Colour Imaging Lab

http://colorimaginglab.ugr.es

*Departamento de Óptica, Facultad de Ciencias,
Universidad de Granada (SPAIN)*

February 21st 2016

CURRENT MEMBERS
Permanent staff:

Javier Romero

Juan Luis Nieves

Javier Hernández-Andrés

Eva M. Valero

Ph.D. students

Miguel A. Martínez-Domingo

Juan Ojeda

Research staff:

Sergi Etchebehere

Master students

and BSc students

FORMER MEMBERS

Miguel A. López-Alvárez
Color Scientist at HP
USA

Timo Eckhard
Innovation and R&D manager
Chromasens GmbH (Germany)

Jia Eckhard
Chromasens GmbH (Germany)

Clara Plata

Daniel Partal

Aida Rodríguez

Felix Navas

RECENT VISITING RESEARCHERS

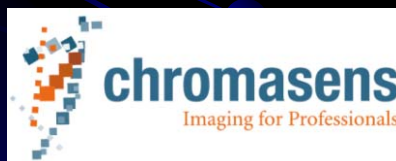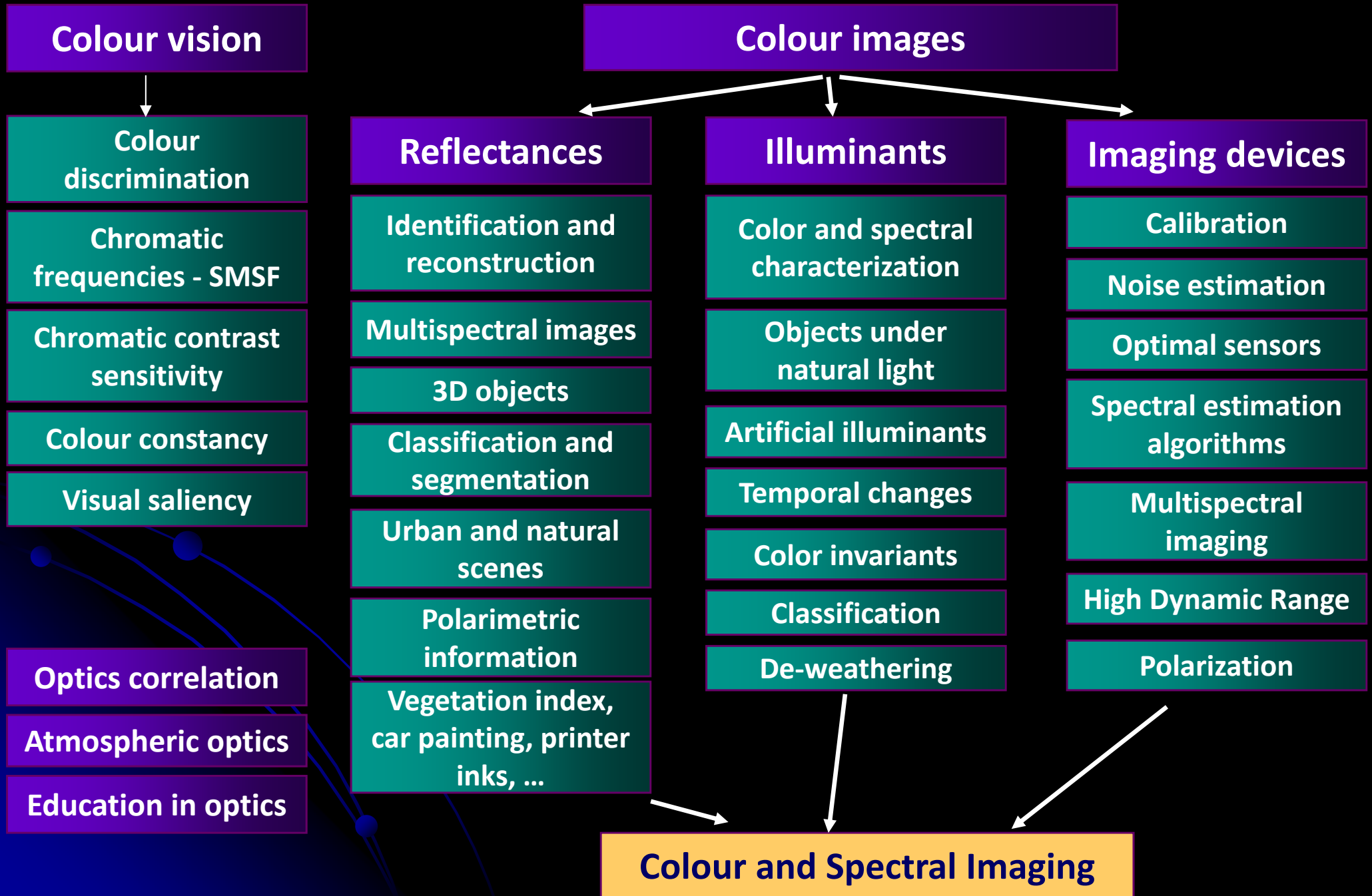**Samra Tanovic** **Shahram Peyvandi** **Ryuji Katagiri** **Taisei Kondo** **Satoshi Katagiri** **Kai Hamamoto** **Kai Shiromi**
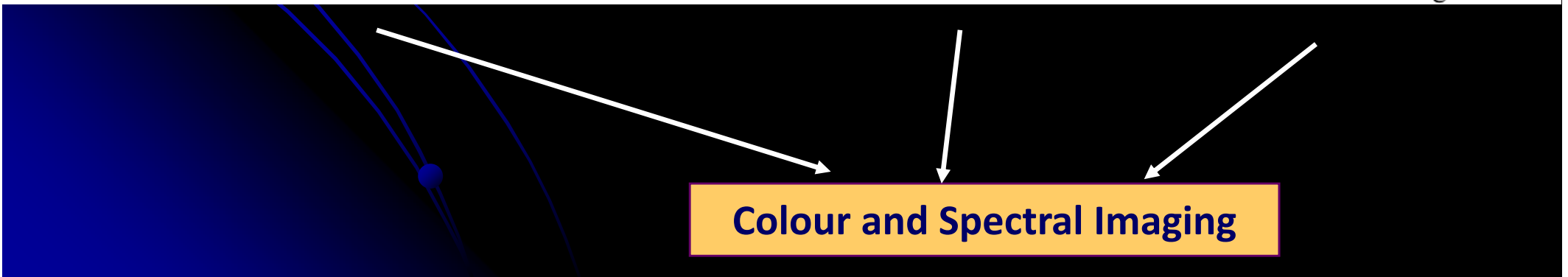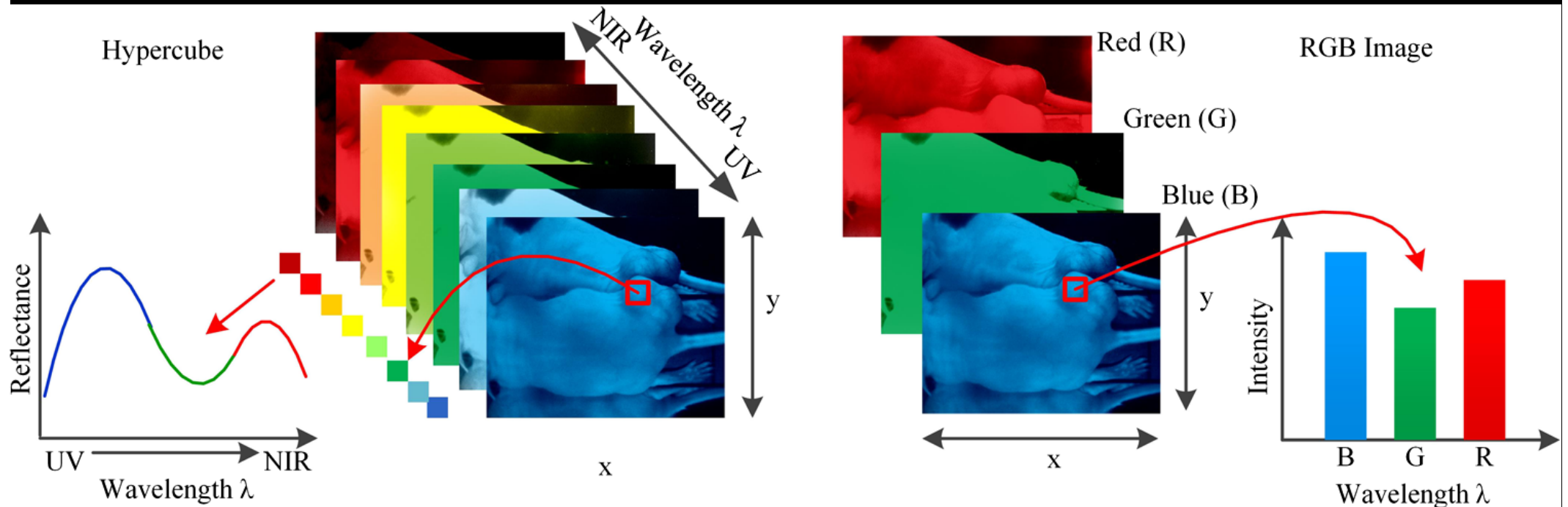
ACTIVE COLLABORATION WITH…

