Image Processing I

Fabrice Meriaudeau

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- **Assessment**
  - Examination in October
    - Test (s)(40%)
  - Examination in January
    - Final written Exam (60%)

- **Reassessment**
  - Final written Exam (60%)
  - Grades obtained during the semester (40%)

Introduction [F. Meriaudeau/ Module Coordinator]

1. **Digital Image Fundamentals (2h) [F. Meriaudeau]**
2. **Image Enhancement - Spatial Domain (3h) [F. Meriaudeau]**
   - Image Enhancement Techniques
   - Image Histograms
   - Histogram equalisation & modification
3. **Spatial Filtering (3h) [F. Meriaudeau]**
   - Convolution and Correlation
   - Spatial Domain
   - Smooting and Sharpening
4. **Filtering in the frequency Space (3h) F. Meriaudeau**
   - 2D Fourier transform

Test [**F. Meriaudeau**]

5. **Non Linear Filtering – Mathematical morphology (6h) [J. Debayle]**

Lab1 : Matlab 2h Joan Massich

Lab2 : Matlab 2h Joan Massich

Lab3 : Matlab 2h Joan Massich

Lab4 : Matlab 2h Joan Massich

Lab5 : Matlab 6h Joan Debayle

6. Color Image Processing (6h) [A. Mansouri]

- Introduction to radiometry and photometry
- Color image formation
- Computational theories of color imaging
- Multispectral imaging

7. Image Segmentation (10h) [F. Meriaudeau]

FInal Exam

Lab 6 : Matlab 8 h

Image Processing I

- Textbooks
  - Digital Image Processing
    - R. Gonzales & R. Woods
  - Two Dimensional Signal and Image Processing
    - J.S. Lim
  - The Image Processing Handbook
    - J.Russ
  - Digital Image Processing
    - Pratt

What is a digital image?

- A 2D array of values (pixels)
- Each value reflects certain properties of the scene being imaged, depending on the sensor.
  - Photographs
  - Sonars
  - Ultrasound
  - Radar
  - Infrared cameras
  - Xrays
  - MRI…

What is Image Processing about?

- The **management** and **exploitation** of image data
- Management:
  - Megabytes of redundant data
    - Representation/ formats/ digitization
    - Coding
    - Storage and transmission
- Exploitation
  - Extracting the useful information
    - Problem dependant…
    - For decision / action / knowledge
    - More and more needed for management (intelligent management to cope with vast amounts of data)

More on Image Exploitation

- Extracting the useful information
  - Image as physical 2D sensing
    - Camera motion btw 2 optical images -> control, 3D
    - Physical property of scene -> Temperature in IR images
  - Image as group of scene/object/areas

➢ Abstract info: the challenge of computer vision

- Data representation
- Segmentation
- Classification/decision

More on Image Exploitation

- Example applications:
  - Detect cancerous growth in x-ray images
  - Flag suspicious behavior in surveillance video
  - Retrieve images “like this one” from the web (keyword or image based search?)
- Our brain is highly trained to process (optical) images
- BUT: Highly difficult problem for machines
  - Sensory Gap
  - Semantic Gap

Applications of Image Processing

- Improvement of pictorial information for human interpretation
- Processing of scene data for autonomous machine perception

Image Processing Techniques

- **Enhancement**
  - Process image to give a result that is more suitable than the original for a given application
- **Restoration**
  - Process that attempts to reconstruct or recover an image that has been degraded by using some a priori knowledge of the degradation
- **Encoding**
  - Techniques for representing an image with fewer bits
- **Segmentation**
  - Descriptions of image components rather than whole images
- **Understanding**
  - Symbolically represents contents of an image

Example Images and applications

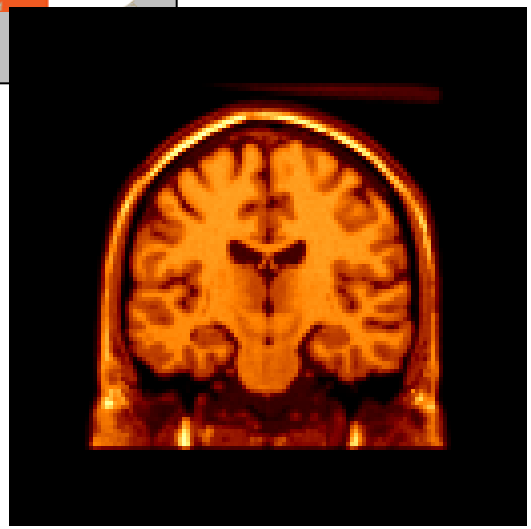
Application Domains

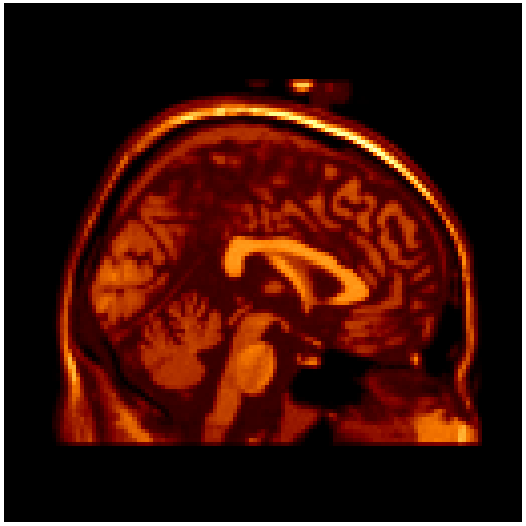
- Space programs
- Medicine
- Remote sensing (geographers/geologists)
- Defence
- Law enforcement
- Forensic
- Physics
- Astronomy
- Industrial inspection
- Media (video games, films…)
- …

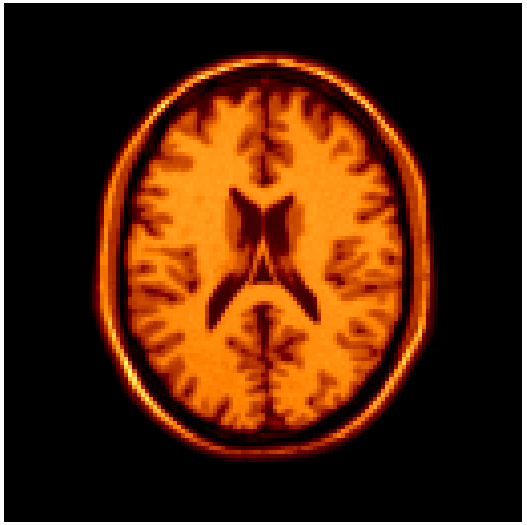
Example sensors

- Cameras, photographs
- Sonars
- Ultrasound
- Radar
- Infrared cameras
- Xrays
- MRI (magnetic resonance imager)
- …

Biomedical



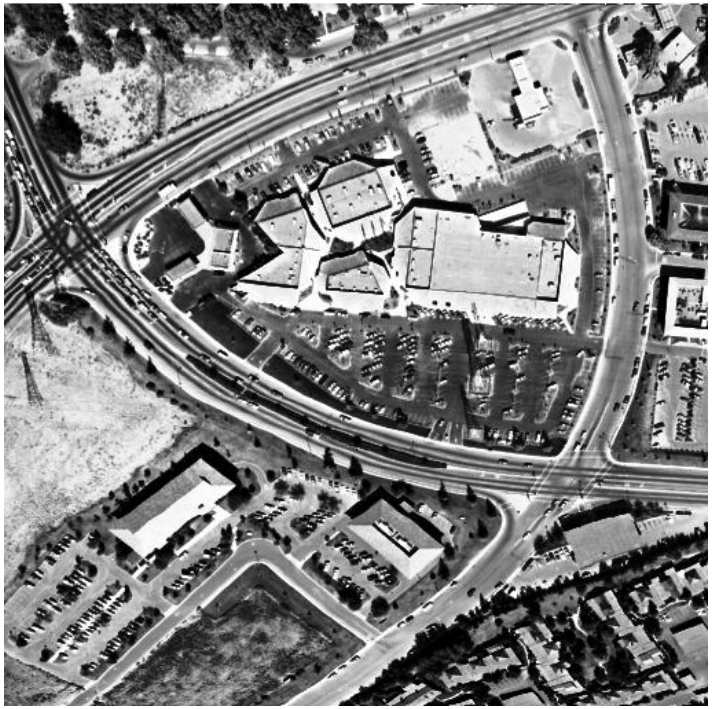




Cartography

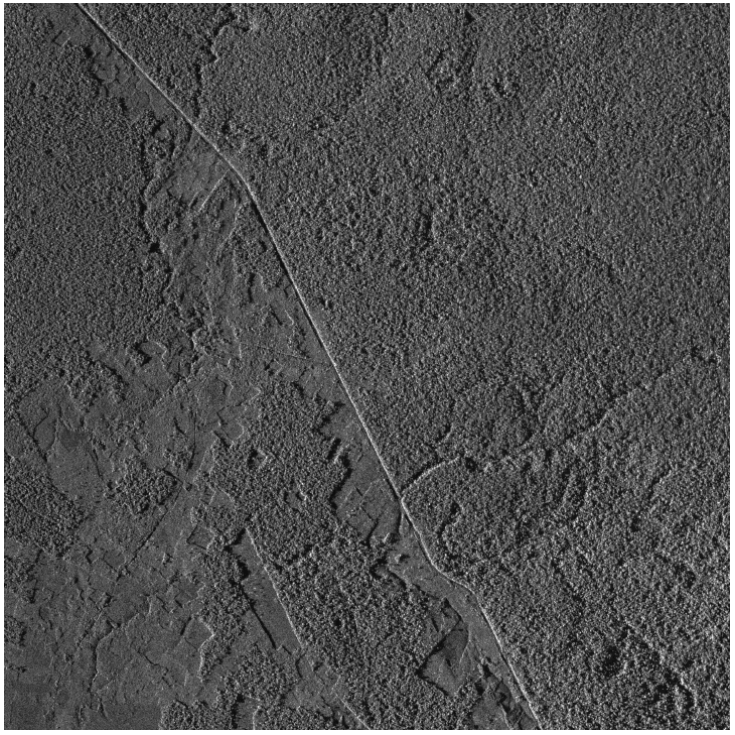
Original

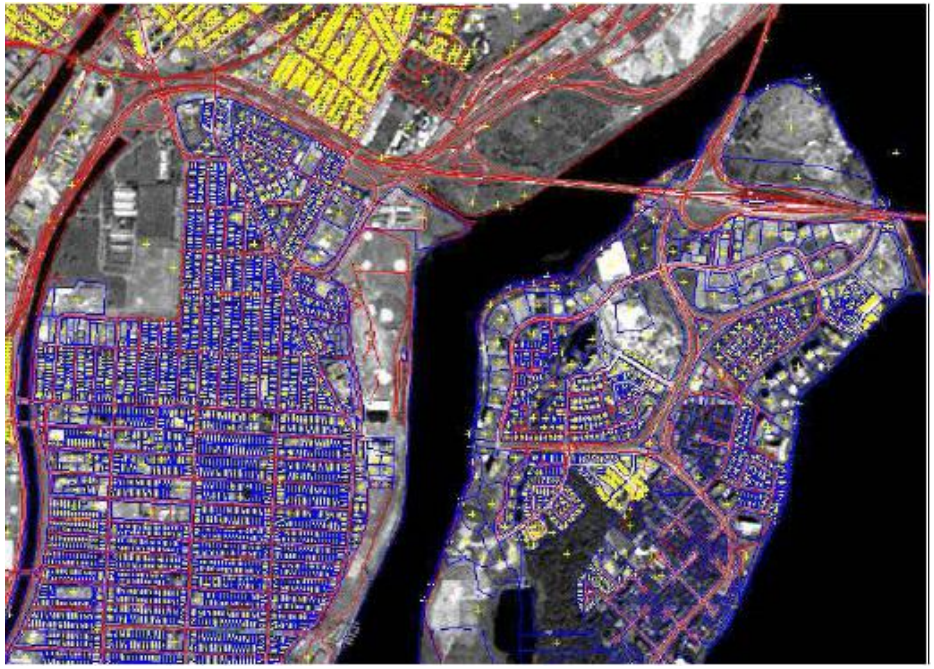
Histogram equalisation



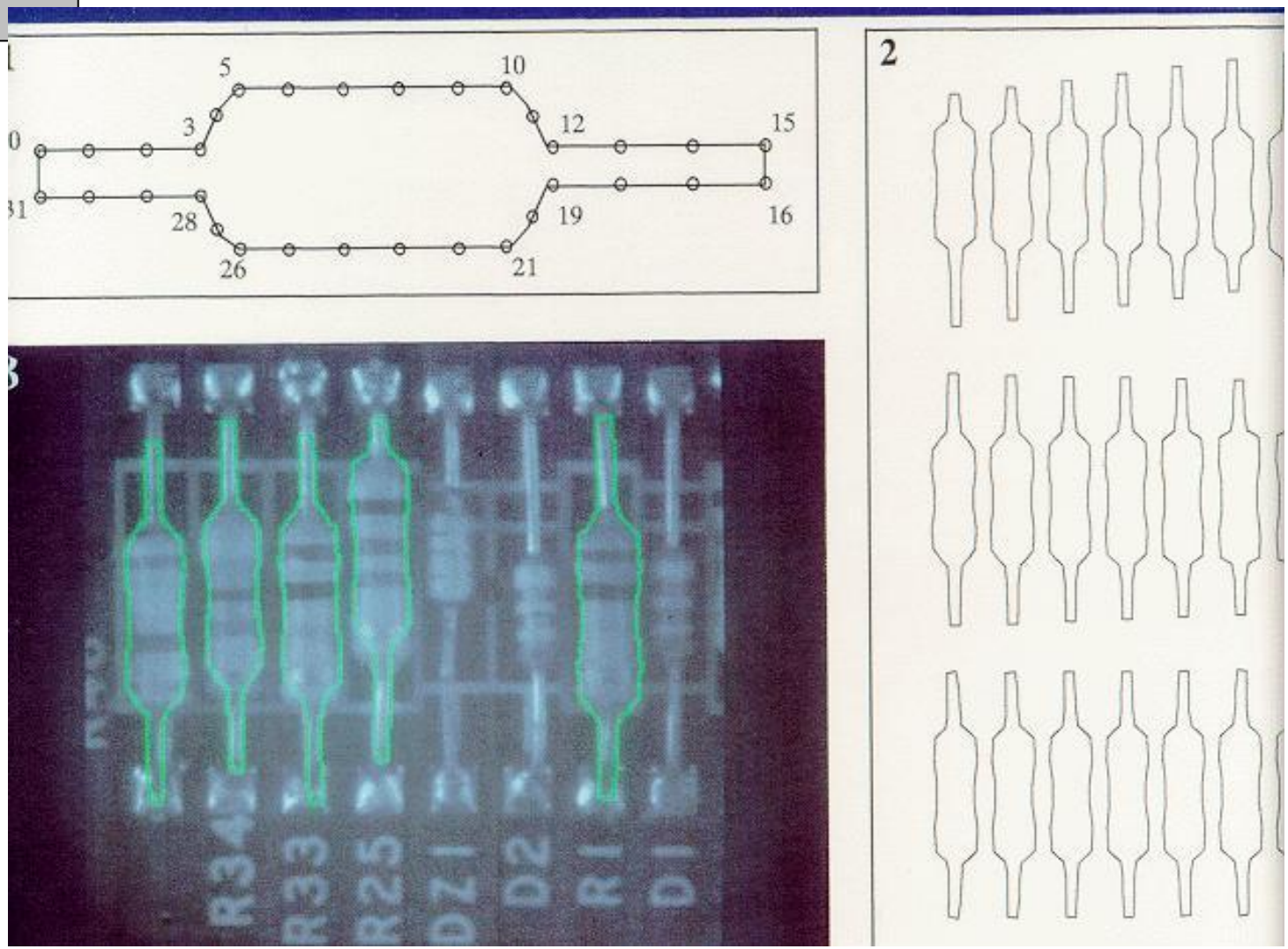
Land monitoring

- Land occupation
  - Synthetic Aperture Radar
  - Vegetation, soil, built areas
  - Boundaries



