Summer School on Image Processing July 8th 2007

UCL

Medical Imaging and Processing:

State of the Art and Future Prospects.

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Welcome to (just outside) Szeged

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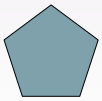
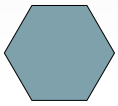
Geometrical Problem

- What geometrical shape can you form from
  - 12 Pentagons
  - 20 Hexagons

  With sides of equal length





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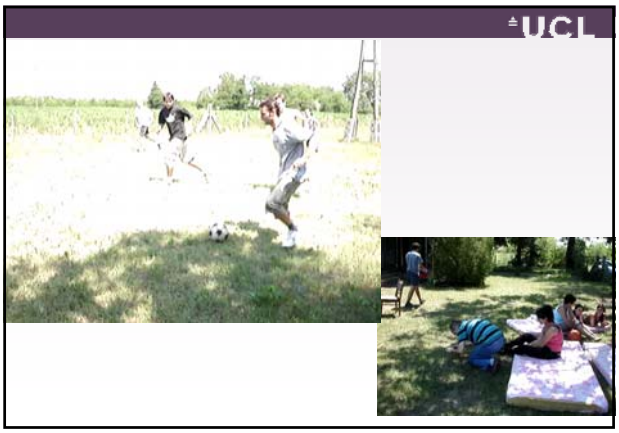
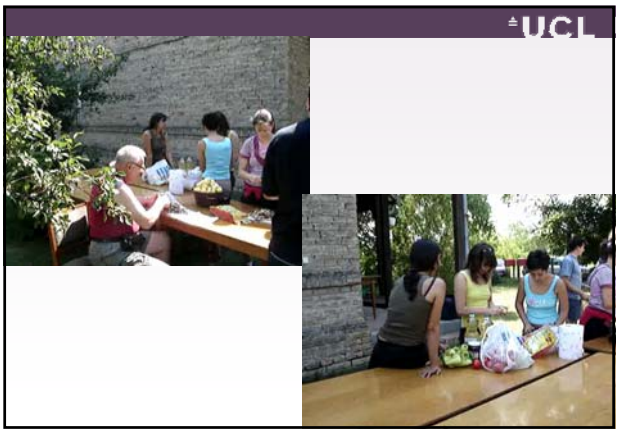
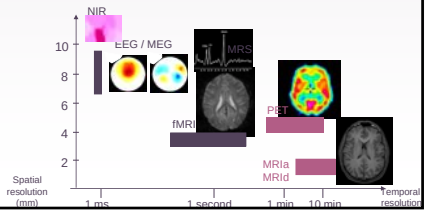




Overview (roadmap)

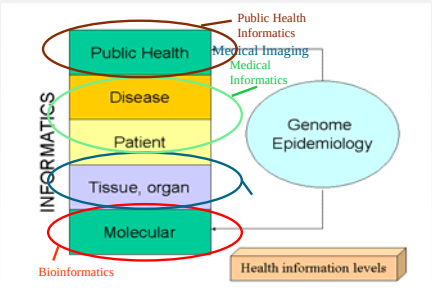
- Some tools
  - Segmentation
  - Registration
  - Quantification
  - Modelling,
- Some issues
  - 1) Issues of Bandwidth
    - Intelligent acquisition
    - Motion correction
  - 2) Partial Volume
    - Multi-scale imaging
  - 3) Image Fusion
    - Therapy



Acknowledgements

Colleagues and Collaborators:
CMIC (in particular Derek Hill and Dave Hawkes), CS, Medical Physics and Bioengineering
MIAS IRC (UCL, Oxford, Imperial, Manchester)
INSERM U494 /U678
Harvard, Georgetown, Leuven, INRIA,
EPSRC, MRC, Welcome, Siemens, Philips, GSK, and many others.

