



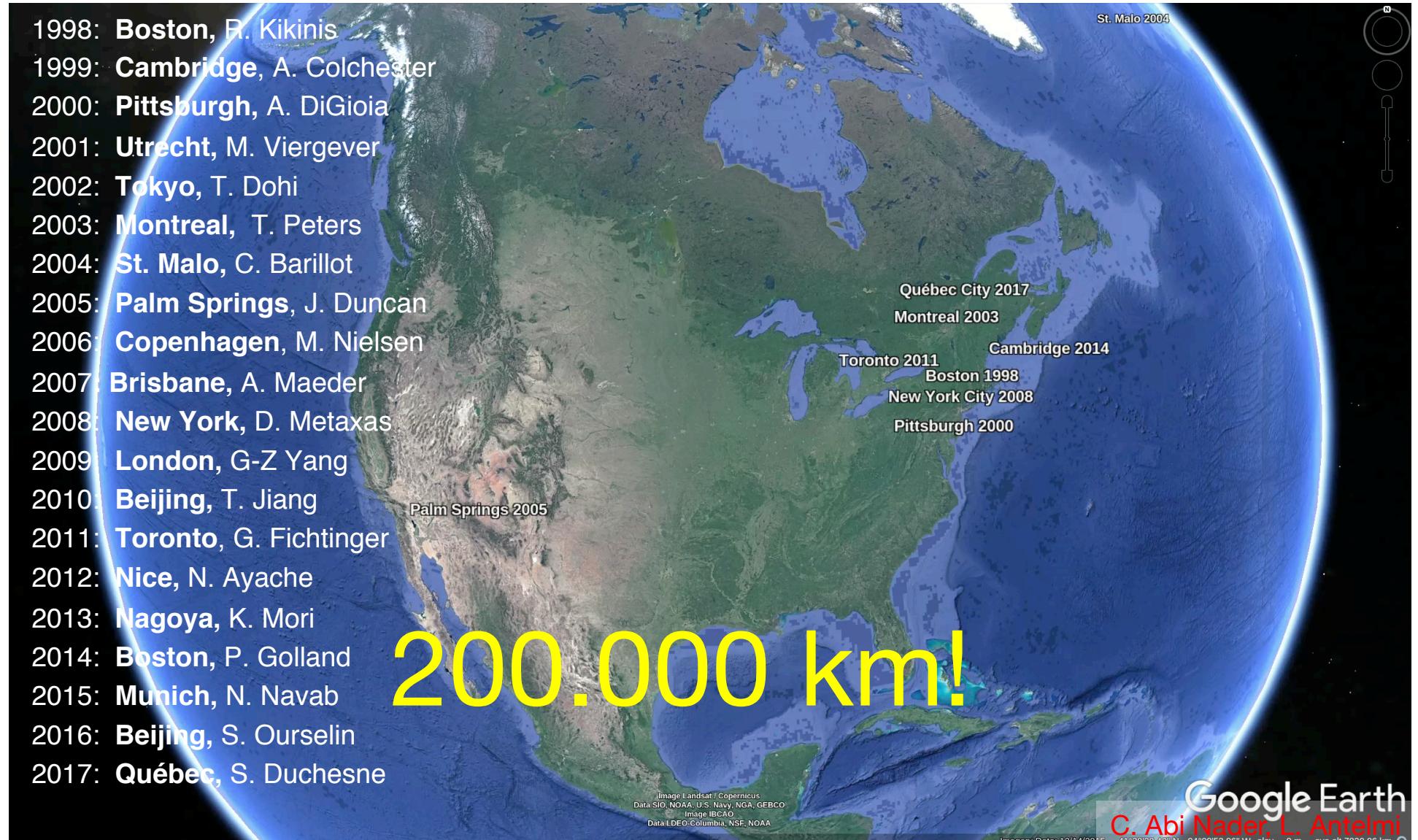
Important MICCAI Contributions of the past 20 years

Nicholas Ayache



20 MICCAI Conferences

- 1998: **Boston**, R. Kikinis
- 1999: **Cambridge**, A. Colchester
- 2000: **Pittsburgh**, A. DiGioia
- 2001: **Utrecht**, M. Viergever
- 2002: **Tokyo**, T. Dohi
- 2003: **Montreal**, T. Peters
- 2004: **St. Malo**, C. Barillot
- 2005: **Palm Springs**, J. Duncan
- 2006: **Copenhagen**, M. Nielsen
- 2007: **Brisbane**, A. Maeder
- 2008: **New York**, D. Metaxas
- 2009: **London**, G-Z Yang
- 2010: **Beijing**, T. Jiang
- 2011: **Toronto**, G. Fichtinger
- 2012: **Nice**, N. Ayache
- 2013: **Nagoya**, K. Mori
- 2014: **Boston**, P. Golland
- 2015: **Munich**, N. Navab
- 2016: **Beijing**, S. Ourselin
- 2017: **Québec**, S. Duchesne



Nicholas Ayache
MICCAI 2017

Important MICCAI contributions
of the past 20 years

What has changed with MICCAI?

- MICCAI topics used to be presented at other conferences:
 - computer vision, image processing,
 - pattern recognition, robotics
- Usually in applied sessions
- But MICCAI is not an application:
it is a new scientific discipline

Why a New Science?

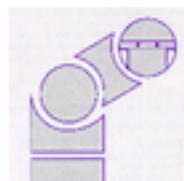
- Specificity of
 - Medical images
 - Medical diagnosis
 - Medical intervention
- Examples:
 - Non-projective volumetric images
 - Physical meaning of intensity, multimodality
 - Knowledge of anatomy and physiology
 - Safety constraints, health regulations, etc.

MICCAI

- Fusion of 3 smaller meetings in 1998 for the first MICCAI conference (Boston)