chromasens — Imaging for Professionals

hp

AkzoNobel

tecnalia — Corporación Tecnológica

CHIBA UNIVERSITY

TOYOHASHI UNIVERSITY OF TECHNOLOGY

UNIVERSITY OF EASTERN FINLAND

NTNU — Norwegian University of Science and Technology

UNIVERSITÉ JEAN MONNET SAINT-ÉTIENNE

COLOR IMAGING LAB
University of Granada
SPAIN

ugr | Universidad de Granada

Colour vision

Colour images

Reflectances	Illuminants	Imaging devices

Colour discrimination

Chromatic frequencies - SMSF

Chromatic contrast sensitivity

Colour constancy

Visual saliency

Identification and reconstruction

Multispectral images

3D objects

Classification and segmentation

Urban and natural scenes

Polarimetric information

Vegetation index, car painting, printer inks, ...

Color and spectral characterization

Objects under natural light

Artificial illuminants

Temporal changes

Color invariants

Classification

De-weathering

Calibration

Noise estimation

Optimal sensors

Spectral estimation algorithms

Multispectral imaging

High Dynamic Range

Polarization

Optics correlation

Atmospheric optics

Education in optics

Colour and Spectral Imaging

Hyperspectral technology overview

Colour images
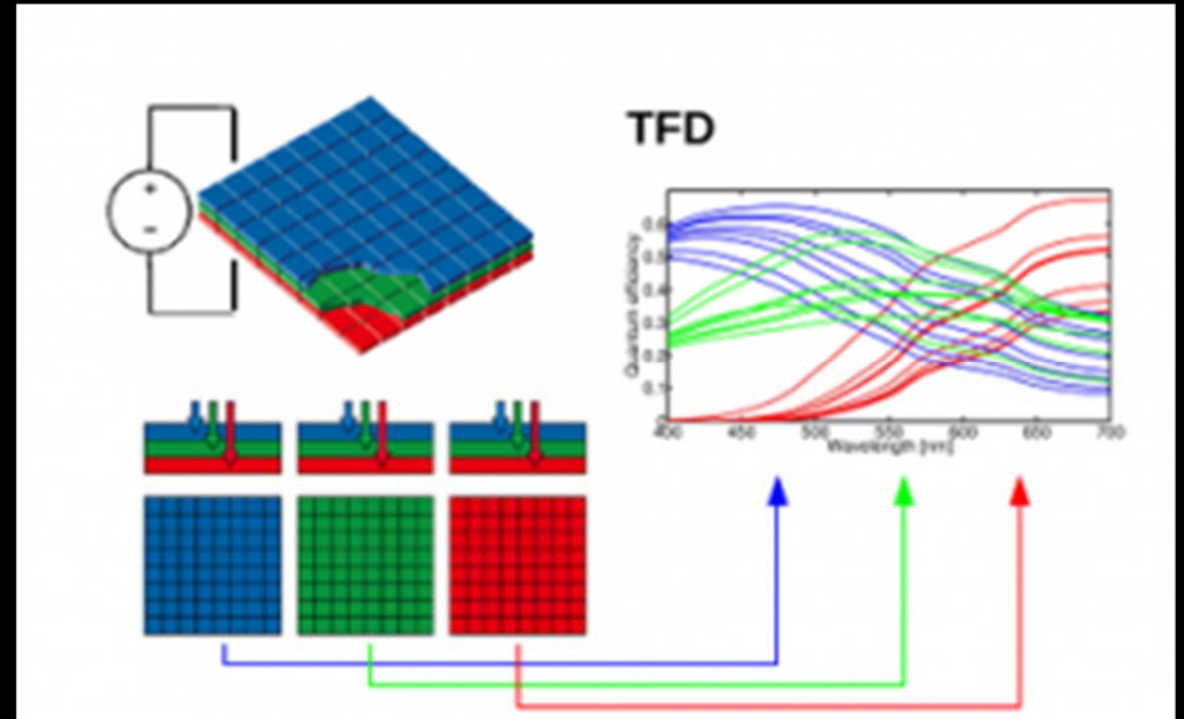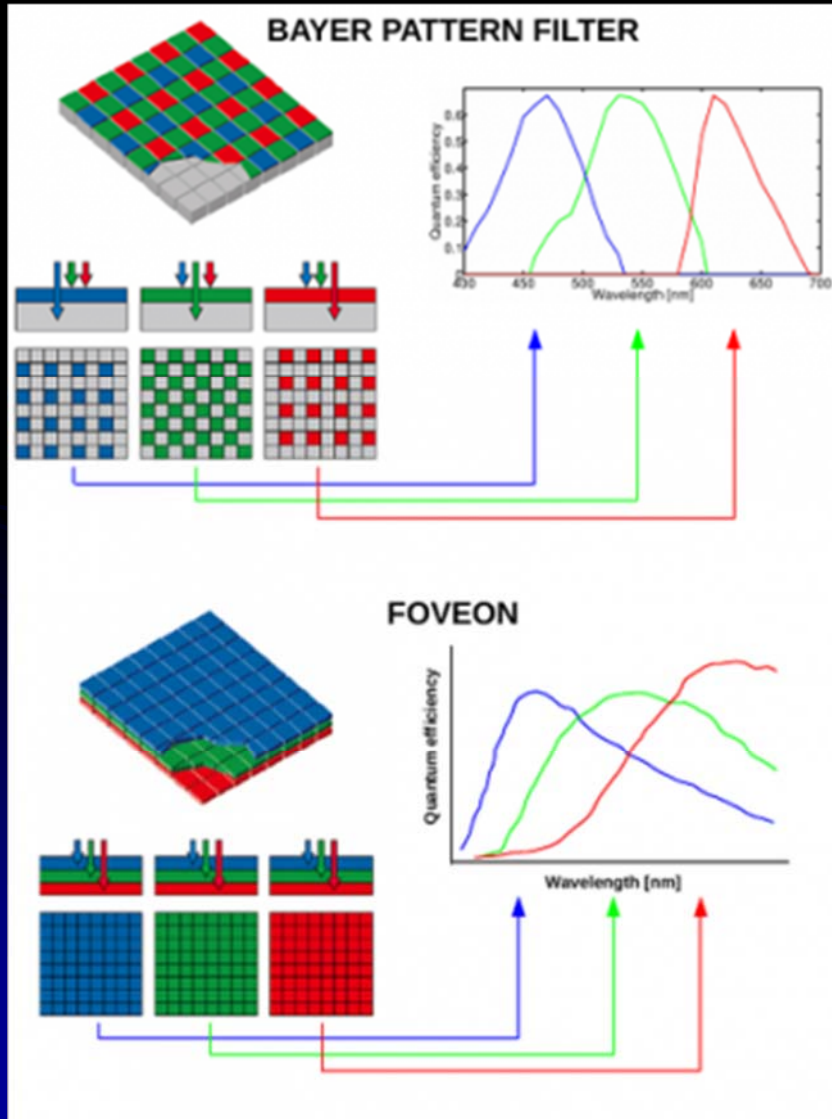
Colour and Spectral Imaging

Spectral imaging system based on Transverse Field Detectors

Combining Transverse Field Detectors and Color Filter Arrays to improve multispectral imaging systems
Applied Optics, vol. 53, C14-C24 (2014)

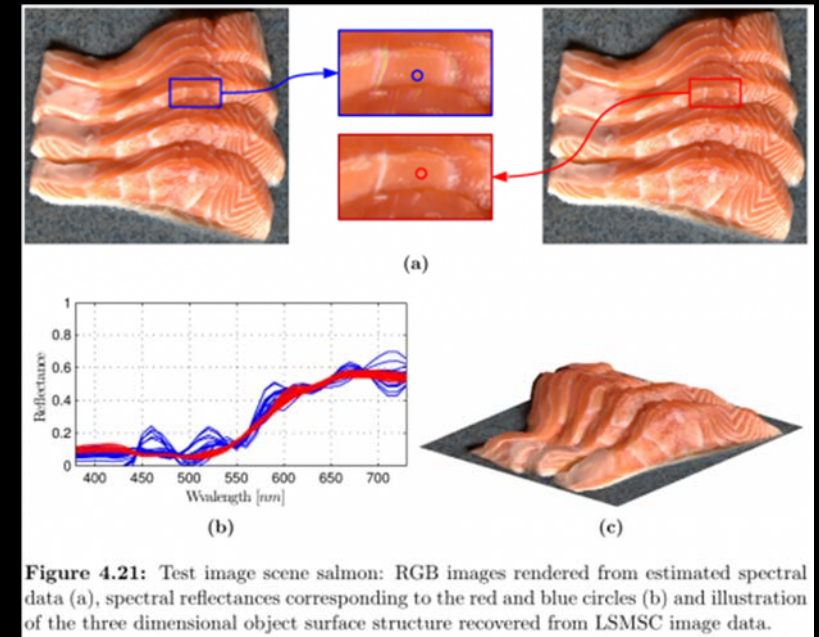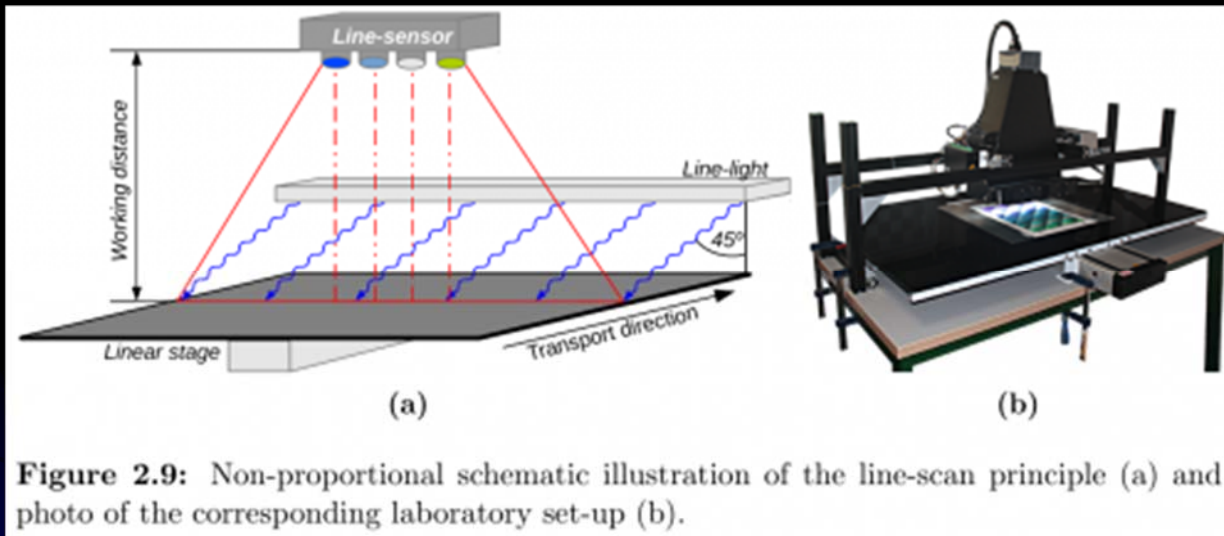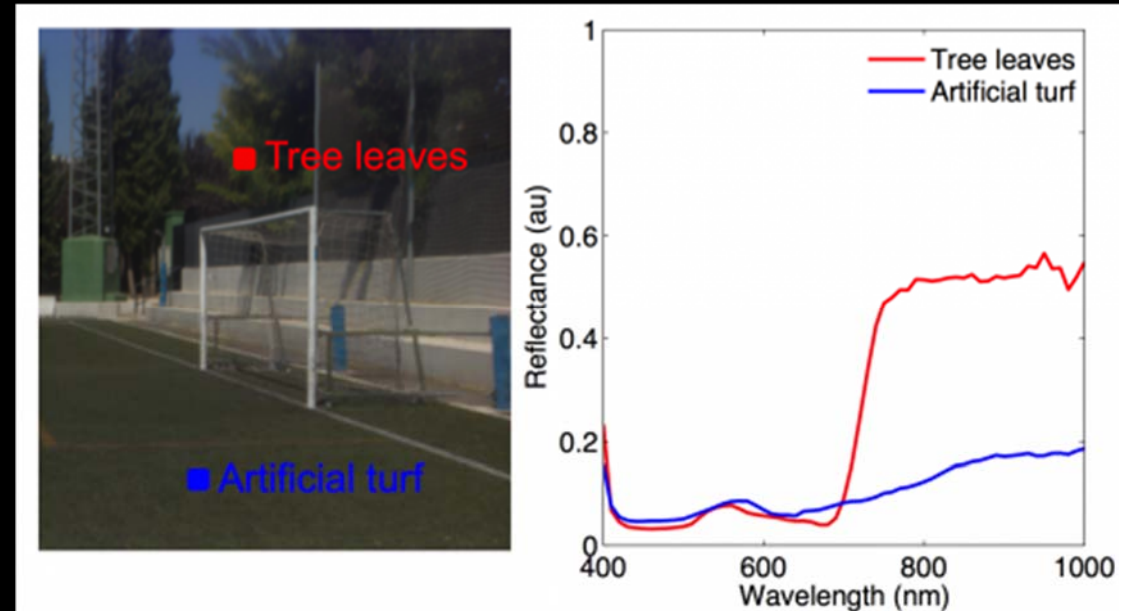# Optimization of a multispectral line scan camera for spectral reflectance estimation