Integrating biomedical data for better health



Synthesis at all "biological levels" **EU – FP7**

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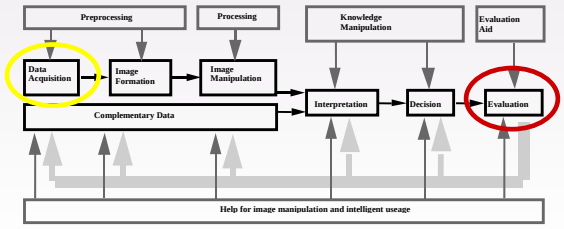
Instrumentation



The Imaging Chain

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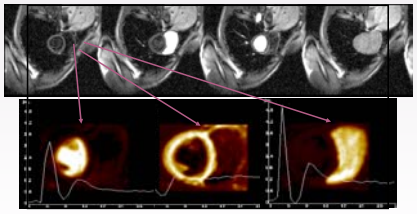
Models
Physical, Mathematical
Physiological

Processing
(Quantification)

Management



Manipulation of
Associated Data

Evaluation

Interpretation

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Myocardial functional imaging

Automatic Estimation of regions of interest from 1st passage in NMR

Imaging of contraction - perfusion

↓

Hibernation - Stunning

Estimation of contraction (Vx) intra-myocardial NMR velocity estimation Markovian approach

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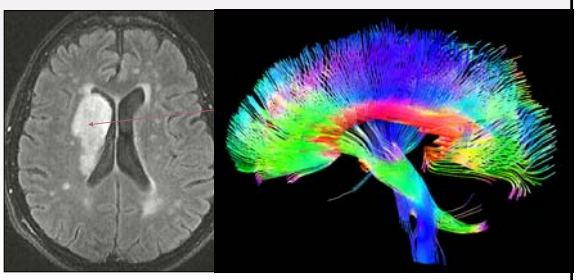
Cerebral Vascular Accident



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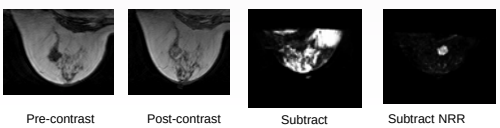
Modelling and Atlases

- Non-rigid registration
  - change detection
  - voxel-based morphometry
  - segmentation

Ack IRC/ Rueckert



Pre-contrast | Post-contrast | Subtract | Subtract NRR

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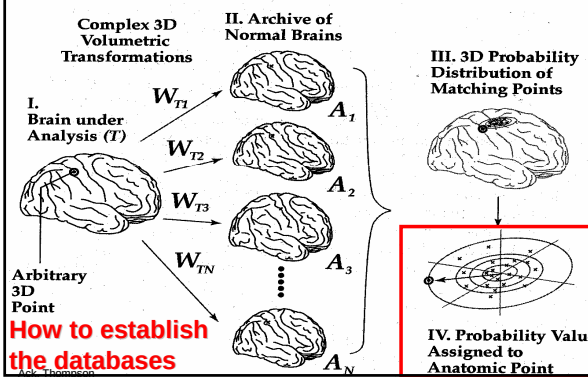
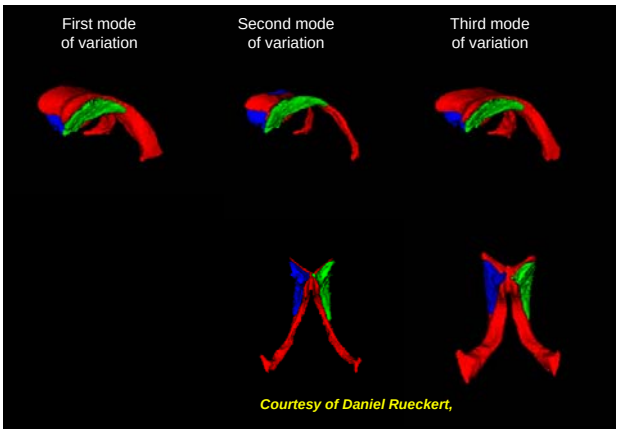
DEFORMABLE PROBABILISTIC ATLAS





Modelling Changes in Brain Morphology:

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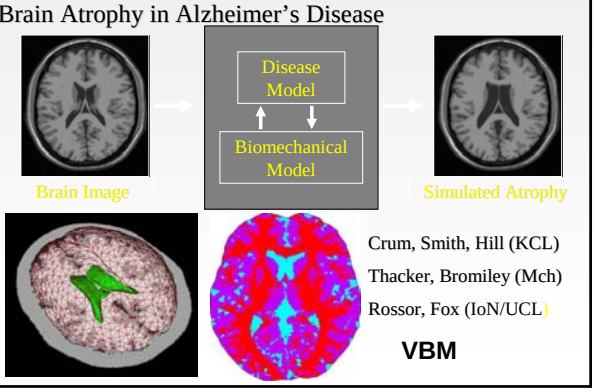
Brain Atrophy in Alzheimer's Disease



Crum, Smith, Hill (KCL)

Thacker, Bromiley (Mch)

Rossor, Fox (IoN/UCL)

VBM

Quantitation in PET/CT

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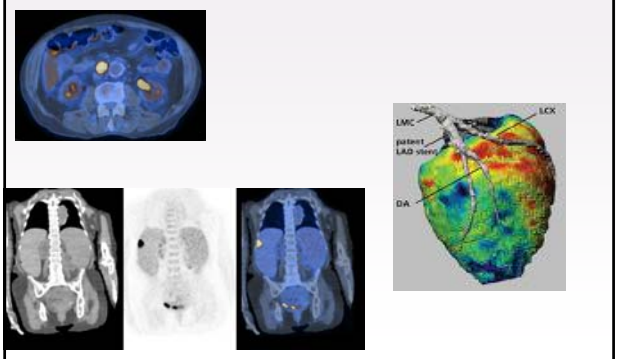

Ack Ell and Schulthess

Models

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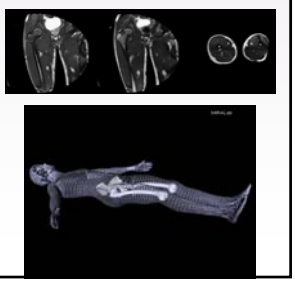
Virtual Human
NLM

The National Library of Medicine's Visible Human Project (TM)

Human-Computer Interaction Lab
Univ. of Maryland at College Park

3DAnatomical Human
->
Physiological Human



3DAH

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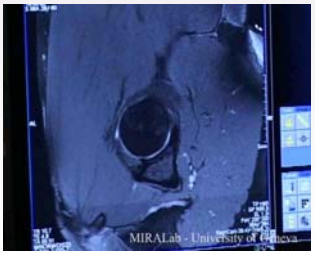

Multi-scale imaging

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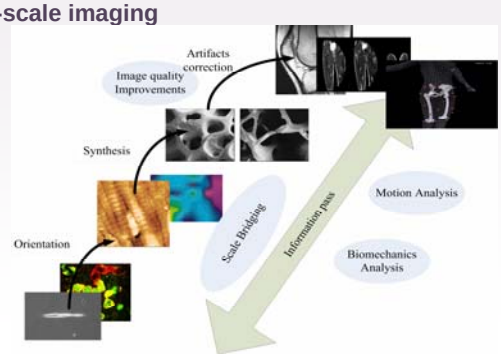
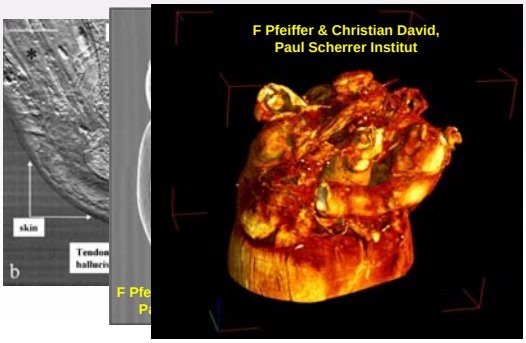


X-ray Phase Imaging (Ian Robinson)

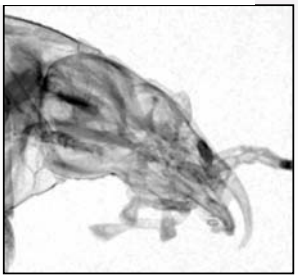


Granja (Medipix project)