CVRMed



VBC



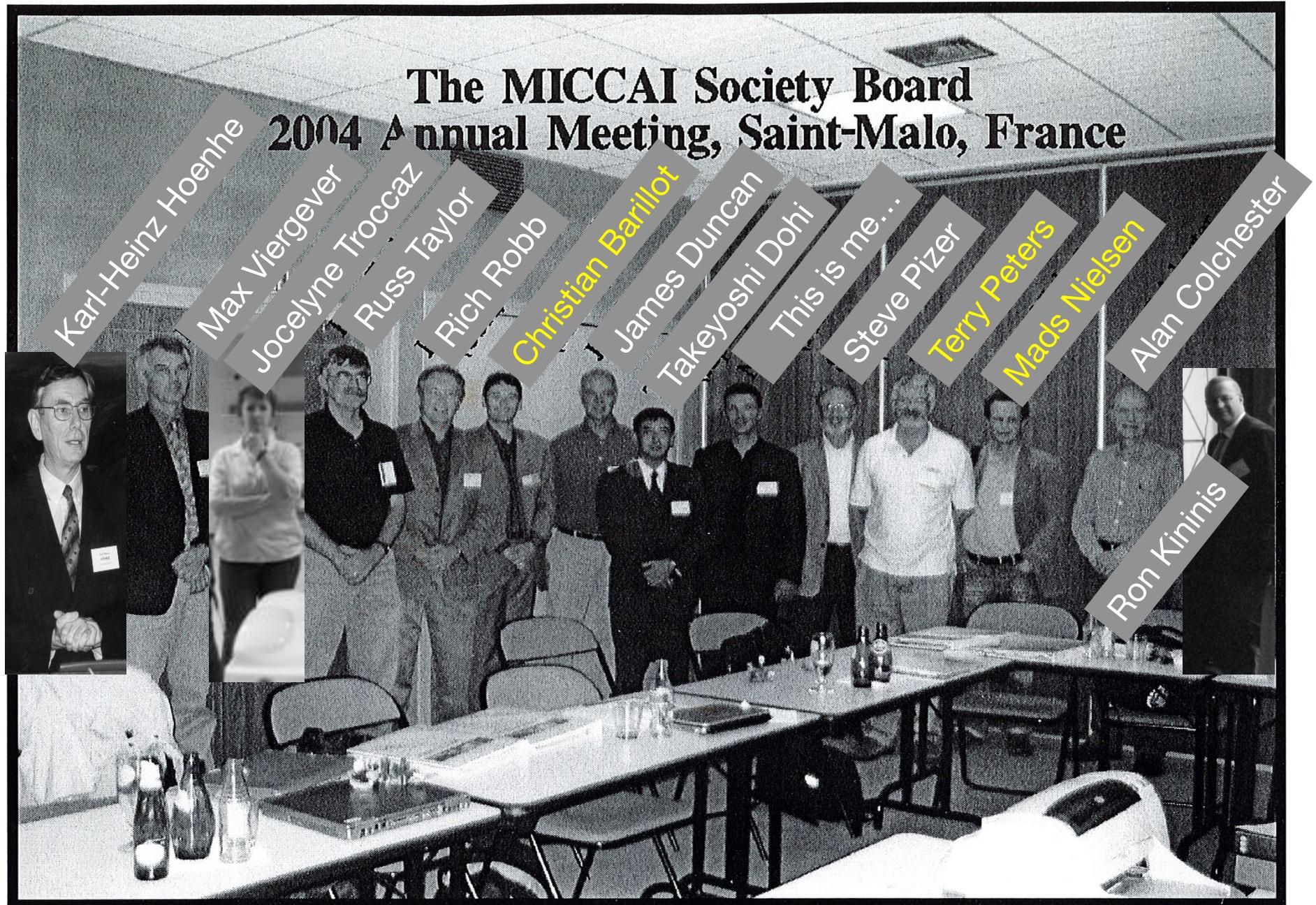
MrCAS

- Board of MICCAI 1998 :
N Ayache, A Colchester, S Delp, A Digioia, J Duncan, E Grimson,
KH Hoehne, R Kikinis, S Lavallee, S Pizer, R Robb, R Taylor, S Wells
- Incorporation of MICCAI Society in 2004



Nicholas Ayache
MICCAI 2017

Important MICCAI contributions
of the past 20 years



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MICCAI 2017

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of the past 20 years

Influential Papers

- I was asked by the organizers to present some of the most influential MICCAI papers
- I tried to find the 20 most cited papers

20 top-cited papers

MICCAI 1998-2017

Source: Publish or Perish
using Google Scholar

Year	Title	Authors	Cites
1998	Multiscale vessel enhancement filtering	AF Frangi, WJ Niessen, KL Vincken...	2685
2000	Image registration by maximization of combined mutual information and gradient information	JPW Pluim, JBA Maintz, MA Viergever	886
1998	The correlation ratio as a new similarity measure for multimodal image registration	A Roche, G Malandain, X Pennec, N Ayache	646
2015	U-net: Convolutional networks for biomedical image segmentation	O Ronneberger, P Fischer, T Brox	501
2001	A generic framework for non-rigid registration based on non-uniform multi-level free-form deformations	JA Schnabel, D Rueckert, M Quist, JM Blackall...	405
2013	Mitosis detection in breast cancer histology images with deep neural networks	DC Cireşan, A Giusti, LM Gambardella...	404
2001	Valmet: A new validation tool for assessing and improving 3D object segmentation	G Gerig, M Jomier, M Chakos	335
1998	Augmented reality visualization for laparoscopic surgery	H Fuchs, MA Livingston, R Raskar, K Keller...	333
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2000	Block matching: A general framework to improve robustness of rigid registration of medical images	S Ourselin, A Roche, S Prima, N Ayache	274
2008	Symmetric log-domain diffeomorphic registration: A demons-based approach	T Vercauteren, X Pennec, A Perchant...	273
2006	Diffeomorphic registration using B-splines	D Rueckert, P Aljabar, RA Heckemann...	259
2006	A log-euclidean framework for statistics on diffeomorphisms	V Arsigny, O Commowick, X Pennec...	259
1999	MR compatibility of mechatronic devices: design criteria	K Chinzei, R Kikinis, FA Jolesz	243
1999	An integrated visualization system for surgical planning and guidance using image fusion and intervention	DT Gering, A Nabavi, R Kikinis, WEL Grimson...	241
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2004	Clustering fiber traces using normalized cuts	A Brun, H Knutsson, HJ Park, ME Shenton...	213

20 top-cited papers

7 MIC : segmentation, detection

Vessels
U-net
Mitosis
Valmet

Graph cuts
DT-MRI
Fibers

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20 top-cited papers

9 MIC : registration

MI
CR
Block-matching
FFDs
B-splines
Demons
Log-demons
Statistics

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4 CAI : AR, robotics, planning, visualization...

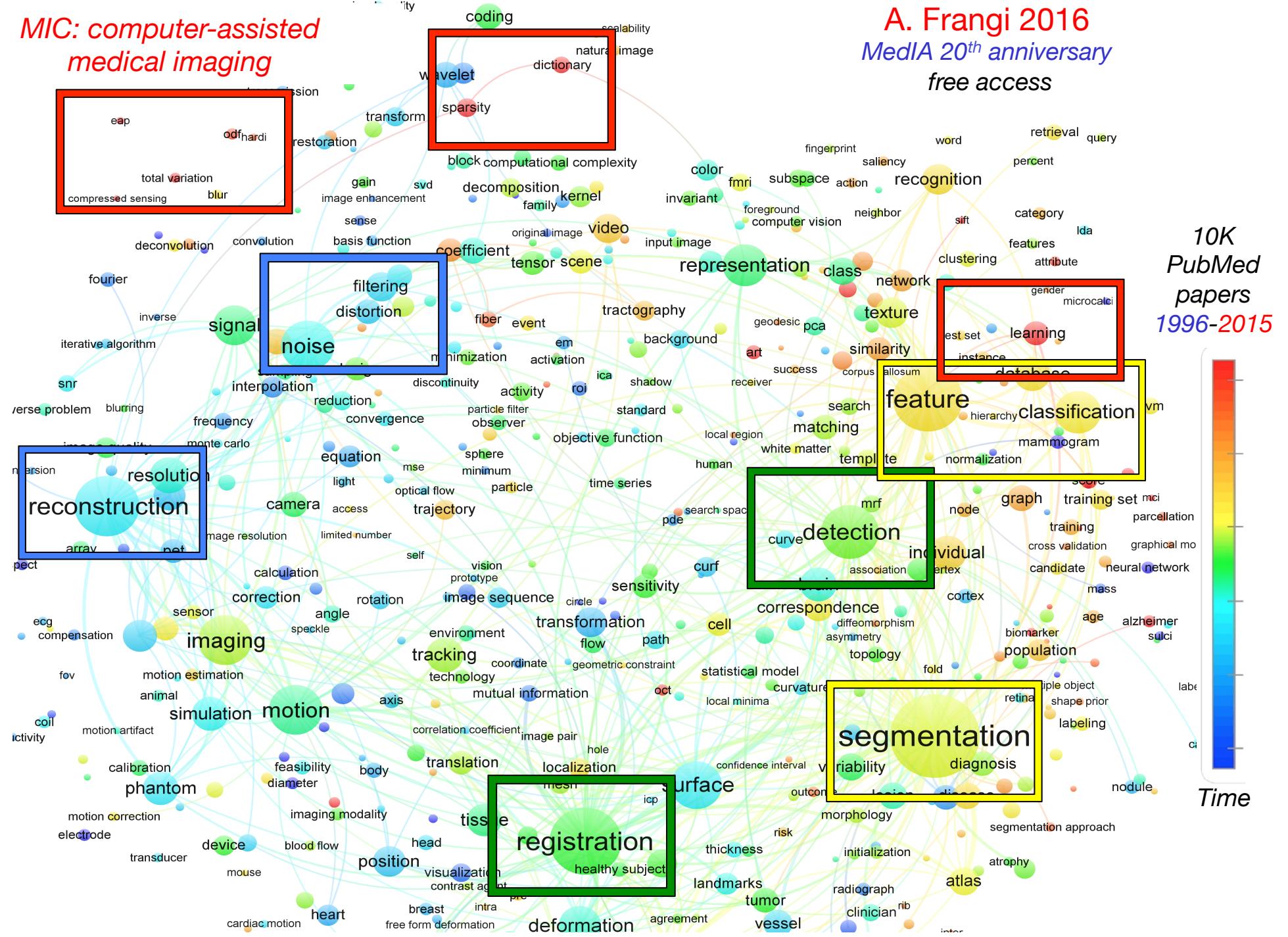
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Diversity of the field

- Top-cited papers both in MIC & CAI with a strong synergy
- But 20 top-cited papers do not cover the extraordinary *diversity* of the field nor its *evolution*

MIC: computer-assisted medical imaging

A. Frangi 2016
Media 20th anniversary
free access



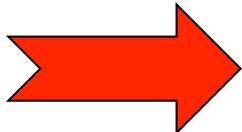
Registration

- from geometric to iconic
- from mono-modal to multimodal
- from rigid to deformable
- from linear to non-linear
- from parametric to non-parametric
- from Euclidean to Riemannian geometry
- from hand-crafted to machine learning!

