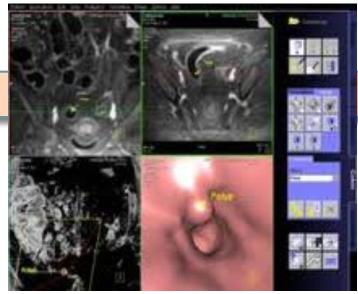
Contributions to Image Processing For Medical Image Analysis

From Computer-Aided-Diagnosis to Embedded Systems For *In Situ* Diagnosis

YESTERDAY

TODAY



TOMORROW

Aymeric Histace
HDR Defense

28-11-2014

Roadmap

- **General Presentation**
  - *Who am I?*

- **Research Activities**
  - *What are my contributions?*

- **Perspectives**
  - *What is my research project?*

Roadmap

- <u>**General Presentation**</u>
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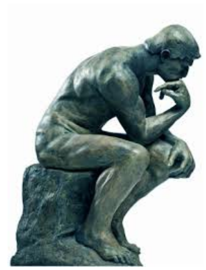


CV

Certificate of Birth

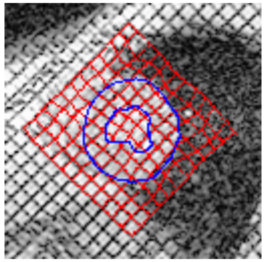
- 4th Sept. 1977, Lyon
- ***Parents:*** B. Histace and D. Ferreyre-Histace

1977

2001

2001

2004



Master of Engineering

- EIGSI La Rochelle
- Industrial Systems Engineering

MSc

- Signal and Image in Biology and Medecine
- University of Angers
- *Wavelet Compression of Thoravision images (X)*

PhD

- *"Detection and tracking of structure in image sequences: application to tagged cardiac MR images"*
- ***Mention:*** "Très Honorable avec les félicitations du jury"
- University of Angers

Professional Experience

2001 | *2004* | *2006* | ***2013*** *28/11/14*

PhD, "Moniteur" → Lecturer → Associate Professor (UCP, ETIS) ***PES***

TODAY

UNIVERSITÉ de Cergy-Pontoise

IUT CERGY PONTOISE

Research

- Member of ASTRE team
- **In charge of the "Embedded Systems for Health" axis**
- Elected Member of the Laboratory Council

Administrative

- **Co-Head** of MSc MADOCS (Methods for Complexe Data Analysis)

Teaching

- Institute of Technology
- Dpt of Electrical Engineering and Industrial Informatic (GEII)
- Member of the "Commission de choix"

Teaching and Responsabilities

2004 Sept 2006 *IUT GEII* 28/112014

Electrical Engineering, Energy, Control (L1, L2+L2 app, L3P)

Lecturer, University of Angers

Sept 2007 *MSc*

Image Processing (Basic, Variationnal approach, Statistical Learning)

Sept 2010 *ENSEA*

Signal Processing for ECG (ENSEA)

Sept 2013

Electronics for Biosensors *CMI*

L2 app (08-14):
Industrial relationships and pedagogical coordination

MSc SIC (11-14):
Pedagogical Coordination « Multimedia Indexing and Data Mining »

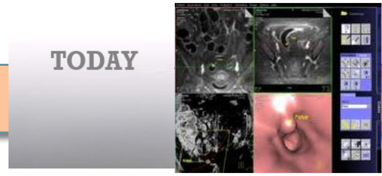
L3P Instru. (07-08)

MSc MADOCS

…L3P ESH

2007 2008 2011 2012 >2014

Research Overview



Step 1

Next Step

<2001 — 2014

Image Processing: Restoration/Segmentation (2006)

→ **Variational approach**

2010 — **Pattern Detection and Recognition**

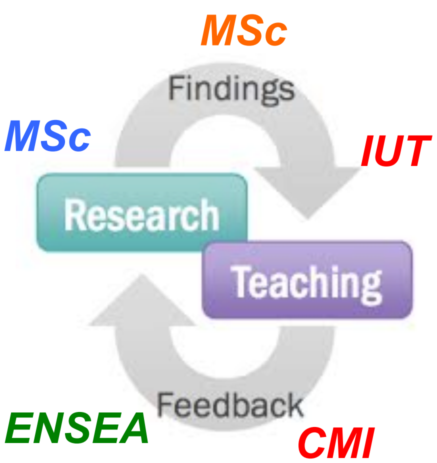
→ **Statistical Learning**

2011 — **Signal Processing**

→ **Physiological data analysis**

2012 — **Electronics**

→ **A. Algo. Archi. Sensors**



Involvement on Projects

Leader

TERAFS (09-11) (International)
Laser Confocal Imaging of Cells for Study of Radiotherapy Insult

SIMBAD (08-…) (Regional, Local)
Biomedical Image Segmentation for CAD

Cyclope (11-...) (Regional, Local; Industrial)
Smart Videoendoscopy for CRC early-diagnosis

TRAPIL (10-14) (Industrial)
Automatic Detection of Default in Pipelines Using Ultrasonic Images

Legend

- *International (EPSRC, AUF)*
- *National (CNRS)*
- *Regional, Local (FUI, ENSEA, UCP)*
- *Industrial (SATT, CIFRE, Subcontract)*

Technological Transfer

Partner

ECSON (07-09) (International)
Oncology Network of Competences

FibroSES, iFib (2013-…) (National; Regional, Local)
In Vivo and In Vitro Electric Characterization of Fibrosis Induced by Electronic Implant

SmartEEG (13-…) (Regional, Local; Industrial)
Smart Mobile System for ExG Signals Acquisition and Analysis

PAPILLON (14-…) (International; Industrial)
On-line Characterization of Dypters using Image Processing

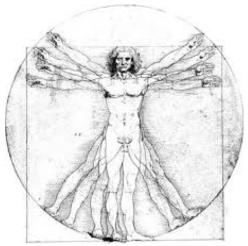
Collaborations (National)

8 Labs

2 Hospitals

3 Companies

6 Projects



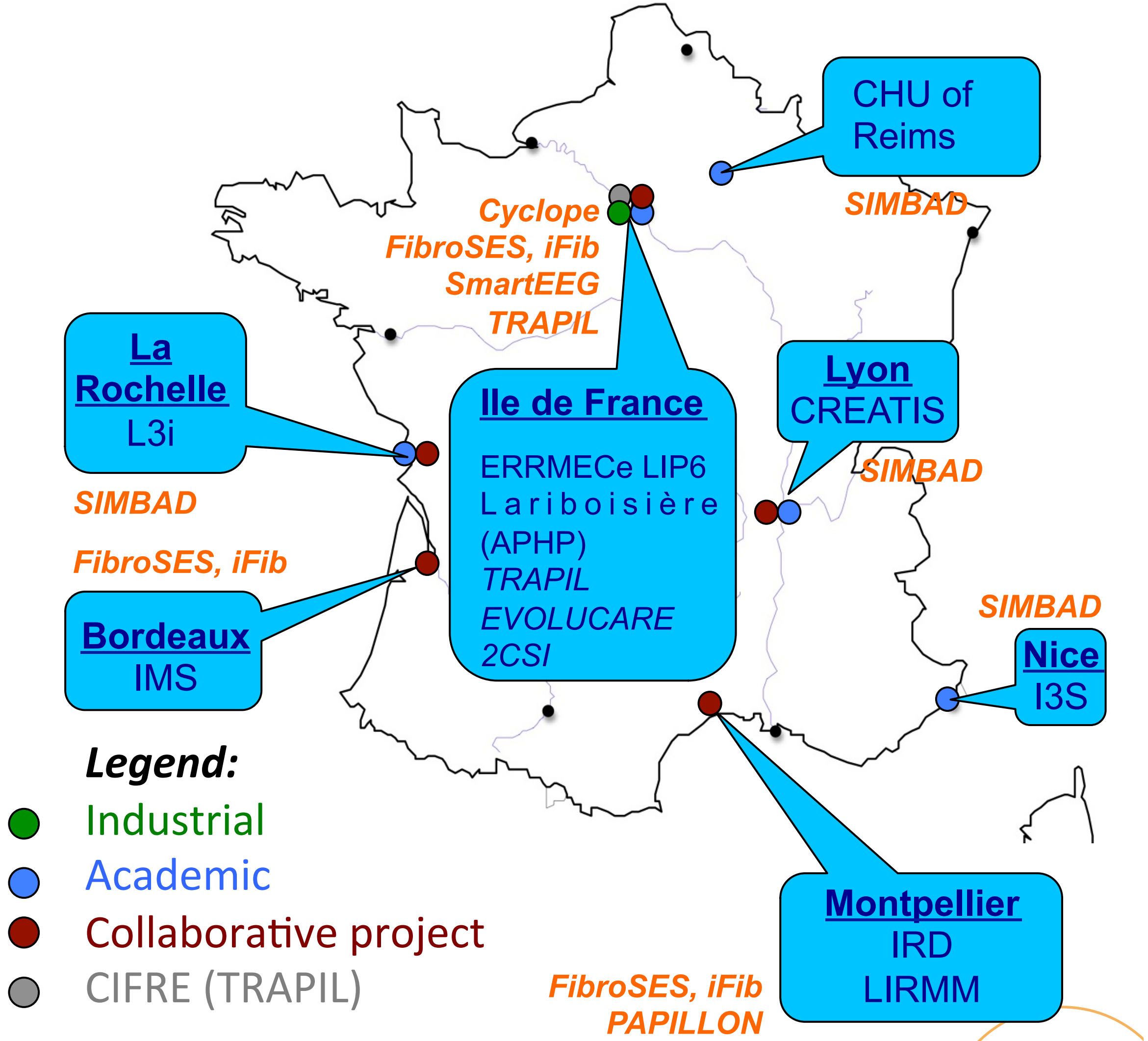
GDR ISIS/SOC-SIP:

- **Sensors and SIP (2012)**
- **Statistical and Variationnal approaches in Medical Image Analysis (2013)**

BioniCamp 2012 (DEFISENS)

DCIS'12 (Special Session)

GEODIFF Workshop (2013)



Collaborations (International)

3 Countries

4 Universities

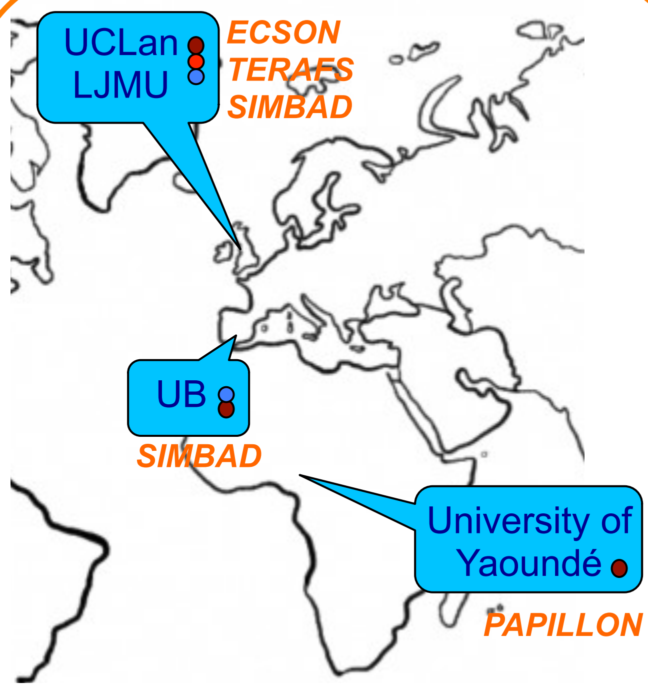
4 Projects

- ECSON
- TERAFS
- SIMBAD
- PAPILLON

3 Student Exchanges

2 Special Sessions
(ECSMIO10, ICIP11)

1 Workshop
(BioSan14)



1 joint PhD

Legend:
- Collaborative projects
- Guest
- Host

Supervising

4 PhD students: 120%+80%

- *2 Defended (11/2013, 06/2014)*
- *2 just started*
  - *- Cyclope (50%, 2014-2017)*
  - *- PAPILLON (30%, Yaounde, 2014-2017)*

7 MSc students: 400%

- *MSc SIC*
- *MSc ESA), SESI (UPMC)*

Others:

- *1 Post-doc (50%-1 year)*
- *1 Research Engineer (50%)*
- *Several Initiation-to-Research projects*

Roadmap

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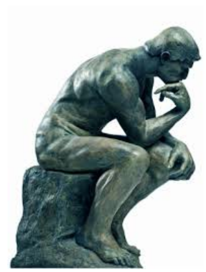
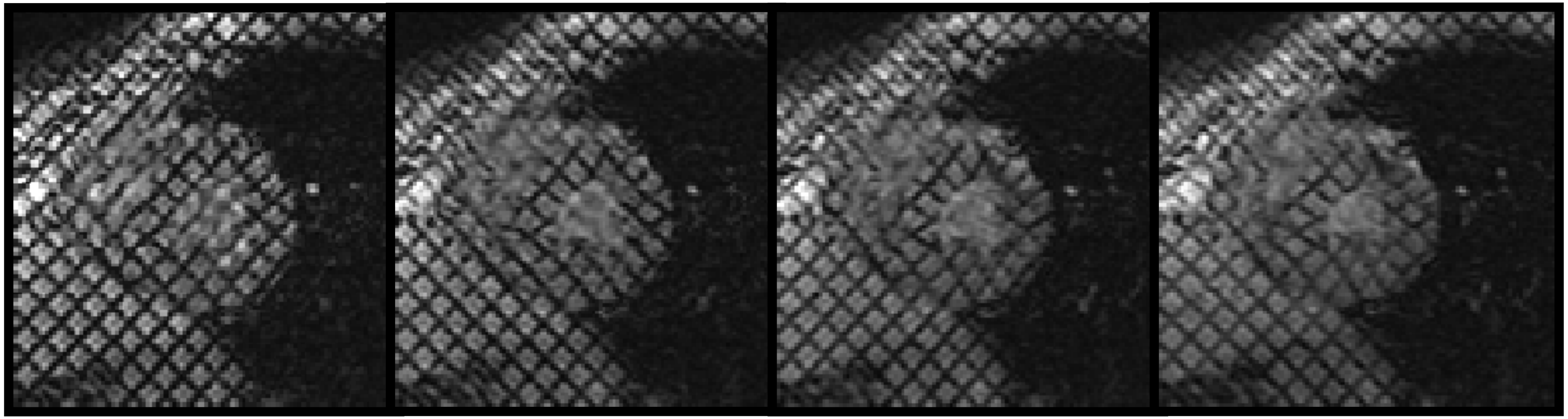


PhD

(Tagged Cardiac MRI)



Quantification of LV contraction

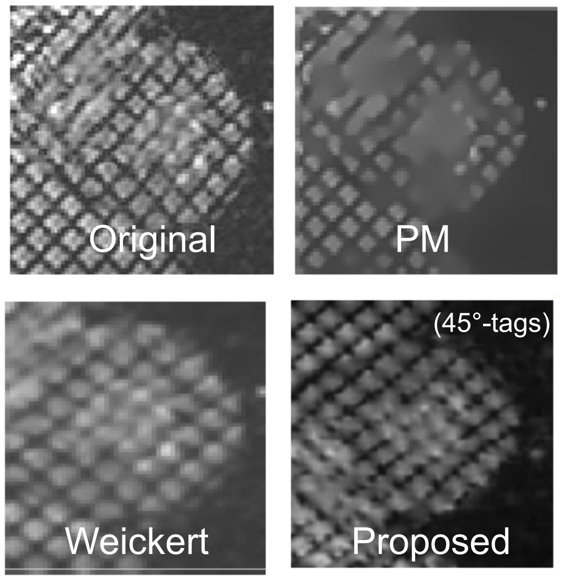
PhD

(Tagged Cardiac MRI)

PDE-based Image Restoration

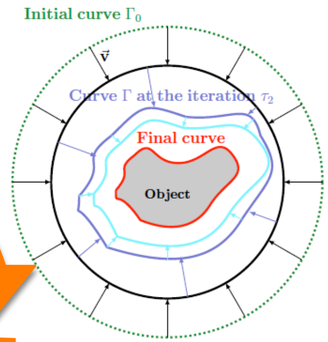
$$\frac{\partial I}{\partial t} = (\nabla - A).(\nabla - A)I$$

A is a prior vector field taking into account the gradient orientation to restore or not

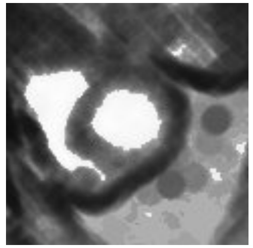


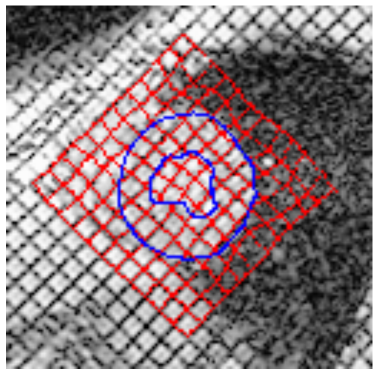
Variational Approach

Active Contour Segmentation

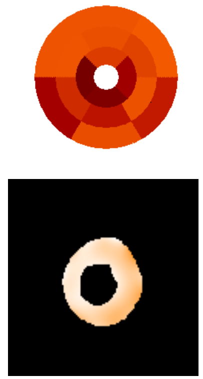


Texture-based approach





Movement Estimation



Quantification

Main Questions

2005 — 28/11/2014

From CAD… …to in situ Diagnosis

Question 1

Can we profit in an original way from the **non-linearity** of the usual **divergence-based** PDE?

$$\frac{\partial I}{\partial t} = div\left(g\left(\|\nabla I\|\right)\nabla I\right)$$

Question 2

Can we profit from the prior knowledge we have in medical image analysis (shape, texture, noise, etc.)?