X–ray imaging

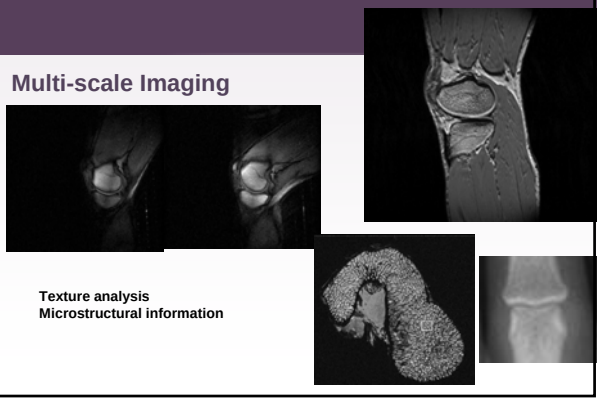
Flat-field correction for hardening of the beam

New Flat–field correction method



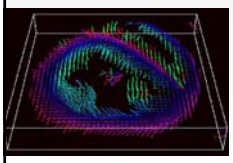
Step 4

Multi-scale Imaging

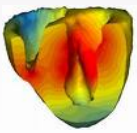


Texture analysis
Microstructural information

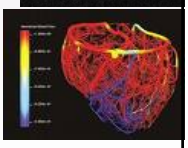
Cardiac Modelling



Ack Harvard

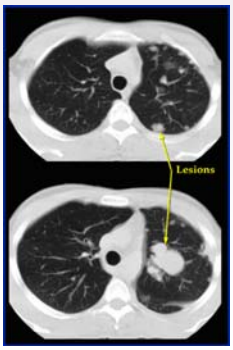


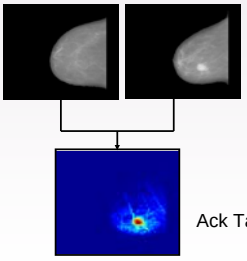
Ack INRIA



Ack Noble/ Hunter

Tracking Change



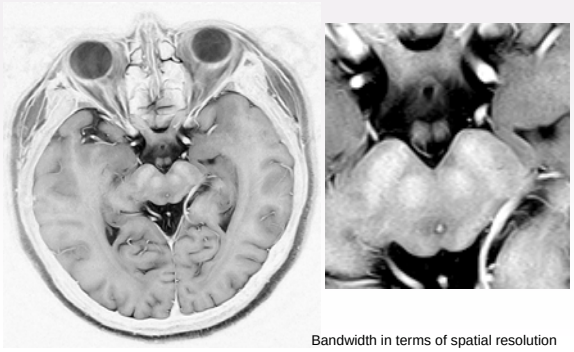


Ack Taylor

1) Bandwidth

- Adequate spatial resolution
- Adequate temporal resolution
- Correct of artefacts (such as motion)

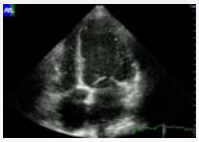
MRI

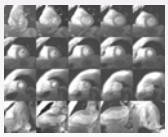


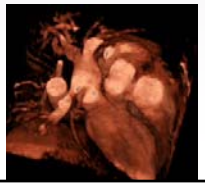
Bandwidth in terms of spatial resolution

Clinical Issues

Cardiac acquisition (and registration)







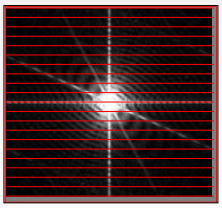
Bandwidth in terms of temporal resolution

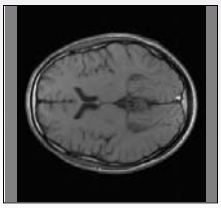
Examples

- Improved temporal resolution through undersampling
- Free-breathing imaging of the heart in 2D

MRI image formation: recap

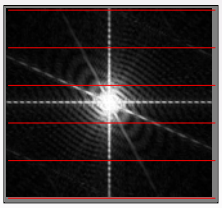
Why does MR take time?
Field of View (FoV)