Sotiras et al. IEEE TMI 2013, Viergever et al + Schnabel et al., Media, 20th anniversary, 2016

The MICCAI Revolution

- Medical images are much more than their intensities
- Images + medical knowledge + devices + models + algorithms



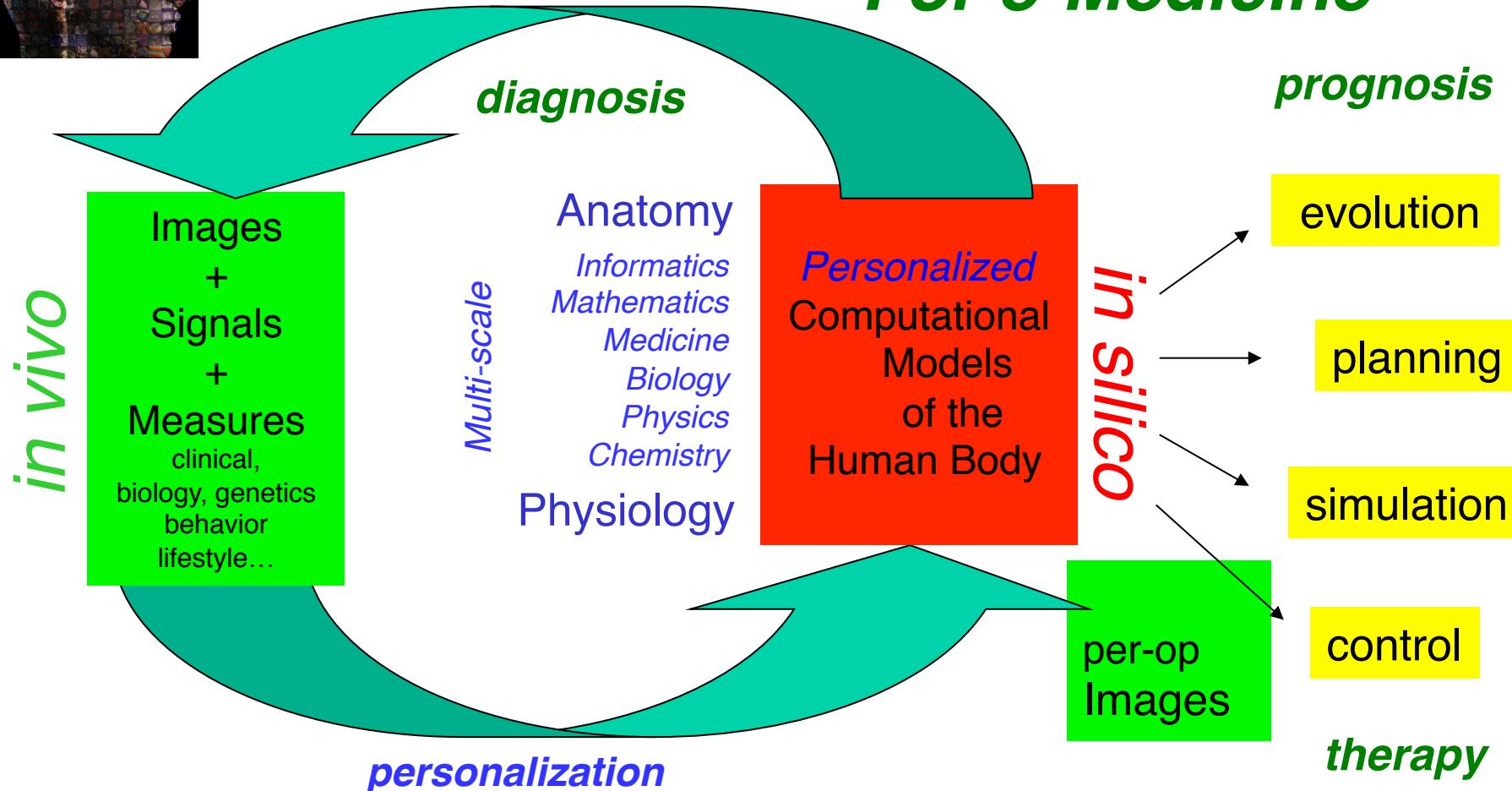
Personalized e-Patient
Precision e-Medicine

CAD, CAP, CAI



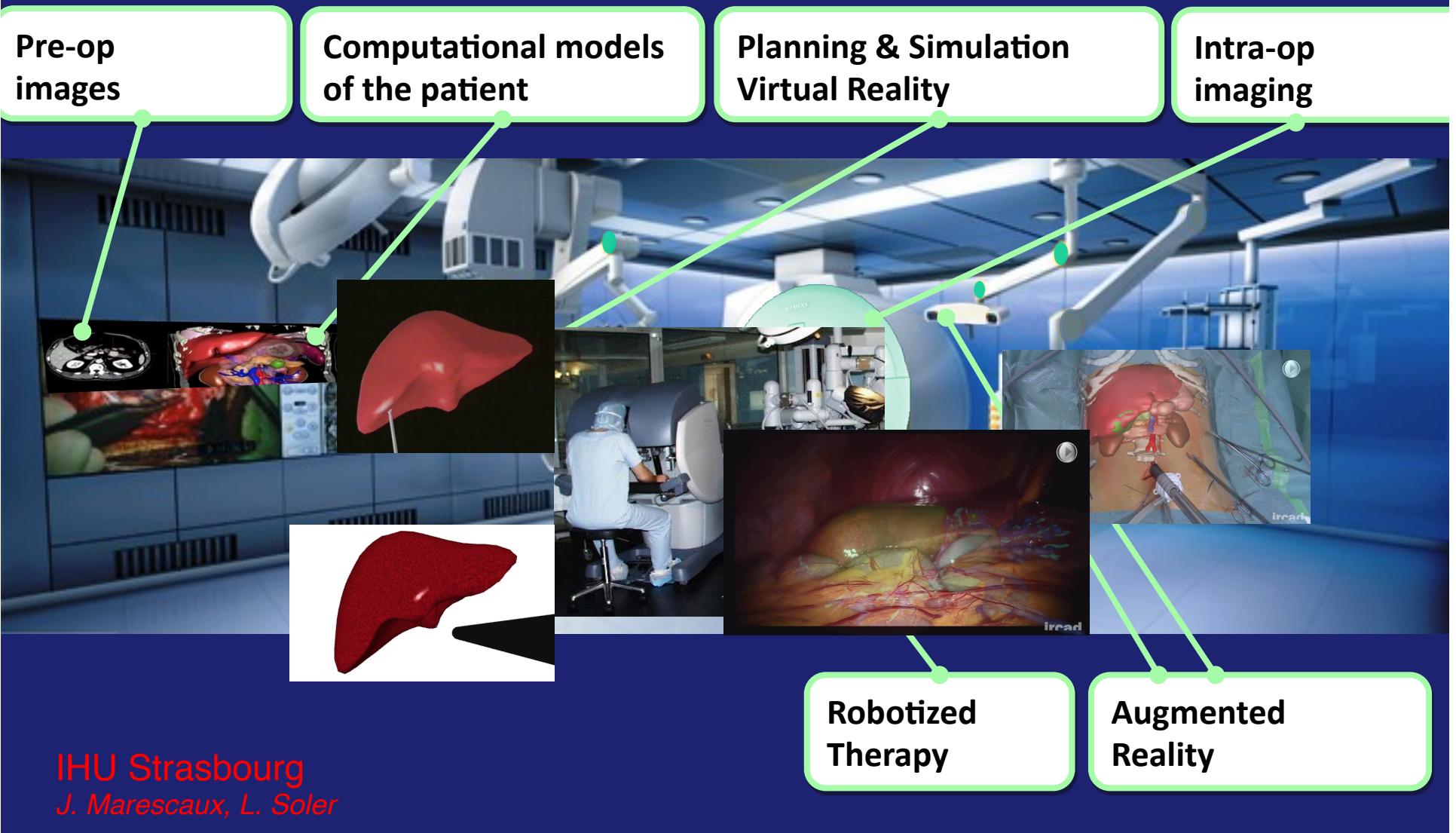
Personalized e-Patient

For e-Medicine



N. Ayache Medical Imaging Informatics: Towards a Personalized Computational Patient IMIA Yearbook of Medical Informatics 2016.