Question 3

Can we propose **CAD methods compatible with embedding constraints**?

CAD: Main Contributions

Stochastic Resonance Non-Linear PDE

$$\frac{\partial I}{\partial t} = div\left(g_\eta\left(\|\nabla I\|\right)\nabla I\right)$$

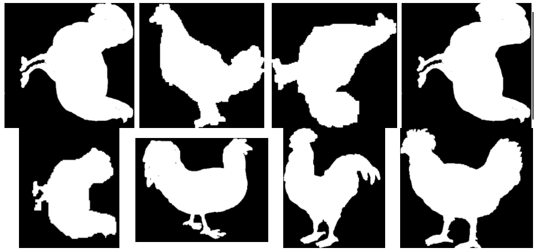
$g_\eta(u) = g(u + \eta(x,y)) \longrightarrow$ Gaussian Noise

Coll. CREATIS
David Rousseau

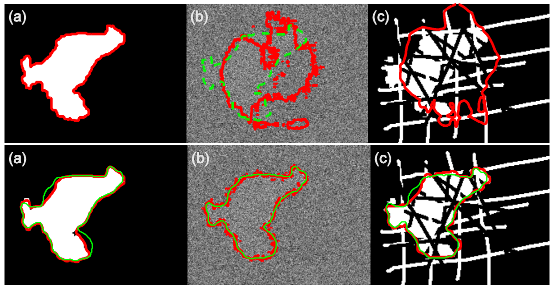
Active Contour With Shape Prior

$E = E_{prior} + E_{image} \rightarrow$ ChanVese

Shape learning



Shape descriptor (Legendre)

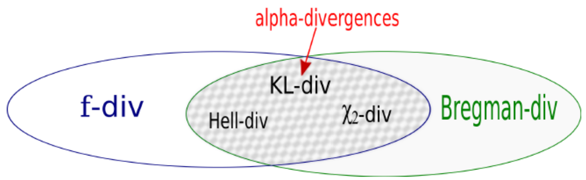


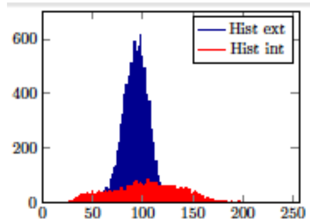
***Up** : Foulonneau, **Down** : Our Approach*

Coll. UCLan
B. Matuszewski

Alpha-Divergence Based Active Contour

$E = E_{histogram} + E_{regularisation}$





Joint Optimization:
-Segmentation Process
-Metric of the divergence

Coll. I3S
PhD Leila Meziou

CAD: Main Contributions

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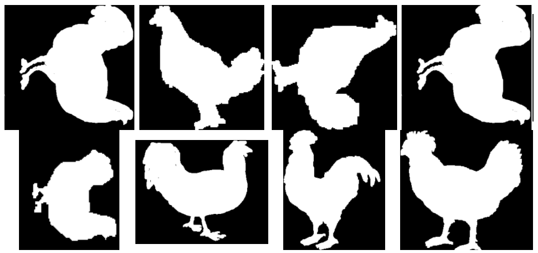

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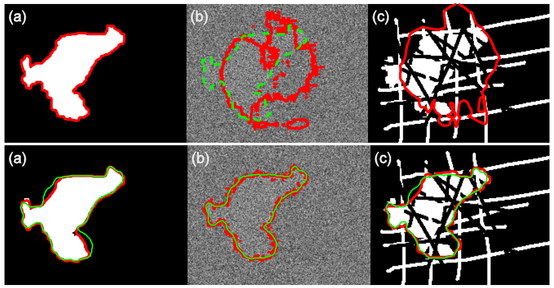

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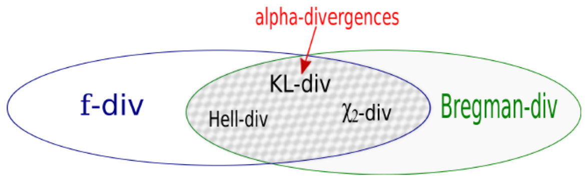
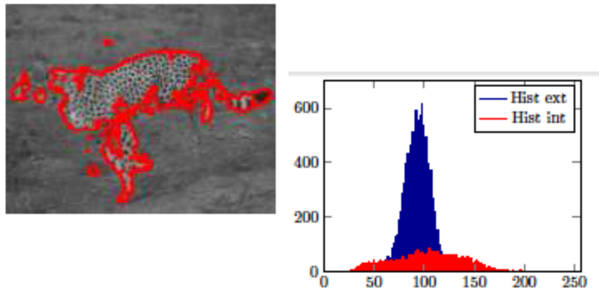




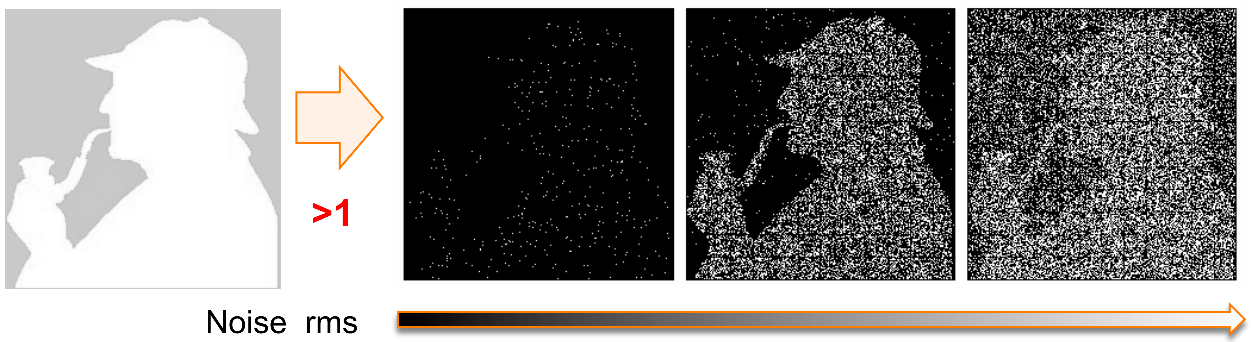
Joint Optimization:
-Segmentation Process
-Metric of the divergence

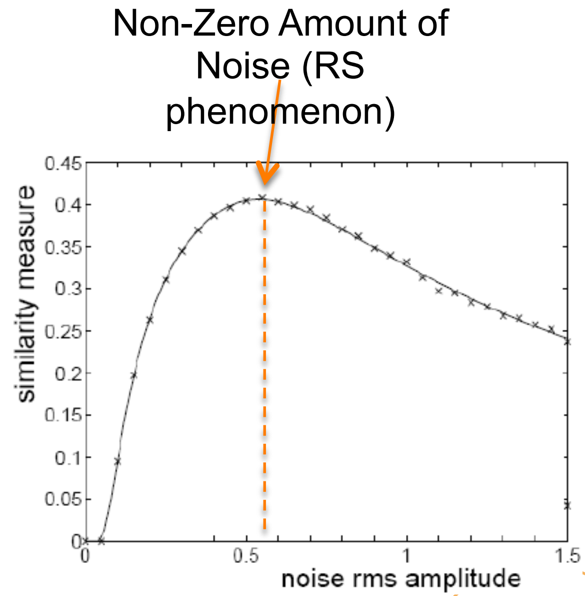
Coll. I3S
PhD Leila Meziou

Useful Noise Effect

Stochastic Resonance

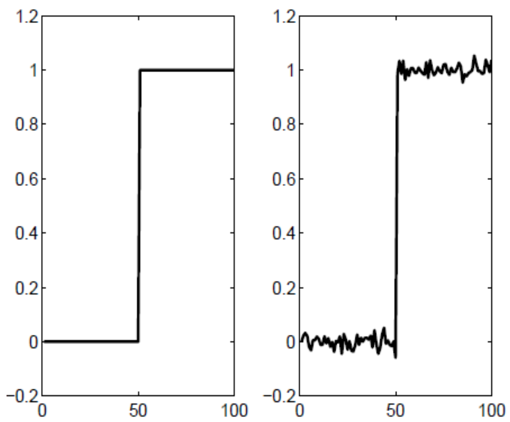
Illustration: **Binary Transmission Aided by Noise**





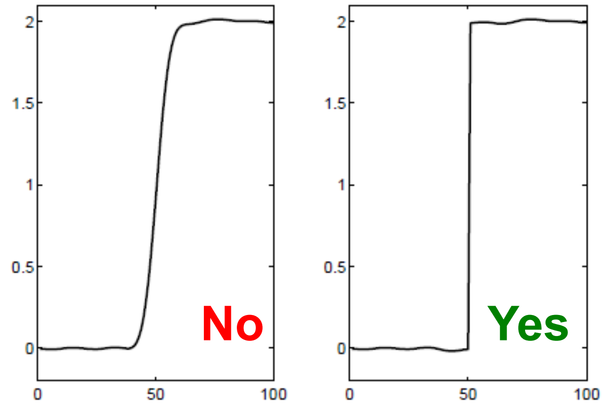
Useful Noise Effect

Application to Image Restoration



Objectives :

- Noise reduction
- Contour integrity



Method

$$\begin{cases} I(x,y,0) = I_0 \\ \dfrac{\partial I}{\partial t} = div\left(g_\eta\left(\|\nabla I\|\right)\nabla I\right) \end{cases}$$

with

$$g_\eta(u) = g(u + \eta(x,y))$$

Stochastic Variant of Perona-Malik process

- ***η*** a noise assumed independent and identically distributed (rms amplitude σ_η)
- ***g*** a decreasing monotonic function

Useful Noise Effect

Experiment 1

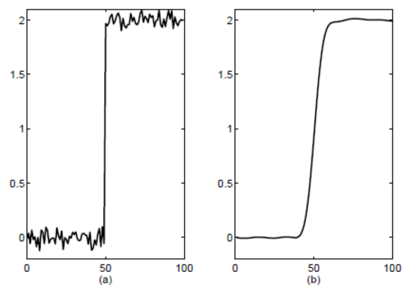
$$g_\eta(u) = g(u + \eta(x))$$

with

$$g(s) = \begin{cases} 1 \text{ if } s \geq k \\ 0 \text{ if } s \prec k \end{cases}$$

Hard-threshold

We consider a case where *k* parameter is badly tuned regarding PM approach :

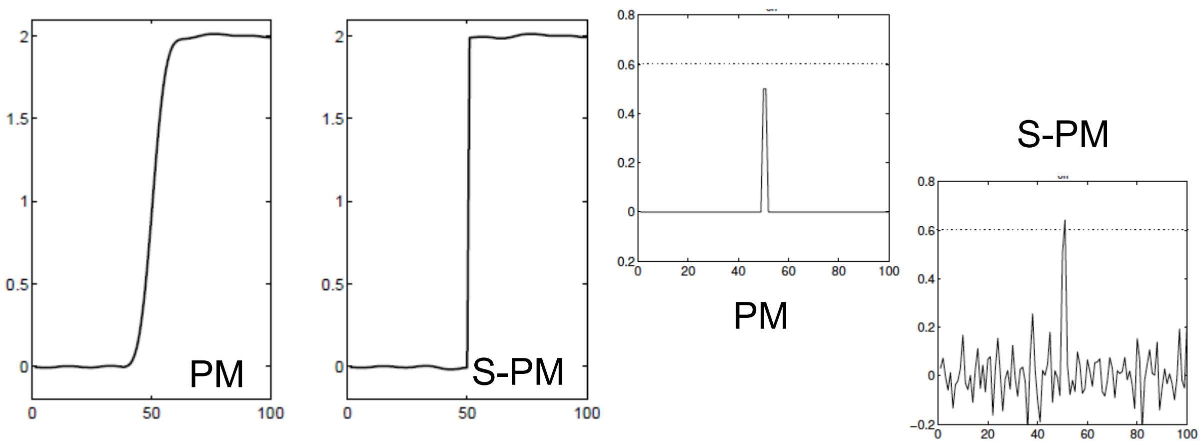


(left) Original noisy contour

(right) Restored one using PM approach with k=0.6

Result

Purposely injection of ***η*** noise in ***g*** function can randomly retune the function



Useful Noise Effect

Experiment 2

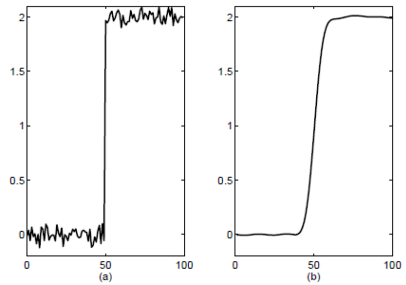
$$g_\eta(u) = g(u + \eta(x))$$

with

$$g(s) = \begin{cases} 1 \; if \; s \geq k \\ 0 \; if \; s \prec k \end{cases}$$

Hard-threshold

We consider a case where *k* parameter is badly tuned regarding PM approach :



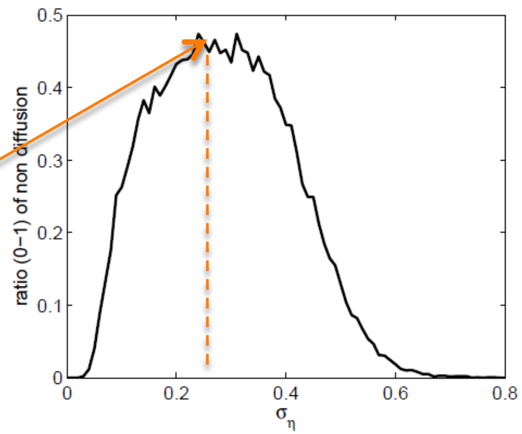
(left) Original noisy contour

(right) Restored one using PM approach with k=0.6

Result (Quantification)

Variation of the ratio of well restored function of the noise rms amplitude (1000 attempts).

The non-diffusion ratio is maximum for a non zero amount of noise



Useful Noise Effect

Extension to image restoration

$$\begin{cases} I(x,y,0) = I_0 \\ \dfrac{\partial I}{\partial t} = div\left(g_\eta\left(\|\nabla I\|\right)\nabla I\right) \end{cases}$$

with $g_\eta(u) = g(u + \eta(x,y))$

and $g(u) = e^{-\frac{\|u\|^2}{k^2}}$

Gaussian Noise (PM, S-PM)

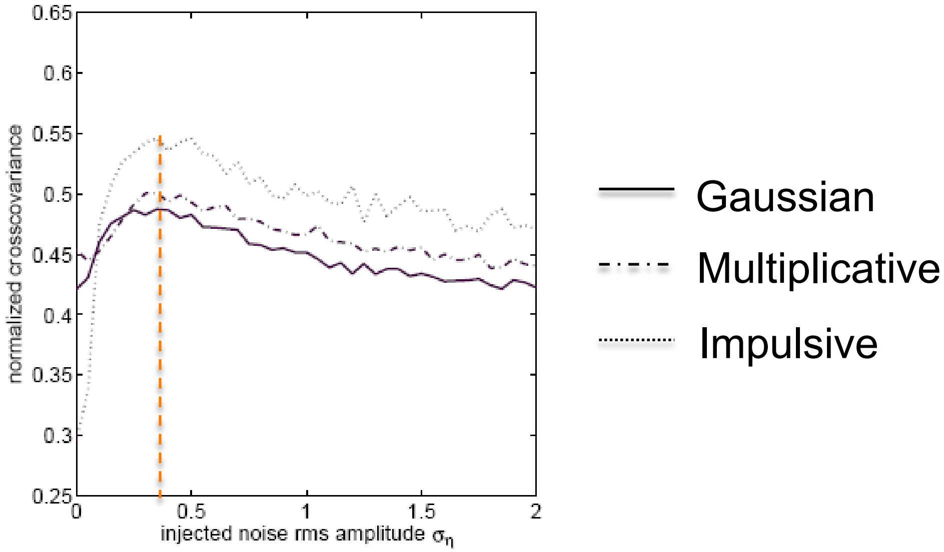
Multiplicative Noise (PM, S-PM)

Impulsive Noise (PM, S-PM)

Useful Noise Effect

Result (quantification)

Normalized Cross Covariance ***wrt the amount of injected noise*** *(1000 attempts)*



Question 1: Answer

In each case the similarity measure is maximum for a non-zero amount of injected noise

Elec. Letters 2006, PSIP 2007, IEEE SocPar 2010, Int Journal of Comp .Infor. Systems and Industrial Management 2012

CAD: Main Contributions

Stochastic Resonance Non-Linear PDE

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Active Contour With Shape Prior

