Discrete Optimization in Image Processing

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and

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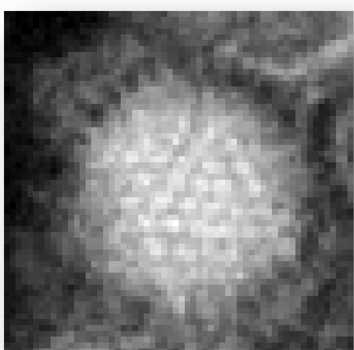
NordConsNet17

Research at Centre for Image Analysis

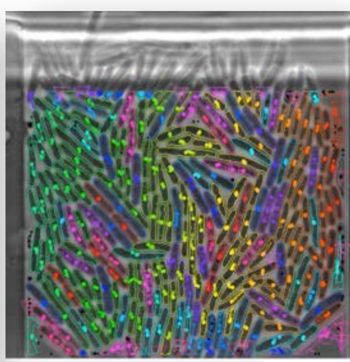
Theory

Applications

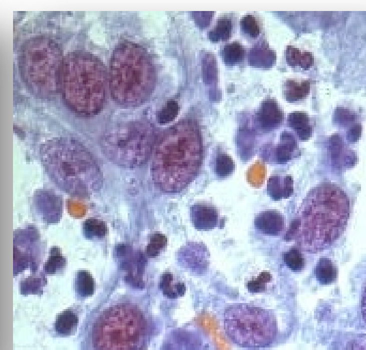
- Digital geometry, mathematical morphology, graph methods
- Object detection and segmentation
- Digital and fuzzy shape & feature measurements
- Visualization of volumetric data
- Haptic interaction & interactive system design
- Biomedicine and forestry
- 2D, 3D, multimodal/multispectral and time-lapse