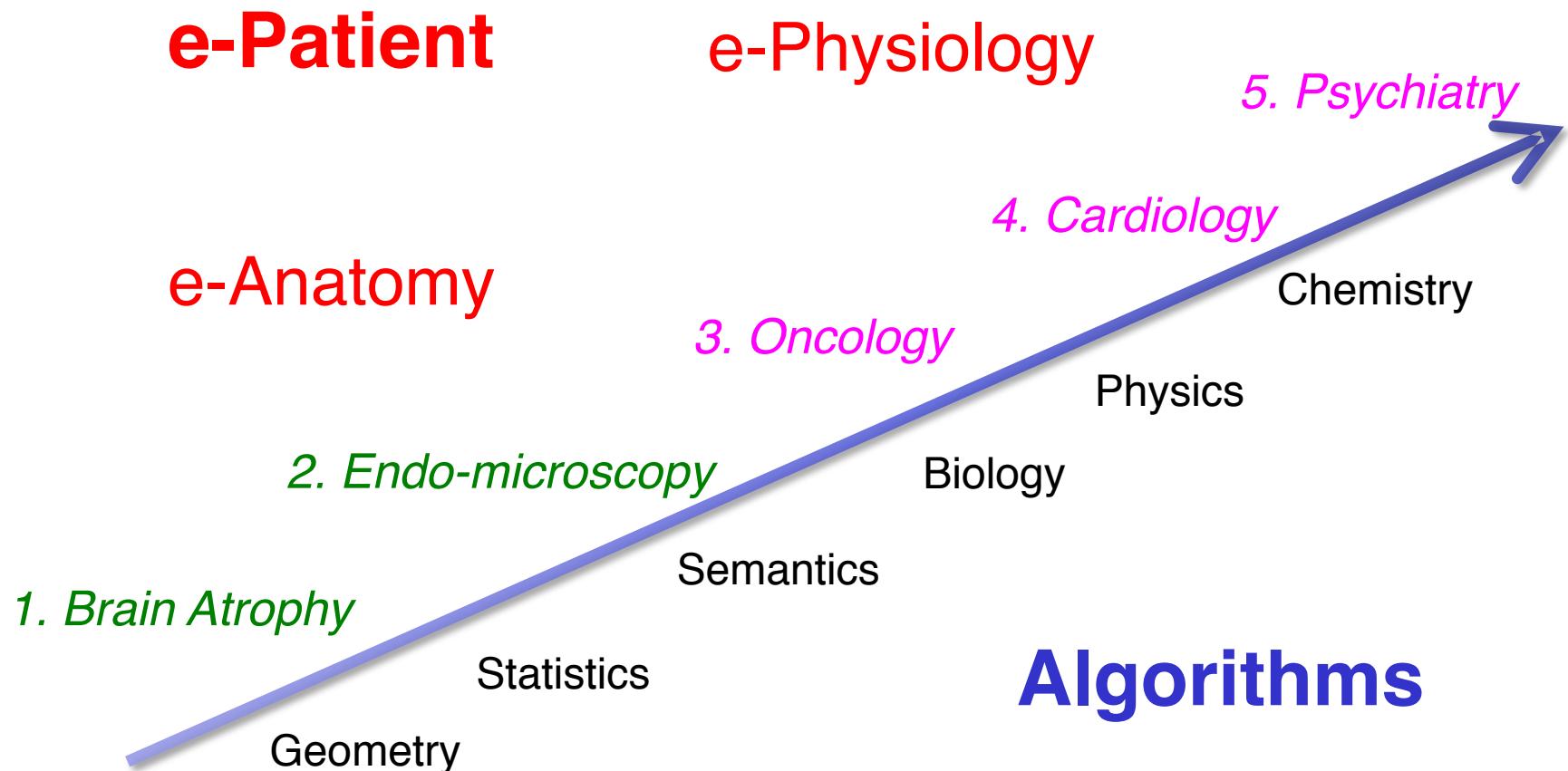
Surgery Room of the Future



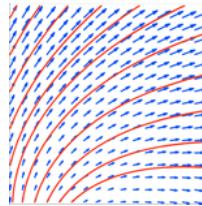
Nicholas Ayache
MICCAI 2017

Important MICCAI contributions
of the past 20 years

A Hierarchy of Models



N. Ayache. From Medical Images to Digital Patients, College de France, 2016.

$$\begin{cases} \frac{\partial \phi(x, t)}{\partial t} = \mathbf{v}(\phi(x, t)) \\ \phi(x, 0) = id \end{cases}$$


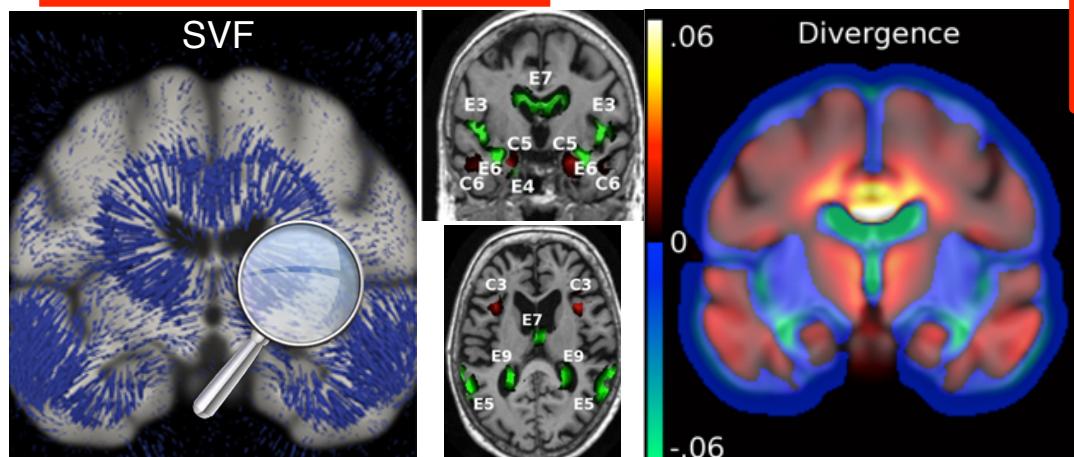
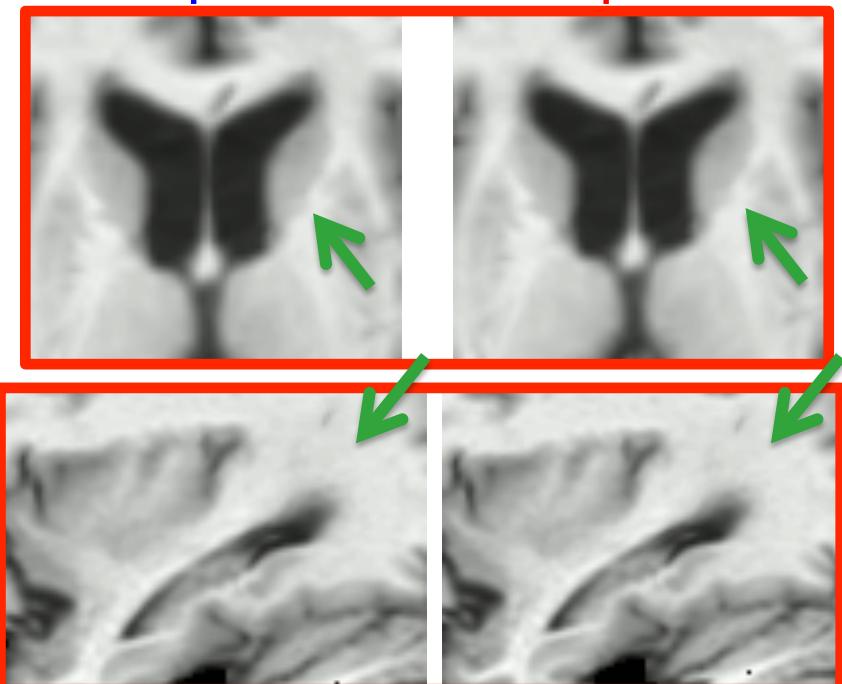
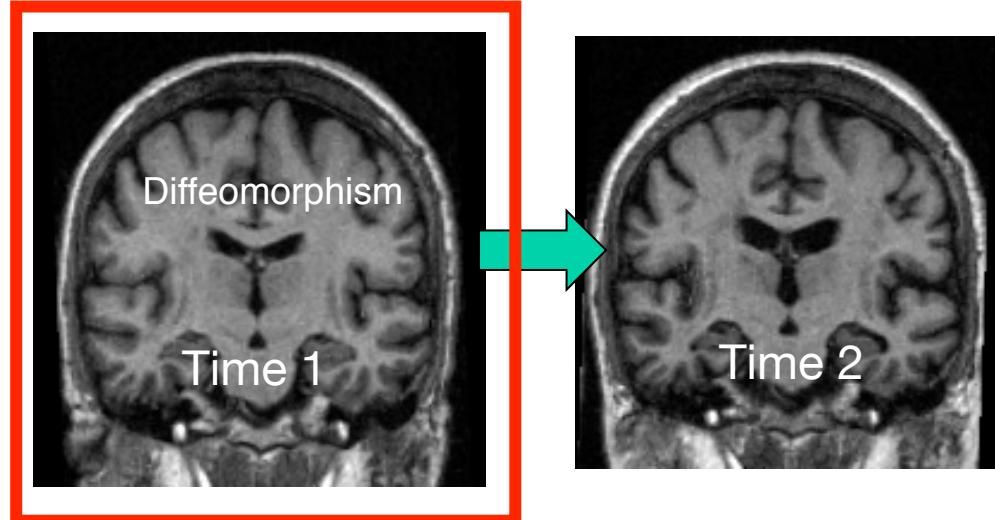
$\phi = \exp(t.v)$