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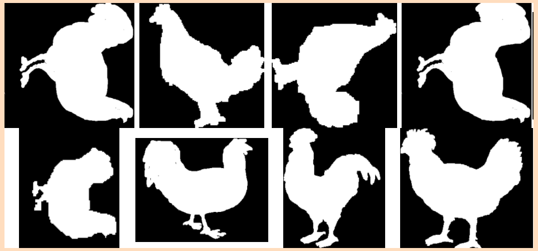
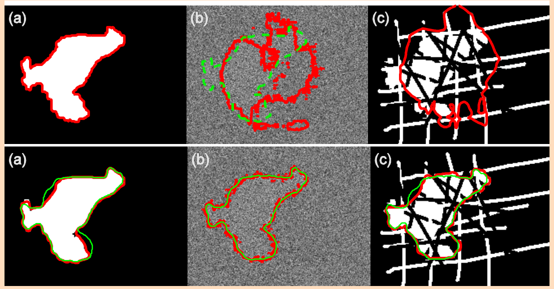
Shape learning



Shape descriptor (Legendre)



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Alpha-Divergence Based Active Contour

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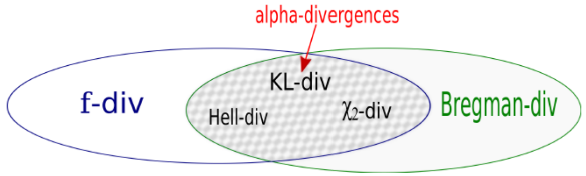
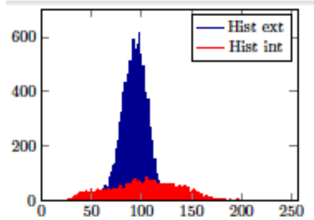


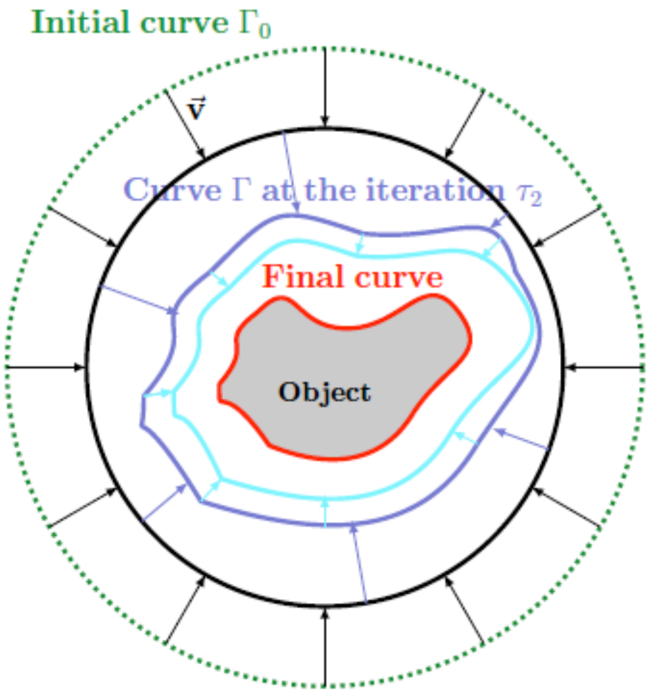


Joint Optimization:
-Segmentation Process
-Metric of the divergence

Coll. I3S
PhD Leila Meziou

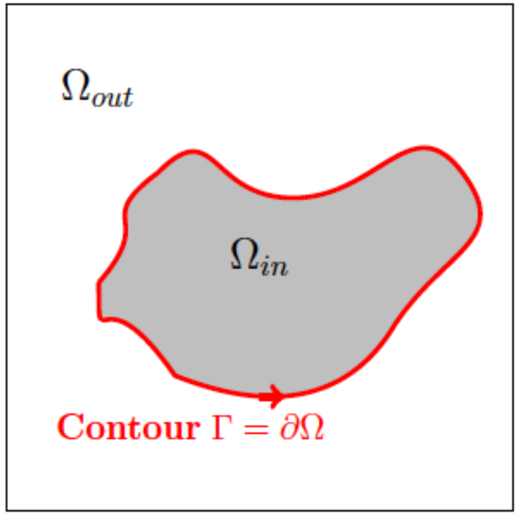
Active Contours

Principle



$$\min\left(E_{image} + E_{regularisation} + \ldots\right)$$

$$\Omega = \Omega_{in} \cup \Gamma \cup \Omega_{out}$$



Gradient-based approach:

$$E(\partial\Omega) = \int_{\partial\Omega} k_b(x,y)\,ds$$

Region-based approach:

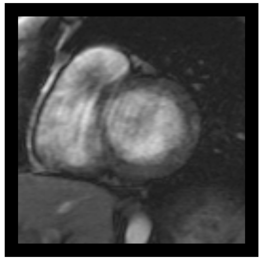
$$E(\Omega_i) = \int_{\Omega} k_b(x,y,\Omega_i)\,ds$$

Shape Prior

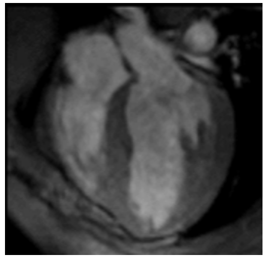
Main Idea

- In Medical Image, the shape of the structure to segment is often "known"
- ***Question:*** Knowing the "mean" shape of an object, can we integrate it in an AC segmentation process ?

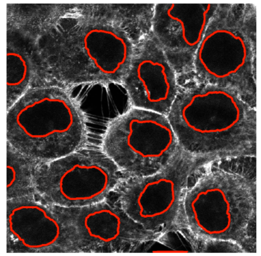
Cardiac MRI



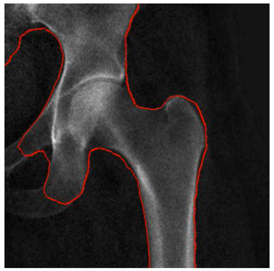
SA



LA



Microconfocal images



X-Ray Radiography (hip bone)

Proposal

$$E(\lambda_r) = E_{prior}(\lambda_r) + E_{image}(\lambda_r)$$

with λ_r a reduced shape descriptor (statistical learning)

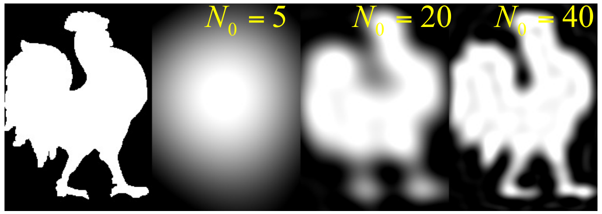
Shape Prior

Shape Space Representation

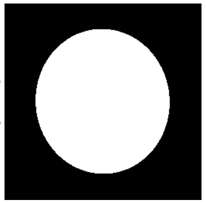
Shape descriptor

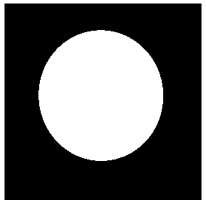
Shape Ω

Moments λ_i such as $\sum_{i=1}^{N_0} \lambda_i$



Zernike moments





Legendre moments

Statistical Learning (PCA)

The chicken image set used to build the statistical shape model

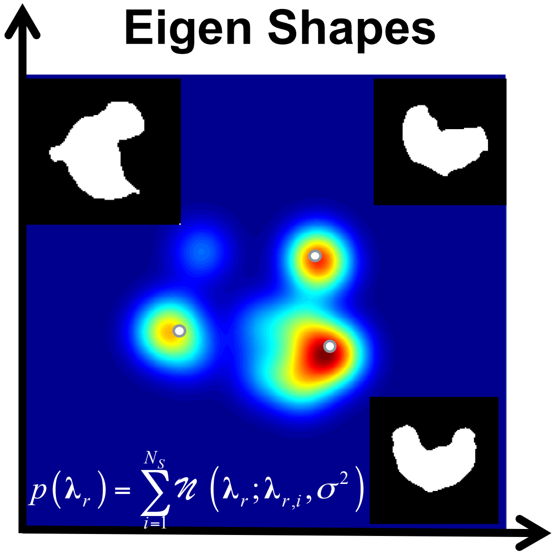
$$\bar{\boldsymbol{\lambda}} = \frac{1}{N_S}\sum_{i=1}^{N_S} \boldsymbol{\lambda}_i \quad \mathbf{Q} = \frac{1}{N_S}\sum_{i=1}^{N_S}\left(\boldsymbol{\lambda}_i - \bar{\boldsymbol{\lambda}}\right)\left(\boldsymbol{\lambda}_i - \bar{\boldsymbol{\lambda}}\right)^T$$

$$\boldsymbol{\lambda}_{r,i} = \mathbf{P}^T\left(\boldsymbol{\lambda}_i - \bar{\boldsymbol{\lambda}}\right)$$

Shape Prior

Shape Space of Moments

Eigen Shapes



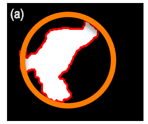
$$p(\boldsymbol{\lambda}_r) = \sum_{i=1}^{N_S} \mathcal{N}(\boldsymbol{\lambda}_r; \boldsymbol{\lambda}_{r,i}, \sigma^2)$$

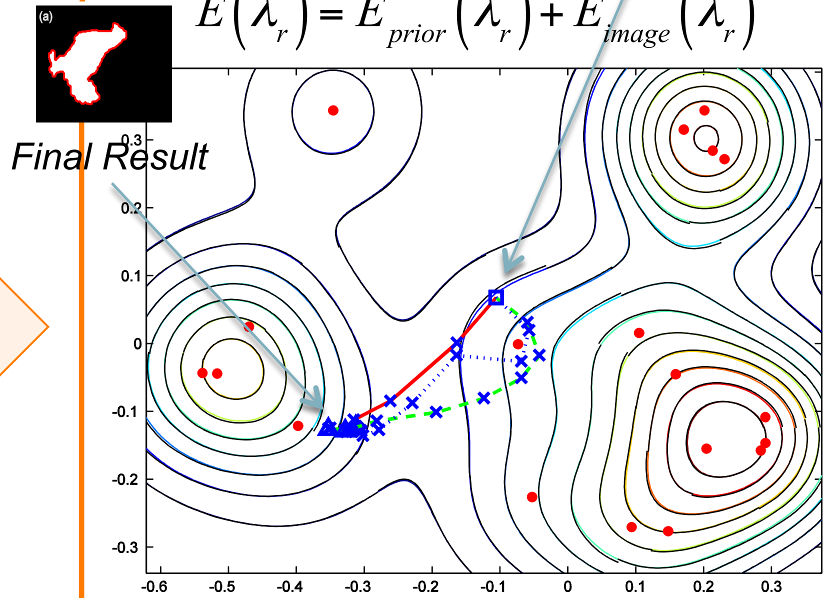
$$\boldsymbol{\lambda} = \lambda_{r,1} \cdot \mathbf{p}_1 + \lambda_{r,2} \cdot \mathbf{p}_2 + \bar{\boldsymbol{\lambda}}$$

$$E_{prior}(\boldsymbol{\lambda}_r) = -\ln\left(\sum_{i=1}^{N_S} \mathcal{N}(\boldsymbol{\lambda}_r; \boldsymbol{\lambda}_{r,i}, \sigma^2)\right)$$

How it works

$$E(\lambda_r) = E_{prior}(\lambda_r) + E_{image}(\lambda_r)$$



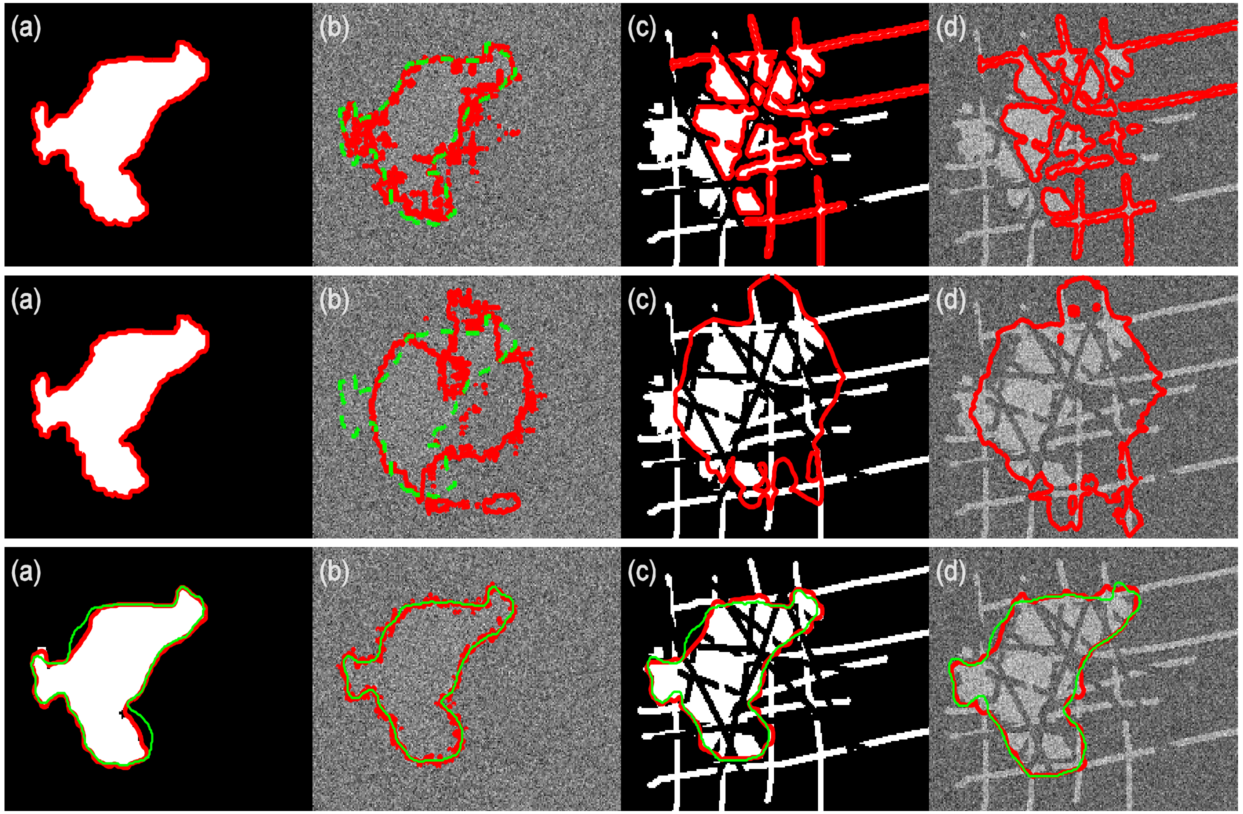


Iterations shown in the feature space spanned by the first two principal axes

Different from Template Matching

Shape Prior

Results 1 (Legendre Moments)



Chan-Vese method

Multi-reference shape prior method (Foulonneau 09)

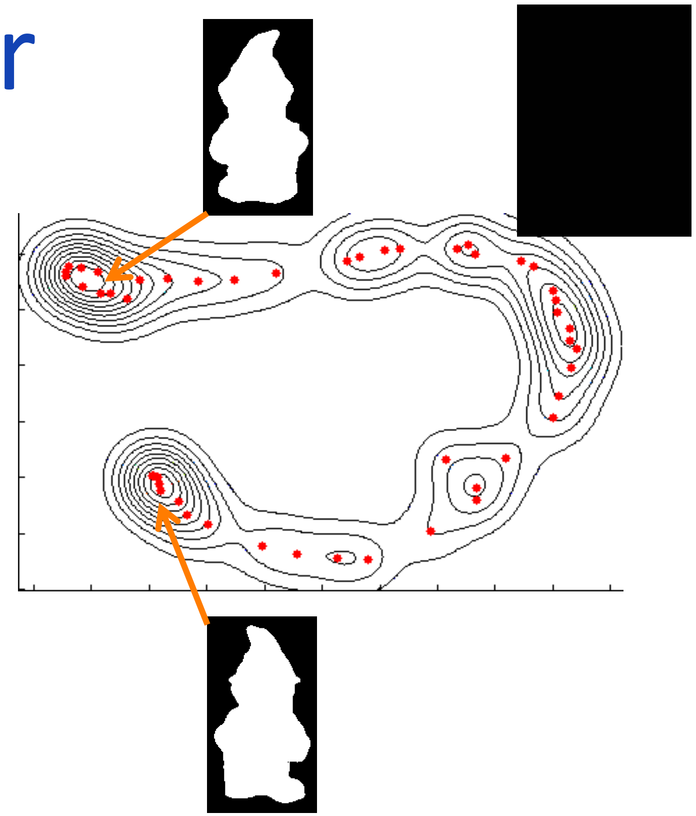
The proposed method

Original binary image | Image with Gaussian noise | Image with structural noise | Image with Gaussian and structural noise

Shape Prior

Results 2

CAIP 2011, Journal of Mathematical Imaging and Vision 2013



Question 2: Answer 1

Space Shape of Legendre Moments makes possible Shape Prior integration different from template matching

CAD: Main Contributions

Stochastic Resonance Non-Linear PDE

$$\frac{\partial I}{\partial t} = div\left(g_\eta\left(\|\nabla I\|\right)\nabla I\right)$$

