - Kiran Deshpande, Phil Green and Micheal R. Pointer.

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Standardization work

- CIE Division 1: Vision and Colour
  - Ludovic Coppel
- CIE Division 8: Image technology
  - Jon Yngve Hardeberg
- CIE TC1-82: Calculation of colour matching functions as a function of age and field size
  - Ivar Farup
- CIE TC8-07: Multispectral imaging
  - Jon Yngve Hardeberg
- TC 8-12 : Image and Video compression assessment
  - Marius Pedersen and Jon Yngve Hardeberg
- CIE technical report R8-10
  - Marius Pedersen
- ISO TC-130: Graphic technology
  - Peter Nussbaum
- ICC honorary member
  - ICC Technical Secretary: Phil Green

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PREVIOUS, EXISTING AND UPCOMING PROJECTS

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Past projects

- Multispectral Image Capture and Reproduction
  - Funded by the The Research Council of Norway as part of the "Strategic University College Programme"
  - 2003-2007
  - 2 postdoctoral researchers and 1 PhD student
- Quality-assured Content Management (KDI)
  - Funded by the Research Council of Norway and industry partners
  - 2003-2005
  - 1 PhD student

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Past projects

- Graphic arts industry
  - NADA
    - Part of Norwegian Media Businesses' Association
    - Evaluation of newspaper printing plants
    - Standardization
  - WEBICC
    - Standardization project together with IGM.
  - Government Administration Services
    - Colour management and evaluation of printer quality
  - Various projects with printing companies
    - Aller Trykk
    - Hjemmet Mortensen

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Past projects

- ICC3D: Interactive color gamut mapping, color gamut metrics, and adaptation for commercialization
  - Funding by PROKOM/Morgenlandet AS
  - 2003-2004
- Color Management in Digital Video
  - Collaboration between Gjøvik and Lillehammer University Colleges
  - Funding by PROKOM/Morgenlandet AS
  - 2003-2004

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Past projects

- Perceptual image difference metrics - a unifying approach to image representation and reproduction
  - Funded by the The Research Council of Norway as part of the "Strategic University College Programme"
  - 2007 – 2012
  - One PhD student and one postdoctoral researcher
- Creation of a metric for perceptual image quality evaluation of color prints
  - Funded by Océ Print Logic Technology, France.
  - 2007-2011
  - One PhD student

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Past projects

- CREATE
  - Colour Research for European Advanced Technology Employment
  - 2007-2010
  - GUC a partner.
  - Organized the final conference in 2010
    - 100+ young color researchers from all over the world came to Gjøvik
  - http://www.create.uwe.ac.uk/

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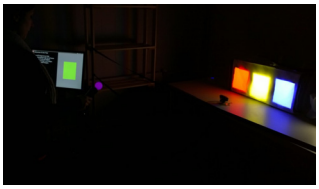
Past projects

- Colourplay
  - Color matching.
  - A game for the science center.
  - Funded by the regional research council
  - 2013-2014



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Past projects

- Colour Printing 7.0: Next Generation Multi-Channel Printing (CP7.0)
  - Training and research project funded by Marie Curie Initial Training Networks (ITN).
- 6 full-partners and 8 associated partners.
- Funding of
  - 7 PhD students
  - 2 Post-doctoral researchers
- Research and new knowledge in colour and printing science and technology.
  - Particularly when it comes to colour and multi-channel printing.