1. Brain Atrophy

2 groups

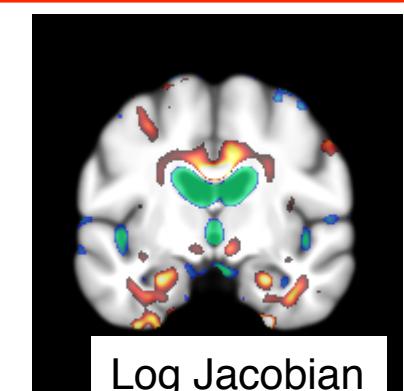
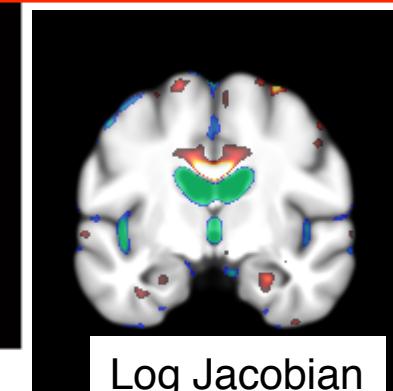
Aβ1-42-

Aβ1-42+



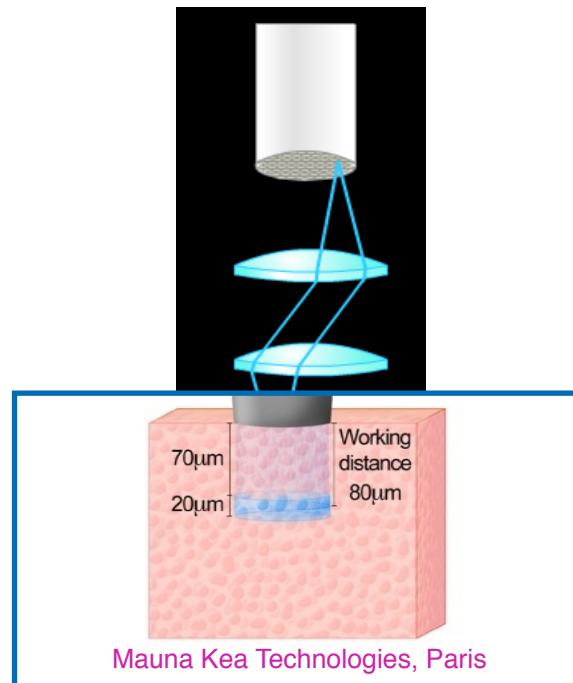
Lorenzi-Ayache-Pennec et al. MICCAI 2011+2012+2013

Khanal et al. , MICCAI 2014 (Simul@tropy) + MICCAI Challenge 2012



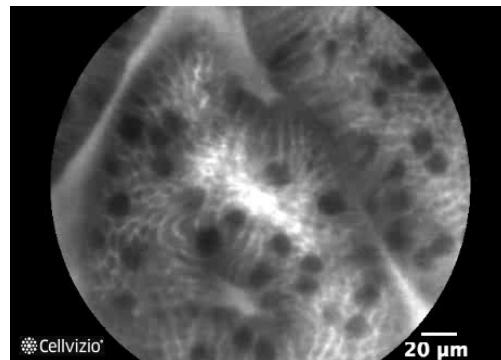
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MICCAI 2017

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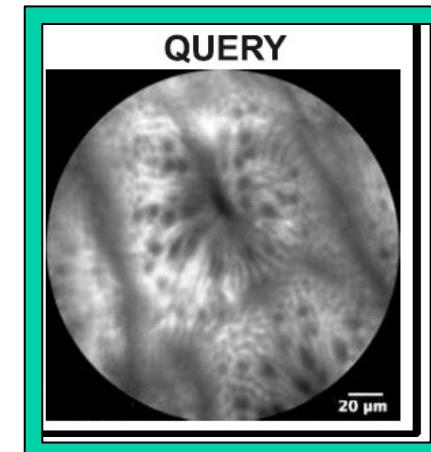