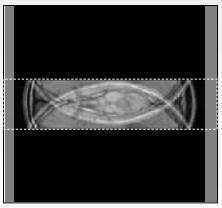




MRI image formation: recap

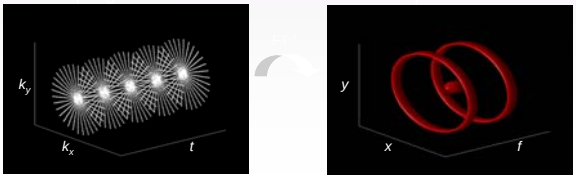
Why does MR take time?
1/4 Field of View (FoV)





Pushing the temporal resolution boundary:

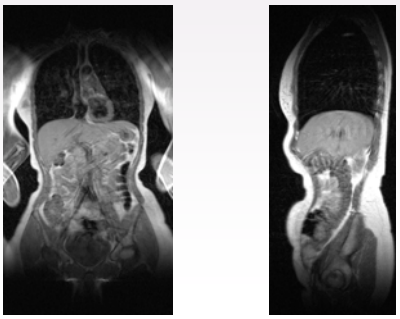
- There are relevant applications where lattice sampling is not possible:



Michael Hansen, et al, ISMRM 2006

Dealing with motion

Respiratory motion



In cardiac imaging, we have to deal with cardiac and respiratory motion

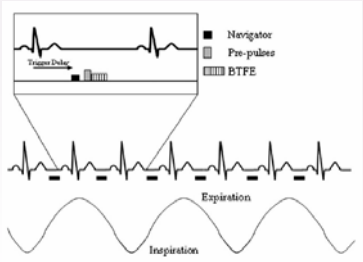
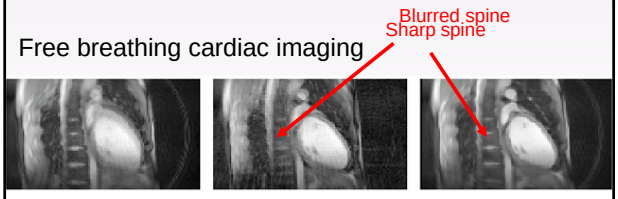


FIG. 4. Sequence timing for data acquisition showing the ECG trace, trigger delay and the position of the navigator, prepulses and acquisition with respect to the trace. Data are acquired continuously throughout the breathing cycle.

Registration

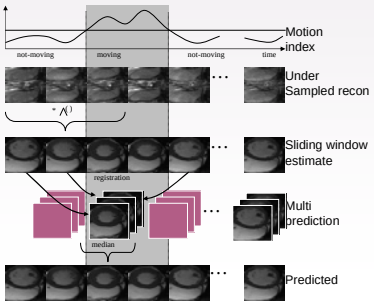
Free breathing cardiac imaging



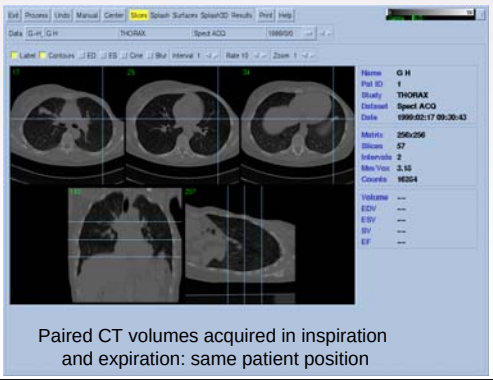
No correction | Rigid body correction | Non-rigid correction using results of fluid regn.