Figure 2.9: Non-proportional schematic illustration of the line-scan principle (a) and photo of the corresponding laboratory set-up (b).
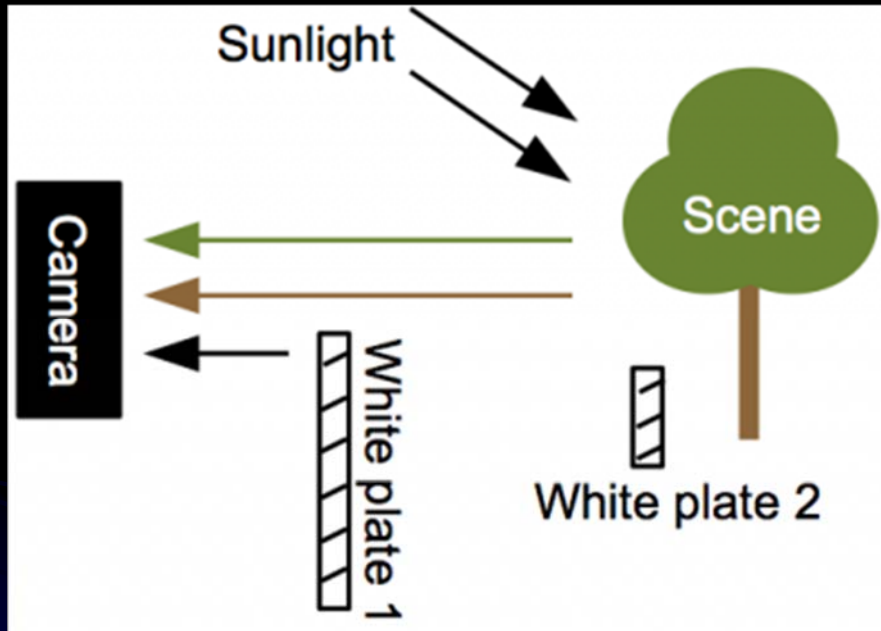
Figure 4.21: Test image scene salmon: RGB images rendered from estimated spectral data (a), spectral reflectances corresponding to the red and blue circles (b) and