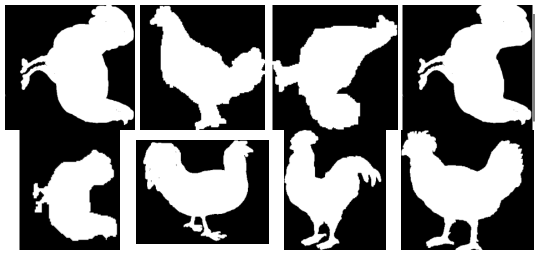
$g_\eta(u) = g(u+\eta(x,y)) \rightarrow$ Gaussian Noise

Coll. CREATIS
David Rousseau

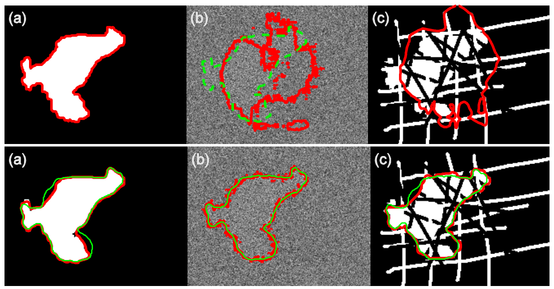
Active Contour With Shape Prior

$E = E_{prior} + E_{image} \rightarrow$ ChanVese

Shape learning



Shape descriptor (Legendre)

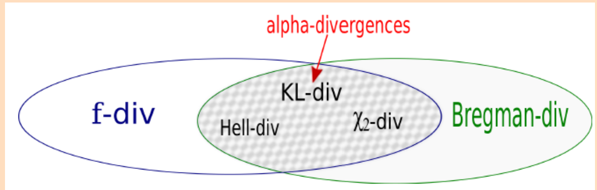


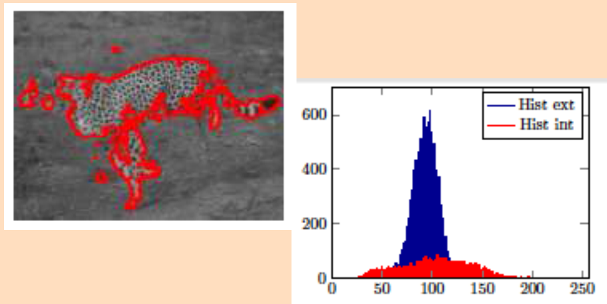
***Up** : Foulonneau, **Down** : Our Approach*

Coll. UCLan
B. Matuszewski

Alpha-Divergence Based Active Contour

$E = E_{histogram} + E_{regularisation}$





<u>Joint Optimization:</u>
-Segmentation Process
-Metric of the divergence

Coll. I3S
PhD Leila Meziou

Alpha-divergence

Histogram-Based Active Contour

$$E = E_{histogram} + E_{regularisation}$$

Divergence

Probability density function

$$D\left(p_1 \,\|\, p_2, \Omega\right) = \int_{\Re^m} \varphi\left(p_1, p_2, \lambda\right) d\lambda$$

with

- φ a similarity function
- p_i the pdf of Ω_i
- λ the quantization level

Questions:

- How to model the pdf p_i (derivation constraints)?
- Which φ function?

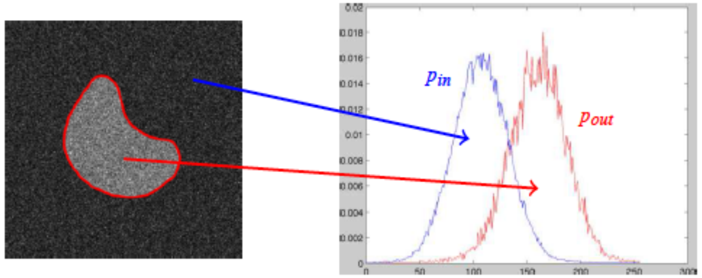
Alpha-divergence

Histogram-Based Active Contour

pdf modeling
(Parzen Window)

$$\hat{p}_i(\lambda,\Omega_i) = \frac{1}{|\Omega_i|}\int_{\Omega_i} g_\sigma(I(\mathrm{x})-\lambda)\,d\mathrm{x}$$

with g_σ a Gaussian kernel of variance σ



Divergence

Usually

- Kullback-Leibler $\alpha=\{0,1\}$
- Hellinger $\alpha=0.5$
- Ki² $\alpha=2$

Our proposal

- *Alpha-divergence*

$$\varphi_\alpha(p_1,p_2,\lambda) = \begin{cases} \dfrac{\alpha p_1 + (1-\alpha)p_2 - {p_1}^{\alpha}{p_2}^{1-\alpha}}{\alpha(1-\alpha)}, & \alpha \in \mathbb{R}\setminus\{0,1\} \\ p_2\, ln\left(\dfrac{p_2}{p_1}\right) + p_1 - p_2\ , & \alpha = 0 \\ p_1\, ln\left(\dfrac{p_1}{p_2}\right) - p_1 + p_2\ , & \alpha = 1 \end{cases}$$

Generalization

Alpha-divergence

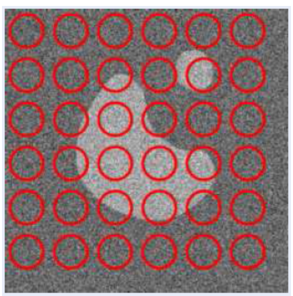
Joint Optimization

Maximization of the divergence

$$\text{argmax}_{\Gamma}\left(D_{\alpha}\left(p_{in} \parallel p_{out}, \Omega\right)\right)$$

Optimization of alpha-parameter

$$\text{argmax}_{\alpha}\left(D_{\alpha}\left(p_{in} \parallel p_{out}, \Omega\right)\right)$$



$$\begin{cases} \dfrac{\partial \alpha}{\partial t} = -\partial D_{\alpha}\left(p_{in} \parallel p_{out}, \alpha\right) \\ \dfrac{\partial \Gamma}{\partial t} = -\partial_{p_{in}, p_{out}} D_{\alpha}\left(p_{in} \parallel p_{out}, \alpha\right) \end{cases}$$

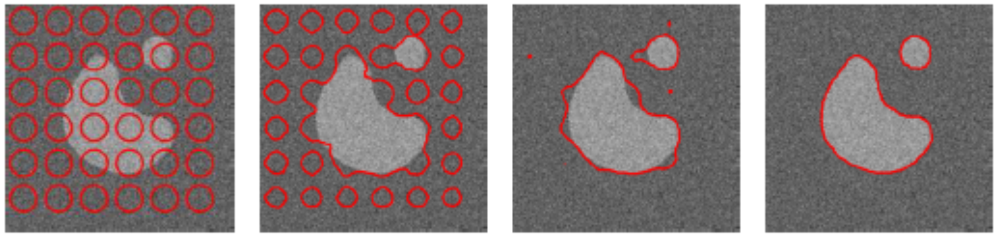
Algorithm

1. α_{t+1} ($\alpha_{init} = 1$)

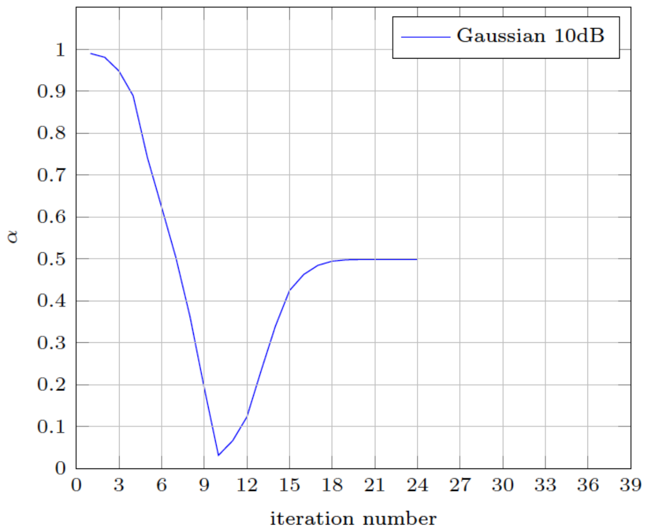
2. Γ_{t+1}

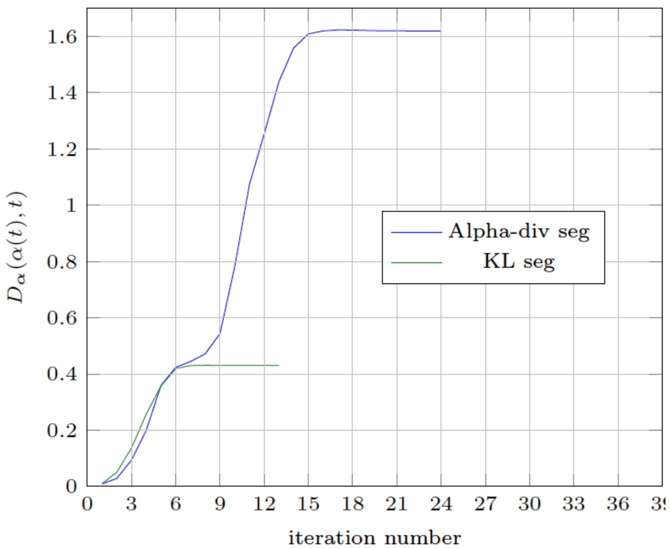
Alpha-divergence

Result 1 (Synthetic images)



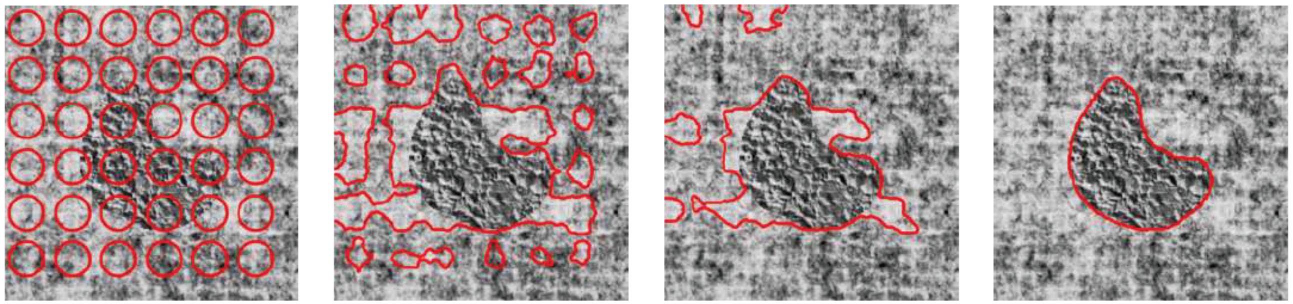
(a) $t = 0$ (b) $t = 5$ (c) $t = 10$ (d) $t = 24$



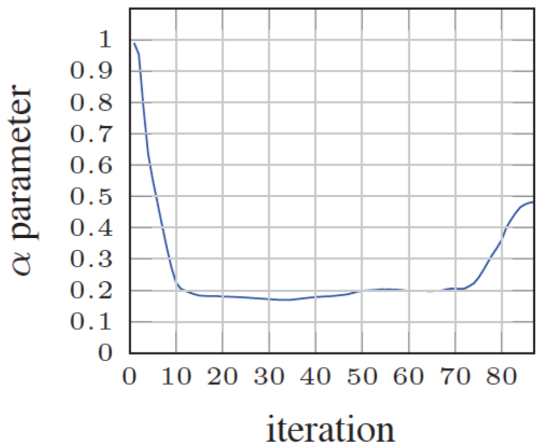


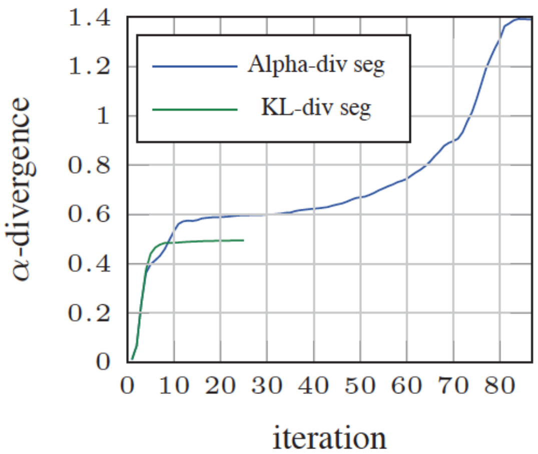
Alpha-divergence

Result 2 (Synthetic images)



(a) Initialization (b) $\tau = 5, \mathrm{KL}$ (c) $\tau = 50$ (d) Final contour

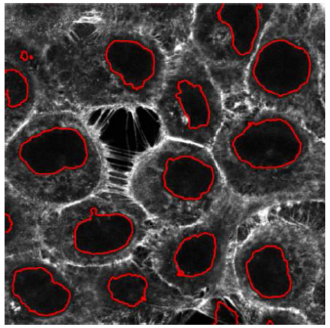




Alpha-divergence

Result 3 (Natural Images)

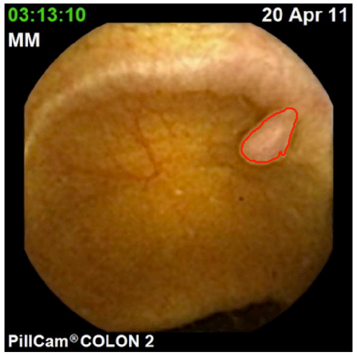
Microconfocal images of cells



Question 2: Answer 2

Alpha-divergence are a flexible tool to cop with different noise scenarios in medical image analysis (but not only)

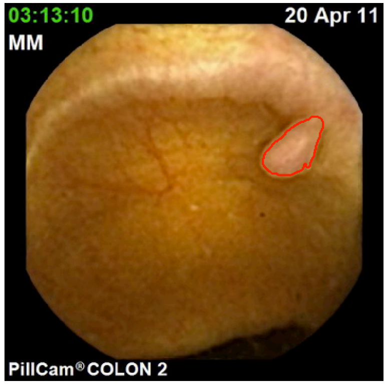
Videocapsule (coloscopy)



X-Ray images

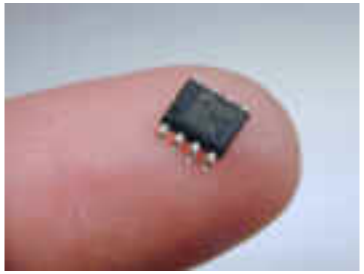
ICIP 2011, ICASSP 2012, MIUA 2012 (Best Student Paper Award), Annals of BMVA 2013, ICIP 2014

CAD to *in situ* Diagnosis



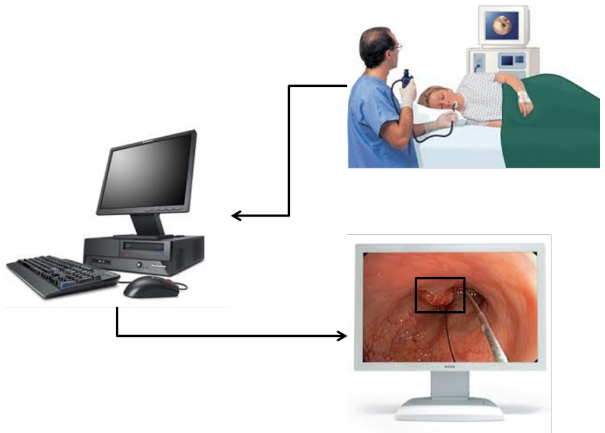
Energy

Interaction



Computation

Size

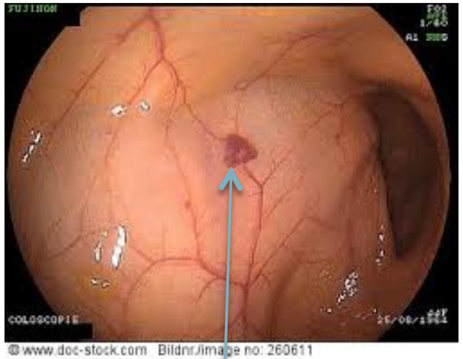


Cyclope Project

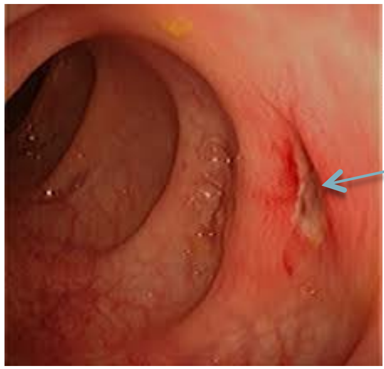
Main idea (induced by Question 3)

To develop a smart autonomous videocapsule with embedded image processing capabilities

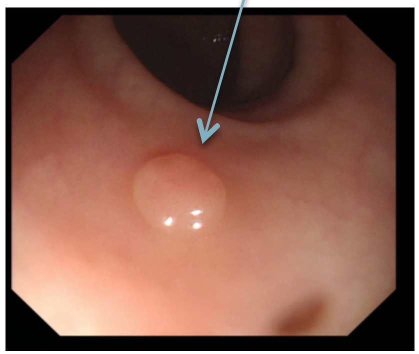
In situ detection of intestinal pathologies



Angioma



Chrone disease



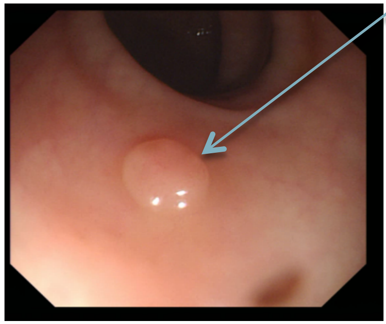
Colorectal Cancer

Cyclope Project

Main idea (induced by Question 3)

To develop a smart autonomous videocapsule with embedded image processing capabilities

Context



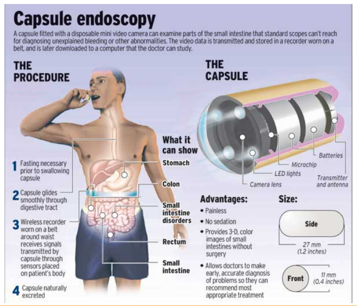
Colorectal Cancer

Advantages

- Total control
- Possibility of biopsy's
- Real-time analysis

Drawbacks

- Anaesthesia
- Hospitalization



Advantages

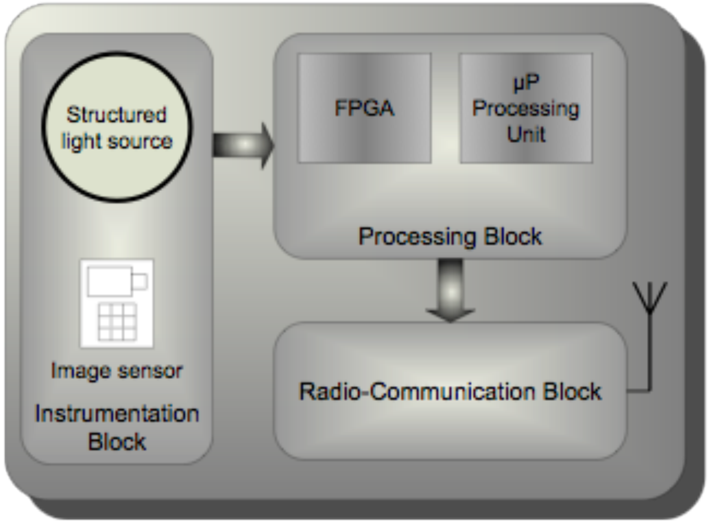
- Painless
- No sedation
- No hospitalization
- Just swallow it!