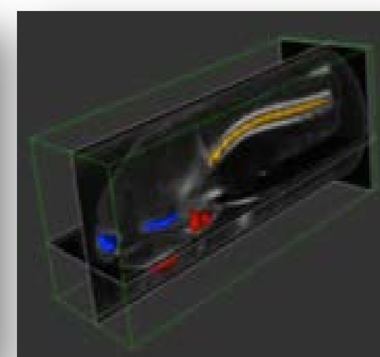
10^{-8}m



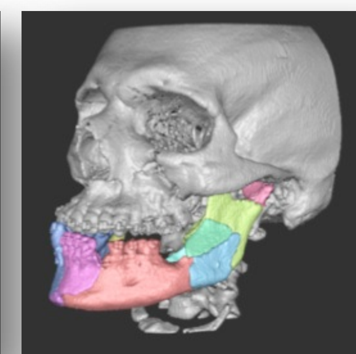
10^{-6}m



10^{-4}m



10^{-3}m



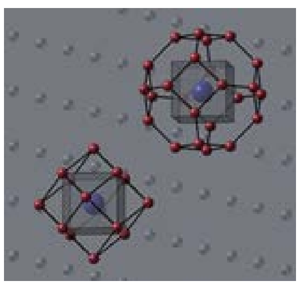
10^{-1}m

My research

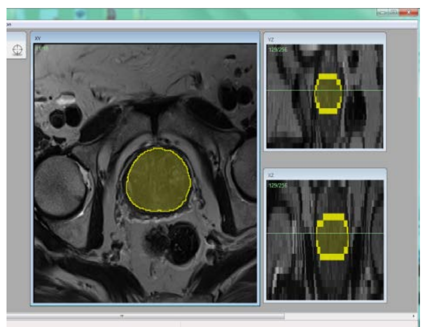
Theory

Image registration
Image segmentation

Medical applications

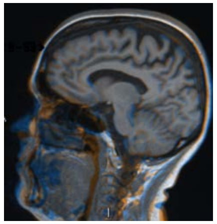


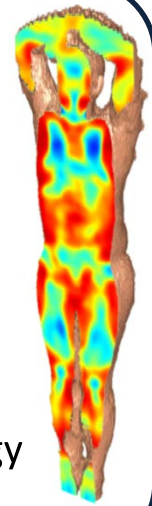
Digital geometry
Graph-based methods



Interactive image processing

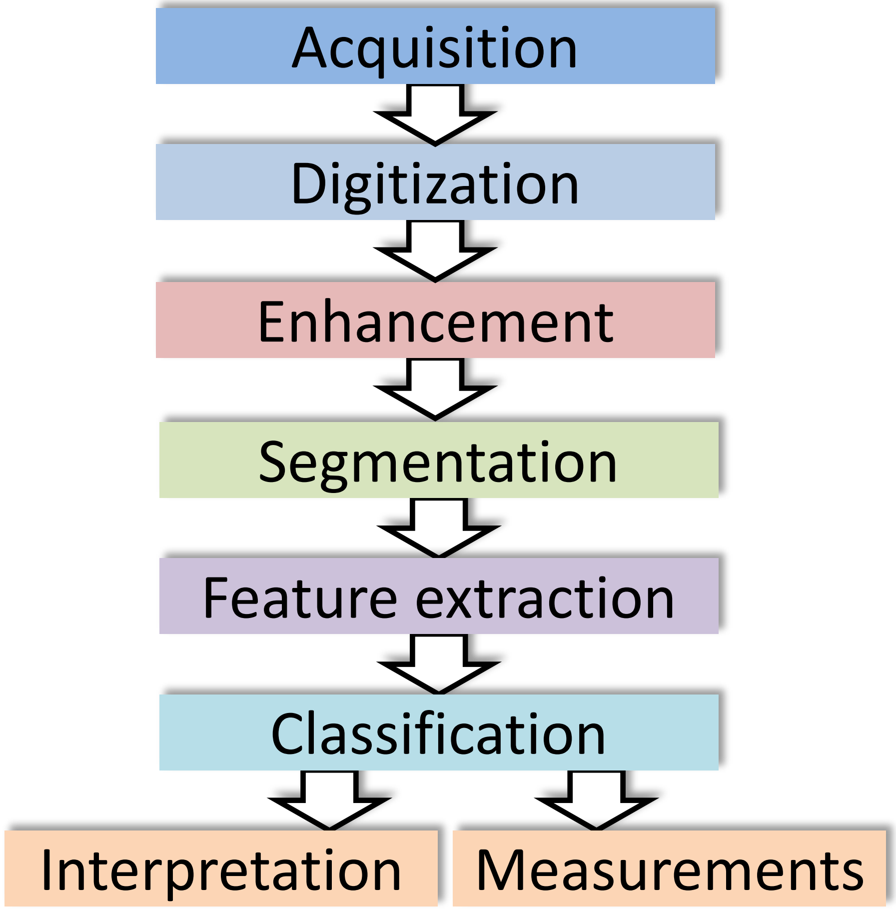