2. Endomicroscopy

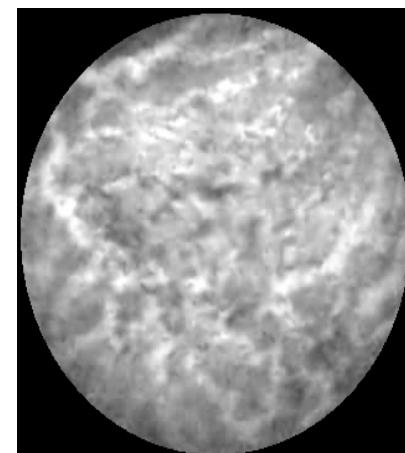
Esophagus



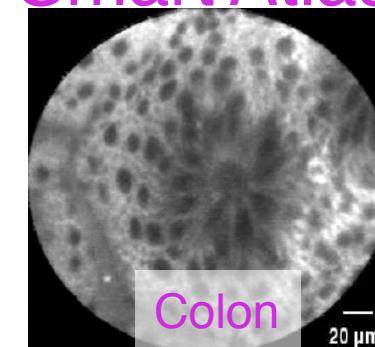
Colon New Image



Pancreas



Smart Atlas



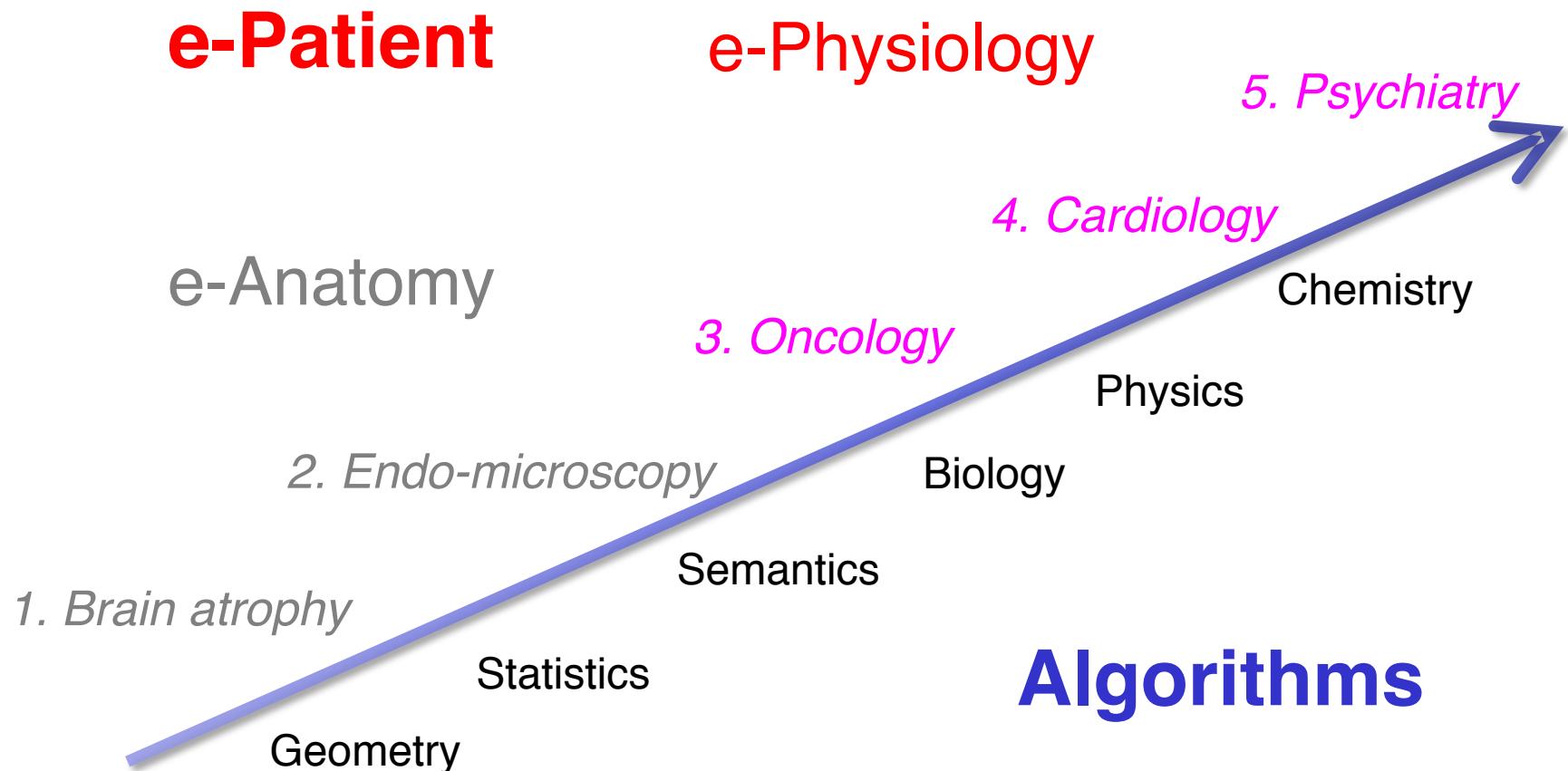
Pathology: Purely Benign
Semantic features: Round crypts, Medium lumen, Normal Goblet Cells

B André, Vercauterens, Wallace, Buchner, Ayache MICCAI 2010, 2011; Savoie et al. MICCAI 2012; Kohandani Tafreshi, et al. MICCAI 2014; Mahé, et al. MICCAI 2015

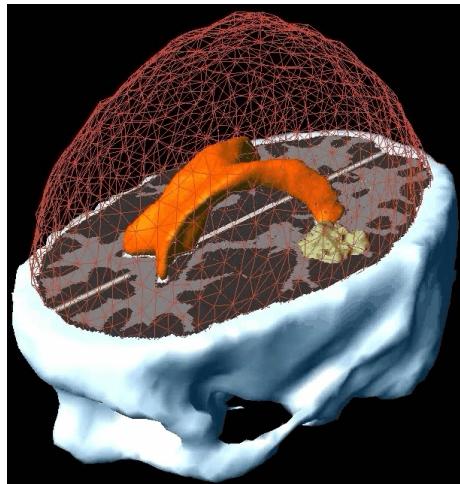
Nicholas Ayache
MICCAI 2017

Important MICCAI contributions of
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A Hierarchy of Models



N. Ayache. From Medical Images to Digital Patients, College de France, 2016.



3. Brain Tumors

Mass. General Hospital, Boston



Migration + proliferation

$$\frac{\partial c}{\partial t} = \nabla \cdot (D \nabla c) + \rho c(1 - c)$$

Fisher-Kolmogorov

$$\min_d \sum_{i \in T} c_i \exp(-d_i(\alpha + \frac{\beta}{\alpha N_f} d_i))$$

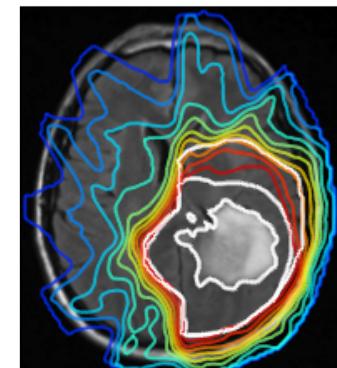
$$\text{subject to } \frac{1}{N_T} \sum_{i \in T} d_i \leq d^p$$

Tumoral cell density

Radiotherapy model

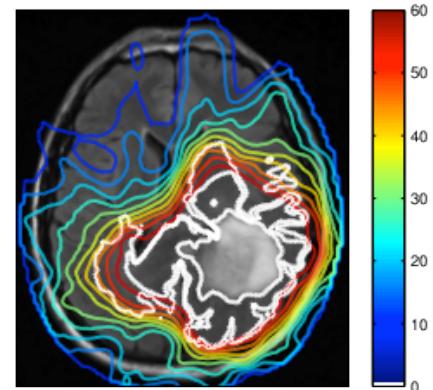
Maximal dose

Standard dosimetry



GTV : 60 Gy - T1Gd + 2cm
CTV 46 Gy - T2Flair + 1.5cm

Optimized dosimetry



Konukoglu, Clatz, et al., MICCAI 2006, MICCAI 2007; Geremia, Menze, Criminisi, et al., MICCAI 2012; Lê, Delingette, ..., Unkelbach, Ayache. MICCAI 2015; Menze et al. MICCAI BRATS 2012 - 2017

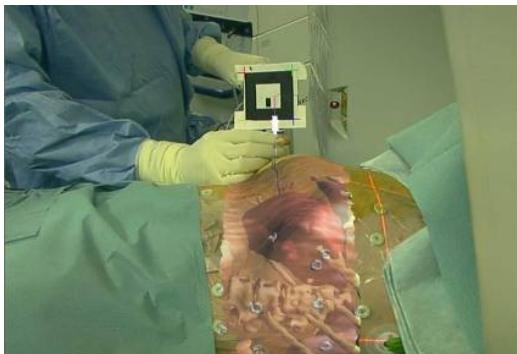
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MICCAI 2017