Drawbacks

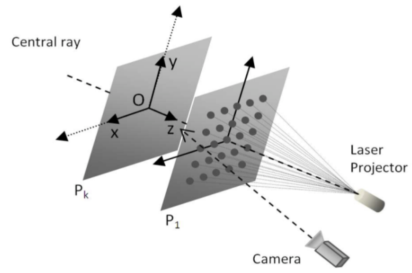
- **Battery life**
- Low resolution
- No control
- ~150k images

The Cyclope Pill

A Multispectral WCE



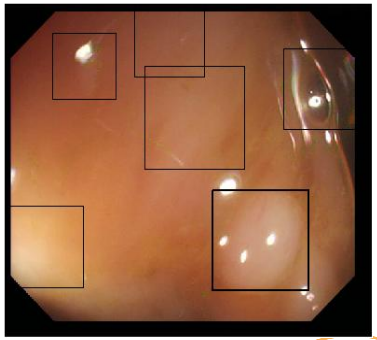
Infrared
(Active Stereo Vision)



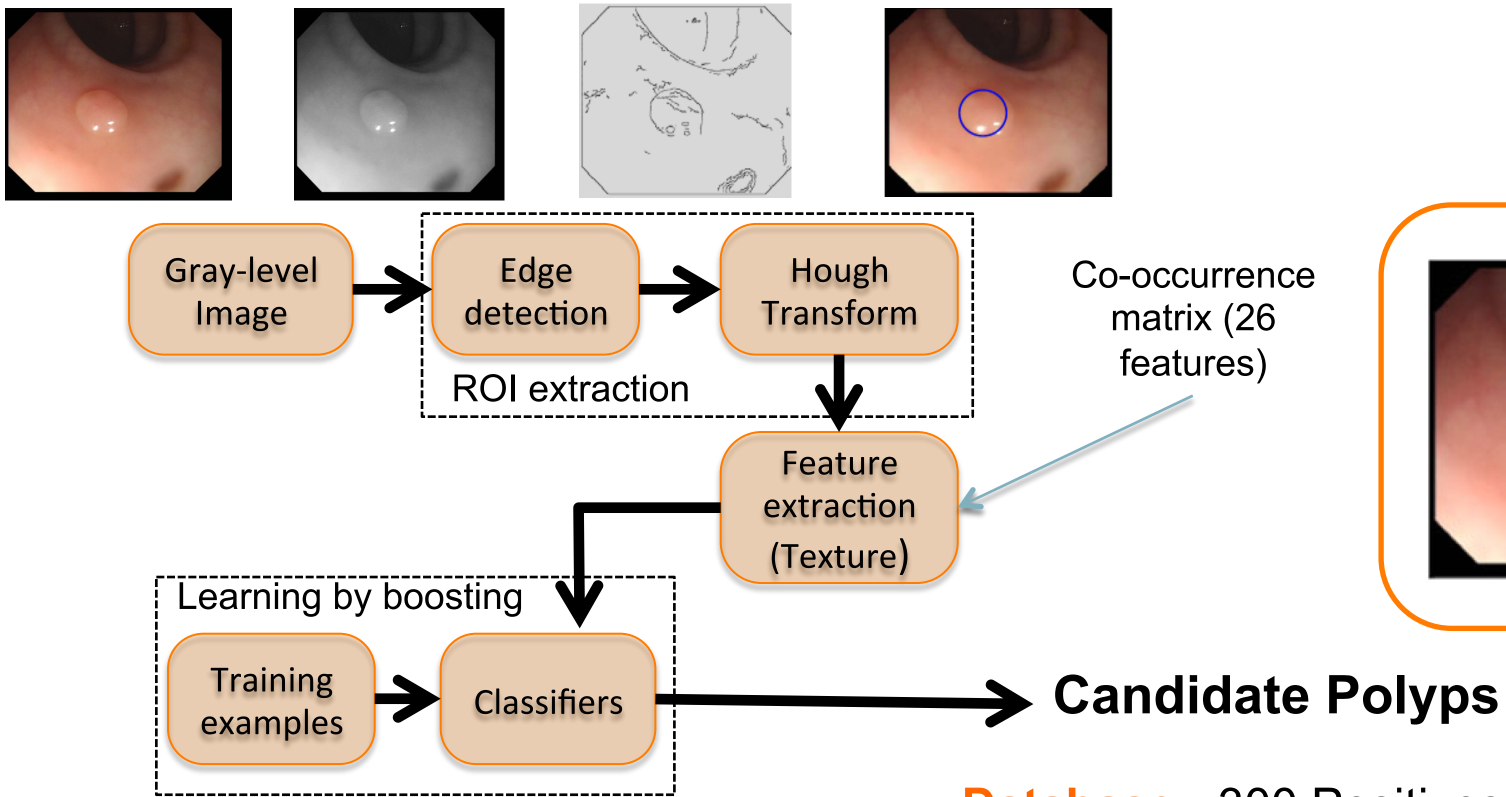
3D feature-based detection

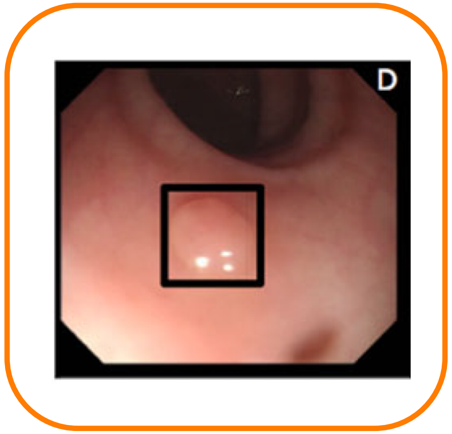
Visible

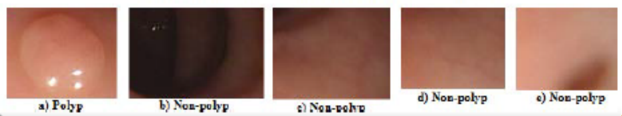
2D feature based detection



2D Detection (Compatible With Embedding Constraints)



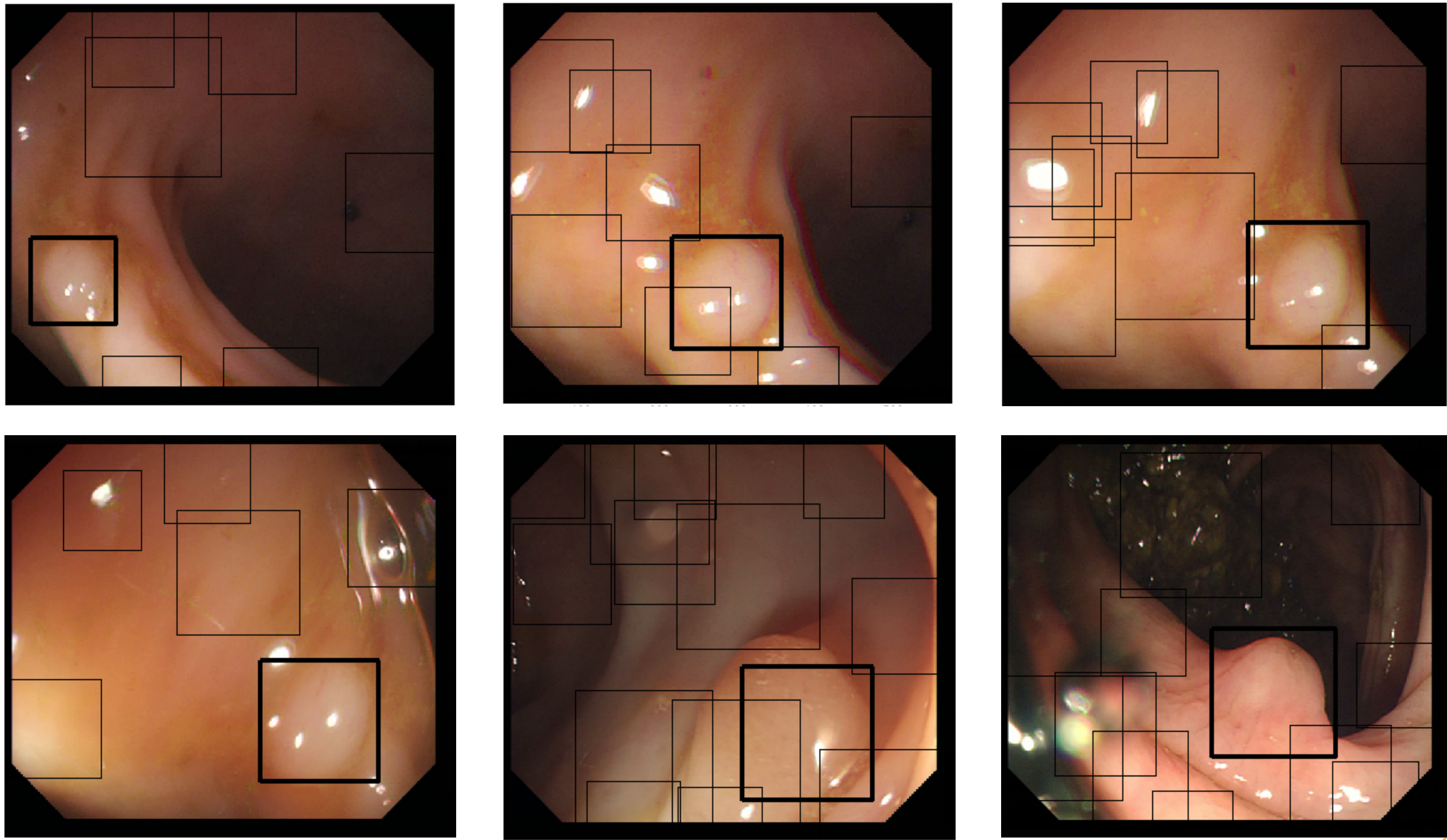




Database : 300 Positives examples, 1200 Negatives ones

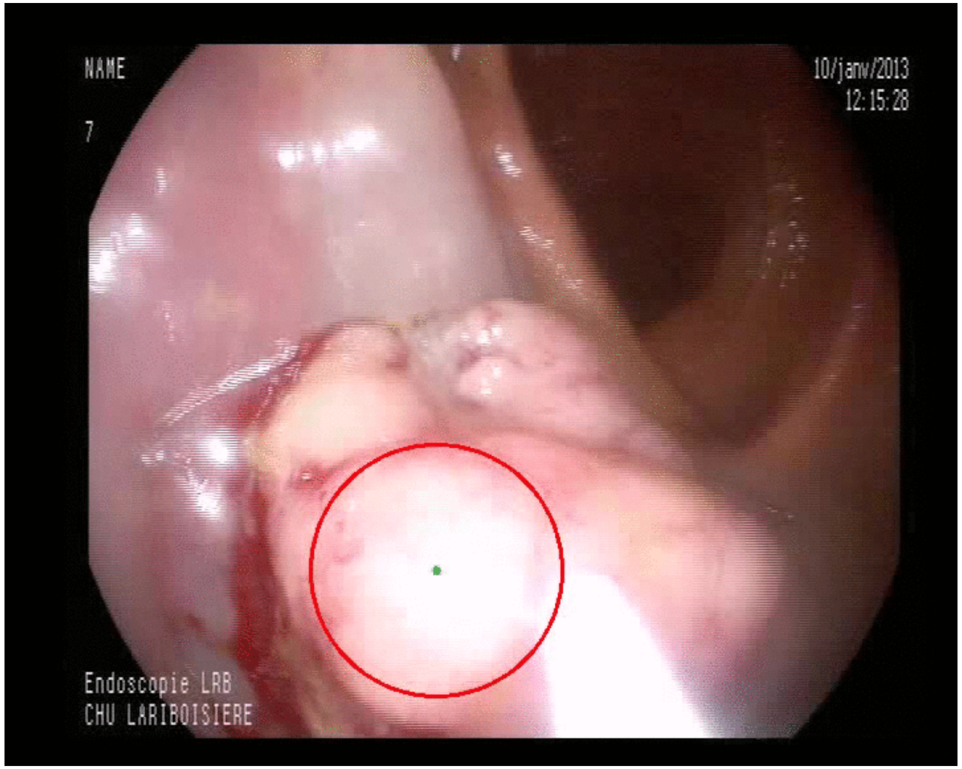
2D Detection

Results and Performance



2D Detection

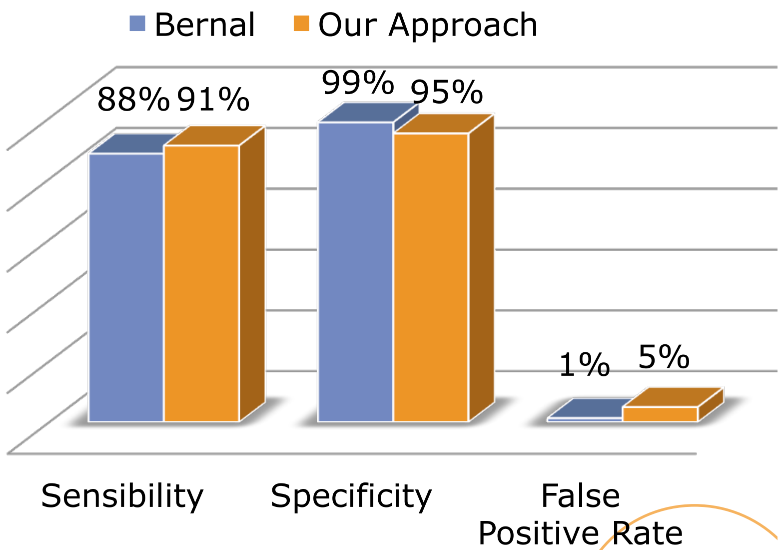
Results and Performance (Real Time Tracking)



DCIS 2012, IEEE EMBC 2013, GRETSI 13, International Journal of Computer Assisted Radiology and Surgery, 2014

Question 3: Answer

It is possible to design low complexity detection/recognition algorithms in accordance with: (i) embedding constraints, and (ii) expected performance



Synthesis of contributions

2005 — 28/11/2014

From CAD… …to in situ Diagnosis

Question 1

- Stochastic Resonance
- Non-linear PDE-based image restoration process
- *Double Well potential*

Question 2

Active contour with:

- Shape Space moments
- Alpha-divergence
- *Fractional entropy*

Question 3

- Early Detection of Colorectal Cancer
- Real-Time tracking of colonic polyps
- In Situ Diagnosis

Related Publications (2006-2014)

9 Journals, 1 Patent:

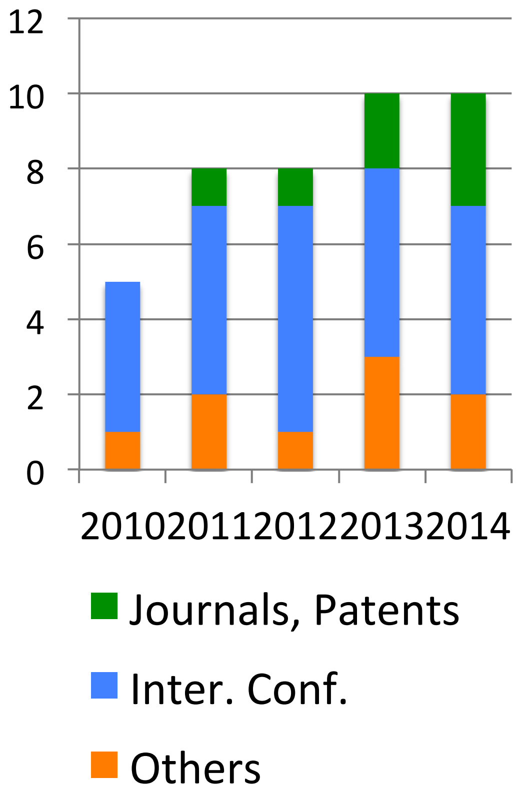
PRL, JMIV*, EL*, IJCARS*+, IJBI+, Annals of BMVA,…*