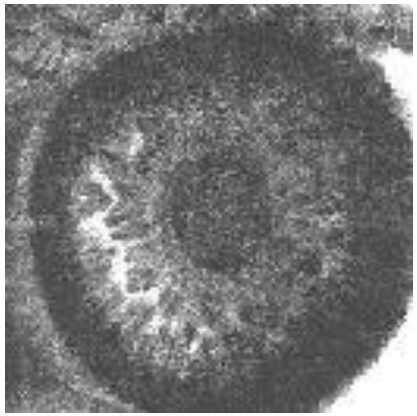


Inspection

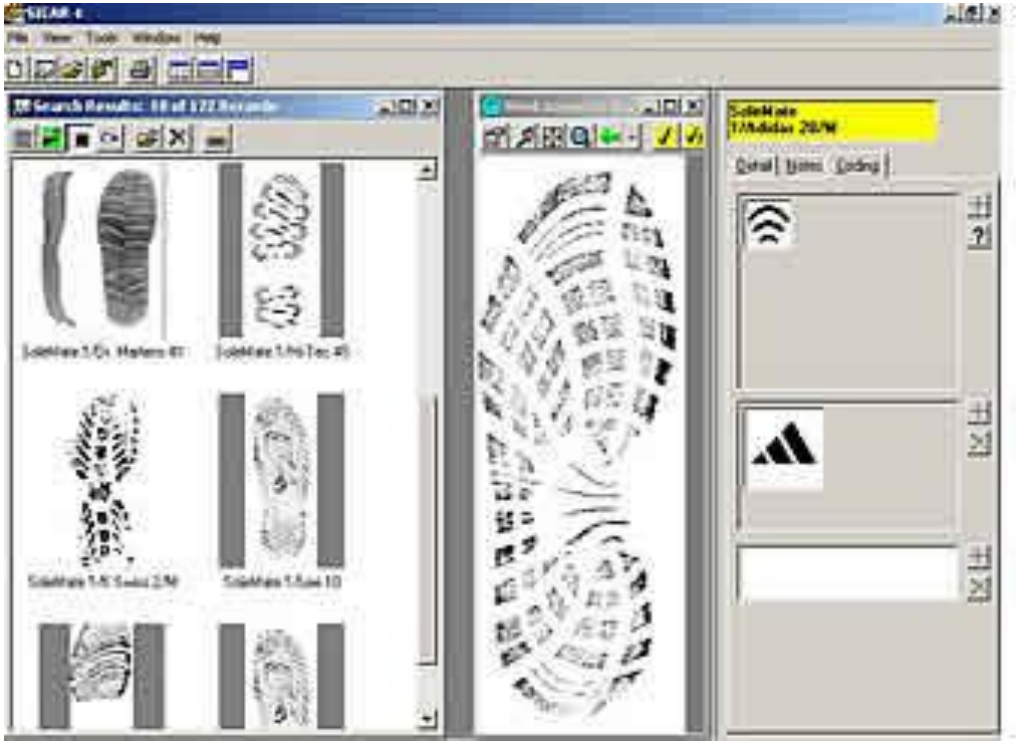


Video Surveillance

Biometrics

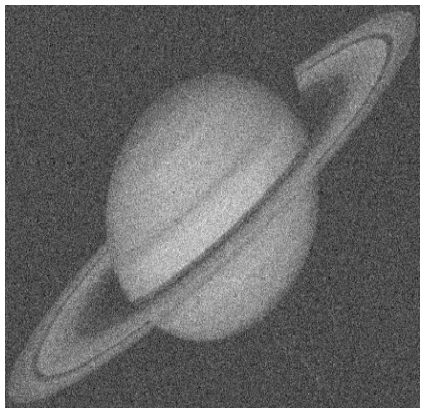


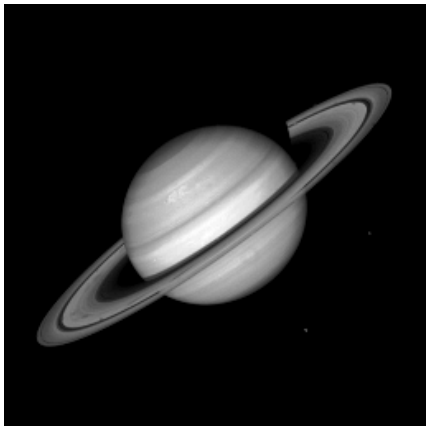
Digital Image data management



- Restoration
- Compression
- Coding
  - MPEG-2 DVD
  - MPEG-7
- Retrieval

Enhanced Visualization





Content Based Image Retrieval

- “Fetch images like this”
- Web / databases applications

?

No

Yes

No

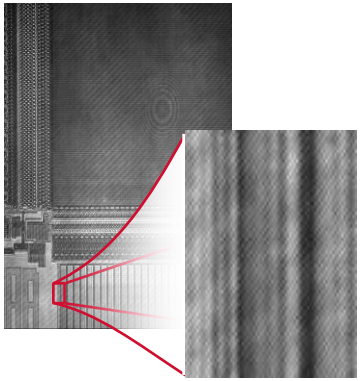
Example Applications at Le2i – Le Creusot

Examples at Le2i

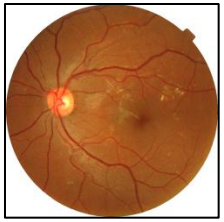
Application Areas

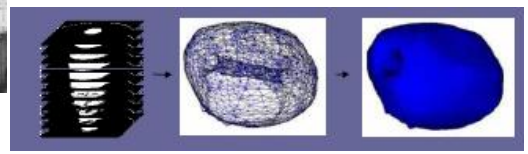
3D INSPECTION

IMAGE COMPRESSION

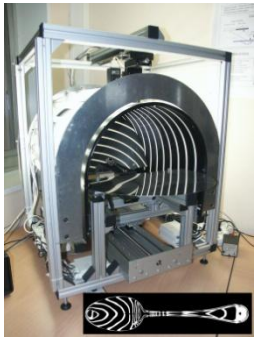


MEDICAL

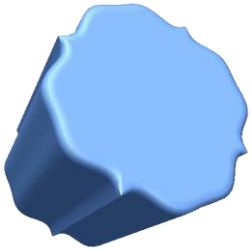


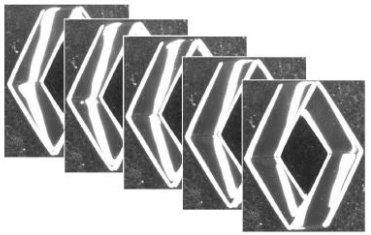


MACHINE VISION

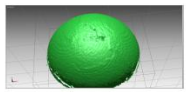


3D Visualization

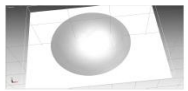




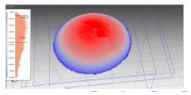
- Scanner Laser.
  - adding opaque coating

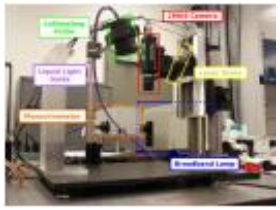


- Polarization system.
  - reconstruction by normals field integration



- Deviation.
  - ±1.5 mm





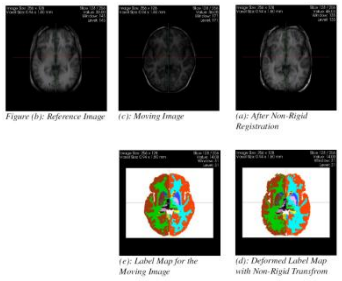
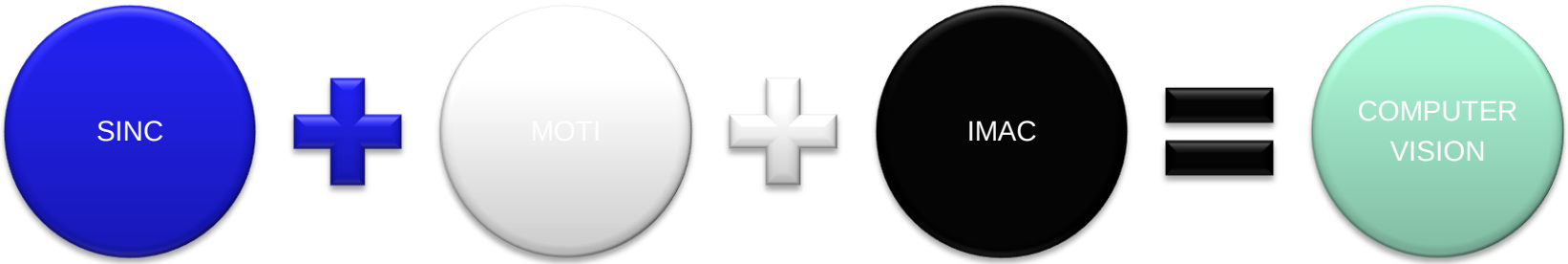


Image Processing I/ F. Mériaudeau

14	23	3	1
Professors	Assoc./Assist Profs	CNRS	uB
• 10 PU • 3 PU-PH • 1 PU collaborator	• 1 MCF-HDR • 1 MCF Chaire CNRS • 18 MCF • 3 MCF collaborators	• 1 IR • 1 IE • 1 TR	• ½ ASI


SINC
MOTI
IMAC
COMPUTER
VISION

Computer Vision

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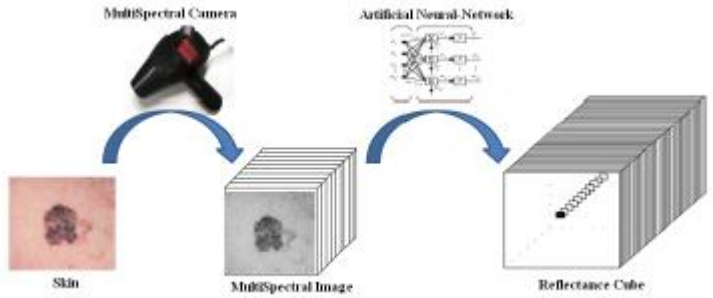

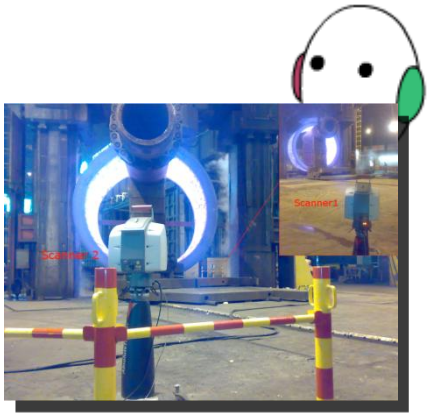

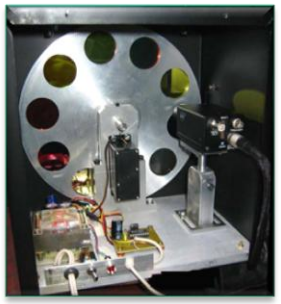

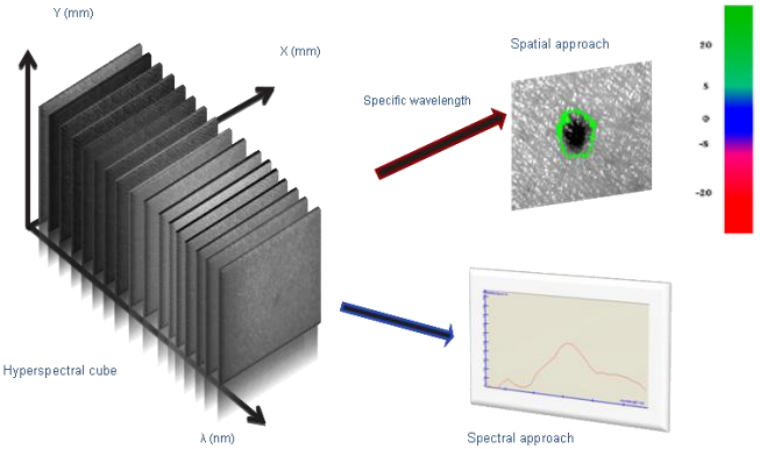

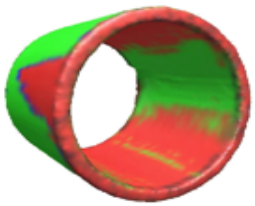

Computer Vision

- Non Conventional Imaging systems **(SINC)**
- Tools and Methods for Image processing **(MOTI)**
- Medical imaging and Clinical Applications **(IMAC)**

Computer Vision

- Non Conventional Imaging systems **(SINC)**
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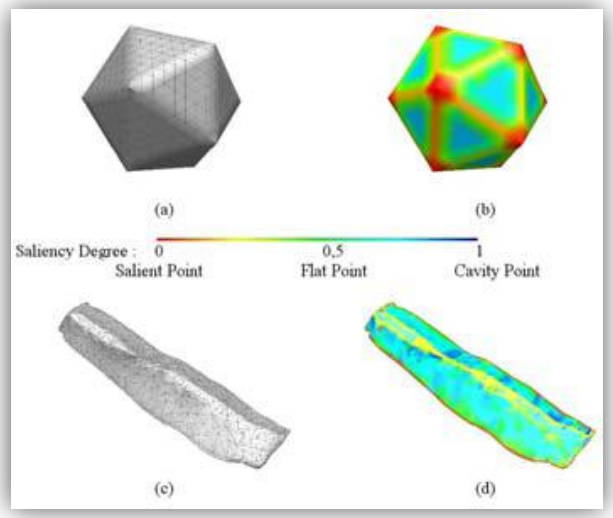
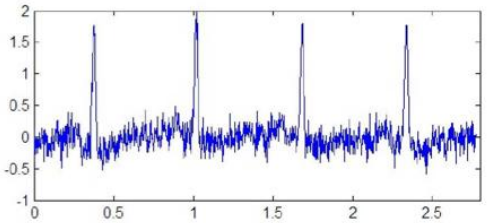
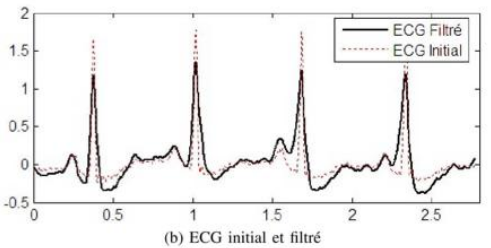
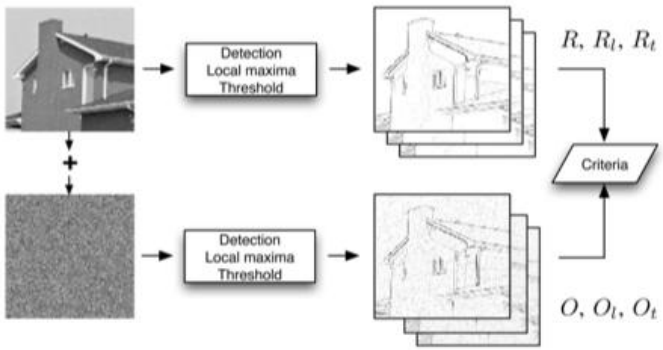
- Imagerie Médicale et Applications Cliniques **(IMAC)**









"*A nonlinear derivative scheme applied to edge detection*", Olivier LALIGANT, Frédéric TRUCHETET, **IEEE TPAMI**, 32 (2), pp. 242-257, February 2010

Computer Vision

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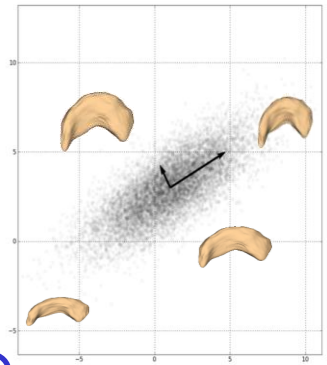
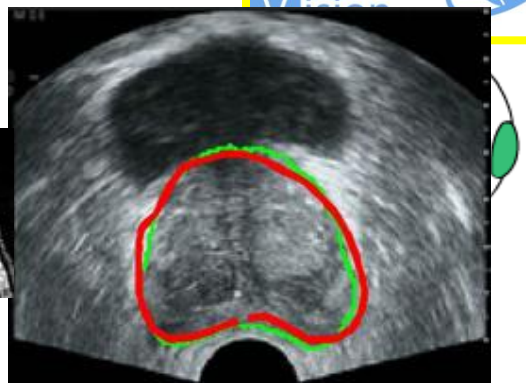
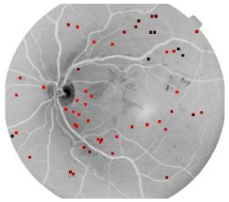
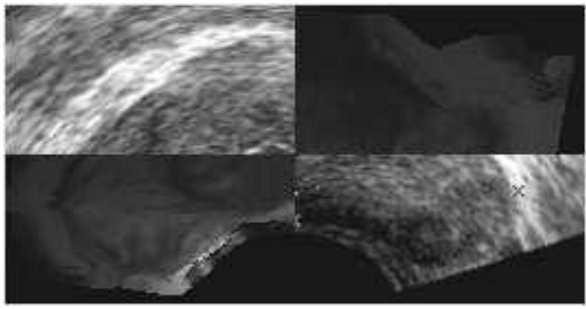
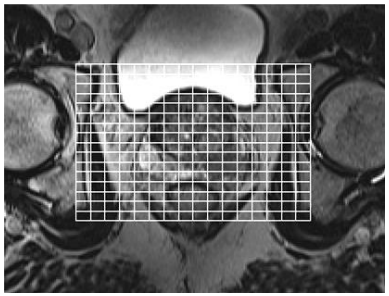
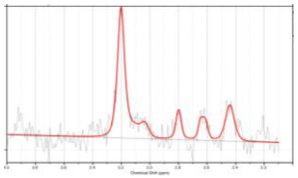


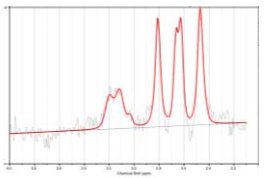


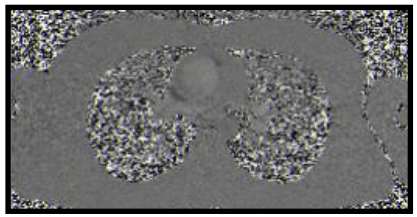


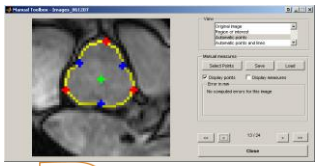


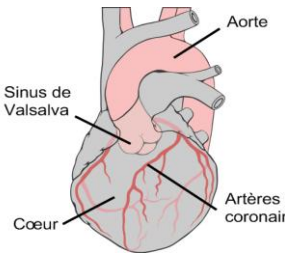


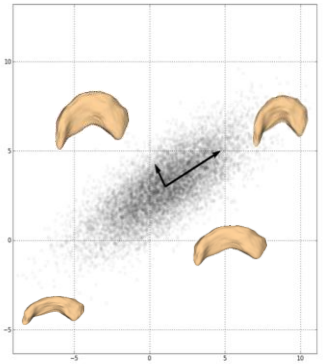


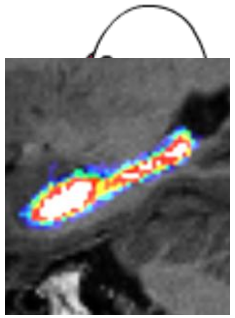








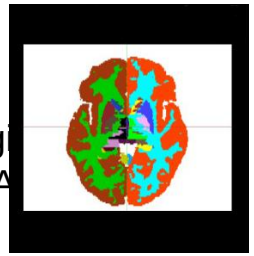




Computer Vision

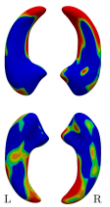
- Non Conventional Imaging systems **(SINC)**
- Tools and Methods for Image processing **(MOTI)**
- Medical Imaging and Clinical Applications **(IMAC)**

- Atlas based segmentation of deep gray matter structures
  - Multi-atlas based segmentation propagation
  - Atlas construction using a supervised method
  - Atlas selection strategies based on Maximal Marg relevance (MMR) and Least Angle Regression (LA



- Statistical shape model (SSM) of hippocampus
  - Building hippocampal SSM
  - Extrapolation of SSM and shape parameter estima

- Shape analysis of hippocampus in Alzheimer's disease
  - Localization of SSM to hippocampal subregions affected by the atrophy
  - Shape analysis on the localized hippocampal subregions



L. Giancardo, et al, "Elliptical Local Vessel Density: a Fast and Robust Quality Metric for Fundus Images," in 30th Annual International Conf. of the IEEE EMBS Vancouver, Canada, 2008.