Important MICCAI contributions
of the past 20 years

3. Liver Tumors

Siemens Princeton
Johns Hopkins
IHU Strasbourg
Inria

Themoablation



Vascular systems

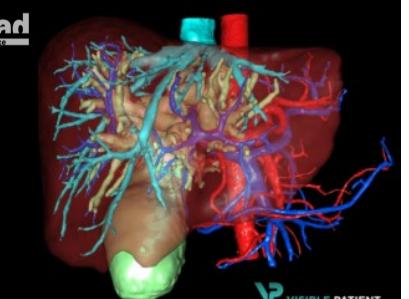


Pre-op



Per-op

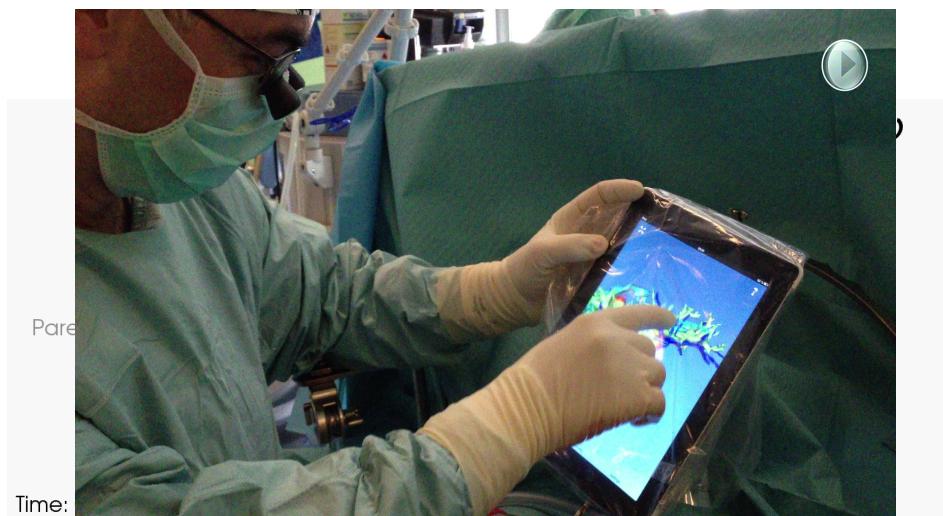
Intra-operative
Zeego acquisition



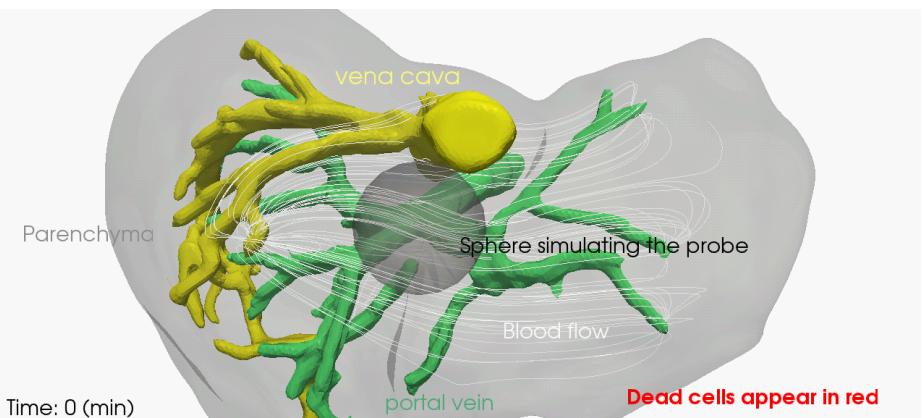
Biophysical model: blood flow, heat transfer, necrosis

PDEs: Navier-Stokes, porous media, reaction–diffusion-advection

Necrosis



Time:



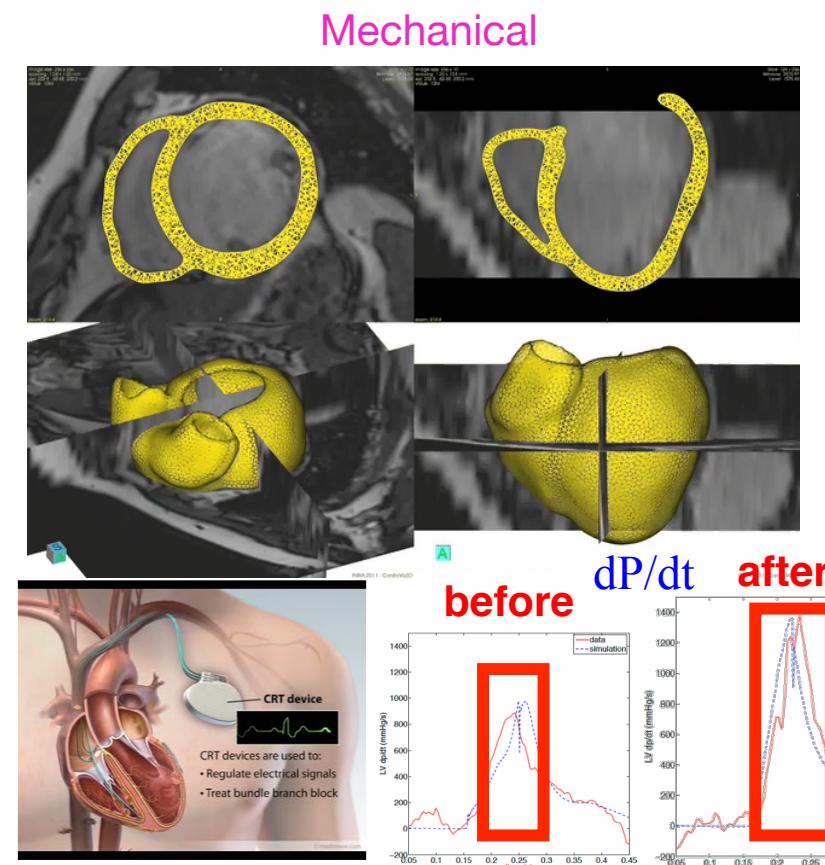
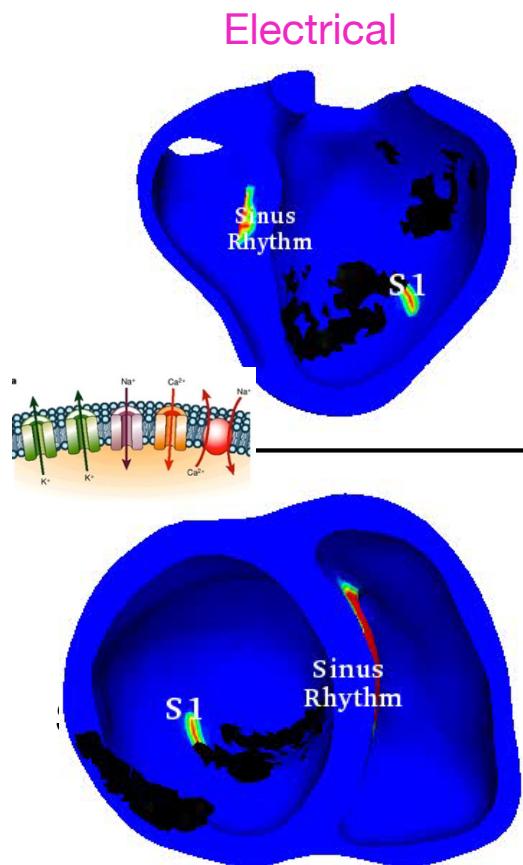
C Audigier, T Mansi, H Delingette, Michael Choti, Ali Kamen, L. Soler... D Comaniciu, N Ayache
MICCAI 2013 + MICCAI WS 2014

Nicholas Ayache
MICCAI 2017

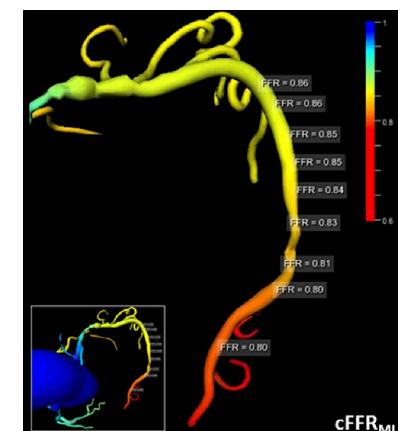
Important MICCAI contributions of
the past 20 years

4 .Cardiology

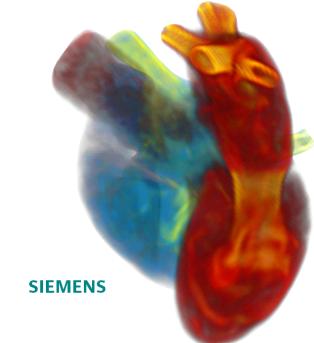
Siemens, Philips, GE
Heart Flow, Arterys,
InHeart, etc.



Haemodynamics



Siemens



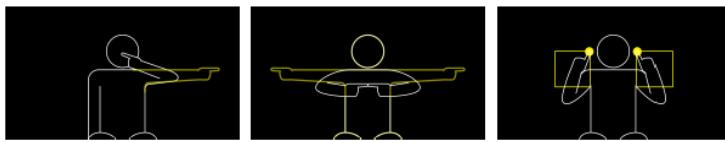
Bestel Clement Sorine : MICCAI 2001; Marchesseau, Delingette, Sermesant, Ayache MICCAI 2012
Zettinig, Mansi, Comaniciu et al. MICCAI 2013; Neumann et al. MICCAI 2015
Camarra, Mansi, Pop, Rhode, Sermesant, Young et al. MICCAI STACOM 2014 + STACOM 2010-2017

Nicholas Ayache
MICCAI 2017

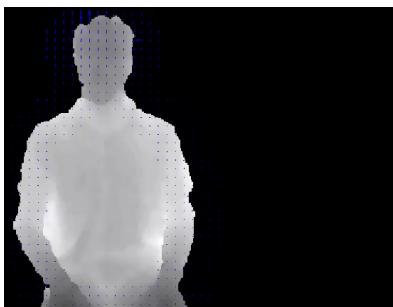
Important MICCAI contributions
of the past 20 years