Radiation therapy





Radiology

Image processing and analysis

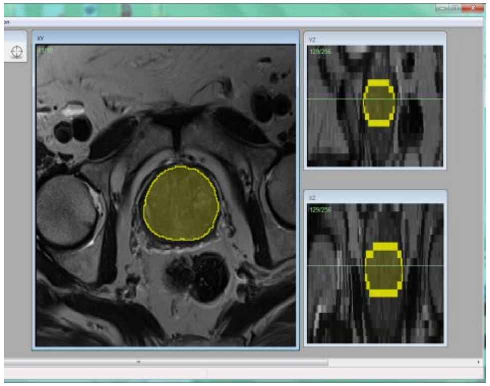


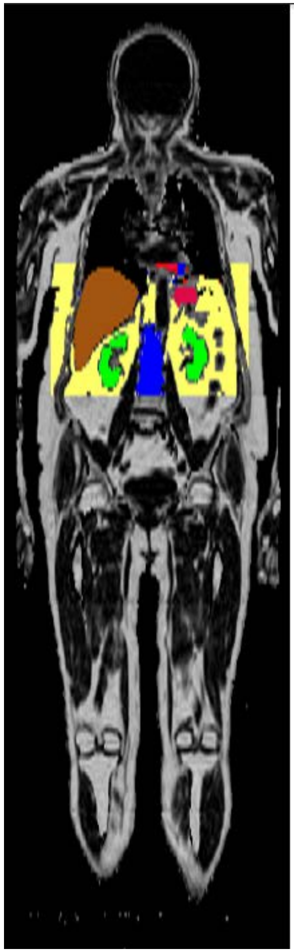
+ image visualization and image data management

Discrete optimization in image processing

Example applications

- Image segmentation
  - Interactive
  - Automatic
- Image registration
- Computer vision
  - Stereo
  - Motion
  - Multicamera scene reconstruction
- Image restoration
  - Filtering
- Image inpainting and



