Atlas construction and image analysis using statistical cardiac models


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WHY DO WE NEED ATLAS ES OF THE HEART?
Why do we need atlases of the heart?

1. **Integrated image-based biomarkers**

Looking at multiple levels

- **Global** shape
- **Local** shape
- **Motion / Deformation**
Why do we need atlases of the heart?

1. **Integrated image-based biomarkers**

   Probabilistic biomarkers

   Encode normality

   P-value of abnormality

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Duchateau et al, STACOM (2010)
Why do we need atlases the heart?

2. Integrated multimodal information for patient-specific modeling
2 EVOLUTIONS AND CHALLENGES IN HEART ATLAS CONSTRUCTION
From single subject to population atlases

Affine + nonrigid diffeomorphic registration

Reference

Average up to affine transform: The atlas image

Segment

Triangulate

Apply inverse transforms

Apply average non rigid transform

Average non rigid transformation
From monomodal to multimodal atlases

POINT DISTRIBUTION MODEL

STATISTICAL INTENSITY MODEL

MODEL TO IMAGE ADAPTATION/MATCHING

Create automatically by image simulation

From **spatial** to **spatiotemporal** atlases

- Two parameterizations
  - $a$ and $b$, subject and cardiac phase
  - Each in their own space with orthogonal basis

From \textbf{spatial} to \textbf{spatiotemporal} atlases

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$\mathbf{x}^{s,p} = \left[ \Phi^V \mathbf{a}^s \right]^V \mathbf{b}^p$

From **single object** to **multi-objects atlases**

- Multiple anatomical levels and topologies
  - 4 chambers
  - Tissue properties
  - Muscle & Purkinje fibers
  - Coronaries
From **scalar objects to vectors & tensors**

- **DTI-based fiber orientation**

  - Muñoz-Moreno, & Frangi ICIP (2010, in press)
  - Toussaint et al. Miccai (2010, in press)
3 CONCLUSIONS & PERSPECTIVES
Shape is not enough
Motion is not enough

Source: http://jcmr-online.com/imedia/1712877943433156/supp1.mpg

Erikson et al. JCMR, 12(9), (2010)
Perspectives

- **On biomarkers**
  - Towards complex indexes
    - Integrate shape (local & global), electrical activation, motion/deformation, and flow
  - Towards new probabilistic biomarkers
    - Distance to populations/manifolds

- **On data integration**
  - Multiple-layers visualization of heart function
  - Multi-level patient specific models
Patient-specific simulation and virtual populations

FEM Model

Geometrical Model

Functional Model

Electrical Multiscale Modeling

Simulation

\[ \nabla \cdot (\sigma_e \nabla \phi_i) = \beta I_m - I_{si} \]

\[ \nabla \cdot (\sigma_e \nabla \phi_e) = -\beta I_m - I_{se} \]

\[ I_m = C_m + \frac{\partial \phi_m}{\partial t} I_{ion} \]

\[ \nabla \cdot (\sigma_i \nabla \phi_i) = \beta I_m - I_{si} \]

Extracellular $\phi_e \sigma_e$

Intracellular $\phi_i \sigma_i$

Extramycocardial $\phi_0 \sigma_0$

$\phi_{body}$

Hoogendoorn et al. STACOM, (2010)
Thanks