28 Int. Conferences:

ICIP, ICASSP, CAIP, EMBC, MIUA, CARS,…

Others:

3 Book Chapters, 1 Book Editing, 1 Proceeding Editing, 6 National Conferences (GRETSI)



* Indexed by JCR
+ Indexed by PubMed

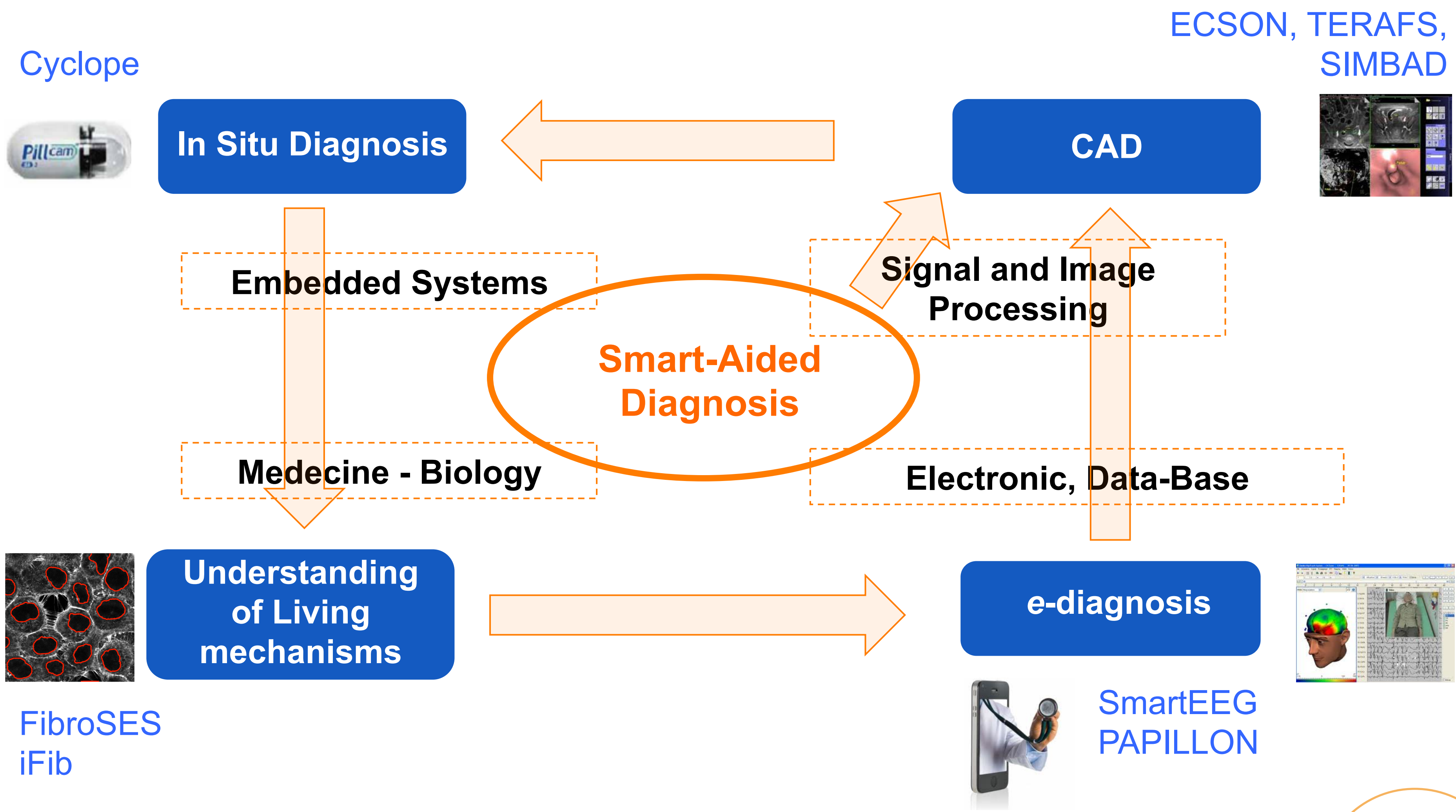
Roadmap

- **General Presentation**
  - *Who am I?*

- **Research Activities**
  - *What are my contributions?*

- **Perspectives**
  - *What is my research project?*

Research Activities-Evolution



Research Project

(Short and Mid Terms)

Image Processing / Pattern recognition

Electronics, Embedded Systems

Alpha-Divergence in Pattern Detection

- Collaboration with *D. Rousseau* (CREATIS Lyon)

Smart-Videoendoscopy

- PhD of Quentin Angermann
- SATT
- Evolucare Medical Imaging

Cell shape characterization

- Collaboration with UCLan and UB

Electrical Characterization of Fibrosis Induced by Implants

- IMS, INL, LIP6, ERRMECe

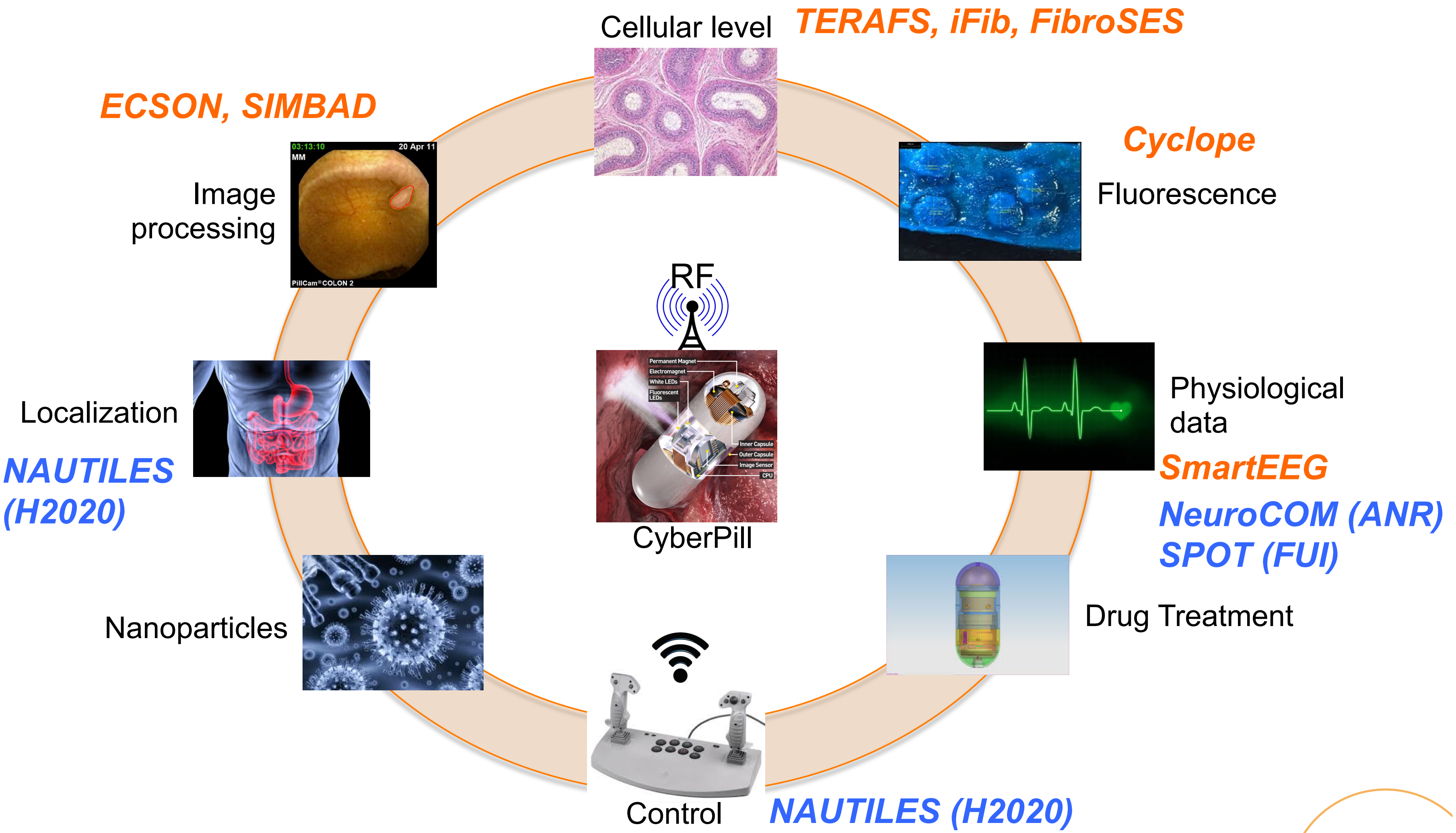
Smart EEG

- LIP6, INL, SME

Cyclope

- H2020 Project (Greece, Switzerland, UK, Spain, France, Belgium)

Research Project



THANKS TO THEM

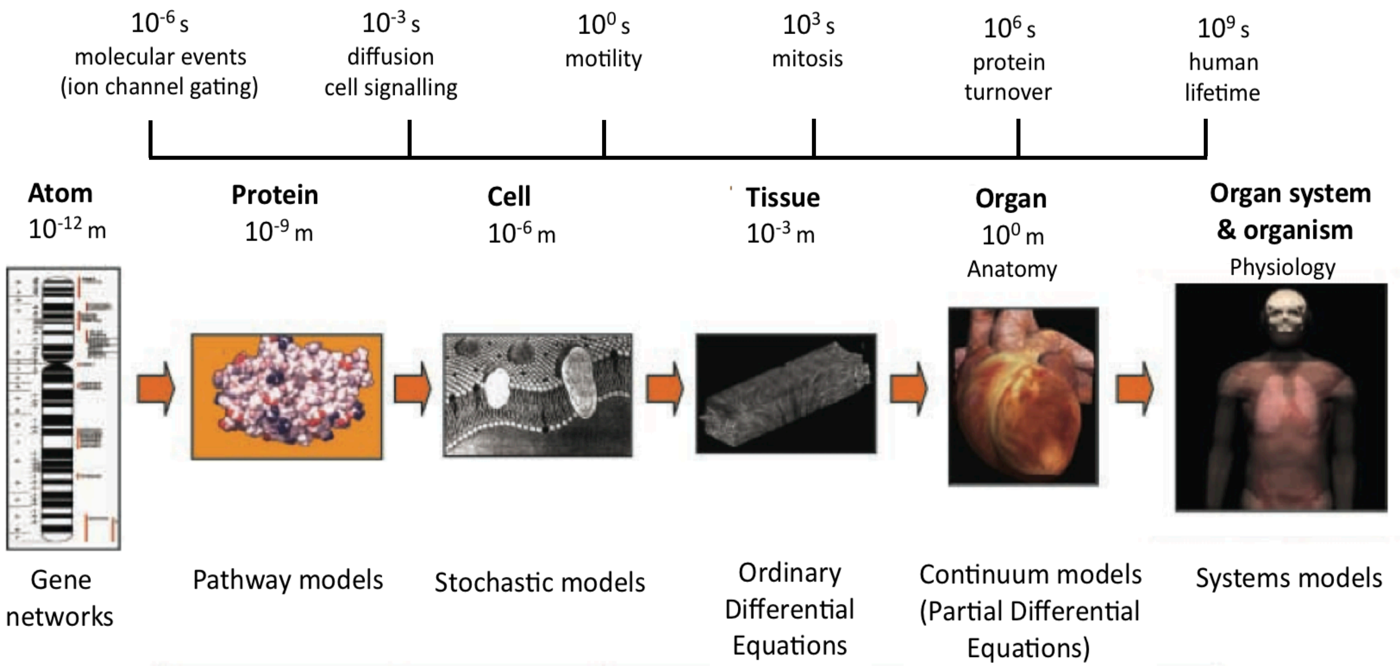
Q. Angermann (2014-…), C. Azib (2013), E. Bonnefoye (2012), M. Breuilly (2009), N. Cazin (2014), M. Degaudez (2007), M.-C. Desseroit (2013), H. Diouane (2014), C. Fouquet (2011-2014), M. Garnier (2009, 2011), C. Georgel (2013), M. Ibouchichene (2014), A. Izard (2013), L.-A. Latchimy (2013), T. Longret (2013), L. Meziou (2010-2013), S. Mouzai (2014), C. Nzuzi (2013), M. Rémignon (2014), A. Riaz (2013), H. Saidi (2014), J. Silva-Quintero (2012), A. Sittadannam (2014), Y. Zhang (2009-2010).


Diplome
du parcours du combattant

THANK YOU FOR YOUR ATTENTION

Research Project

From Nano to Macro



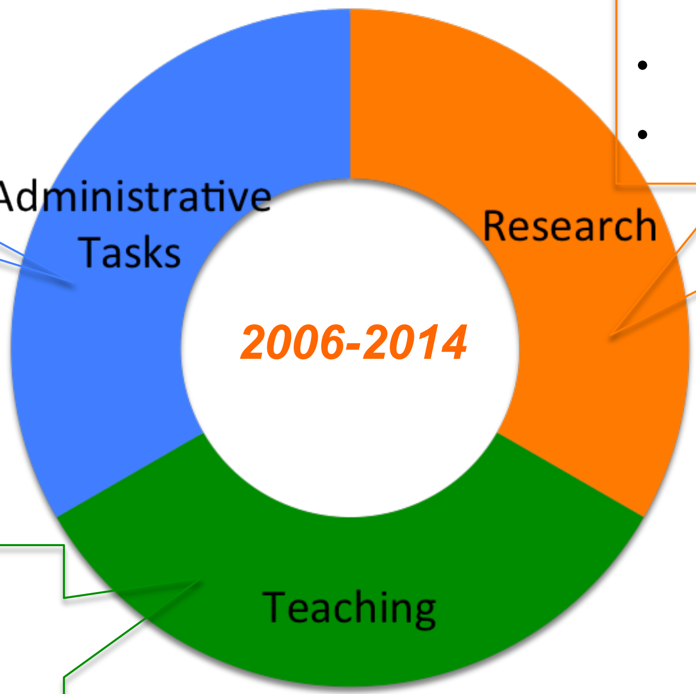
Mathematics Biology Imaging Technic Signal and Image Processing Electronic

To understand manifestations of a same pathologic phenomenon from cell to organ scales (even nano) and draw some possible connections

Synthesis

- Elected member of the Research Council of ETIS
- Co-head of MSc MADOCS
- Different types of experiences (IUT, UCP)

- In charge of the SES axis of ASTRE team
- 8 research projects
- Active inter. and Nat. Collaborations
- 8 Journal papers, 28 Int. Conf.
- 2 defended PhD, 2 on-going



- L1, L2, L3, MSc, ENSEA
- Interaction Teaching/ Research
- In charge of the industrial relationship (2008-2014)

And what about the future now ?