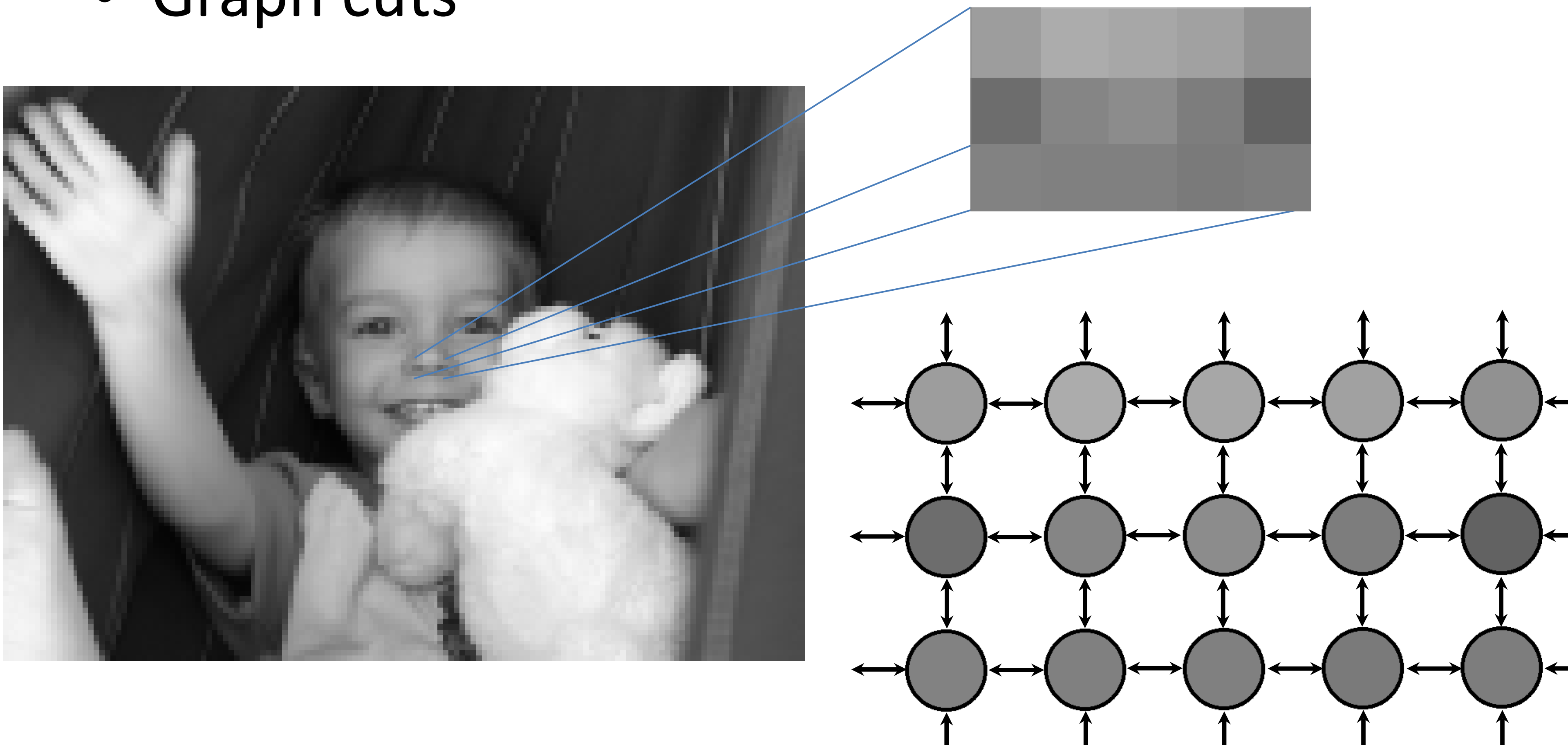


F. Malmberg, …, R. Strand, …, SmartPaint — A Tool for Interactive Segmentation of Medical Volume Images Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization, 2017

…and work in progress

Discrete optimization in image processing

- Pixel adjacency graphs
- Graph cuts



Discrete optimization in image processing

- Graph $\mathcal{G} = (\mathcal{V}, \mathcal{E})$, where $\mathcal{V}$ is a set of vertices and $\mathcal{E}$ is a set of edges.
- Labeling problem $f\colon \mathcal{V} \to \mathcal{L}$, where $\mathcal{L}$ is a set of labels.
- A class of simple energy functions (only unary terms):

$$\mathrm{E}(f) = \sum_{v \in \mathcal{V}} D_v(f_v),$$

where $D_v(f_v)$ is the cost of assigning label f_v to vertex v.

Discrete optimization in image processing
Segmentation

$$E(f) = \sum_{v \in \mathcal{V}} D_v(f_v).$$

Data term
Similarity in intensity

Segmentation result (4 labels)

Discrete optimization in image processing
Segmentation

Spatial regularization by adding a binary smoothness term

$$E(f) = \sum_{v \in \mathcal{V}} D_v(f_v) + \sum_{v,w \in \mathcal{N}} V_{v,w}(f_v, f_w),$$

Data term
Similarity in intensity

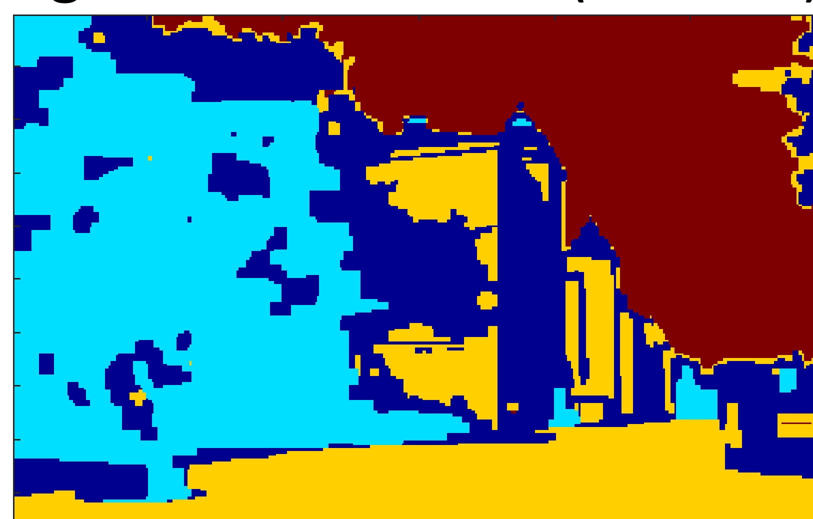
Spatial smoothness

where $\mathcal{N}$ is a neighborhood system of vertices and $V_{v,w}$ gives the cost of assigning labels f_v, f_w to v, w.