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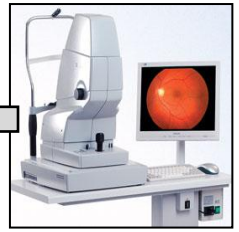
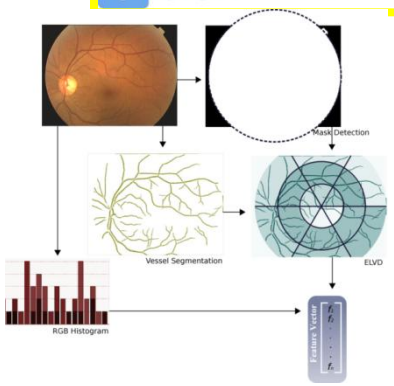
Image capture (camera)



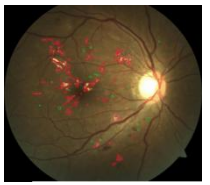
Quality assessment



Locate anatomic structures

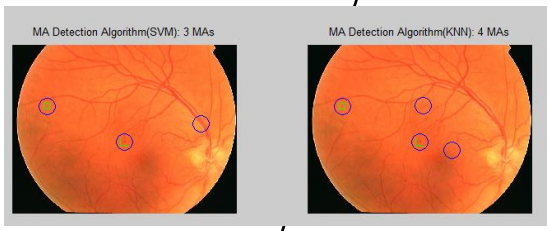
Detect lesions

Extract features



Perform query

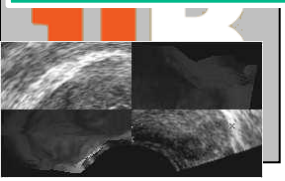
Generate diagnosis

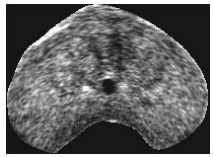


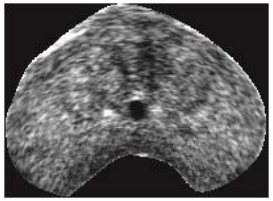
CBIR database

Giancardo, L., et. al, (2010), Microaneurysms detection with the Radon Cliff operator in retinal fundus images, Proc. SPIE Medical Imaging, San Diego CA, 7623:7623

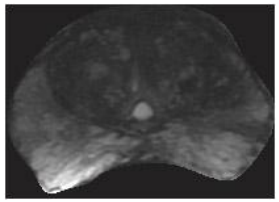
Giancardo et al. MIA, 2012







$$\varphi(\cdot) \neq \varphi^{-1}(\cdot)$$



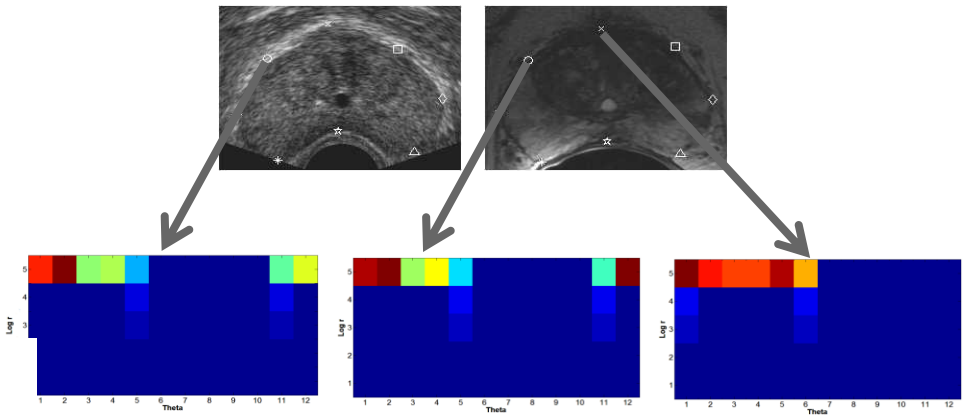
Computer Vision

- Non Conventional Imaging systems **(SINC)**
- Tools and Methods for Image processing **(MOTI)**
- Medical Imaging and Clinical Applications**(IMAC)**

$$\int \omega(\,\square\,) = \int \omega(\varphi(\,\square\,))$$

Thin-plate spline function

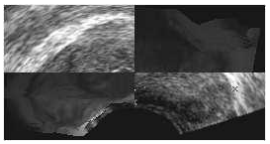
Domokos et al. 2012,IEEE TPAMI



UdG VICOROB Computer Vision and Robotics

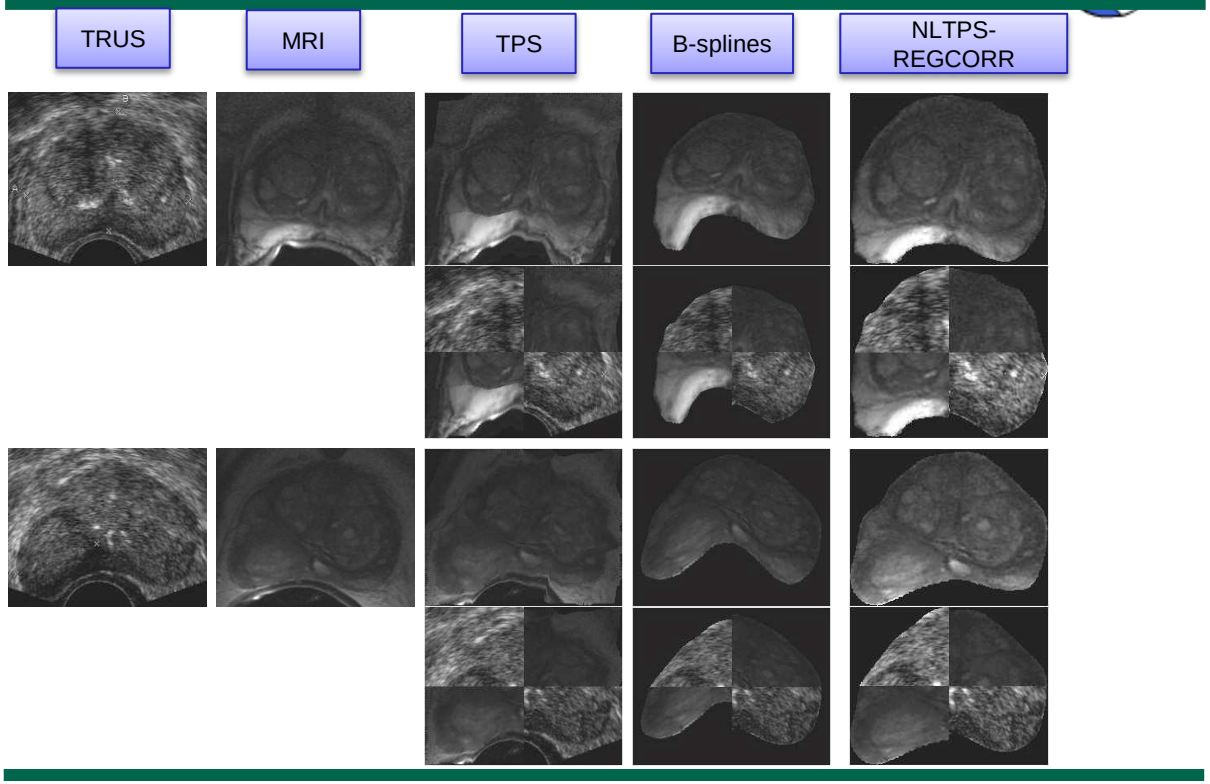
UNIVERSITÉ DE BOURGOGNE

Clínica Girona



Computer Vision

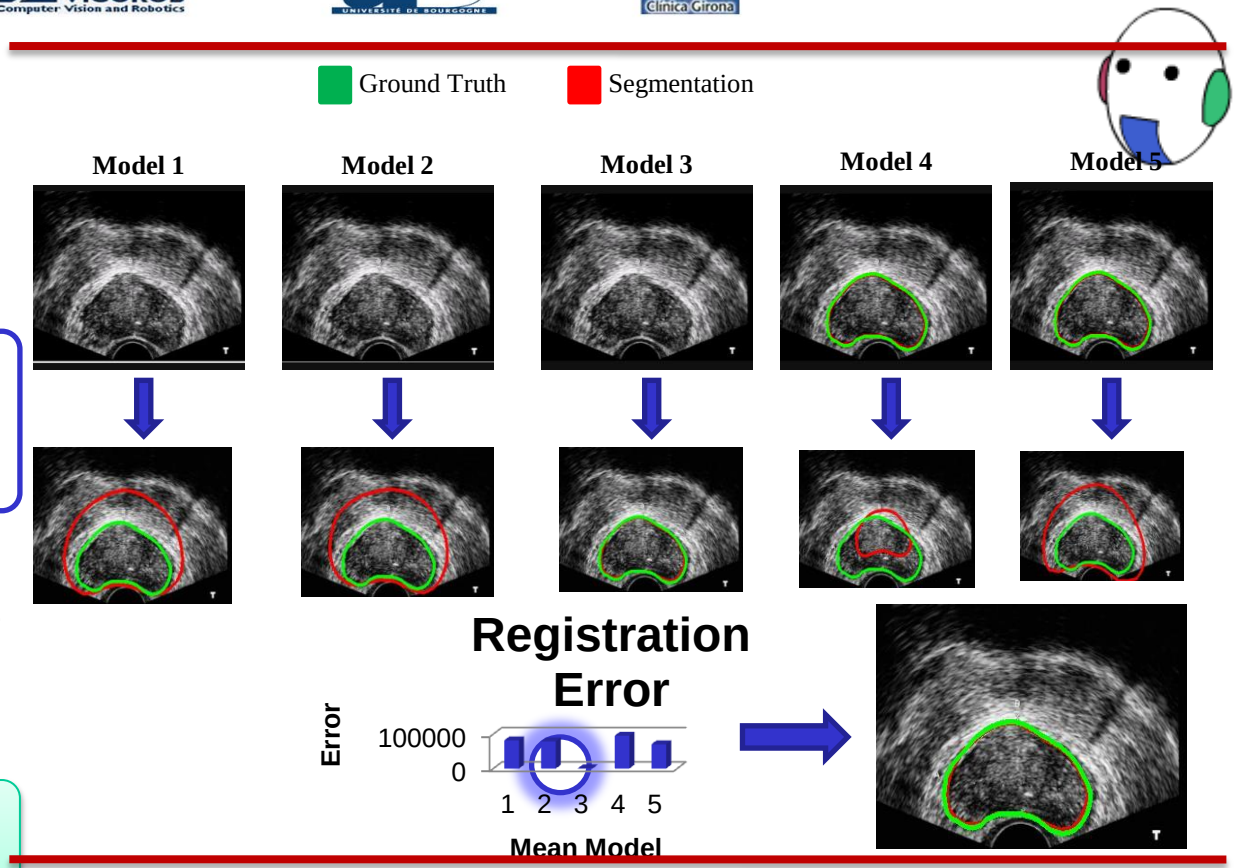
- Non Conventional Imaging systems **(SINC)**
- Tools and Methods for Image processing **(MOTI)**
- Medical Imaging and Clinical Applications **(IMAC)**



Mitra et al. MIA, 2012

Computer Vision

- Non Conventional Imaging systems **(SINC)**
- Tools and Methods for Image processing **(MOTI)**
- Medical Imaging and Clinical Applications **(IMAC)**

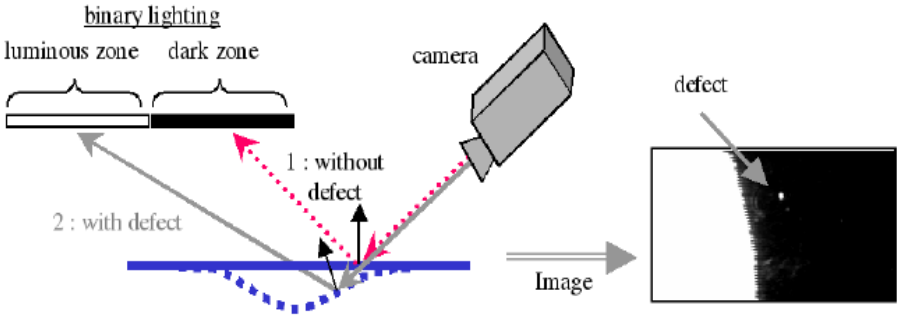


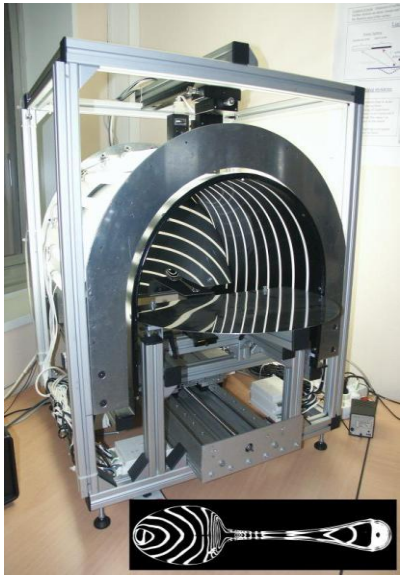
Computer Vision

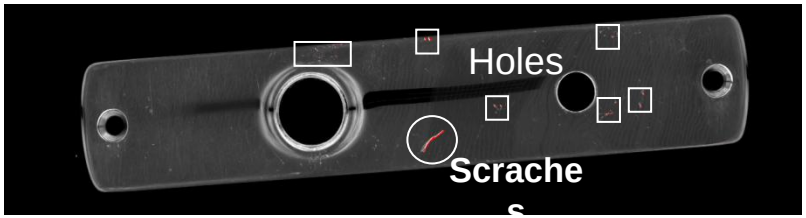
- Non Conventional Imaging systems **(SINC)**
  - *IEEE TIM, Optics Express, Applied Optics,Optical Engineering, IEEE ICPR…..*
- Tools and Methods for Image processing **(MOTI))**
  - *IEEE PAMI, IEEE Signal Processing Letters, IEEE Visualisation and graphics, Optical Engineering…. IEEE ICIP….*
- Imagerie Médicale et Applications Cliniques **(IMAC)**
  - *Neuroimaging, Medical Imaging Analysis, MAGMA, European Journal of Oncology…. MICCAI…..*