McLeish et al MRM 52: 2004

Registration and Prediction



Respiration correction and PET/CT



Paired CT volumes acquired in inspiration and expiration: same patient position

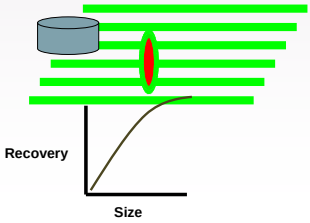
Ack Slomka

2) Partial volume effects

- Correction
- Towards multi-scale imaging

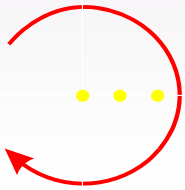
Partial volume effects

- When slice is not fully occupied
- When object is comparable to resolution in slice
- Spatially variant
- Dependent on object shape
- Probably the key limitation with respect to quantification



Depth Dependent Resolution Recovery

3 Point Sources



Ack. O'Connor

The use of higher resolution data (CT…) to correct for Attenuation and partial volume

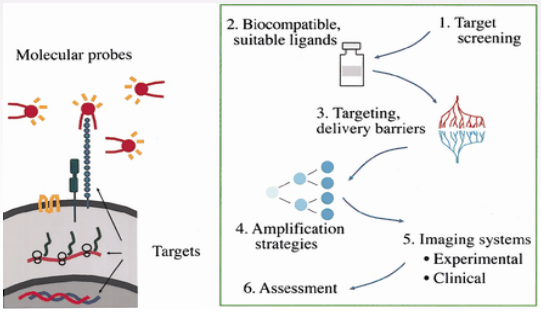
Patient projections → *Scatter correction (Generalized Linear Multi-window)* → *reconstruction (OSEM)* → *Registration (MRI, SPECT)* → *Generation of attenuation And PV map* → *Attenuation & detector response corrections + Reconstruction (OSEM)*

G El Fakhri et al.Absolute activity quantitation in simultaneous I-123/Tc-99m brain SPECT. *J Nucl Med* 2001; 42 : 300-308.

Molecular Imaging

- Viewing physiological processes
  - Direct uptake of tracers
  - Indirectly via activated receptors
  - Major applications
    - Oncology
    - Cardiology
    - Neurology
  - Impact on gene expression and therapy

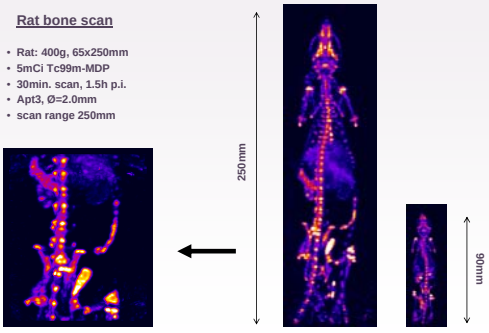
The process



Drug discovery and small animal scanners

Rat bone scan

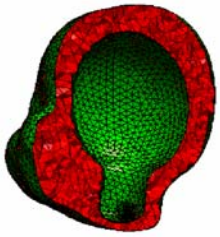
- Rat: 400g, 65x250mm
- 5mCi Tc99m-MDP
- 30min. scan, 1.5h p.i.
- Apt3, Ø=2.0mm
- scan range 250mm

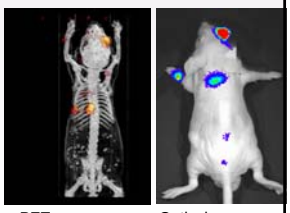


zoom of rat spine | 400g rat | 30g mouse

Ack Schramm

Dual Modality Imaging

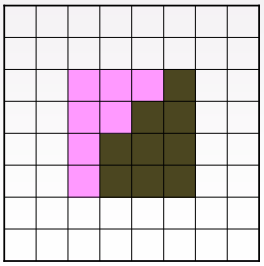




PET Optical

Sub-voxel operations

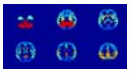
- Label on sub-pixel are defined from higher resolution image
- Higher resolution image resolution downgraded to SPECT/PT pixel size
- PVE defined if no. of compartments (labels) is fixed.