Discrete optimization in image processing
Segmentation

$$E(f) = \sum_{v \in \mathcal{V}} D_v(f_v) + \sum_{v,w \in \mathcal{N}} V_{v,w}(f_v, f_w) .$$

Segmentation result (4 labels)



Discrete optimization in image processing Segmentation

$$\mathrm{E}(f) = \sum_{v \in \mathcal{V}} D_v(f_v) + \sum_{v,w \in \mathcal{N}} V_{v,w}(f_v, f_w)\,.$$

- $V_{v,w}$ should impose smoothness *and* be *edge-preserving*
  - Typically non-convex
- Efficient optimization in binary labeling if $V_{v,w}$ is *submodular,* i.e. if

$$V_{v,w}(0,0) + V_{v,w}(1,1) \leq V_{v,w}(0,1) + V_{v,w}(1,0)$$

  - Multiple labels by for example the *expansion move algorithm*

Discrete optimization in image processing

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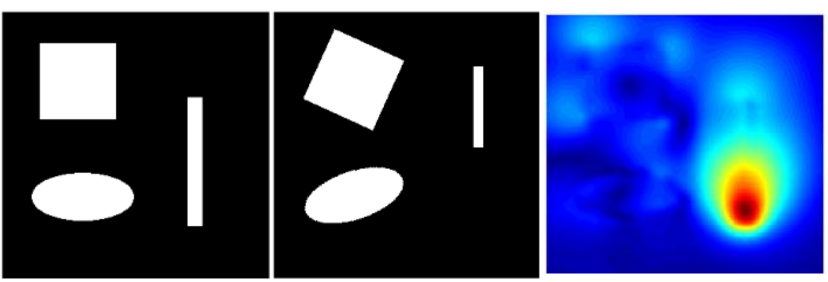
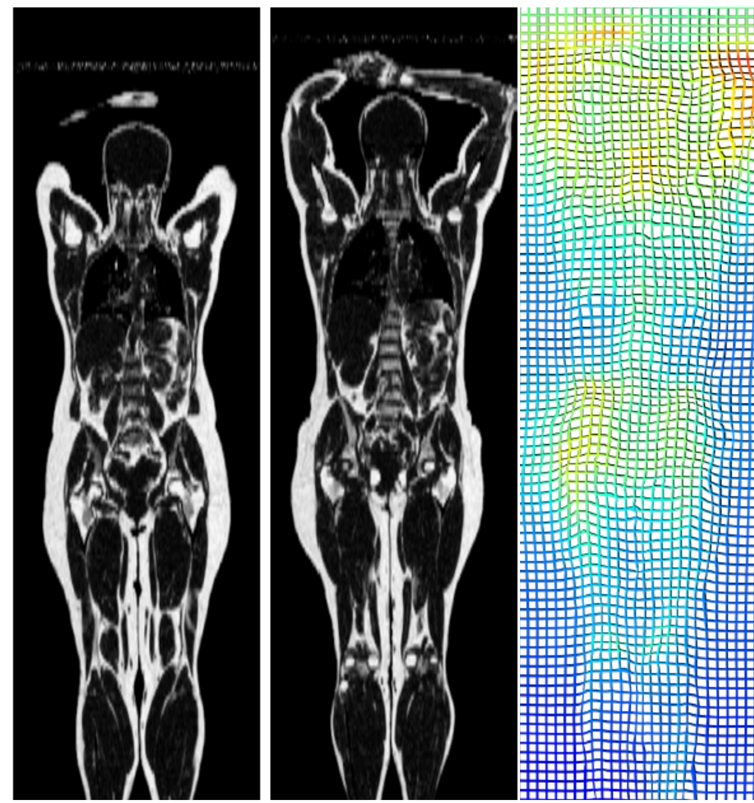
Discrete optimization in image processing
Image Registration

- Problem: Find the optimal deformation field
- $f: \mathcal{V} \rightarrow \mathcal{L}$: Which vectors should be updated (binary)
- $D_v(f_v)$: Similarity in intensity
- $V_{v,w}(f_v, f_w)$: Spatial smoothness
- Iterative algorithm