illustration of the three dimensional object surface structure recovered from LSMSC image data.
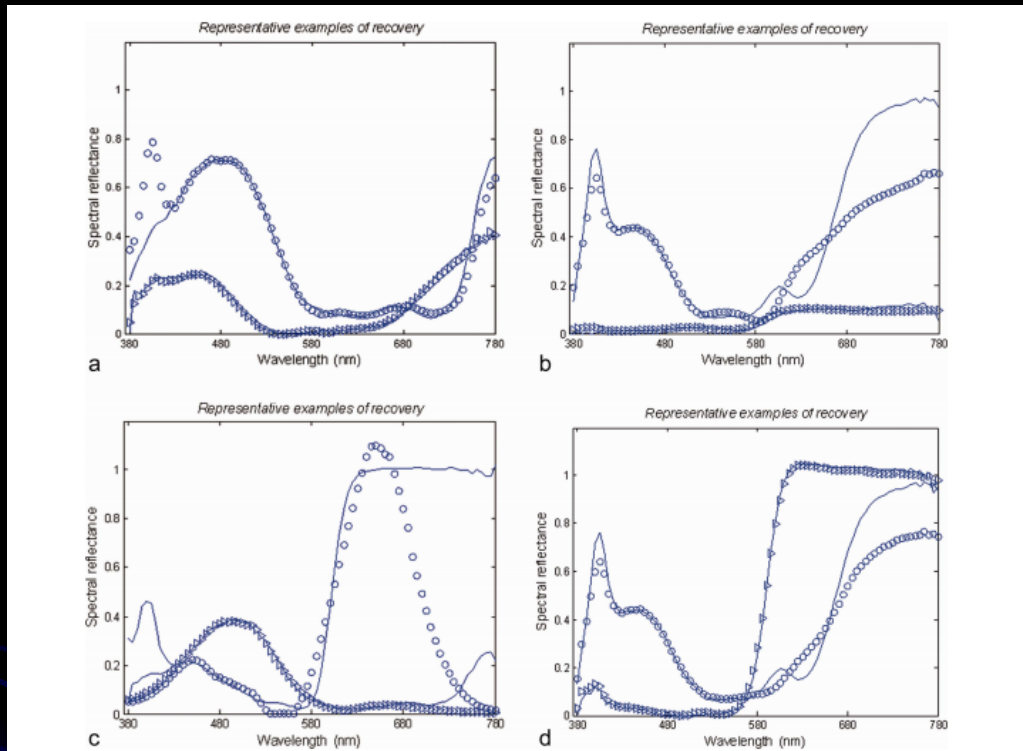
Hyperspectral Imaging of outdoor scenes with a Bragg-grating based spectral imaging device
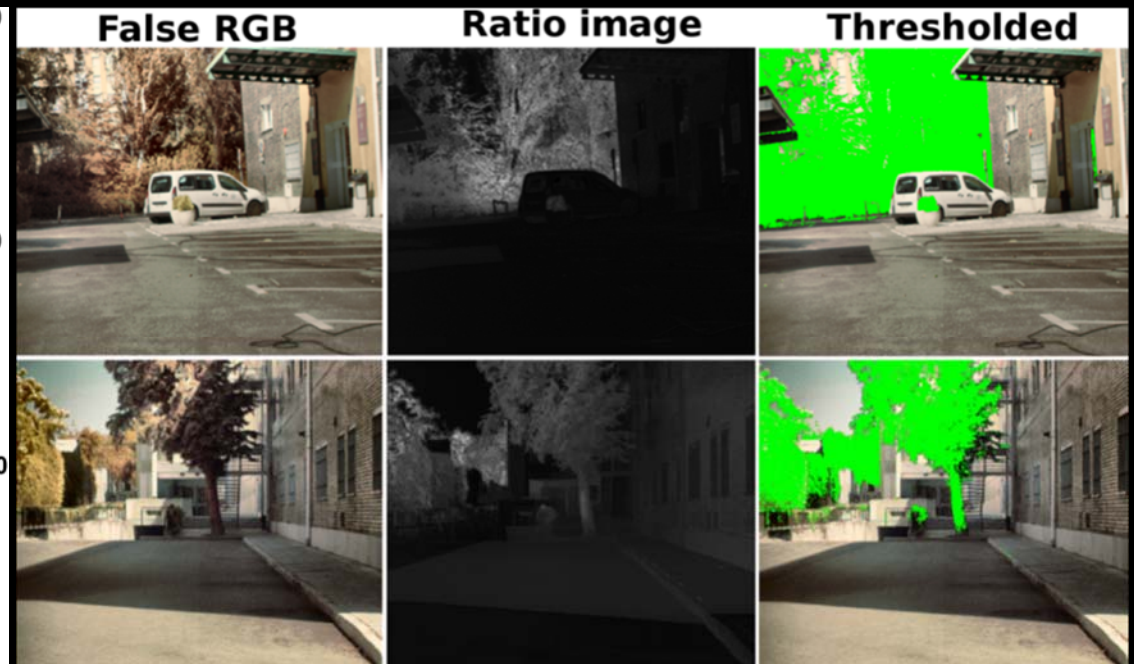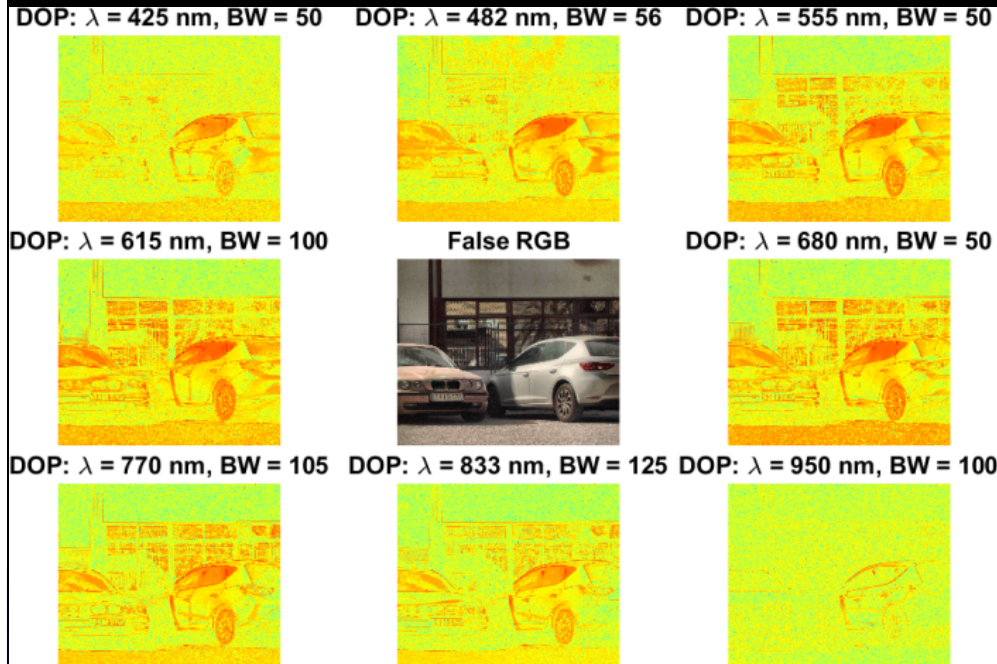
Spectral estimation from few sensors