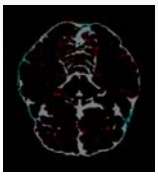


PVE corrections

- PVElab (FP6 project)

[1] Meltzer CC. J Cereb Blood Flow Metab 1996;16:650-8
[2] Muller-Gartner HW, et al. J Cereb Blood Flow Metab 1992;12:571-83
[3] Rousset OG, et al. J Nucl Med 1998;39:904-11
[4] Prinster A, et al, HBM2002,S20183



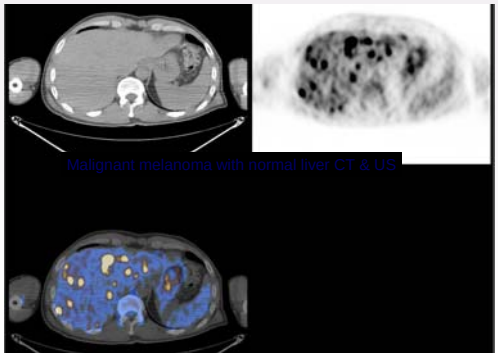


3) Fusion: toward therapy

- PET/CT
- Reconstruction using priors
- Respiration and therapy

PET / CT

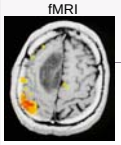
Courtesy of: Liselotte Højgaard,MD DMSc, Annika Eigtved, MD ph.d., Anne Kiil Berthelsen, MD. PET & Cyclotron Unit, Dept. Nuclear Medicine, Rigshospitalet, University of Copenhagen.



A Project –

Ack Unité 494 INSERM, LENA UPR 640 CNRS, Unité 483 INSERM, Centre MEG, Service de Neuroradiologie, Hôpital Pitié-Salpêtrière

Pre-operative fMRI



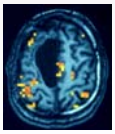
Pre-operative multi-modality visualisation

Establishing a clincal interface

Integrating statistical models *

Per-operative Cortical stimulation

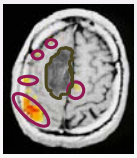
Post-operative fMRI



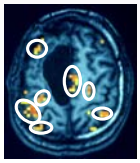
How to make it practical/ routine

*in collaboration with existing projects

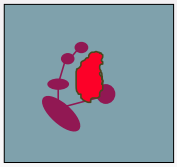
Functional images and surgery



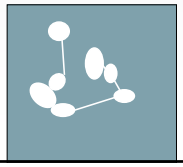
Ativation maps



Before surgery

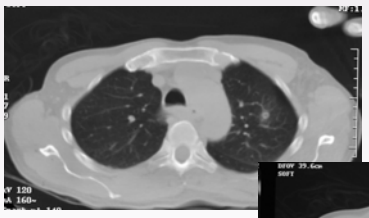


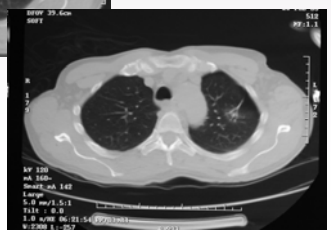
Association maps



After surgery

RF Ablation of Lung Tumours



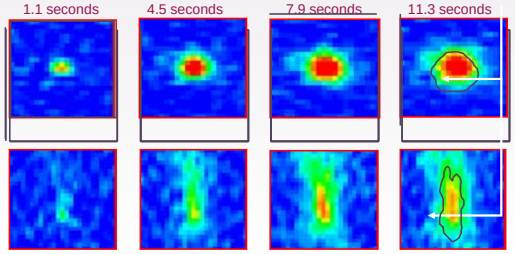


Images Courtesy of Bill Lees

Temperature buildup during sonication

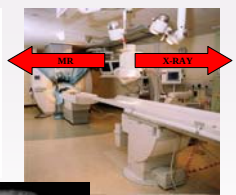
100% Necrosed

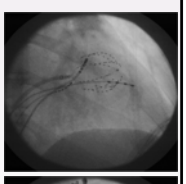
1.1 seconds | 4.5 seconds | 7.9 seconds | 11.3 seconds