Def. field magnitude



S Ekström, F Malmberg, …, R Strand, Deformable Registration of Whole-Body Fat-Water Magnetic Resonance Images Using Discrete Optimization, manuscript 2017

Discrete optimization in image processing

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Discrete optimization in image processing
Stereo

- Problem: Compute the depth for each pixel (vertex), given two views of the same scene
- $f: \mathcal{V} \rightarrow \mathcal{L}$: Depth
- $D_v(f_v)$: Similarity in intensity
- $V_{v,w}(f_v, f_w)$: Spatial smoothness

V. Kolmogorov et al. Multi-Camera Scene Reconstruction via Graph Cuts, ECCV 2002

Discrete optimization in image processing

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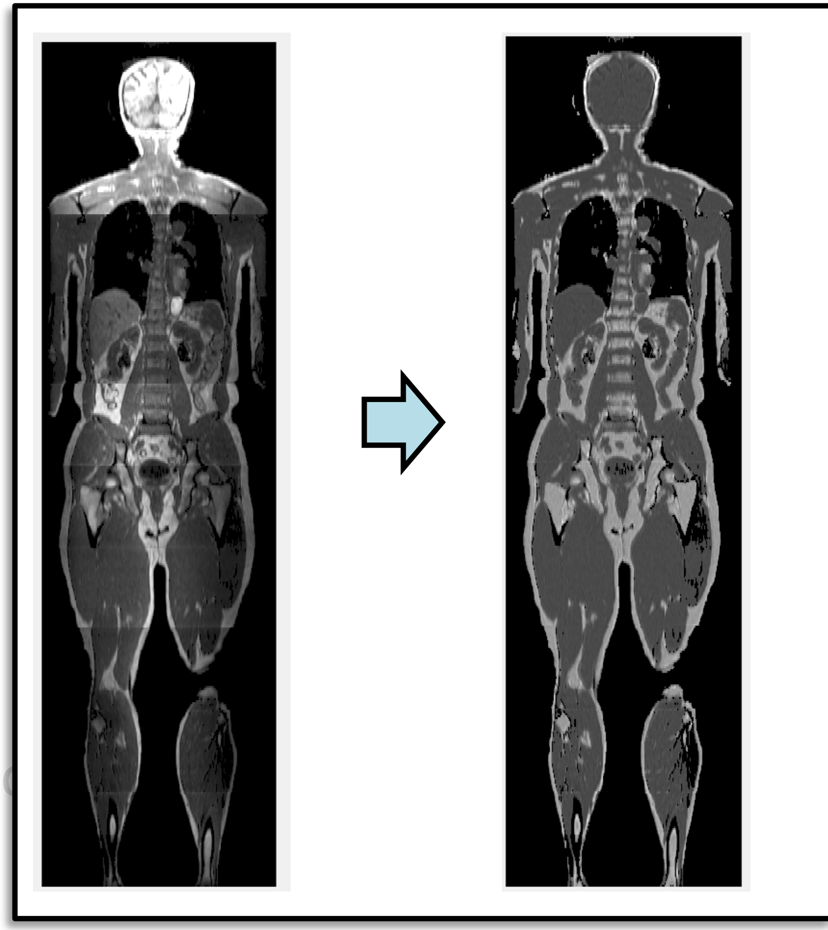

T. Sjöholm , …, F Malmberg , R Strand et al., Intensity inhomogeneity correction of whole body fat-water images using fat and water fraction information on a 3T PET/MR scanner, ISMRM 2017

Discrete optimization in image processing

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V. Kwatra et al, "GraphcutTextures: Image and Video Synthesis Using Graph Cuts," SIGGRAPH 2003

Imiomics

Definition: *Imiomics* (imaging –omics) is an image analysis concept, including image registration, that enables statistical and holistic analysis of whole-body image data.

Holistic for three reasons: 1) The whole body is studied, 2) All image data is used, 3) all non-imaging data can be integrated.