Today-Teaching

- **Neuville Intitute of Technology, UCP, ENSEA**

Students	Classes	Lecture and Tuto (h)	Labs (h)
1st year (L1)	Electrical Engineering and Energy	32	
2nd year (L2)	Electrical Engineering and Energy		48
2nd year (L2)	Control Theory	28	
2nd year App. (L2)	Control Theory	54	32
Prof. Licence (L3)	Electrical Engineering and Energy	30	
MSc SIC	Image Processing	15	
MSc MADOCS	Statistical Learning	6	
ENSEA 3rd year (EIB)	Signal Processing for ECG	6	
Total		**171**	**80**

Today-Supervising

3 PhD students: 120%+50%

- *2 Defended* *(11/2013, 06/2014)*
- *1 just started* *(50%)*

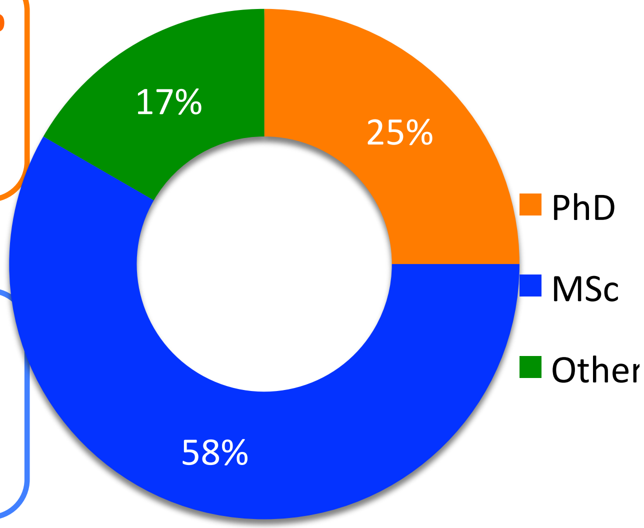
7 MSc students: 330%

- *MSc SIC, ESA*

Others:

- *1 Post-doc* *(50%-1 year)*
- *1 Research Engineer* *(50%)*
- *Several Initiation-to-Research projects*

Synthesis



Useful Noise Effect

Theory (particular case)

$$g_\eta(u) = g(u+\eta(x))$$

with

$$g(s) = \begin{cases} 1 \; if \; s \geq k \\ 0 \; if \; s \prec k \end{cases}$$

Hard-threshold

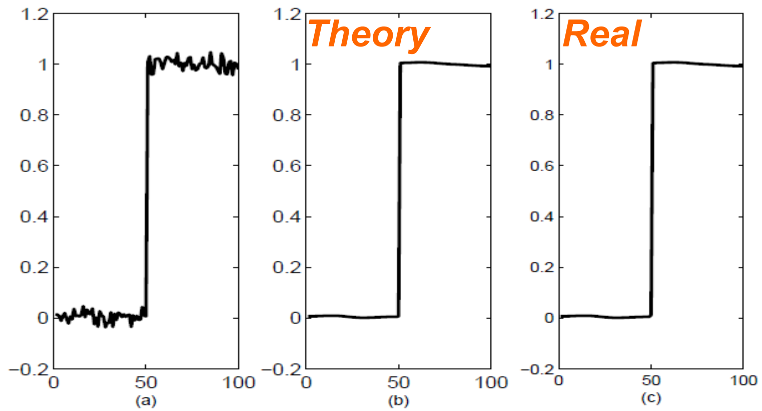
- g_η : a static or memory less non-linear function
- Shaping by noise of the input-output characteristic:

$$g_{eff}(s) = E\left[g\left(s+\eta(x,y)\right)\right] = \int_{-\infty}^{+\infty} g(u) f_\eta(u-s)\,du$$

$f_\eta(u)$: pdf of purposely injected noise (uniform)

Experiment 1

Comparison between real stochastic diffusion process and theoretical one.



Useful Noise Effect

Theory (particular case)

$$g_\eta(u) = g(u + \eta(x))$$

with

$$g(s) = \begin{cases} 1 \; if \;\; s \geq k \\ 0 \; if \;\; s \prec k \end{cases}$$

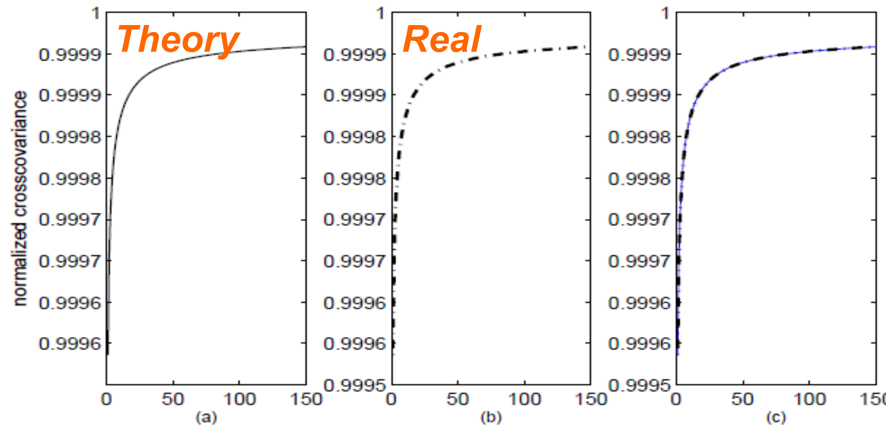
Hard-threshold

- **g_η :** a static or memory less non-linear function
- Shaping by noise of the input-output characteristic:

$$g_{eff}(s) = E\left[g\left(s + \eta(x,y)\right)\right] = \int_{-\infty}^{+\infty} g(u) f_\eta(u-s)\,du$$

Experiment 2

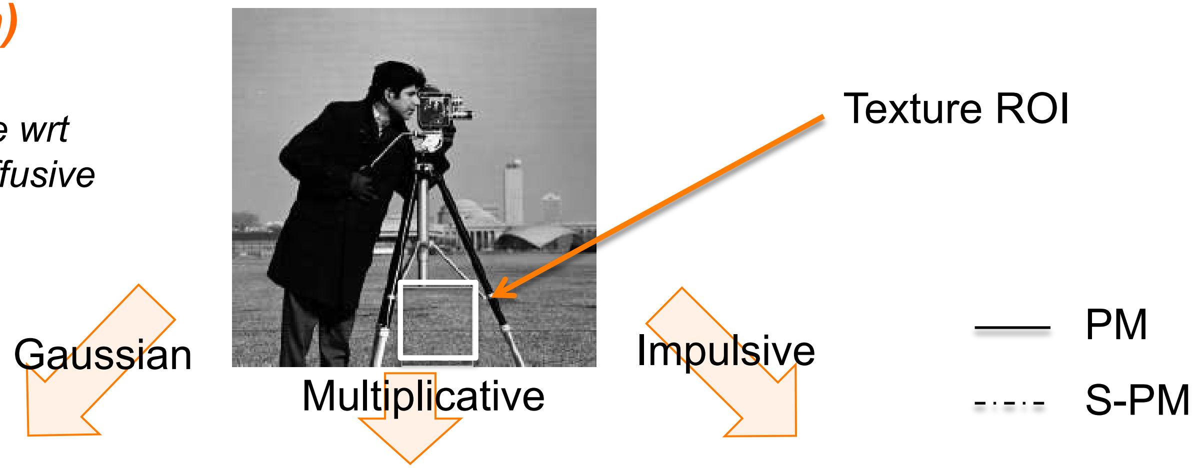
Comparison of the evolution of normalized cross-covariance (1000 attempts)

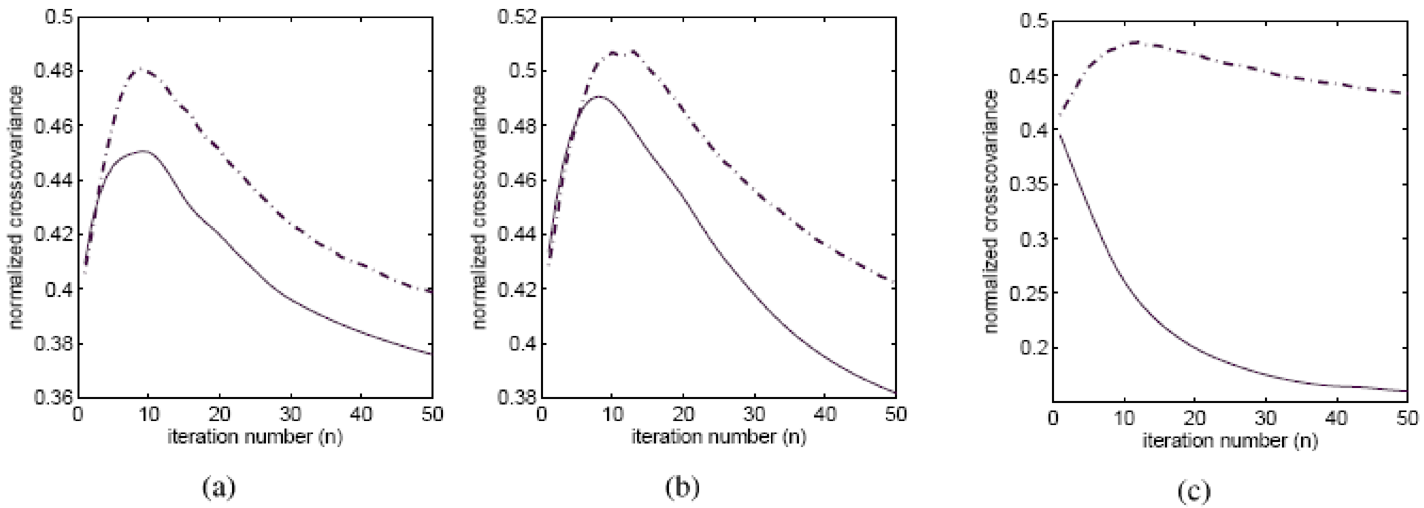


Useful Noise Effect

Result (quantification)

Normalized Cross Covariance wrt the iteration number of the diffusive process





Useful Noise Effect

Extension to Image Restoration

$$\begin{cases} I(x,y,0) = I_0 \\ \dfrac{\partial I}{\partial t} = div\left(g_\eta\left(\|\nabla I\|\right)\nabla I\right) \end{cases}$$

with $g_\eta(u) = g(u + \eta(x,y))$

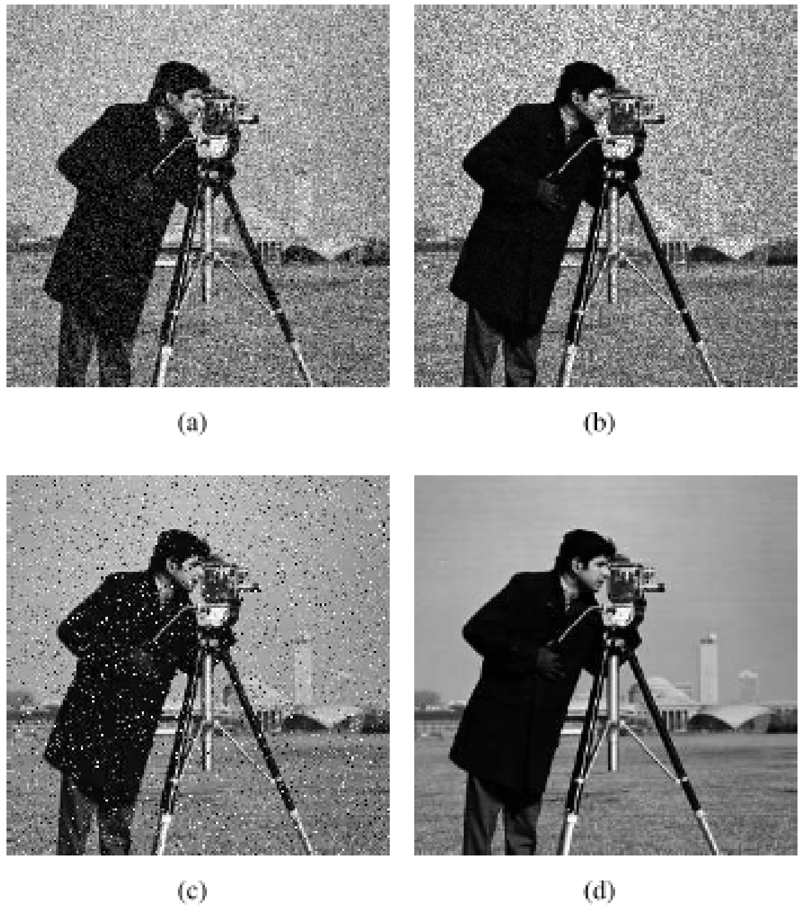
and $g(u) = e^{-\frac{\|u\|^2}{k^2}}$

(a) Additive zero-mean Gaussian noise with $\psi_0 = \psi_{ori} + \xi$

(b) Multiplicative Gaussian noise of mean unity with $\psi_0 = \psi_{ori} + \xi \,.\, \psi_{ori}$

(c) Impulsive noise

(d) Original image



Shape Prior

Shape Space of Legendre Moments

Legendre Moments

Shape Ω

$$\lambda_{qp} = \frac{1}{|\Omega|} \int_{\Omega} L_{pq}(x, y, \Omega) dxdy$$

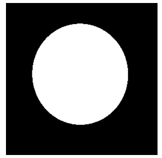
with

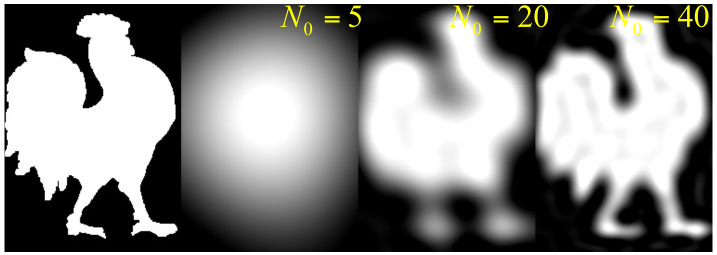
$$L_{pq}(x, y, \Omega) = L_p\left(\frac{x - \bar{x}}{|\Omega|^{1/2}}\right) L_q\left(\frac{y - \bar{y}}{|\Omega|^{1/2}}\right)$$

$$L_n(x) = \sqrt{\frac{2n+1}{2}} \frac{1}{2^n n!} \frac{d^n}{dx^n}\left[\left(x^2 - 1\right)^n\right]$$

Reconstruction

$$\sum_{p,q}^{p+q \le N_0} \lambda_{pq} L_{pq}(x, y)$$





Images reconstructed from the Legendre moments for different moments' order N_0

Shape Prior

Shape Space of Legendre Moments

Greedy algorithm

• $\Omega^{(k)} \rightarrow \Omega'^{(k)}$

$$\frac{\partial \varphi}{\partial t} = \left(\left(I-\mu_{\Omega}\right)^2 + \left(I-\mu_{\Omega^c}\right)^2\right)|\nabla \varphi| + \gamma \nabla\left(\frac{\nabla \varphi}{|\nabla \varphi|}\right)|\nabla \varphi|$$

E_{image} *(Chan Vese)*

• $\Omega'^{(k)} \rightarrow \boldsymbol{\lambda}_r^{(k)}$

$$\boldsymbol{\lambda}_r^{(k)} = \mathbf{P}^T\left(\boldsymbol{\lambda}_r - \bar{\boldsymbol{\lambda}}\right)$$

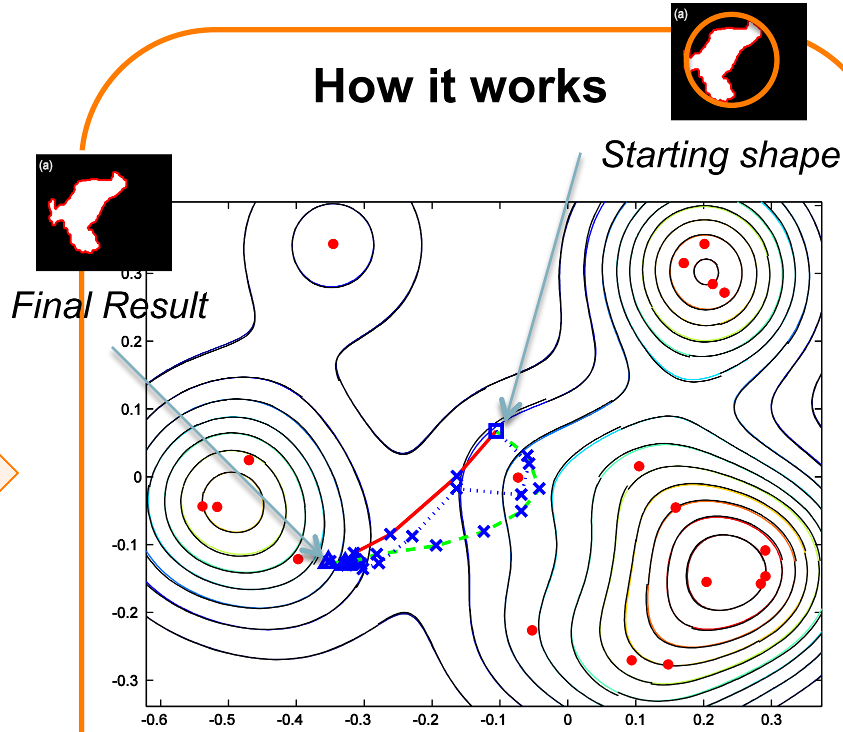
• $\boldsymbol{\lambda}_r^{(k)} \rightarrow \boldsymbol{\lambda}_r'^{(k)}$

$$\boldsymbol{\lambda}_r'^{(k)} = \boldsymbol{\lambda}_r^{(k)} - \beta \frac{\partial E_{prior}}{\partial \boldsymbol{\lambda}_r}\Big|_{\boldsymbol{\lambda}_r = \boldsymbol{\lambda}_r^{(k)}}$$

• $\boldsymbol{\lambda}_r'^{(k)} \rightarrow \Omega^{(k+1)}$

$$\Omega^{(k+1)} = \left\{(x,y) : \left(\sum_{p,q}^{p+q \le N_0} \lambda'^{(k)}_{pq} L_{pq}\left(x,y,\Omega'^{(k)}\right)\right) > 0.5\right\}$$