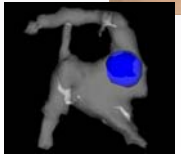


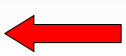
Ack Dov Maor. Insightec

Combined X-ray and MR guided ElectroPhysiology









Rhode et al TMI 2003 and 2005; Razavi et al, Lancet 2003, Guy's Hospital, London

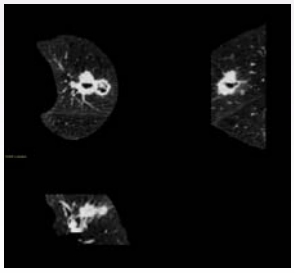
Real-time Guidance

- MR surface displayed on live x-ray at 3 frames per second
- Helical ablation catheter in left upper PV

Rhode et al TMI 2003 and 2005; Razavi et al, Lancet 2003, Guy's Hospital, London

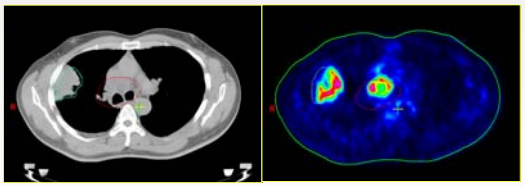
Motion modelling in lung radiotherapy

Blackall et al WCOMP 2003, McClelland et al SPIE Med Imag 2005, ESTRO 2005



PET/CT improving cancer treatment

[A different type of quantification]



Tracers- F18- FDG tumour cell volume
IUDR tumour growth MISO hypoxia

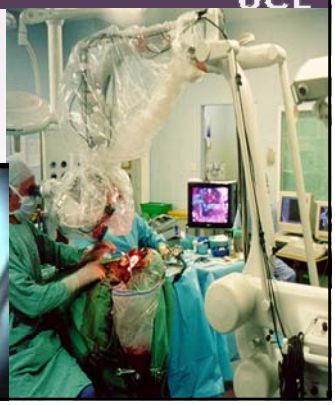
Courtesy of Holy Name Hospital

Dizendorf, Univ. of Zurich: Diagnostic Imaging – PET/CT Fusion Proves Its Worth

MAGI system in the Operating Room:

Overlay of 3D preoperative image data on stereo field of view of binocular operating microscope

(Edwards et al IEEE-Trans Med Imag 2000)

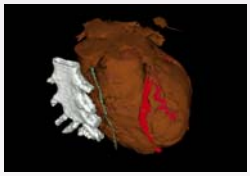


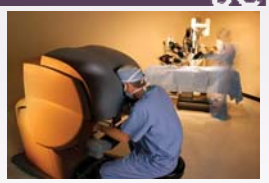
Virtual + Real reality

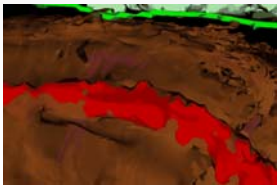
Simulated surgery

Separation.avi

Edwards et al, Imperial College London







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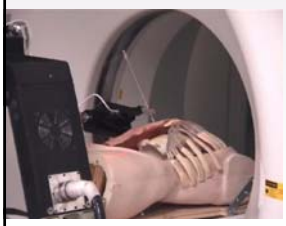
Robotically Assisted Lung Biopsy Under CT Fluoroscopy



Robotically Assisted Lung Radiotherapy Using Optical tracking (Accuray's Synchrony)

Kevin Cleary et al Georgetown University, Washington

UCL

But: How do you evaluate?

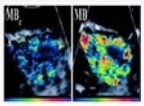
- True positive and false positive rates
- Probabilistic distances
  - Hausdorf distance (largest difference)
- Volume and volume overlap
- Interclass correlation coefficient
  - Williams (modified) index
- ??? How to measure false negatives???

- Valmet software www.ia.unc.edu.public.valmet

UCL

The Future of Medicine?

- Preventive medicine
  - Including environment
- Personalised Medicine
  - Using the –omics (genomics/ proteomics …)
- Keyhole/ robotic surgery
  - Implanted devices
- Nanotechnology
  - Biolab
  - MEMS (micro electro-mechanical systems)
  - Lab-on-a-chip micro-arrays and diagnosis
  - Drug production
- Complex Systems
  - Mathematical biology
  - Modelling and simulation
  - CAD?



The End?

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