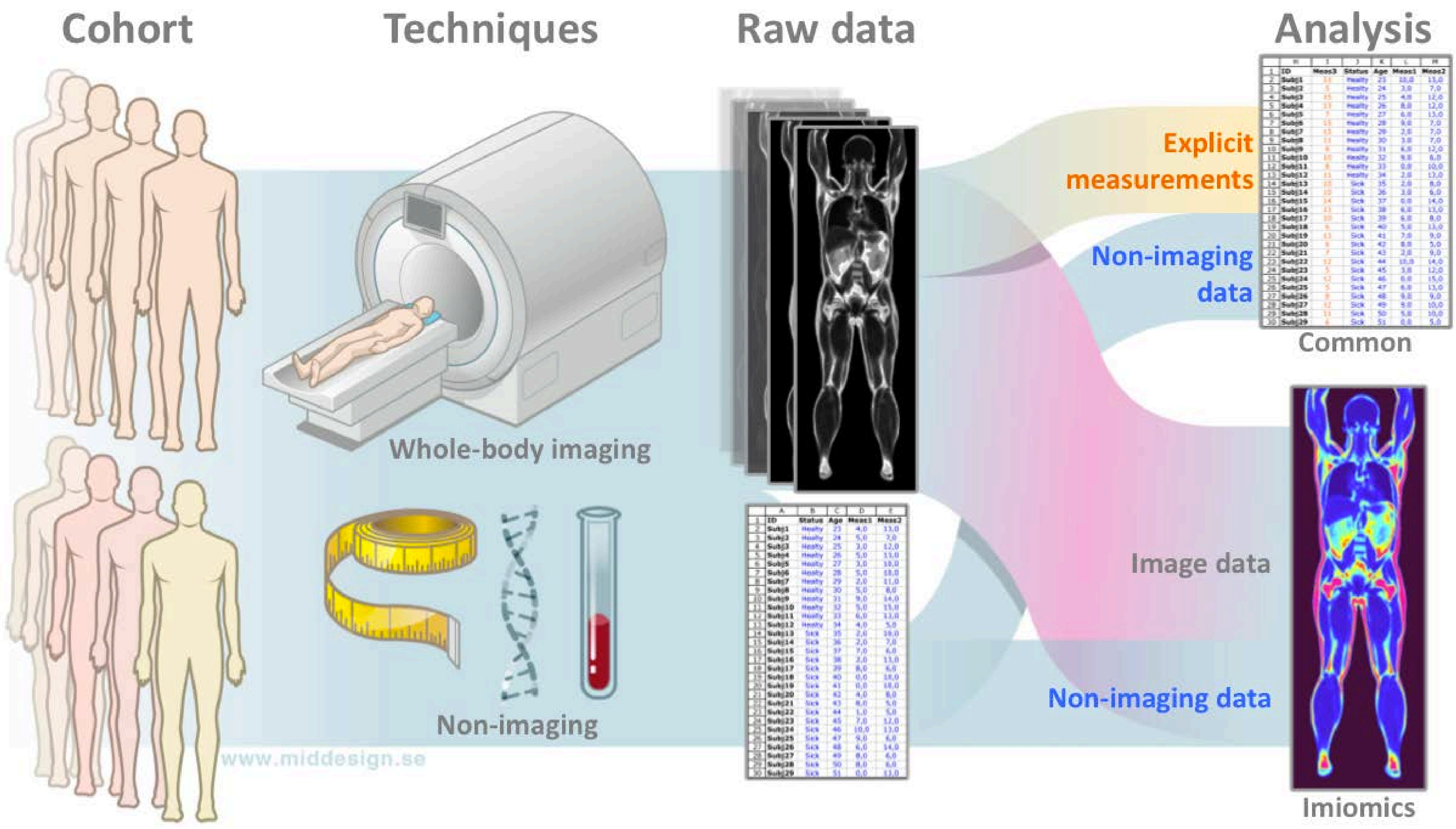