- Comparative performance analysis of spectral estimation algorithms and computational optimization of a multispectral imaging system for print inspection, **Color Research and Application**, vol 39, 16-27 (2014)
- Evaluating a logarithmic kernel for spectral reflectance estimation - effects on model parametrization, training set size and number of sensor spectral channels, **Journal of the Optical Society of America A**, vol. 31, 541-549 (2014)

Multispectral HDR Polarimetric VIS+NIR imaging

Image Processing Pipeline for Segmentation and Material Classification based on Multispectral High Dynamic Range Polarimetric Images, **Pattern Recognition** (submitted, 2017)
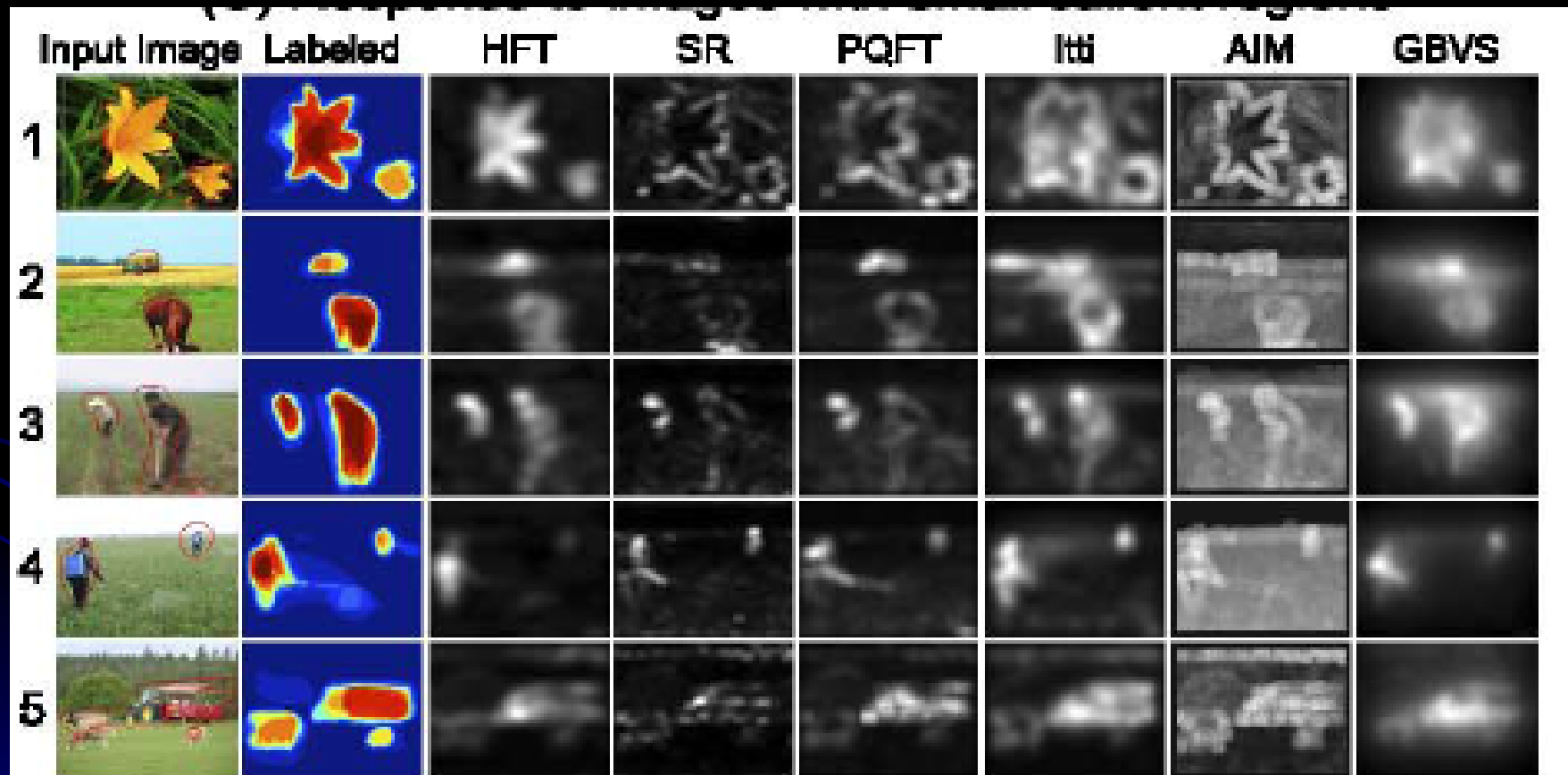
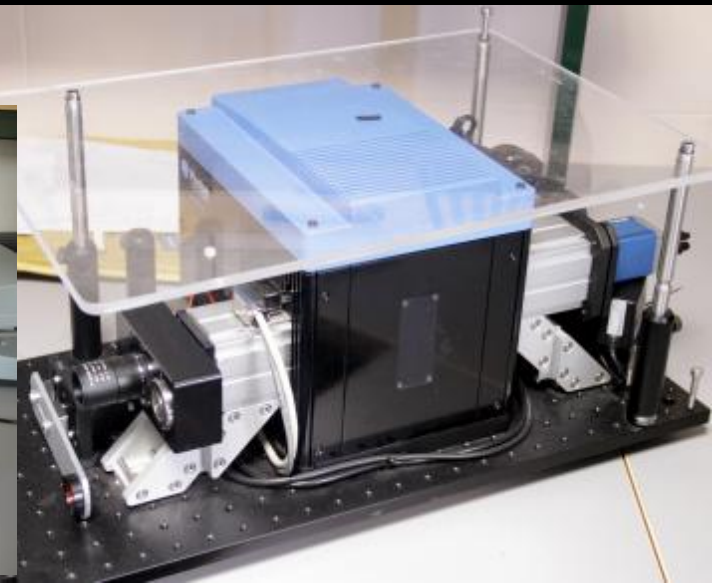# Hyperspectral Images of effect coatings for car paints

Automatic identification of salient information from annotated multispectral images
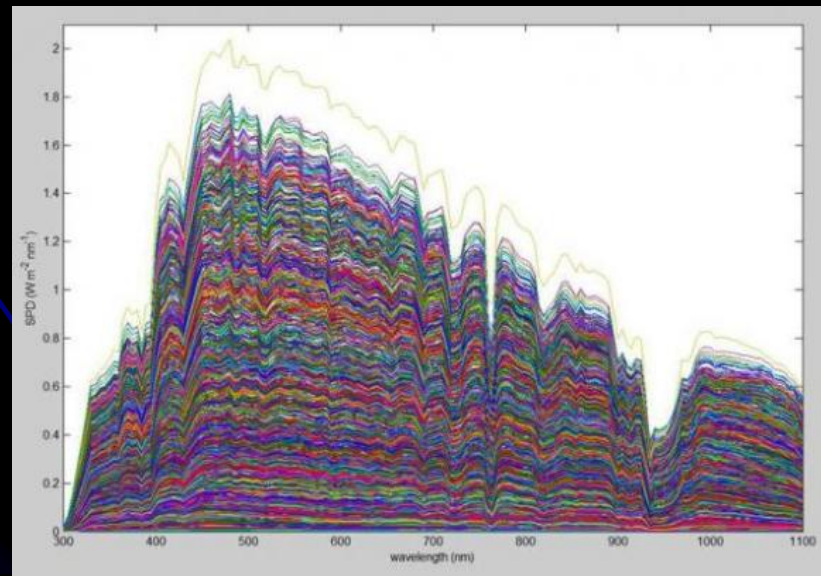
1. Color atlases
2. RGB Canon EOS 7D
3. PhotonEtc V-EOS Bragg grating-based Hyperspectral Imager (400-1000 nm)

4. CRI Varispec Liquid Crystal Tunable Filter (400-720 nm)
5. VIS+NIR Spectroradiometer Photoresearch 745 (380-1080 nm)
6. PixelTeq VIS+NIR SpectroCam (400-1000 nm)

7. RGB CCD camera QImaging Retiga 1300
8. Monochrome CCD camera QImaging Retiga SRV
9. Chromasens Multispectral 12-channels line scanner TruePixa Sensor: multichannel CCD.