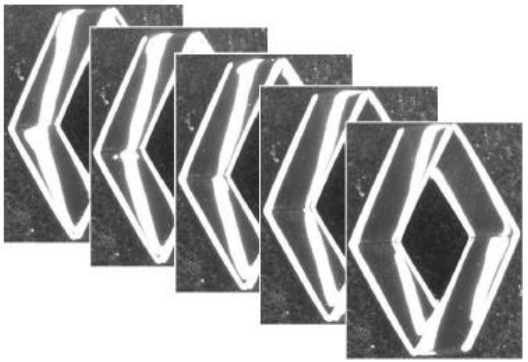
Some more Examples at Le2i

Reflective product inspection: Cosmetic lid, Silverware, Automotive parts……







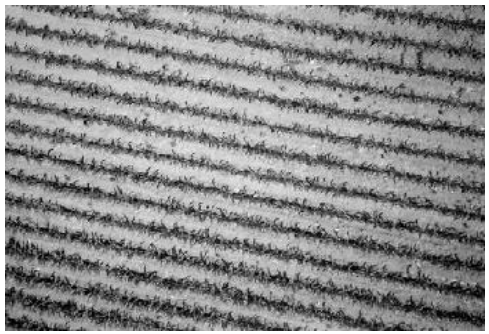


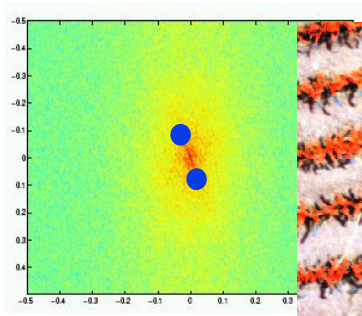
Machine Vision and Applications (2008) 19:35–42
Characterization of surface deformation with the Edge of Light™ technique, Z. Liu · M. Genest · A. Marincak · D. S. Forsyth

⇨ **Crop/Weed discrimination from image processing**

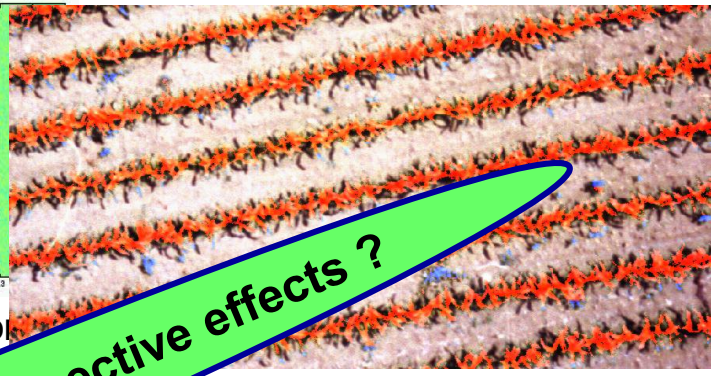
- **crop periodicity (FFT2+Gabor filter)**

Aerial image





Fast Fourier Transfo

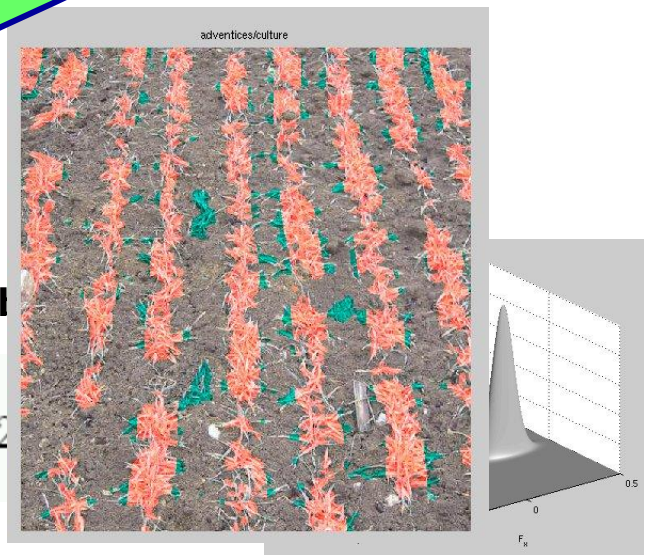


Line detection for images with perspective effects ?

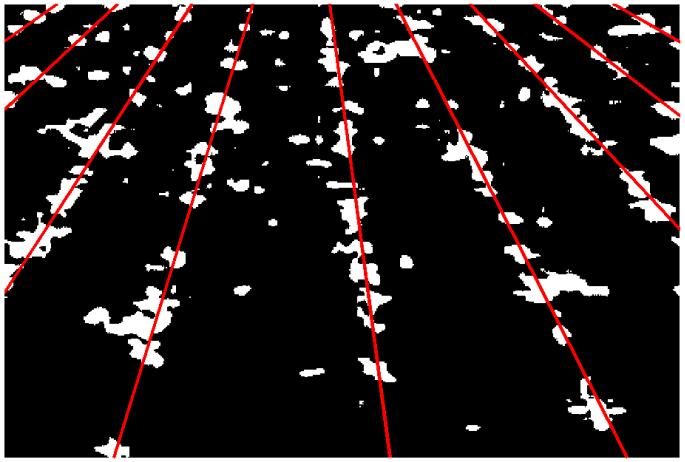
In-field image

Pass-band filter : 2D oriented Gal

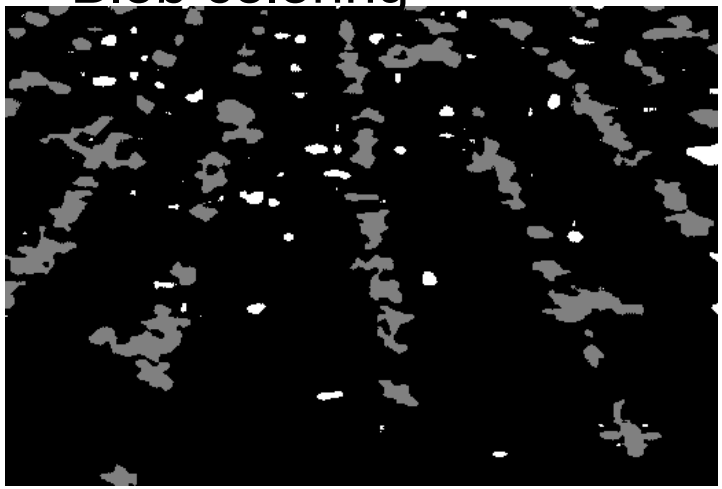
$$g(x,y) = e^{-\frac{1}{2}[-\frac{x_\theta^2}{\sigma_x^2}+\frac{y_\theta^2}{\sigma_y^2}]}.\cos(2$$



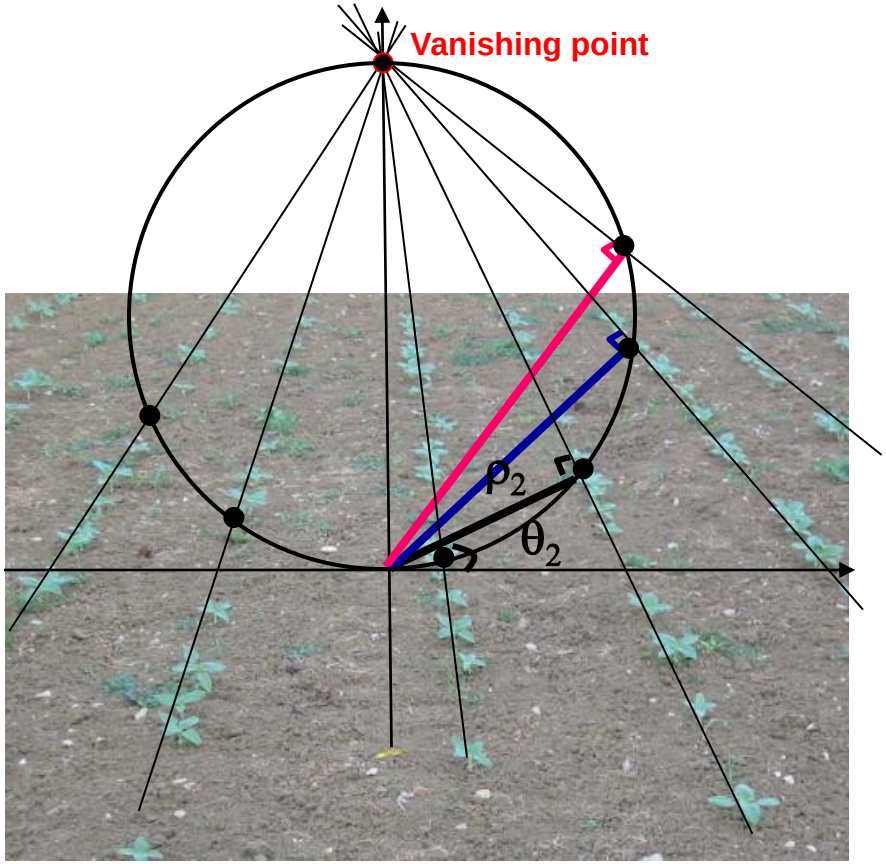
- Line detection



- Blob coloring



- 1st Method: standard detection



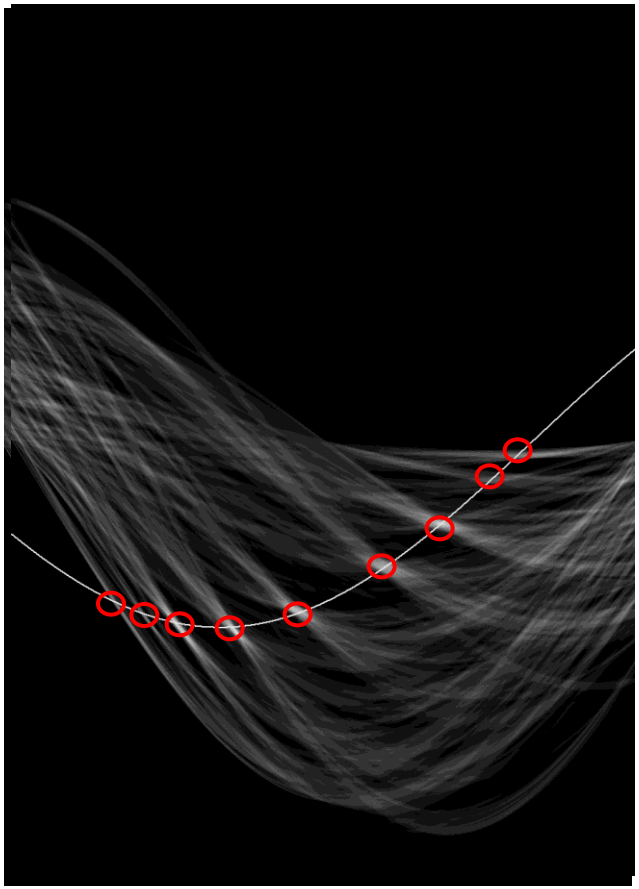
- Line detection

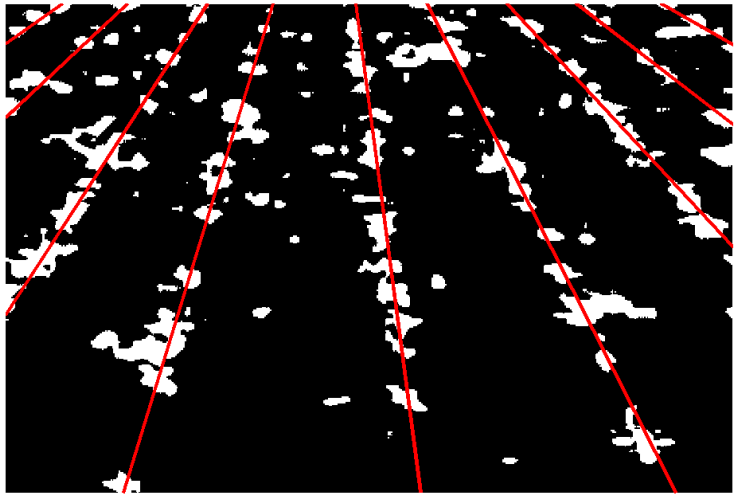
Hough Transform :

Accumulator (ρ,θ)

ρ = x cos θ + y sin θ

Spatial space		Hough space
one point	⟺	one sinousoid
one line	⟺	one point (ρ,θ)