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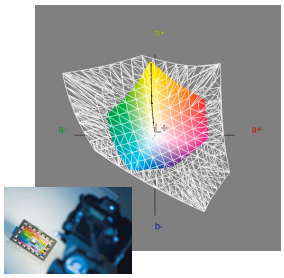
Current projects

- HyPerCept – Color and Quality in higher dimensions
  - Funded by the The Research Council of Norway as part of the "Strategic University College Programme"
  - 2013 - 2015
  - 9 PhD students, 2 Postdoctral researchers, 20% adjunct professor.
  - The principal objective is to push the scientific boundaries of color and image quality within a broadly defined media computing context.
  - Extensive internal, national and international collaboration.
    - 9 national partners
    - 6 international partners



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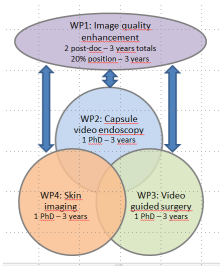
Current projects

- IQ-MED: Image Quality enhancement in MEDical diagnosis, monitoring and treatment
  - Funded by the The Research Council of Norway as part of the IKTPLUSS scheme
  - 2016 - 2018
  - 3 PhD students, 2 Postdoctral researchers, 20% adjunct professor.
  - The principal objective is to enhance the quality of medical images for the best possible diagnosis
  - National and international collaboration.
    - 2 national partners
    - 3 international partners



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Upcoming projects

- FRIPRO Toppforsk project «Measuring and Understanding Visual Appearance".
- 25 million NOK over 5 years, funded by the Research Council of Norway.
  - Starting summer 2016.
- Three PhD students and two post doctoral researchers.
- Research council:
  - «Toppforsk satser på fagmiljøer med stort potensial».
  - «Bygge opp internasjonalt ledende forskningsmiljø»

The Research Council of Norway

The Norwegian Colour and Visual Computing Laboratory — NTNU

Upcoming projects

- FRIPRO mobility stipend project «CCSF-Quality: Defining new Chromatic Contrast Sensitivity Functions for improved quality assessment and quality enhancement".
  - 1 out of 4 projects funded.
- 3-year post doctoral position for Dr. Ali Amirshahi funded by the Research Council of Norway.
  - Starting December 2016.
- In collaboration with Univeristy of Paris 13, France.
- FRIPRO:
  - vitenskapelig kvalitet i internasjonal forskningsfront
  - dristig og nyskapende forskning

The Research Council of Norway

The Norwegian Colour and Visual Computing Laboratory — NTNU

EDUCATION

The Norwegian Colour and Visual Computing Laboratory — NTNU

Applied computer science

- 2 year master programme (120 ECTS)
- Two tracks:
  - Web/Mobile/Games
  - Colour, image and video processing
    - Colour imaging
    - Audio and video signal processing
- Courses:
  - Cross-color media reproduction
  - Image processing
  - Color imaging
  - Image quality

CIMET

- MSc programme: Color in Informatics and Media Technology
- Collaborative effort supported by the EU
  - Bringing together the best European forces to attract the best brains to Europe
  - University of Saint-Etienne (France, coordinator), the University of Granada (Spain), the University of Joensuu (Finland), and NTNU (Norway)
- Prestigeous for institutions and students
- Sample of courses
  - Color Science, Image Processing, Algorithms, Data analysis, Optics and photonics, Advanced colorimetry, Video processing, Compression, Pattern Recognition, Spectral Imaging,...
- http://www.master-erasmusmundus-color.eu/

The Norwegian Colour and Visual Computing Laboratory

NTNU

COSI (COlour in Science and Industry)

- A two-year scientific Erasmus+ Master Degree
- Aiming to train the next generation of highly-skilled industrial experts in applied colour science.
- Two focus areas:
  - spectral technologies and applied colour imaging.
- Academic partners:
  - University of Saint-Etienne (France, coordinator), the University of Granada (Spain), the University of Joensuu (Finland), and NTNU (Norway)
- Associated industrial partners:

The Norwegian Colour and Visual Computing Laboratory

NTNU

3D multimedia technology

- Two-year Master in 3D Multimedia Technology (3DMT).
- The objective is to educate students in advanced methodologies and models in computational 3D imaging
- Collaboration between University Jean Monnet Saint-Etienne (France) and NTNU.

MASTER

3D Multimedia Technology

French-Norwegian Master Programme

The Norwegian Colour and Visual Computing Laboratory

Thank you for your attention

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