Public available databases from our group

1. UGR Hyperspectral Image Database

2. Granada daylight spectral database

3. Granada SKYLIGHT spectral database

4. Labial Teeth and Gingiva Image Database - LTG-IDB

5. Multispectral HDR Polarimetric VIS+NIR imaging

Erasmus+ COSI: Building a long-lasting European center of academic excellence

Juan Luis Nieves (jnieves@ugr.es)
Departamento de Óptica - Facultad de Ciencias
Univesity of Granada, Granada (SPAIN)

Changing lives, opening minds

The European Union programme for education, training, youth and sport

2014-2020

Erasmus+

COSI
COLOUR
in science
& industry

ERASMUS MUNDUS JOINT MASTER DEGREE
COLOUR IN SCIENCE AND INDUSTRY
CO·SI

Erasmus+
European Joint
Master Degree

http://master-colourscience.eu/

EUROPEAN MASTER DEGREES IN COLOUR SCIENCE

PROGRAMMES ⌄   APPLICATION ⌄   CORPORATE RELATIONS   COMMUNITY ⌄

who are we?

COSI
COLOUR
in science & industry

Université Jean Monnet SAINT-ETIENNE

ugr Universidad de Granada

UNIVERSITY OF EASTERN FINLAND

HØGSKOLEN I GJØVIK

https://master-colorscience.eu/

Brussels, 29/07/2014

EACEA/A3/MH/ (2014)

With the support of the Erasmus+ programme of the European Union

Subject: Erasmus+ Programme - Joint Master Degrees (JMD)
           Call for proposals 2014 (EAC/S11/13)

Title: COlour in Science and Industry

Reference: 553342-EPP-1-2014-1-FR-EPPKA1-JMD-MOB
           (Please quote this number in all correspondence)

The Consortium is a joint venture, involving top European and Asian universities at the forefront of fundamental and applied research and knowledge transfer in colour science and industrial leaders in their fields, in sectors where expertise in colour-related applications is growing fast.

COSI

EUROPEAN MASTER DEGREE

< COLOUR IN SCIENCE AND INDUSTRY >

industrial partners #15

Be where the future of colour science will happen

Asian universities #5

towards Asian markets & knowledge economies

ACADEMIC PARTNERS

TOYOHASHI UNIVERSITY OF TECHNOLOGY

global academic excellence meeting worldwide colour markets

SUPPORTING INDUSTRIAL PARTNERS

technicolor

Fraunhofer IGD

AkzoNobel

barbieri

CEIBioTic Granada

SEDOPTICA   CSIC

IO   Beckers   FFCI

ASSOCIATED INDUSTRIAL PARTNERS

OLYMPUS
Your Vision, Our Future

chromasens
Imaging for Professionals

tecnalia
Corporación Tecnológica

Specim   _SC SOFTCOLOR

innovative university business cooperation at the heart of our programme development.
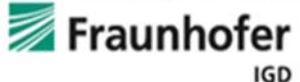
building an European center of academic excellence

cross-fertilization of research and knowledge transfer

#4 European universities

Université Jean Monnet SAINT-ETIENNE

UNIVERSITY OF EASTERN FINLAND

ugr Universidad de Granada

https://master-colorscience.eu/

EUROPEAN MASTER'S DEGREES IN COLOUR SCIENCE

ABOUT ▼   APPLY ▼   COMMUNITY ▼   STUDENT AFFAIRS ▼

https://master-colorscience.eu/

We are an **European academic consortium in colour science** offering 2 Master's Degrees designed and operated by an unique world leading university-business cooperation of 4 European universities, 5 Asian universities and 15 industrial leaders across the globe:

COSI / COLOUR IN SCIENCE AND INDUSTRY /   Erasmus+

a two-year scientific Erasmus+ Joint Master's Degree, aiming to train the next generation of highly-skilled industrial experts in applied colour science, in various cutting-edge industries (photonics, optics, spectral imaging, multimedia technologies, computer graphics and vision) in a diverse range of sectors (including multimedia, health care, cosmetic, automotive, food-processing). The two areas of focus are spectral technologies and applied colour imaging.

⌈ **CALL FOR APPLICATIONS FOR 2017-2018 intake open! The deadline for EMJMD scholarships is 03/03/2017. Self-financed students can apply till 15/05/2017 (non-Eu students) and 30/06/2017 (EU students)** ⌋

APPLY

CIMET / COLOUR IN INFORMATICS AND MEDIA TECHNOLGY /

a two-year research Master's Degree in fundamental color science, preparing students for a doctoral research and engaging them to undertake cutting-edge research projects in photonics, computer vision & imaging science, computer science & multimedia technology. The programme leads graduates to research careers in the academia or research institutes.

NO CALL FOR APPLICATIONS in 2017

APPLY

COSI
COLOUR
in science
& industry

Call for Applications for 2016-2018 intake is NOW OPEN !

Apply online before the 03rd of March 2017 and benefit from a scholarship to finance your degree

UJM Foundation (3DMT, COSI and MLMD master's degrees programmes)
10,000 € to the best applicant

Erasmus + (COSI programme)
35,000 € scholarship grants for EU students, 49,000 € for non-EU students

50% fee-waiver (COSI) programme
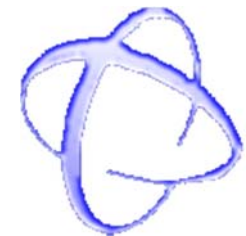 4,500 € for European students; 9,000 € for non-European students