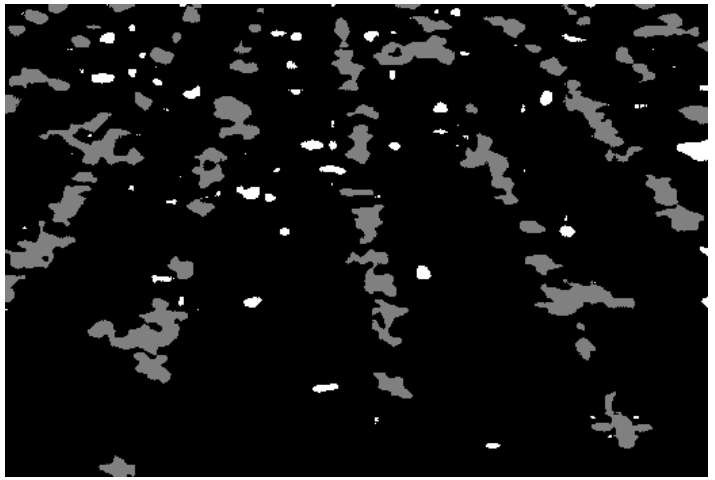




- Blob coloring: region-based segmentation

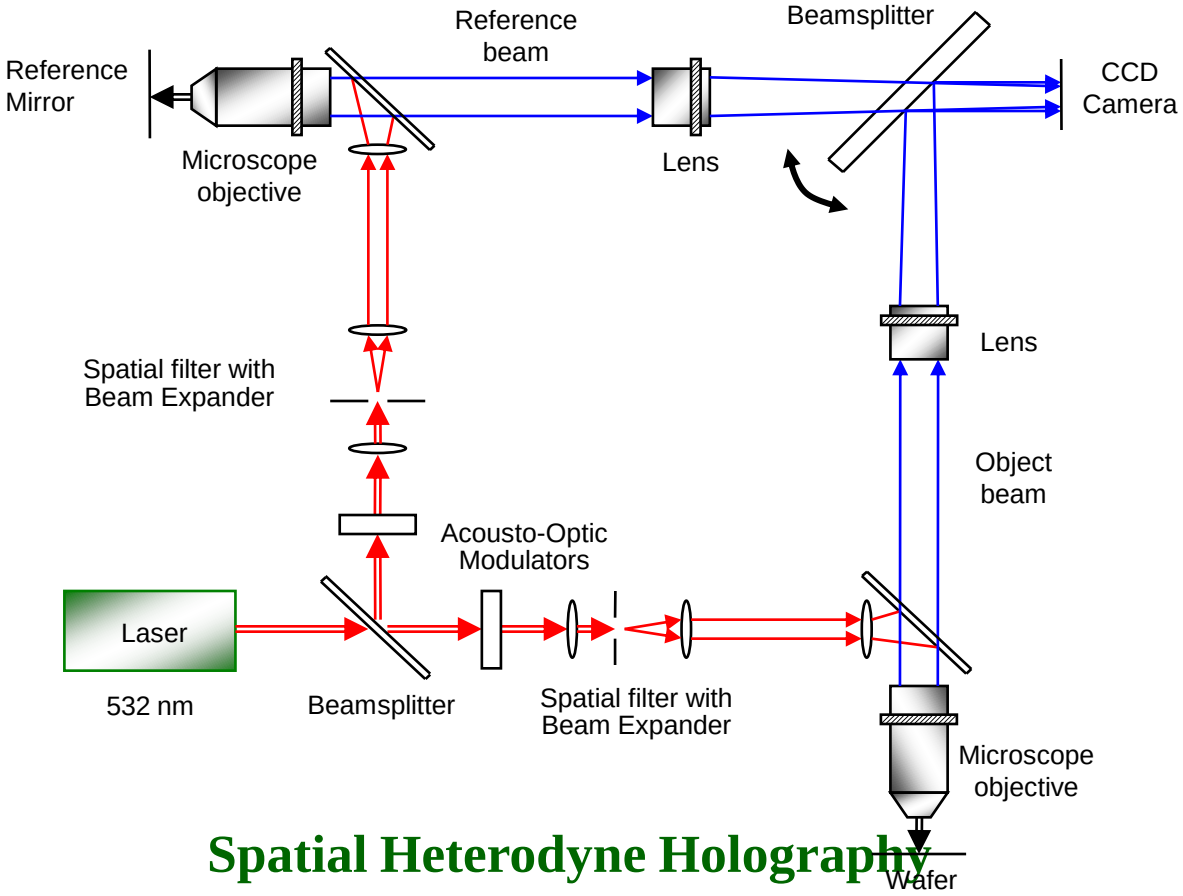
Pixel state

If Region ∈line ⇒crop
else ⇒weed



WIR (Weed Infestation Rate) =11.6%

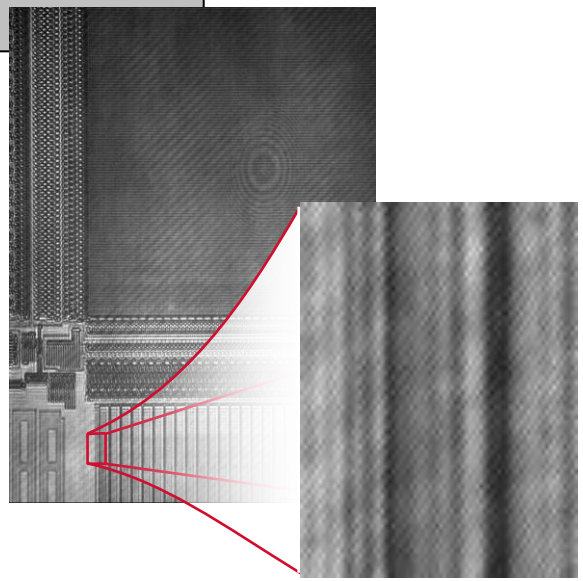
Digital Holography

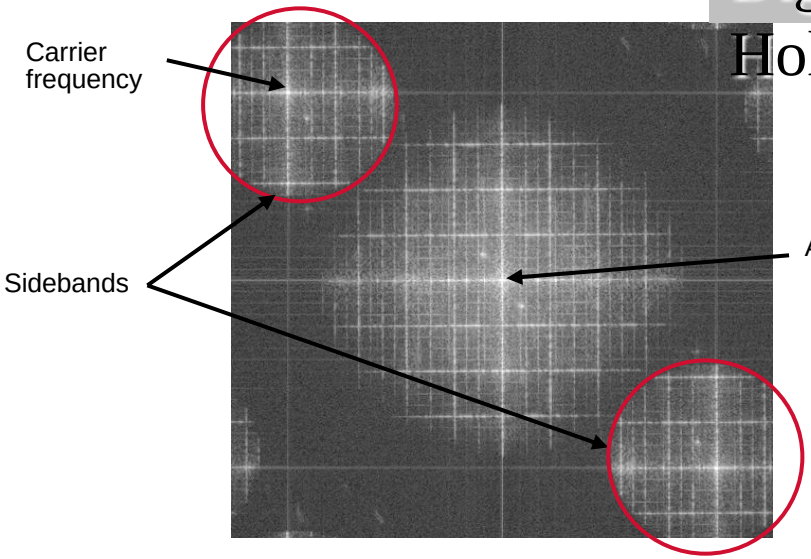


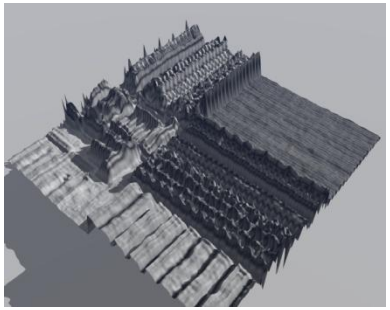
Spatial Heterodyne Holography

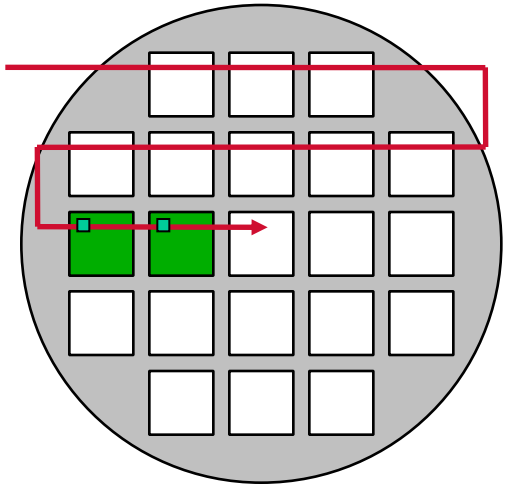
A small angle between the object and the reference beam creates interference fringes that carry the phase information.

Digital Holography

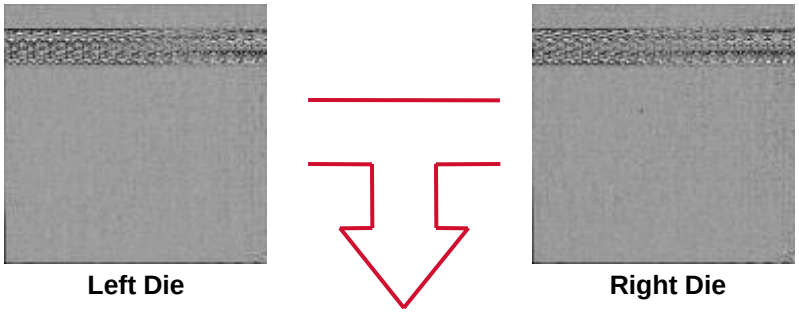






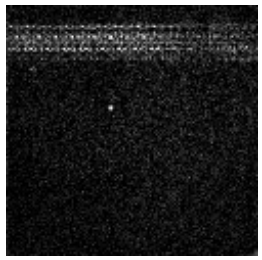


Wafer



Left Die

Right Die



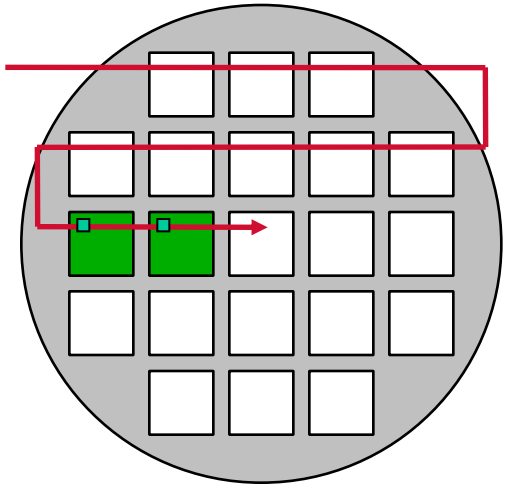
Difference Image

Set a global threshold based upon the noise level in the difference image

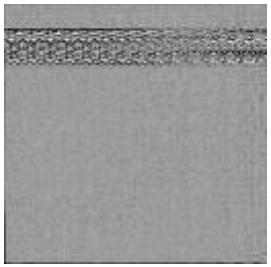
$$T = K.\sigma + \mu$$

Defect Mask

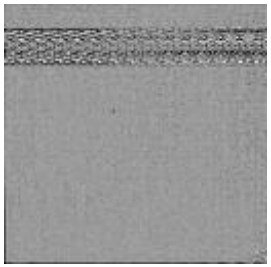
A global threshold is unable to find the defect without generating false detections



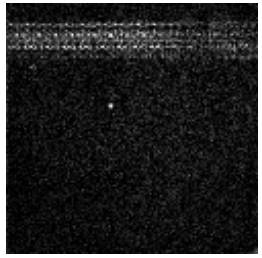
Wafer



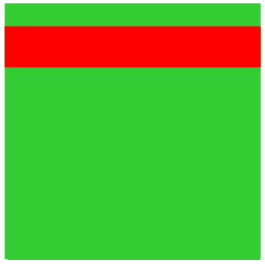
Left Die



Right Die



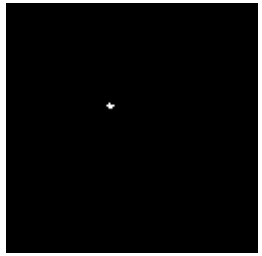
Difference Image



Mask of the Different Structures

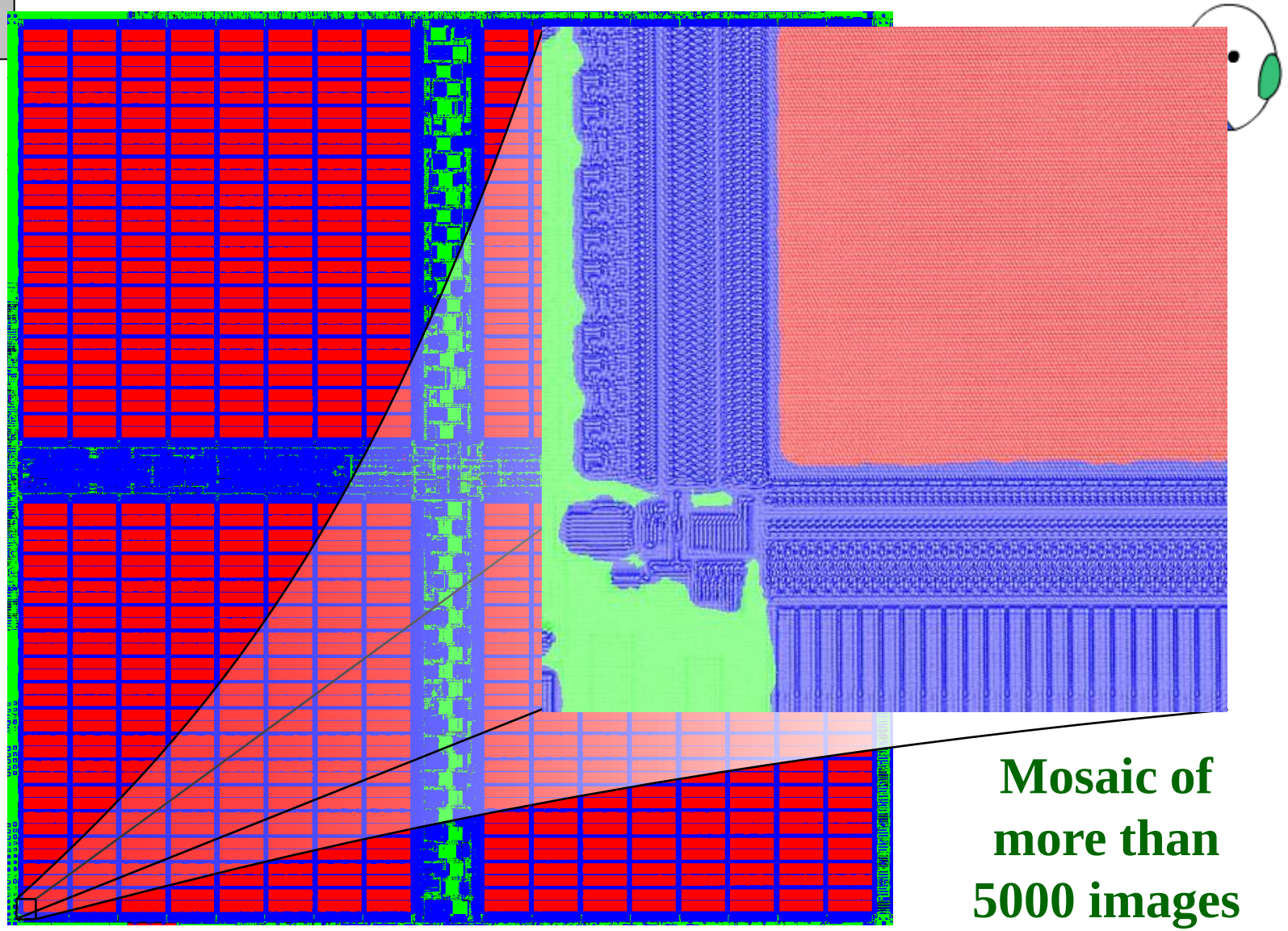
Set a threshold for each region, based upon the noise level in each region of the difference image

$$T_R = K_R.\sigma_R + \mu_R$$



Defect Mask

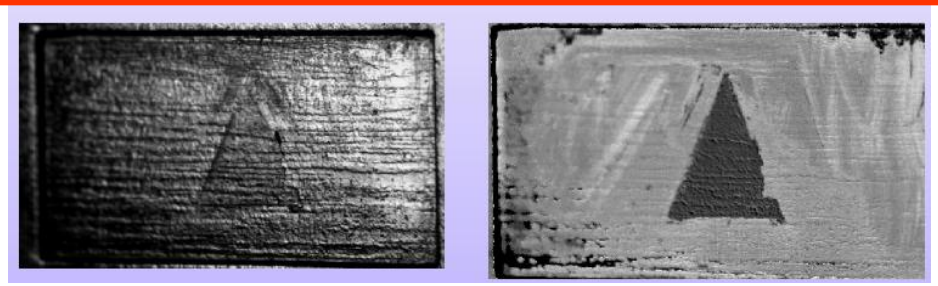
A local threshold is able to find the defect without generating false detections



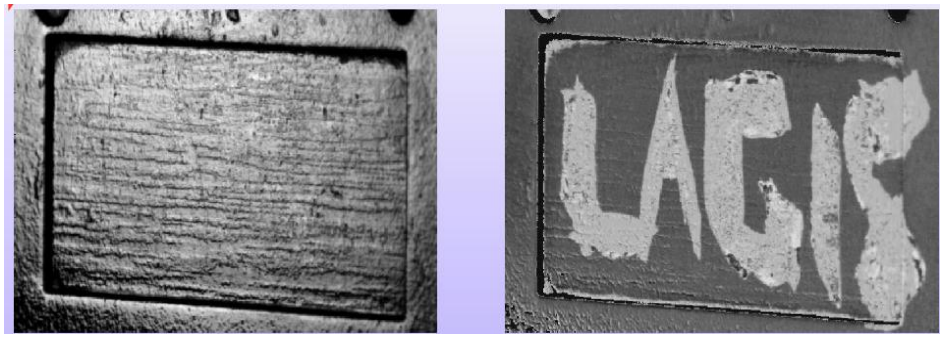
Mosaic of more than 5000 images

Polarimetry

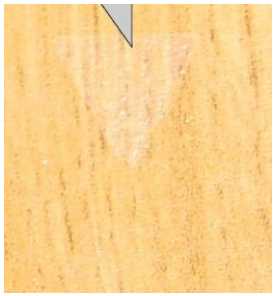
« Détection de l'inhomogénéité de la rugosité d'une surface par imagerie polarimétrique », P. Terrier, V. Devlaminck, Jourhéé d'Optique Non Conventionelle, EEA-SFO, Paris, Mars 2008.

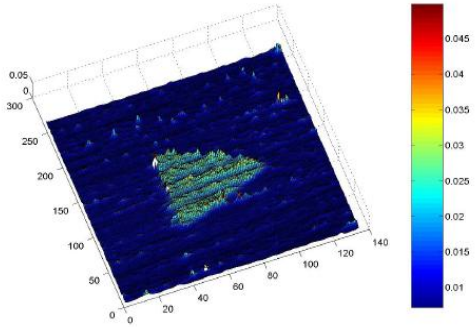


Metal/dielectrique



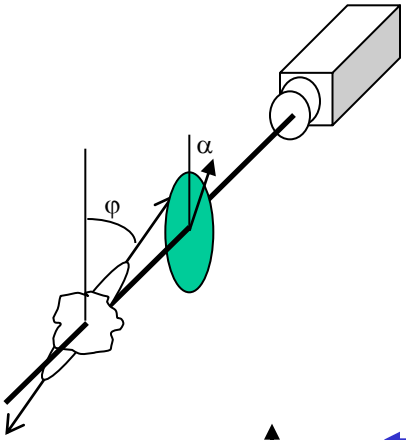
Varnish layer





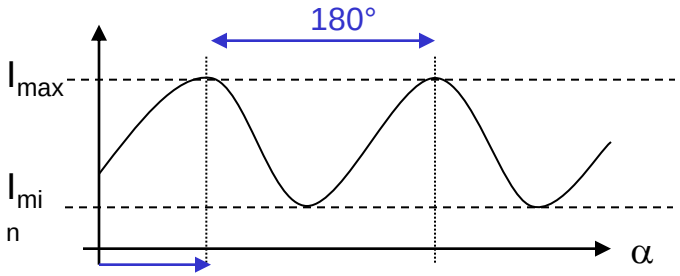
Physical principle: after reflection on a surface, an unpolarized light wave becomes partially linearly polarized.