5. Behavior

Patient's motion



Multiple Sclerosis



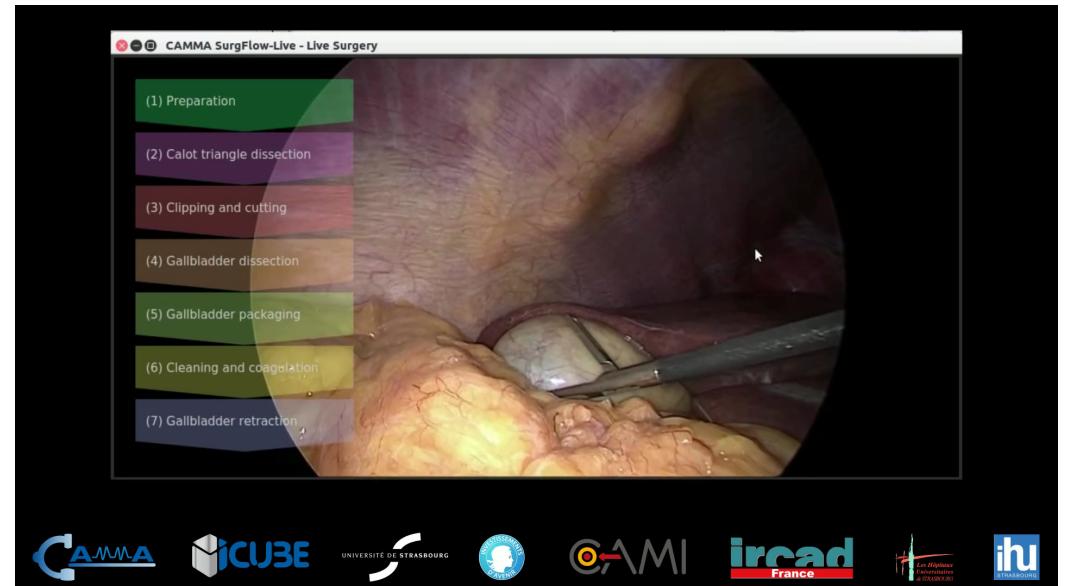
Microsoft
Research
Cambridge

INSELSPITAL
BERN UNIVERSITY HOSPITAL
Universitätsspital
Basel

VUMC
VU University
Medical Center
Amsterdam
NOVARTIS

P. Kotschieder, A. Criminisi et al.,
MICCAI 2014

Surgeon's activity



I. Aksamentov, A.P. Twinanda, D. Mutter, J. Marescaux,
N. Padoy, MICCAI 2017

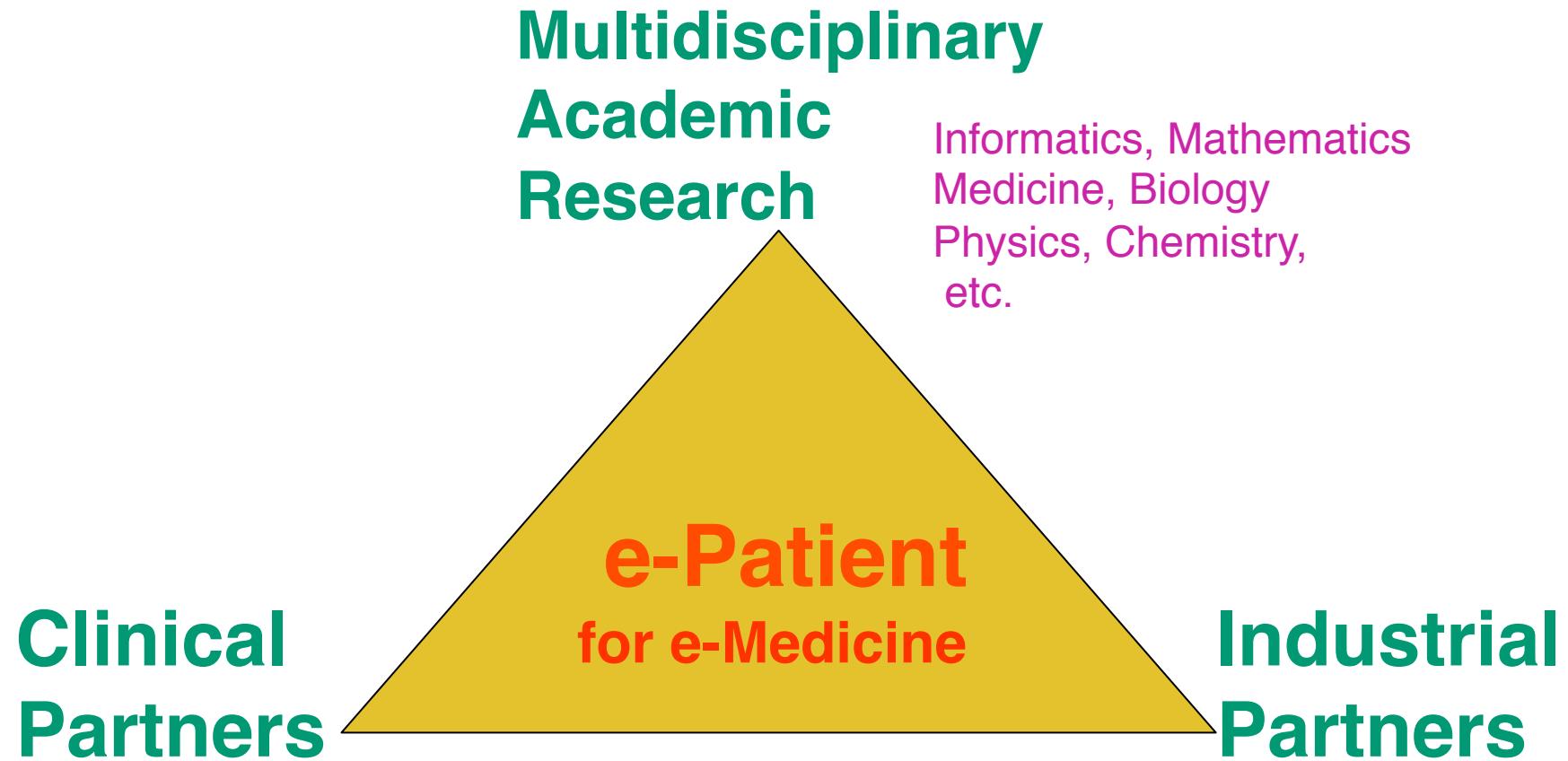
Nicholas Ayache
MICCAI 2017

Important MICCAI contributions
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What's Next ?

- New image modalities, new sensors
- More power & memory
- More data (real & simulated)
- More biophysical modeling (even for ML)
- More inter-disciplinarity
- More clinical and industrial transfer

A Virtuous Triangle



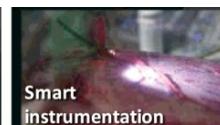
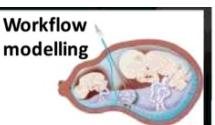
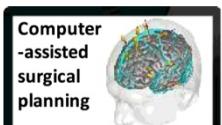
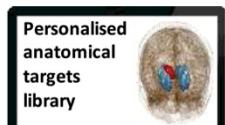
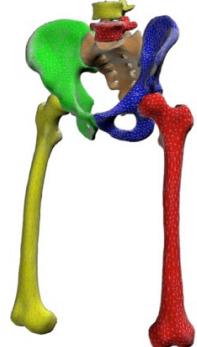
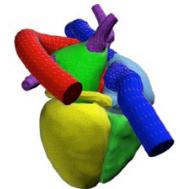
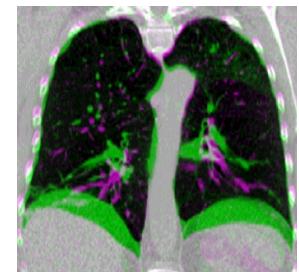
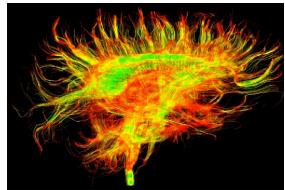
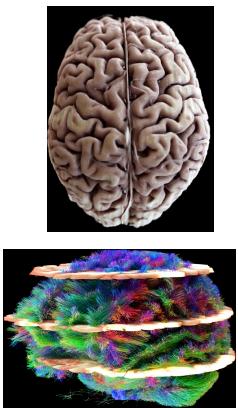
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