COSI scholarship
5,000 € granted to the best applicant

Óptica Aplicada
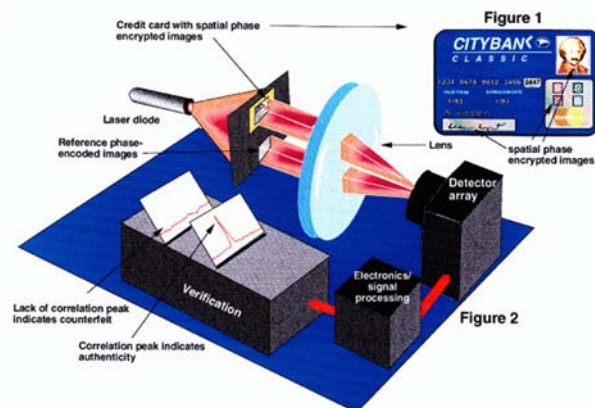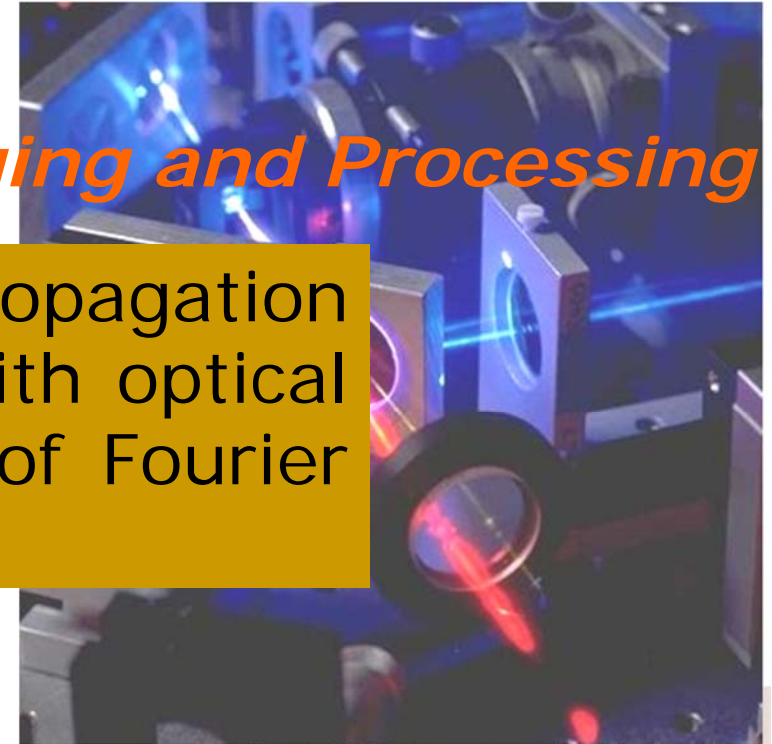
Asignatura optativa 4º curso (semestre 1)

Juan Luis Nieves
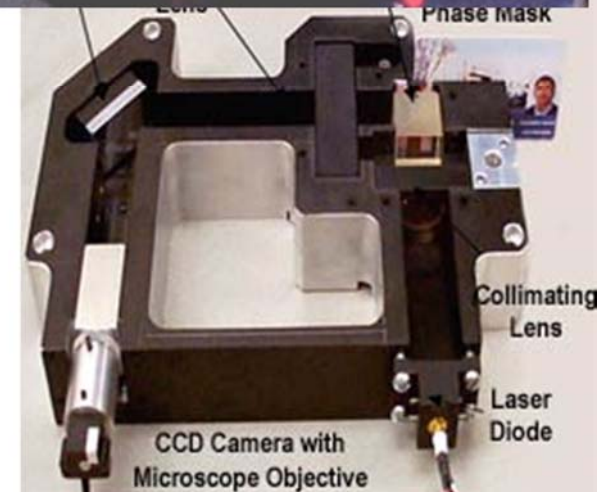**Javier Romero Mora**

Departamento de Óptica, Facultad de Ciencias,
Universidad de Granada, 18071-Granada (SPAIN)

'Fourier Optics': Optical Imaging and Processing

It refers to the study of the propagation of light and its manipulation with optical systems using the framework of Fourier Transform.

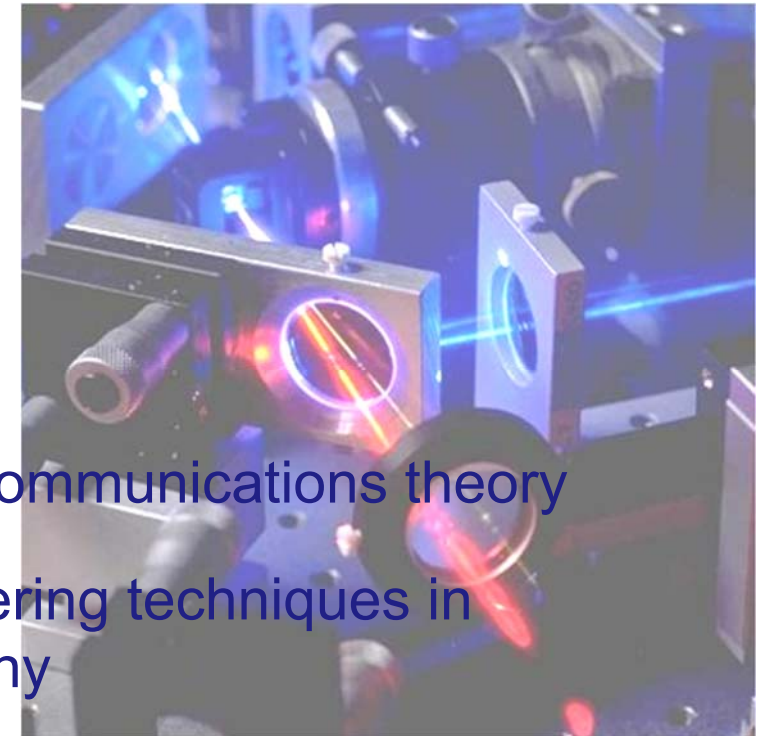Spatial Phase Encrypted Credit Card andOpto-electronic Pattern Recognition System for Verifying Cards

But… when?

Pierre Michel Duffieux
(1891- 1976)

Fourier optics has its origins in 1946 from one of Duffieux's book…

50's

P. Elias *et al.* ⟶ Optics and communications theory

A. Maréchal ⟶ Spatial filtering techniques in photography

60's

Vander Lugt ⟶ Holographic spatial filter

A.W. Lohmann ⟶ Optical object recognition

23

Fig. 1. Principle of the double random phase encryption scheme.

Plain Image P, First phase key X, Object plane, Fourier transform of $P \cdot X$, Fourier plane, Second phase key Y, Ciphered Image, Output plane

Figure 1

CITYBANK CLASSIC

Credit card with spatial phase encrypted images

Laser diode

Reference phase-encoded images

Lens

spatial phase encrypted images

Detector array

Electronics/signal processing

Verification

Lack of correlation peak indicates counterfeit

Correlation peak indicates authenticity

Figure 2

Spatial Phase Encrypted Credit Card andOpto-electronic Pattern Recognition System for Verifying Cards

$$C = Y \cdot F[P \cdot X]$$

Brute force attack: try every possible key

- 2 keys
- N pixels/key
- L phase levels
- ? L^{2N} combinations

Phase key

100 x 100 pixel keys
16 phase levels,

? 10^{24000} combinations

Exponential complexity ? intractable

A.W. Lohmann ⟶ Optical object recognition

Óptica Aplicada (= Óptica de Fourier)