- Polarization state of a light wave:
  - Goal: study the state of a partially linearly polarized light
    - No need to have a stokes polarimeter



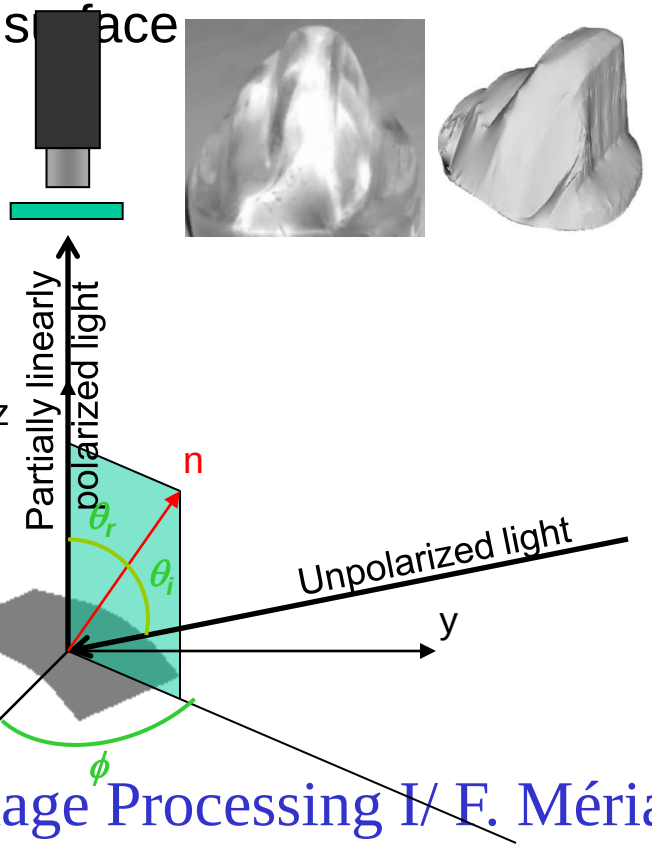
$$I_p(\alpha) = \frac{I_{max} - I_{min}}{2}\cos(2\alpha - 2\varphi) + \frac{I_{max} + I_{min}}{2}$$, of the camera

3 parameters:



- Magnitude of the light: $I = I_{max} + I_{min}$
- Angle of polarization: φ
- Degree of polarization: $\rho = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$

- Principle:
  - Unpolarized light
  - Reflective surface



. Saito, Y. Sato, K. Ikeuchi, and H. Kashiwagi, "Measurement of Surface Orientations of Transparent Objects by Use of Polarization in Highlight," J. Opt. Soc. Am. A, vol. 16, no. 9, pp. 2286-2293, Sept. 1999.
D. Miyazaki, M. Saito, Y. Sato, and K. Ikeuchi, "Determining Surface Orientations of Transparent Objects Based on Polarization Degrees in Visible and Infrared Wavelength," J. Opt. Soc. Am. A, vol. 19, no. 4, pp. 687-694, Apr. 2002.

$$\vec{n} \begin{vmatrix} p = \tan\theta_r \cos\phi \\ q = \tan\theta_r \sin\phi \\ 1 \end{vmatrix} \Rightarrow (\phi, \theta_r)\ ?$$

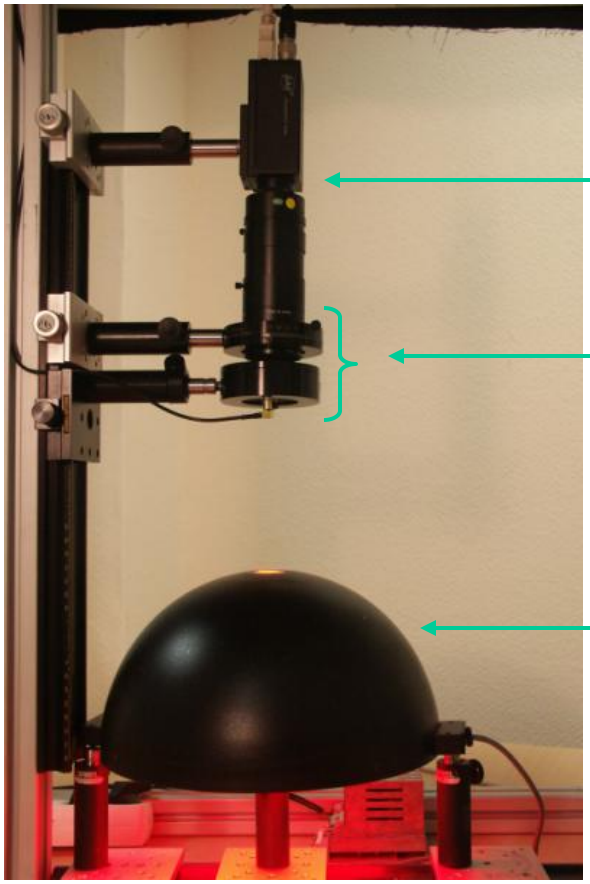
Fresnel reflection coefficients

- Angle of polarization φ
  $\Rightarrow \phi$
- Degree of polarization ρ
  $\Rightarrow \theta_r$

Polarimetry

- Experimental set up:

O. Morel, C. Stolz, F. Meriaudeau, P. Gorria, "Active Lighting Applied to 3D Reconstruction of Specular Metallic Surfaces by Polarization Imaging", Applied Optics, 45 (17), pp. 4062-4068, June 2006

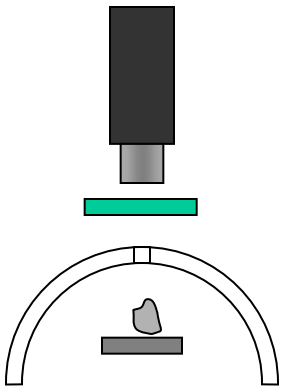


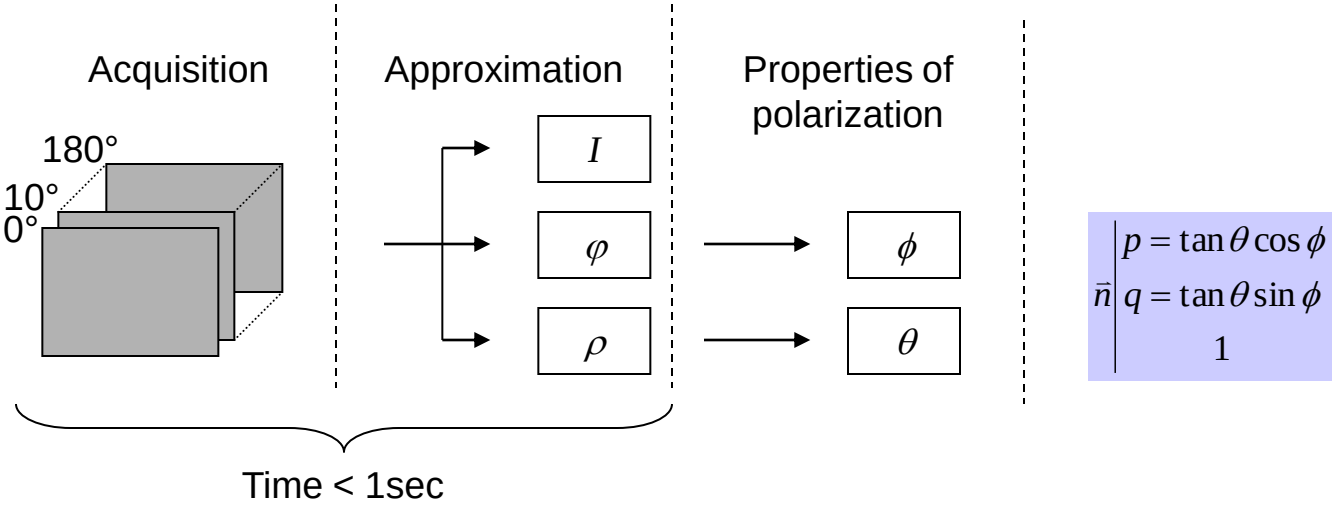
10 bits CCD Camera

Liquid crystal polarization rotator

Diffuse dome light

- Polarization images computing:





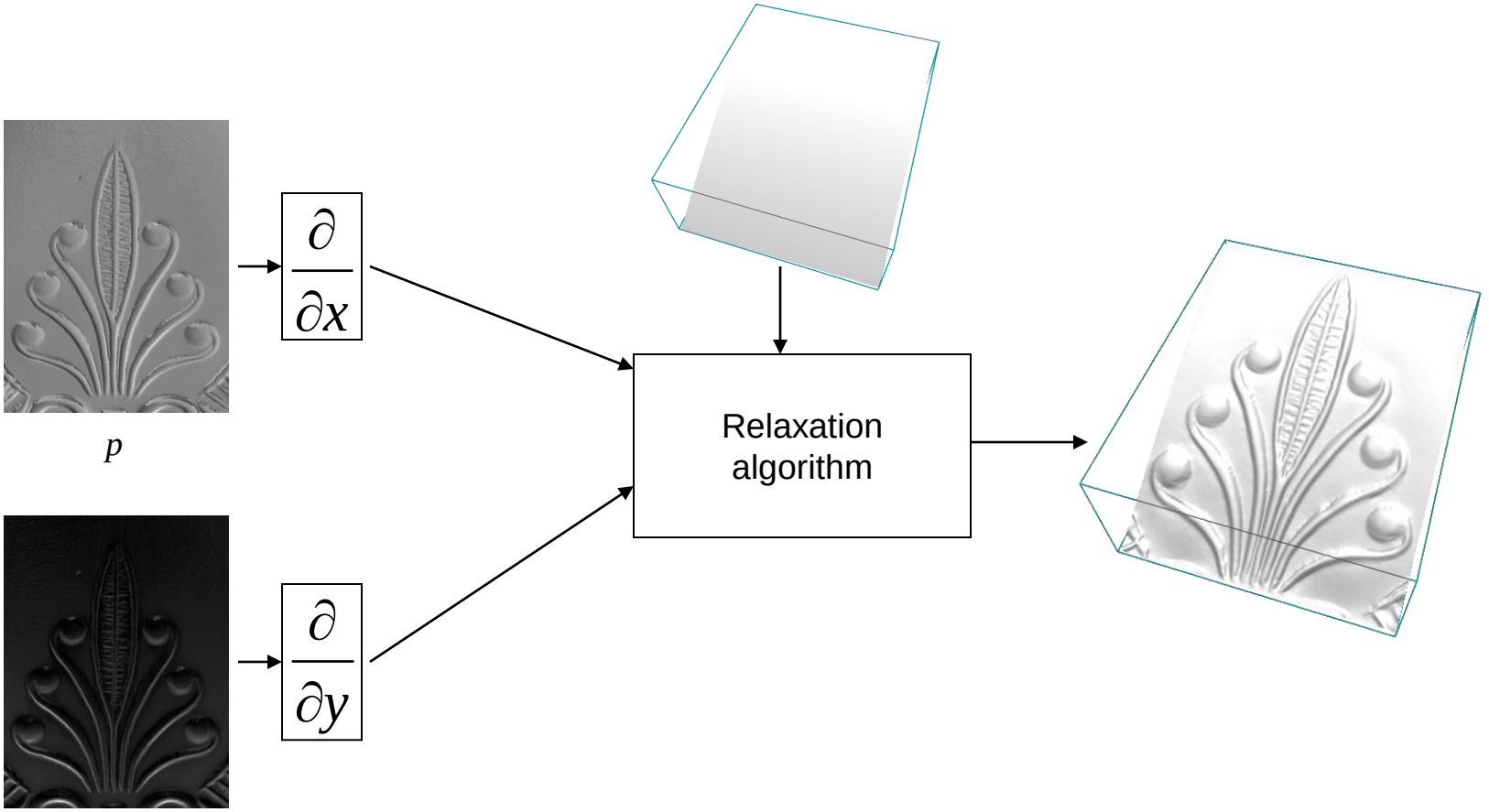
$$\vec{n}\begin{vmatrix} p = \tan\theta\cos\phi \\ q = \tan\theta\sin\phi \\ 1 \end{vmatrix}$$

I

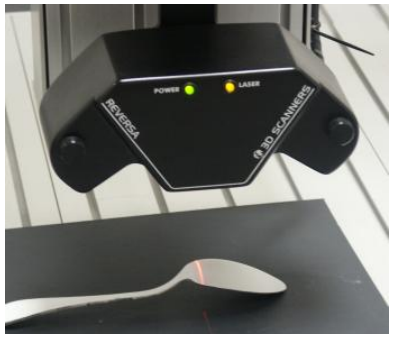
φ

ρ

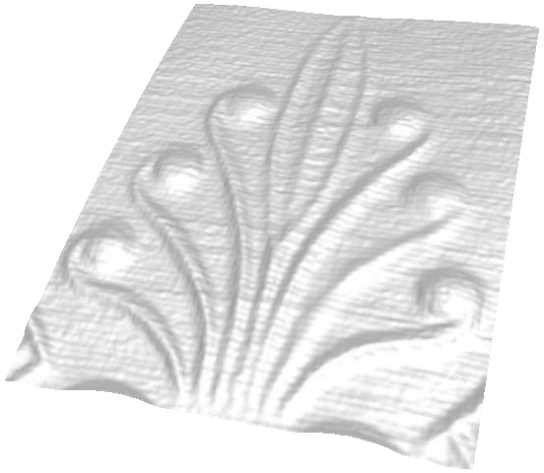
- 3D surface reconstruction:



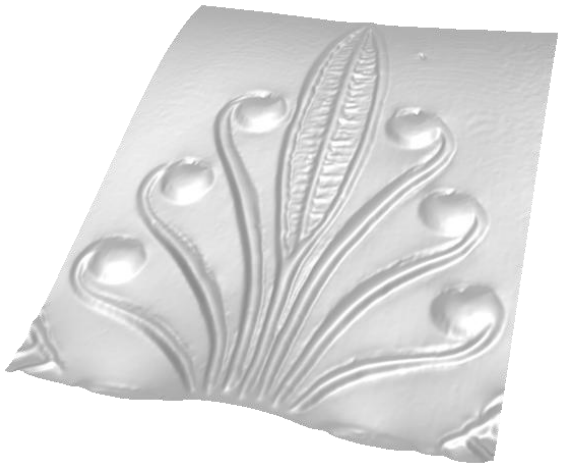
- Results:



Scanner Replica, x-y resolution: $50\mu m$ and z precision: $20\mu m$

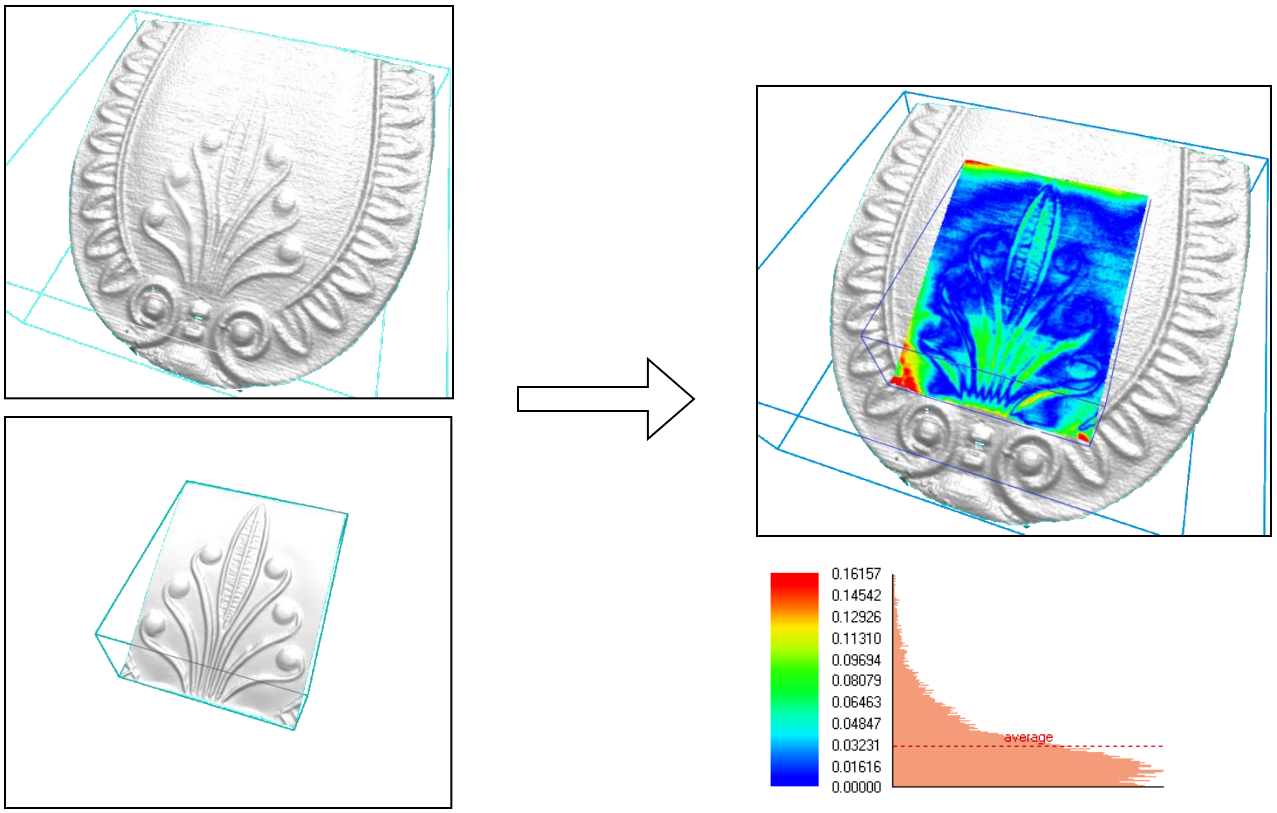


Surface from the 3D Scanner

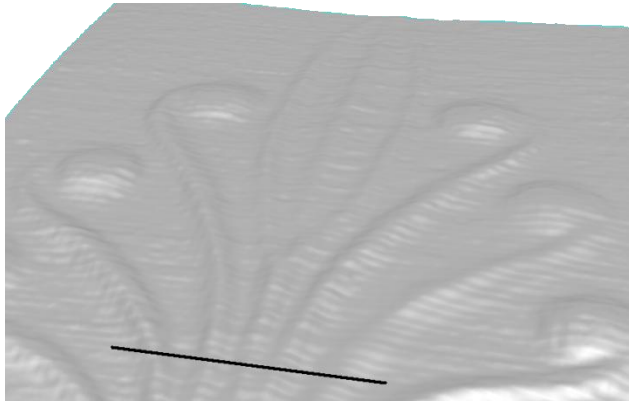


Surface from our method

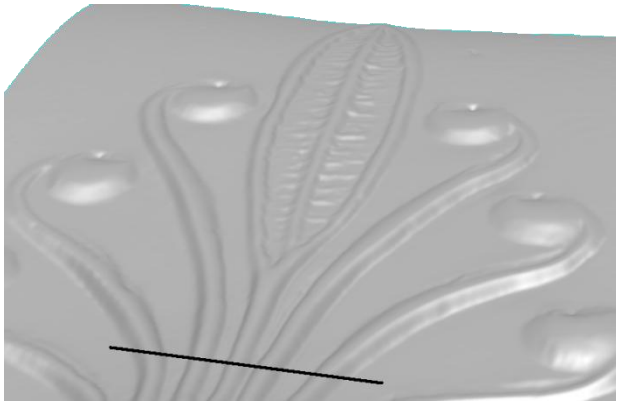
- Mean deviation:



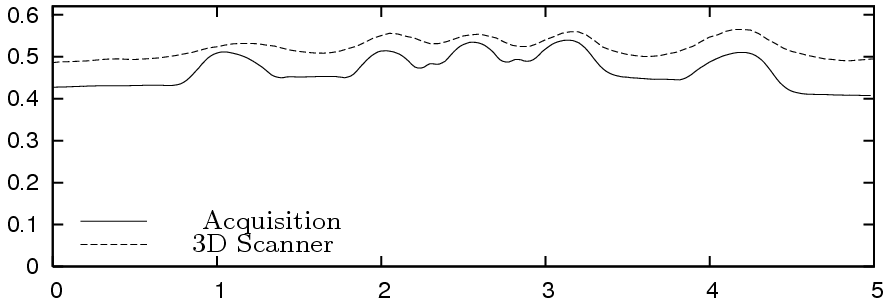
- Cross-section:



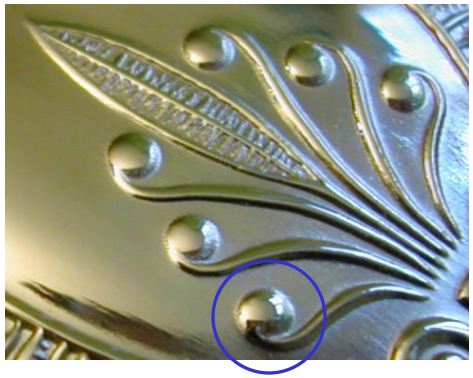
3D Scanner

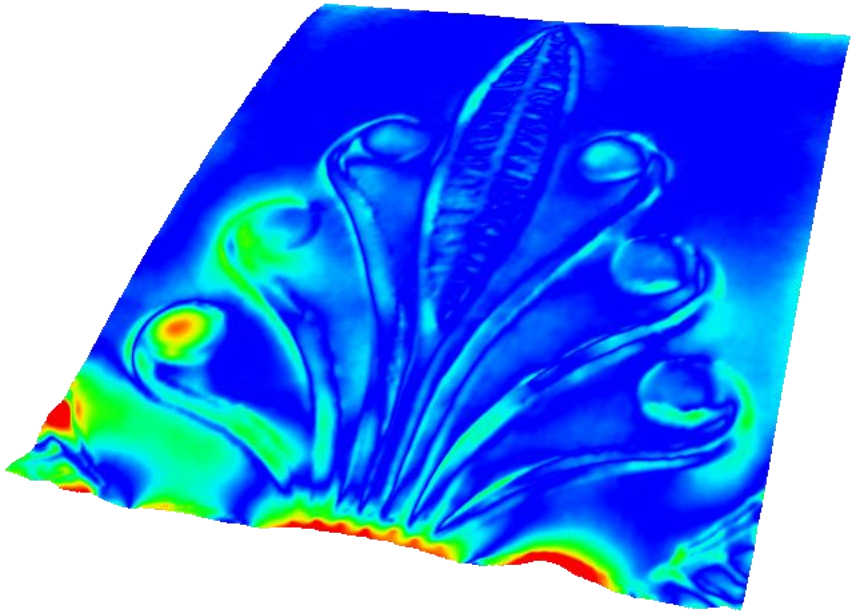


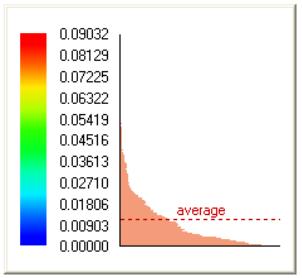
Acquisition

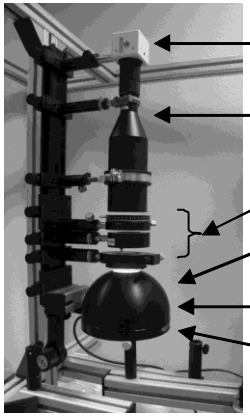


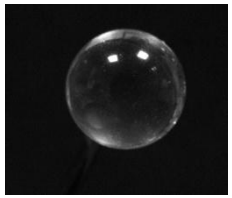
- Shape defect detection

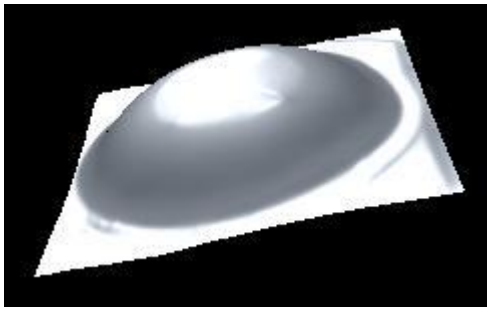


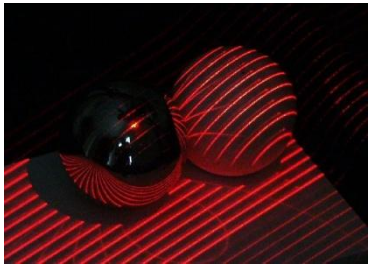


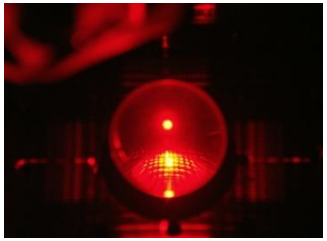


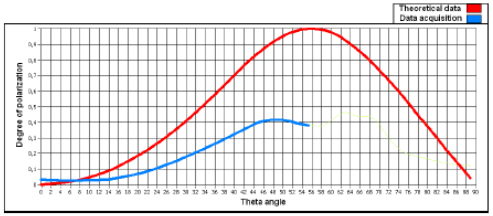




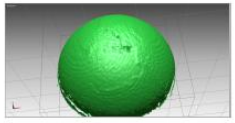




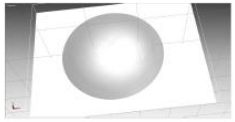




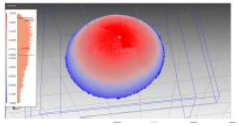
- Scanner Laser.
  - adding opaque coating

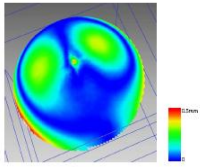


- Polarization system.
  - reconstruction by normals field integration



- Deviation.
  - ±1.5 mm





M. ferraton, C. Stolz, F. Meriaudeau, Optics Express, 2009.

C. Stolz, M. Ferraton and F. Meriaudeau, Optics Letters, October 2012.

Quantitative Imaging of Subcutaneous Veins with Multispectral Illumination and 3D Modeling

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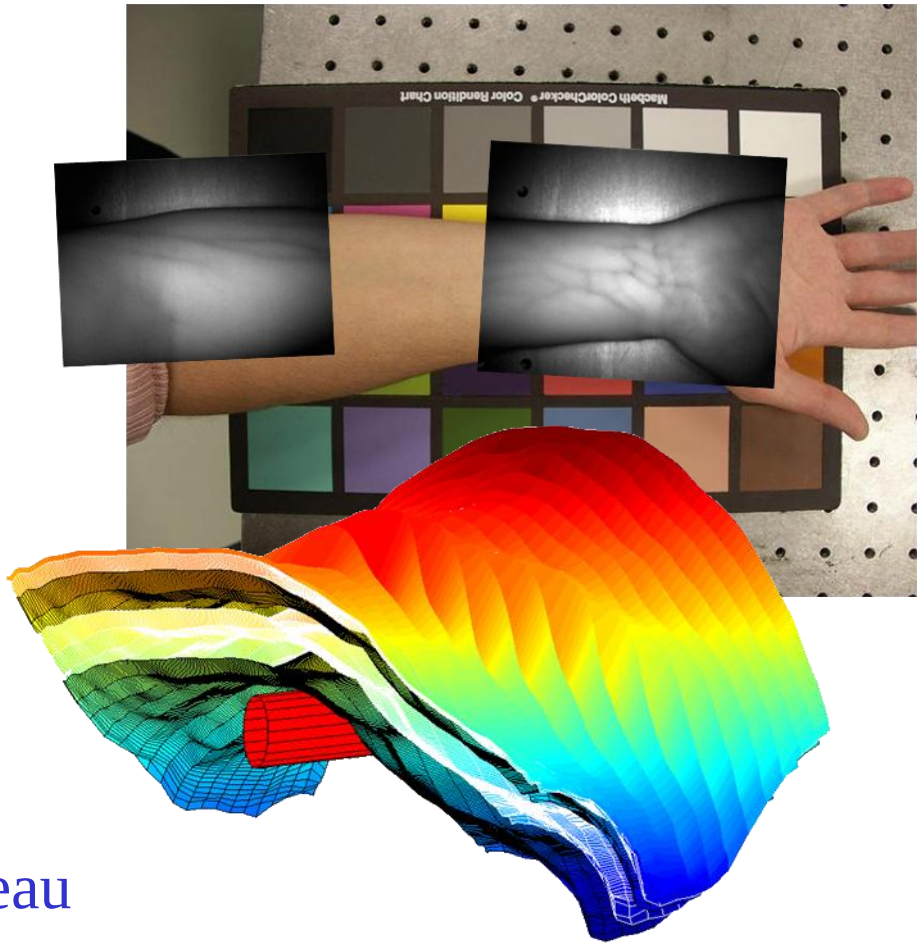


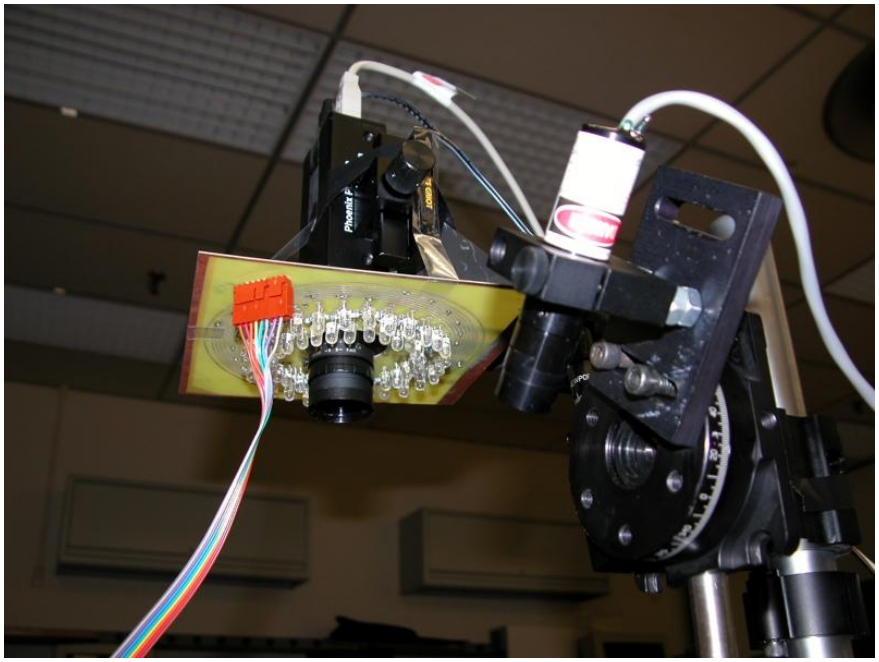
Image Processing I/ F. Mériaudeau

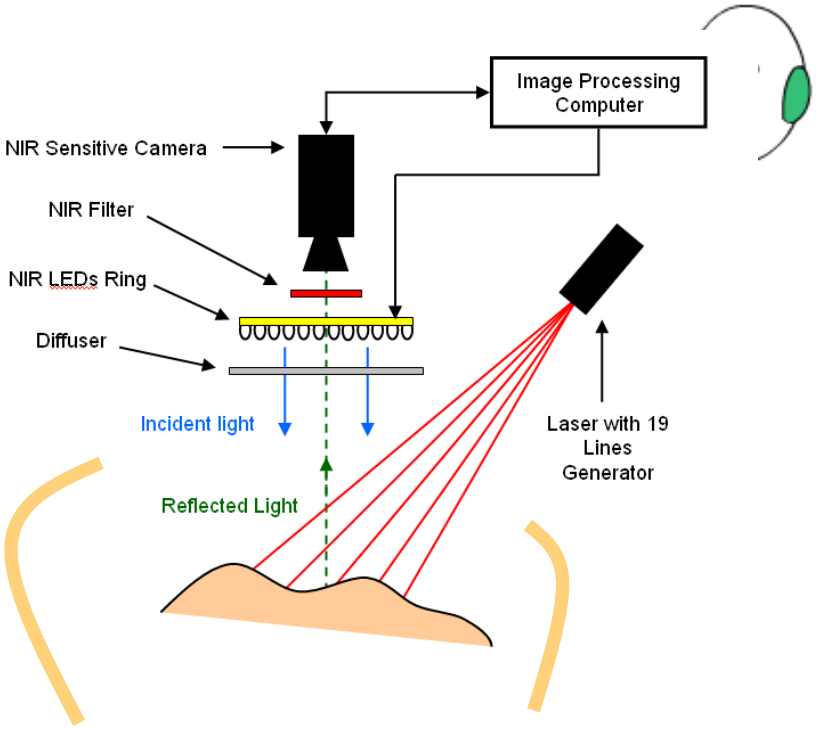
Hardware:

– NIR sensitive CMOS camera + NIR high pass filter

– NIR ring of LEDs at 740nm

– Laser and line generator module for 3D triangulation



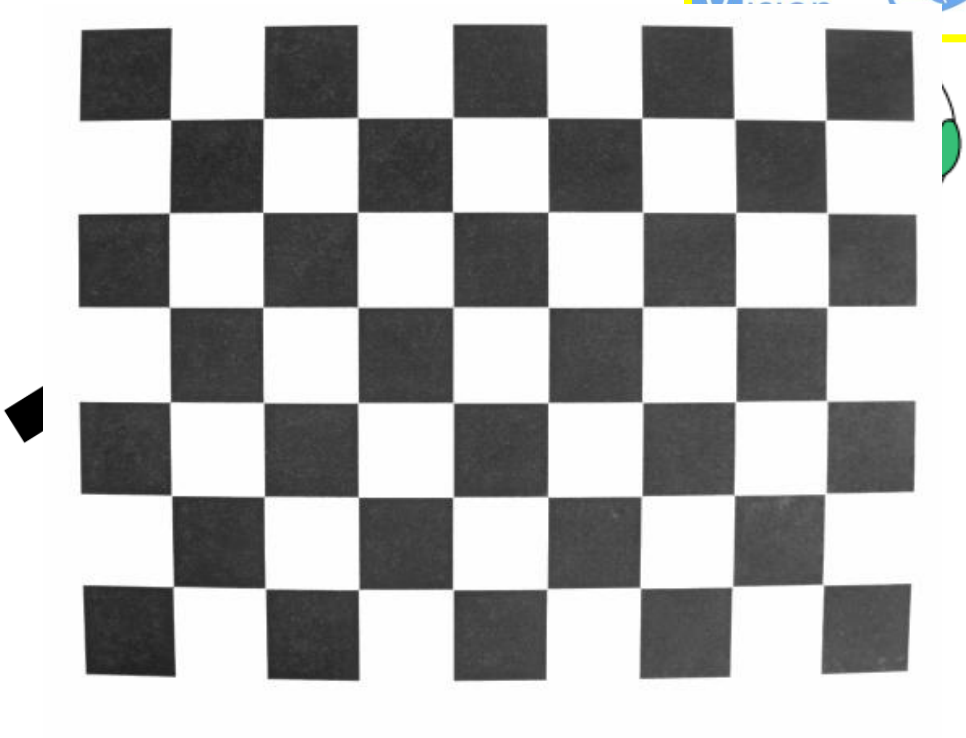


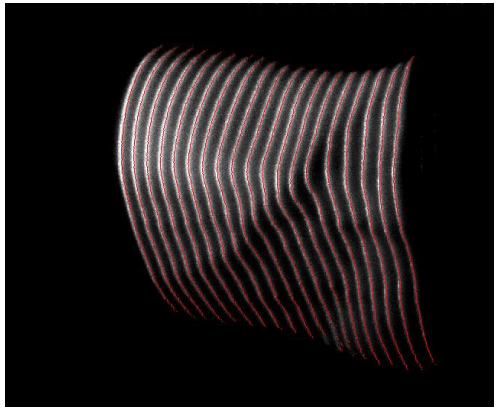
NIR image of the surface

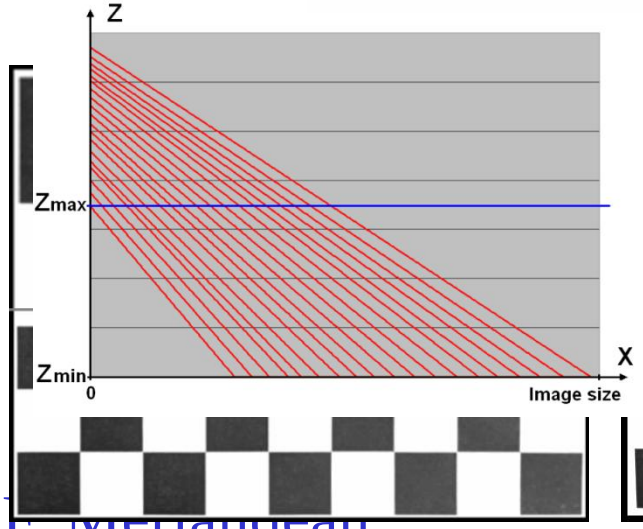
Topology measured w/ structured light

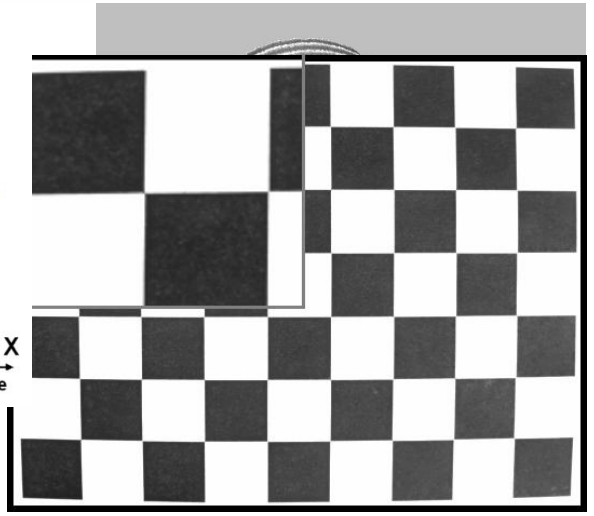
Calibration

- Distortion correction
  - Bouguet (2008), Matlab Toolbox
  - OpenCV (2008)
- 3D modeling
  - Besl (1989)
- Reflectance
  - Pan (2003)