How it works

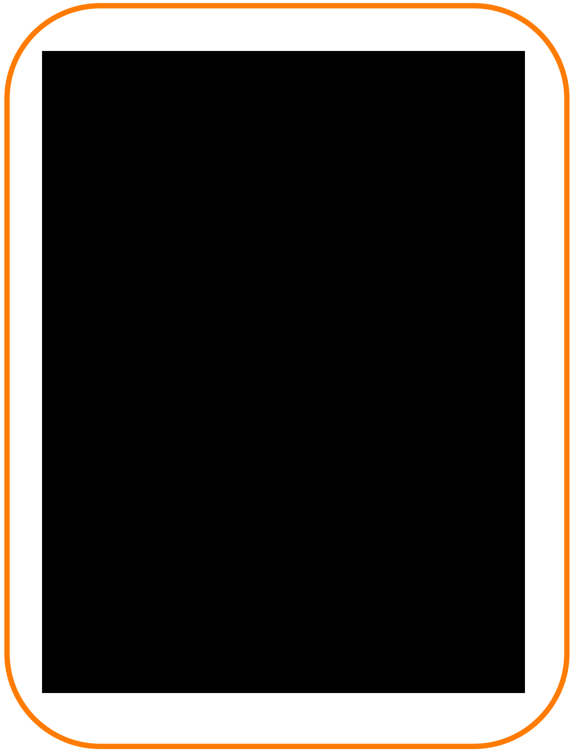


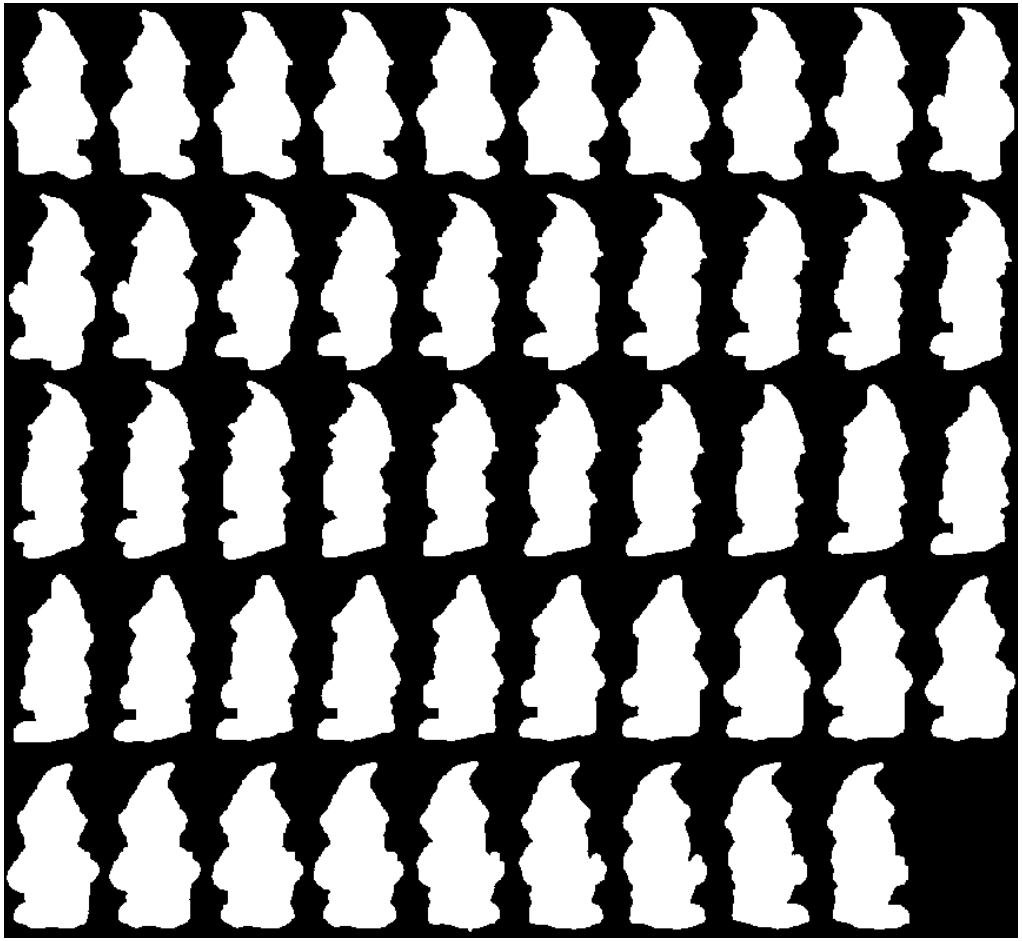
Iterations shown in the feature space spanned by the first two principal axes

Different from Template Matching

Shape Prior

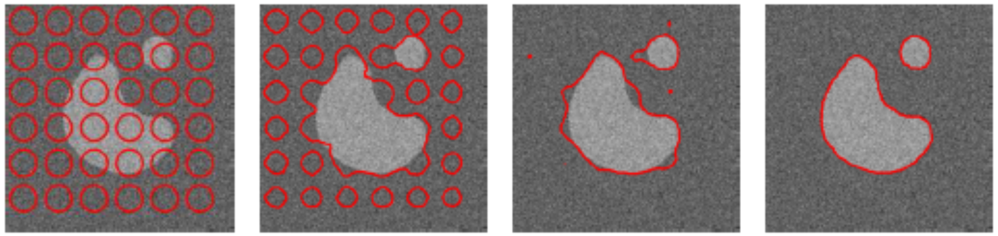
Results 2



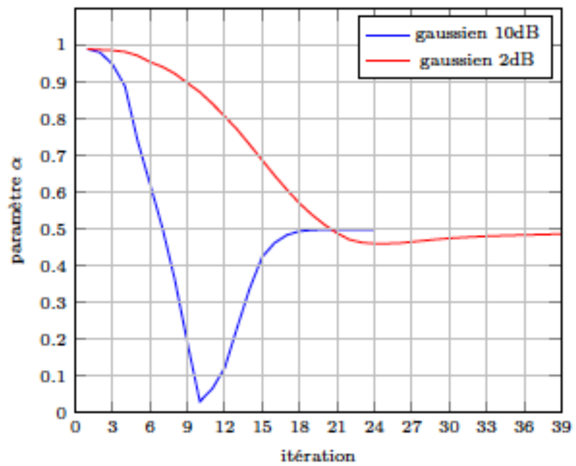


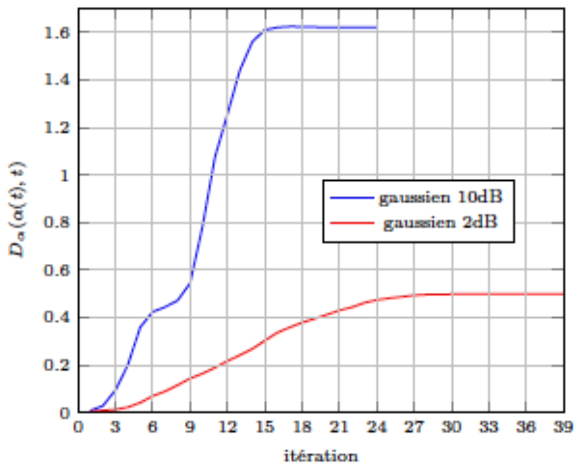
Alpha-divergence

Result 1 (Synthetic images)



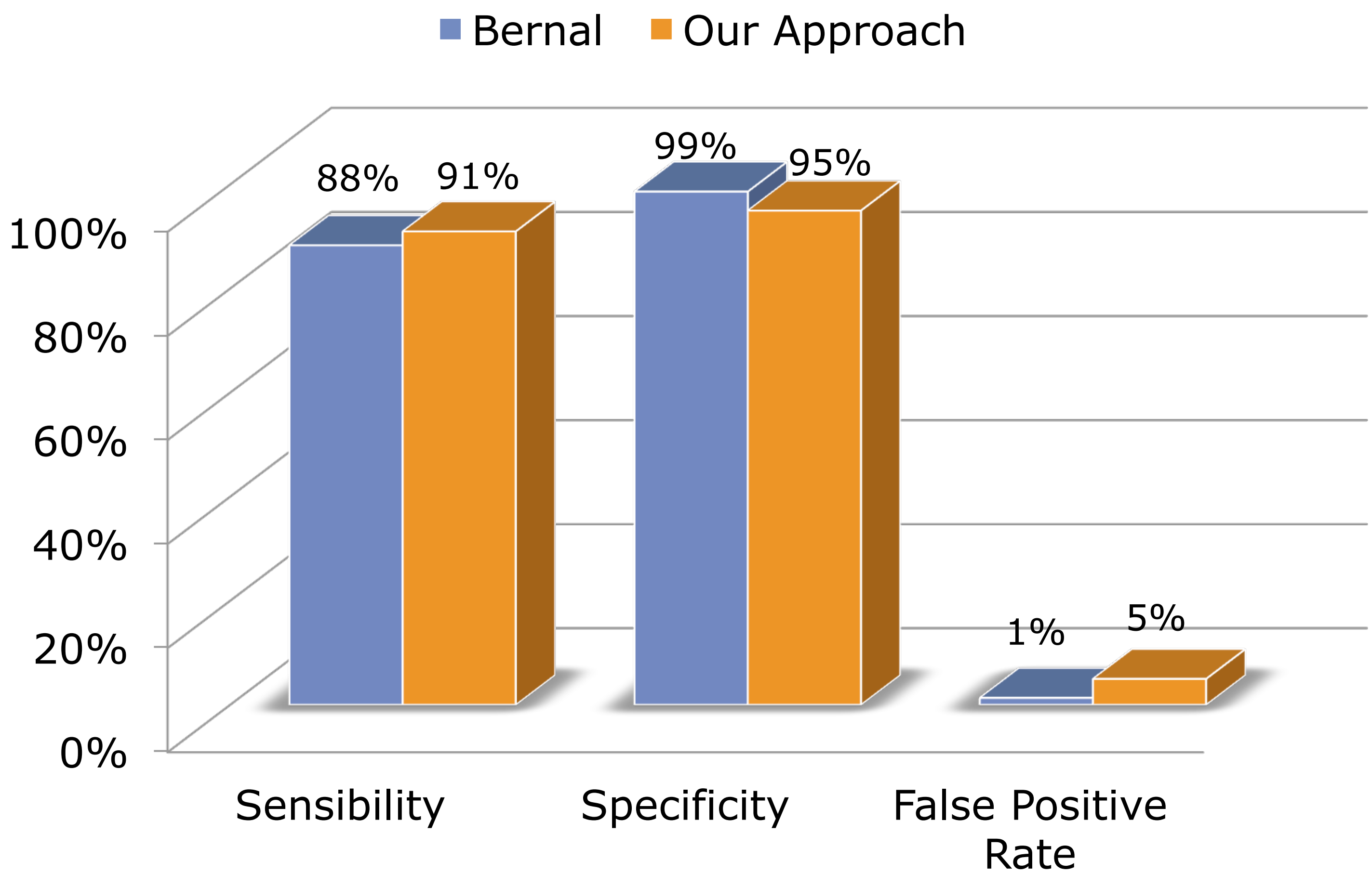
(a) $t = 0$ (b) $t = 5$ (c) $t = 10$ (d) $t = 24$



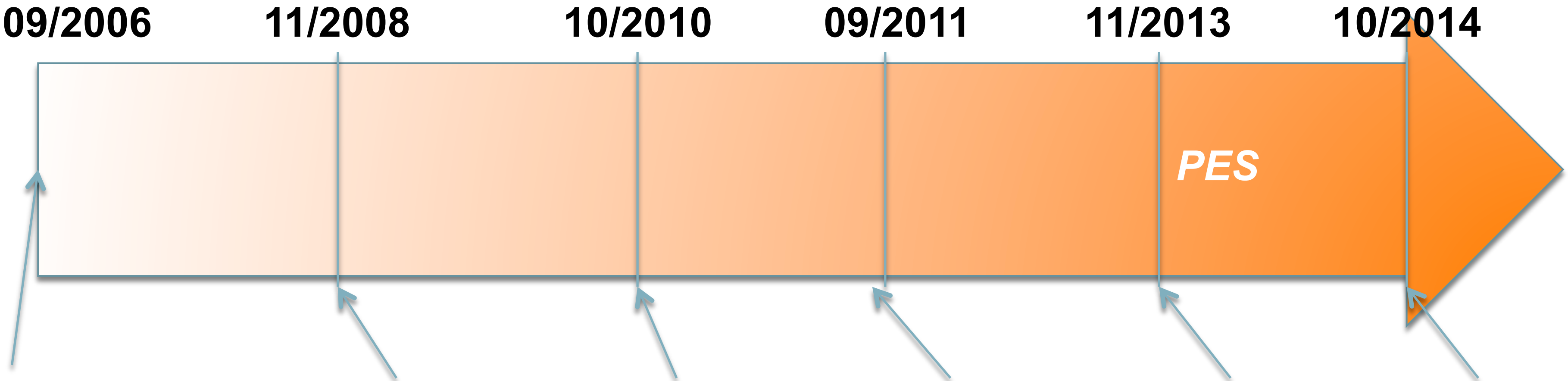


2D Detection

Results and Performance



From 2006 to 2014



Associate Professor

- ETIS Lab- ICI Team
- Cergy-Pontoise Institute of Technology
- GEII Department

SIMBAD Activity

- Collaboration with F. Preciosio (MIDI team)
- Beginning of the collaboration with the University of Central Lancashire, UK

First PhD Student

- Leila Meziou
- ``Histogram-Based Active Contour Using Alpha-Divergence: Application to Medical Image Segmentation''
- Co-supervised with F. Precioso

Cyclope Project

- Embedded Image Processing for Smart Videocapsule

- ASTRE Collaboration

L. Meziou's PhD Defense

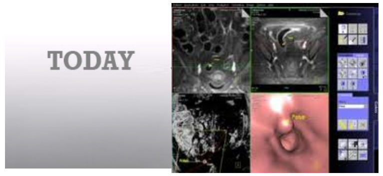
- 1 Journal Paper
- 8 Int. Conf. (1 Best Student Paper Award)
- 1 Nat. Conf. (GRETSI)
- 1 GDR presentation

Member of ASTRE Team

- 3rd PhD Student
- ``Smart videoendoscopy for CRC early detection''
- Co-supervised with Olivier Romain

Research/Teaching

Computer-Aided Diagnosis



<2001 – *2006* – *2014*
Image Processing: Restoration/Segmentation
→ **MSc SIC,MADOCS**

2010
Pattern Detection and Recognition
→ **MSc SIC, MADOCS**

2011
Signal Processing
→ **ENSEA**

2012
Electronic
→ **CMI BioSan, IUT**

8 Research Projects

(2006-...)

International

Local`
(UCP, ENSEA, Region)

ECSON (07-09)
Oncology Network of Competences
(partner)

EPSRC

TERAFS (09-11)
Laser Confocal Imaging of Cells for Study of Radiotherapy Insult
(WP co-Leader)

PAPILLON (14-…)
On-line Characterization of Dypters using Image Processing
(partner)

AUF

BQR, Scientific Council

SIMBAD (08-…)
Biomedical Image Segmentation for CAD
(Leader)

Cyclope (11-...)
Smart Videoendoscopy for CRC early-diagnosis
(Leader)

BQR, Doctoral School, SATT

National

FibroSES, iFib (2013-…)
In Vivo and In Vitro Electric Characterization of Fibrosis Induced by Electronic Implant
(WP Leader)

CNRS DEFISENS

UCP Fundation

LE, SME

TRAPIL (10-14)
Automatic Detection of Default in Pipelines Using Ultrasonic Images
(Co-Leader)

FOR YOUR EYES ONLY

CIFRE Trapil

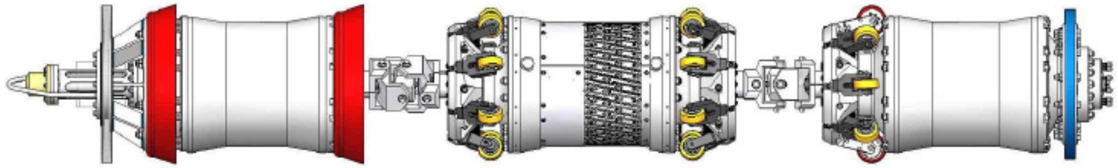
SmartEEG (13-…)
Smart Mobile System for ExG Signals Acquisition and Analysis
(WP Leader)

FUI

TRAPIL project

Objectives :
CAD for automated detection of defect signatures in pipelines using Ultrasonics imaging technology

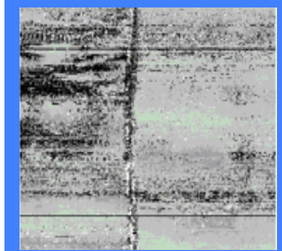
Ultrasonic probes for pipeline inspection

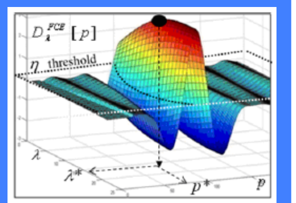


Cleaning | US Sensors | Energy and Control

Ultrasonic Images
[NDT2011,ICNDT13]

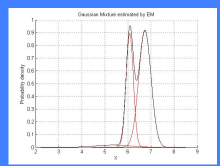
1. Weld detection
[NDT in Progress 12]



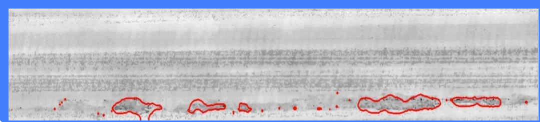


- Restoration
- Rupture detection

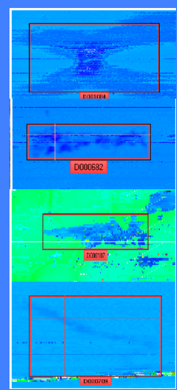
2. Default detection and segmentation



EM and Active Contours
[ICNDT13]



3. Pattern recognition (RF) *[ECNDT2014]*



Enfoncement

Corrosion

Délaminage

Sous-épaisseur