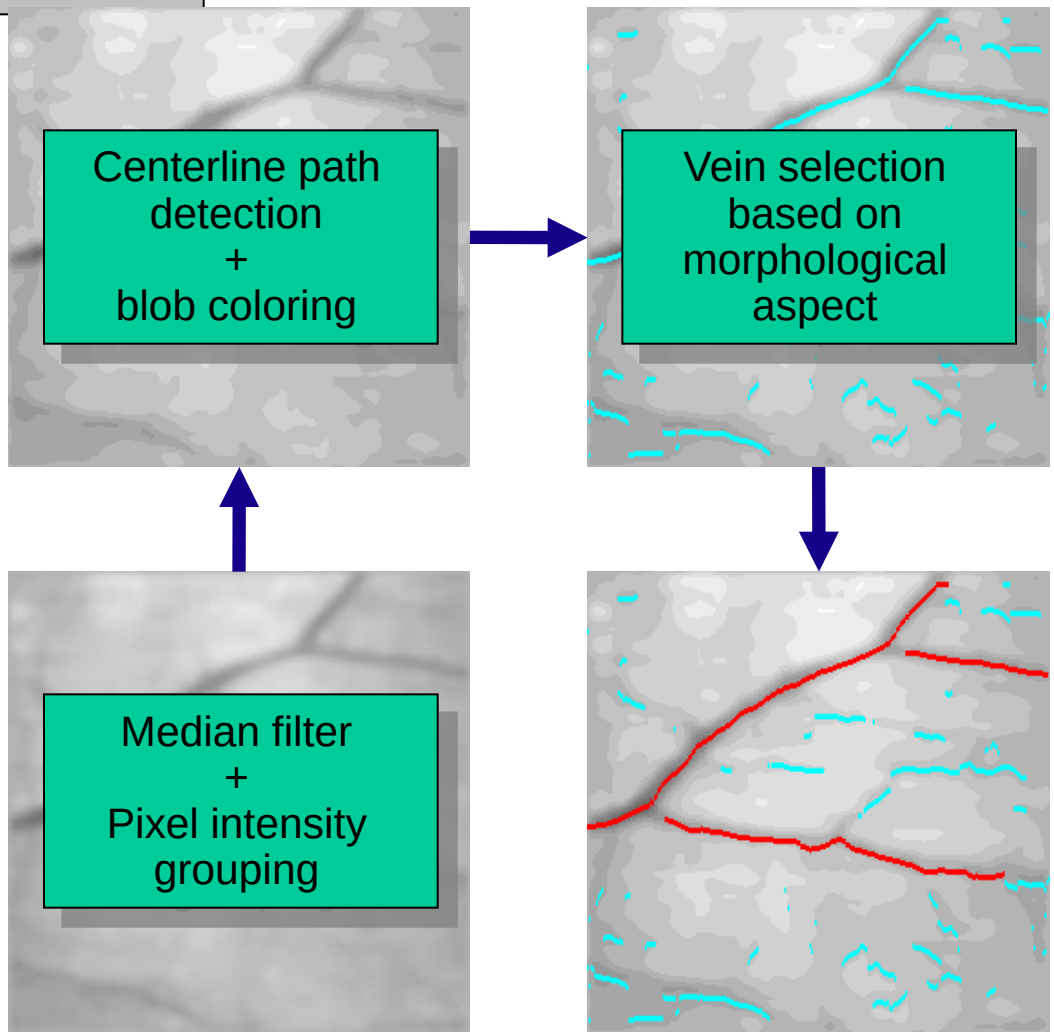


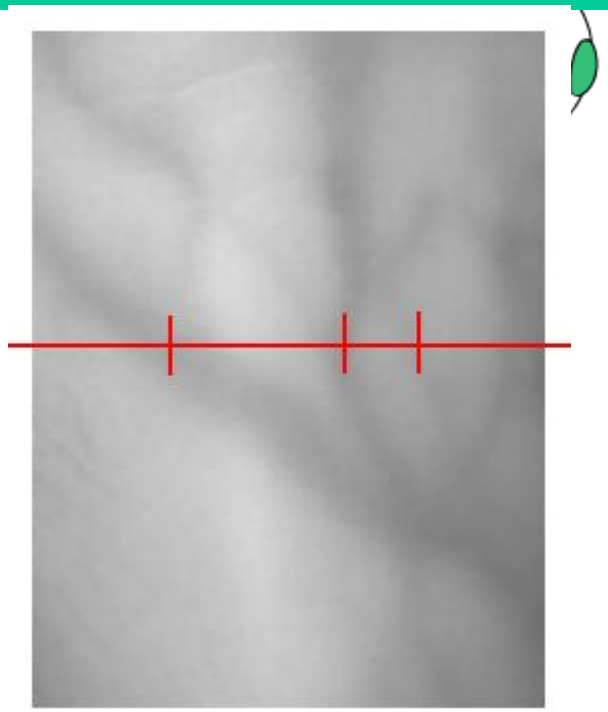


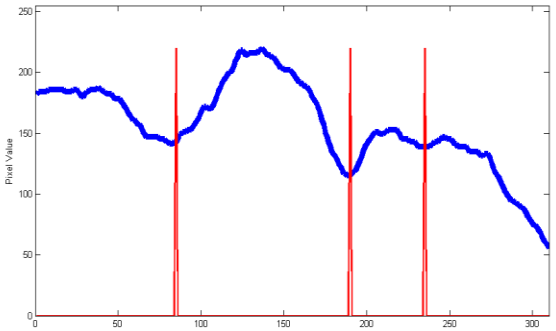


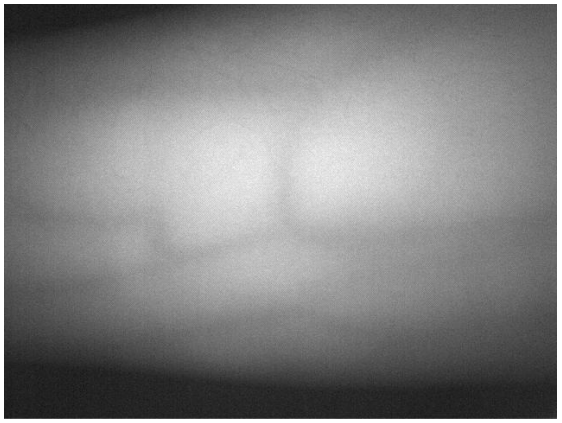
Videos of what can be seen in the visible range of light (left) and in the near infrared range (right). Example of a Caucasian male.

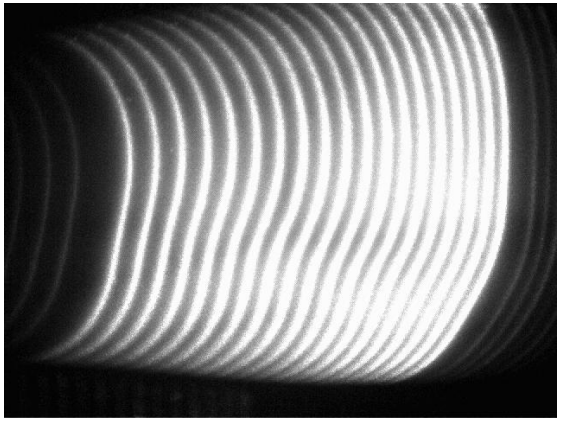
Vein Detection and Selection

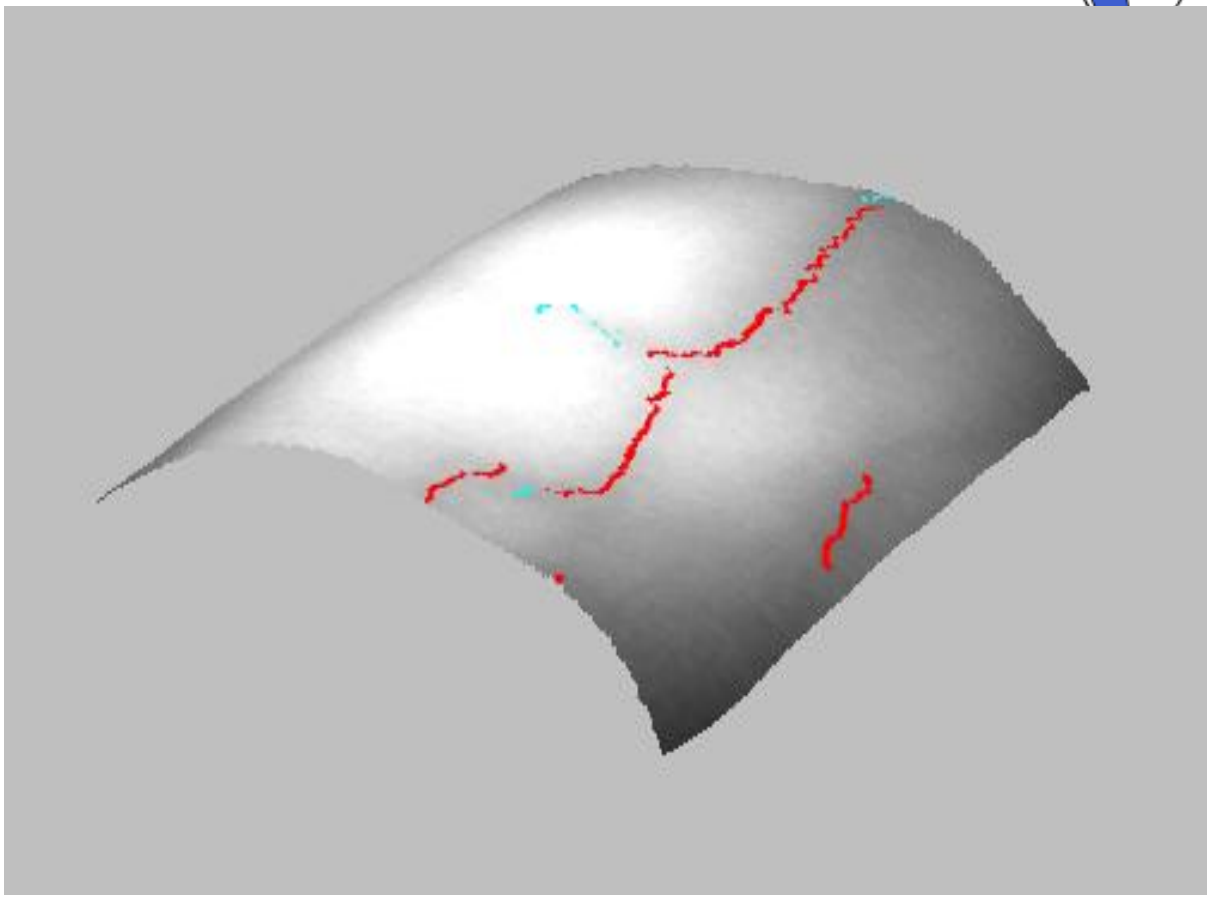


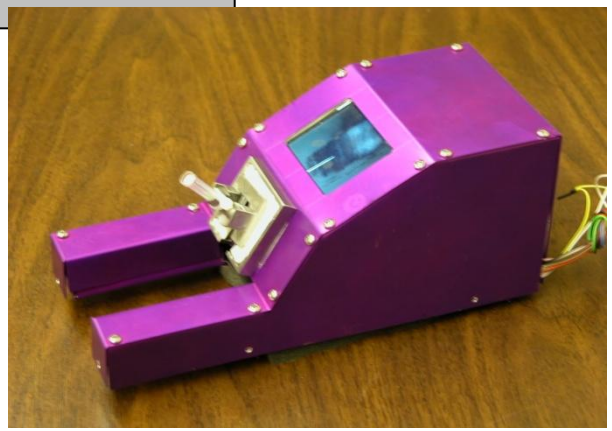


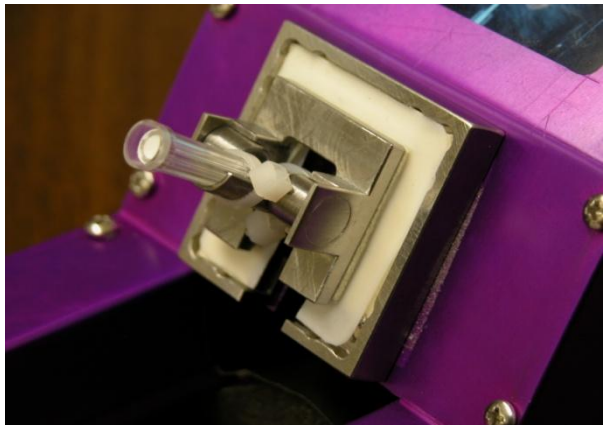












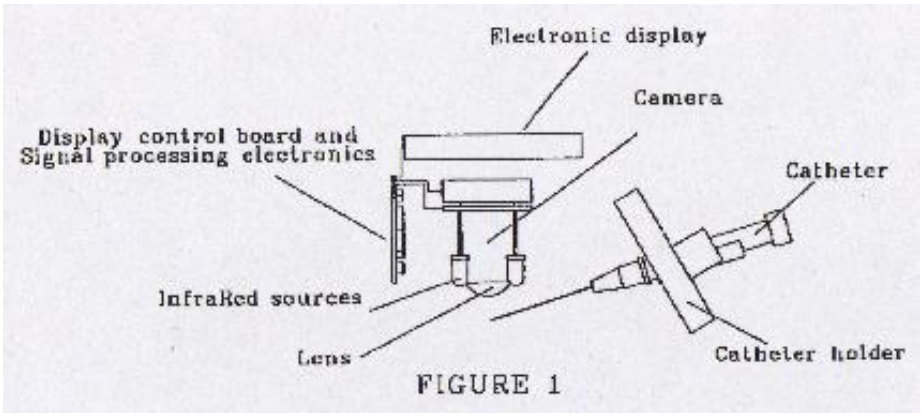
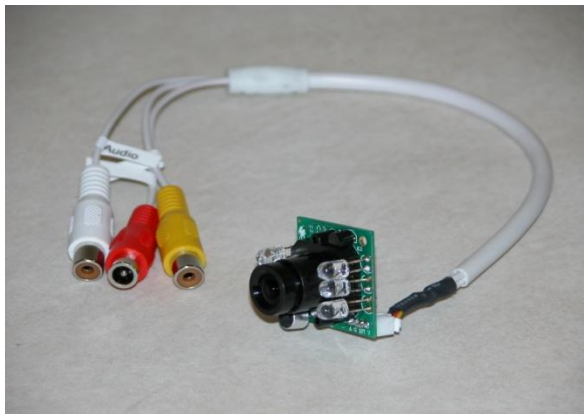


FIGURE 1



"***Invention disclosure: Self-contained Compact Venous Imager for Catheter Insertion***", Thomas FERRELL, David HEDDEN, Rubye H. FARAHI, Vincent PAQUIT, Fabrice MERIAUDEAU, University of Tennessee - Knoxville, USA, 22 December 2005.