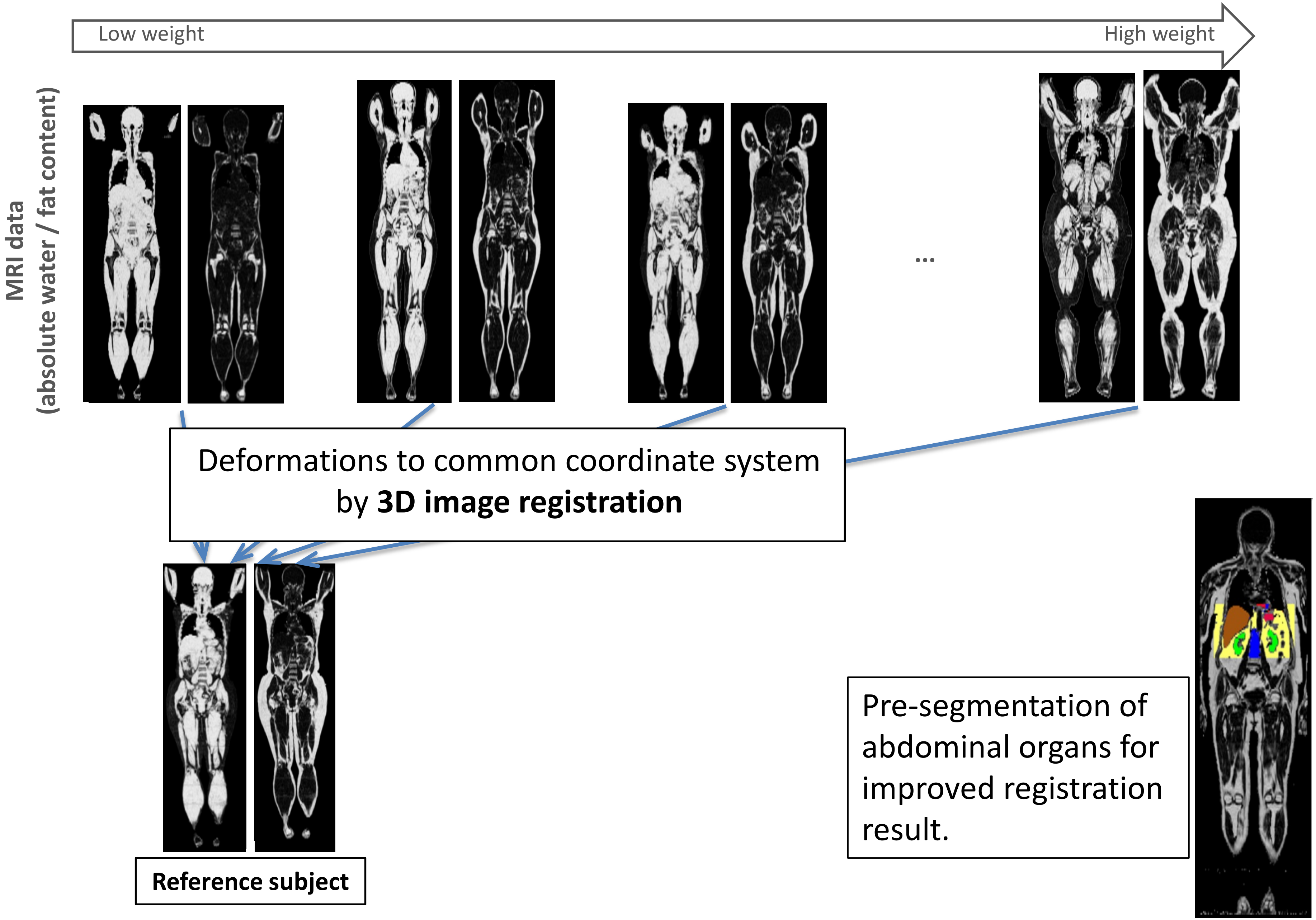
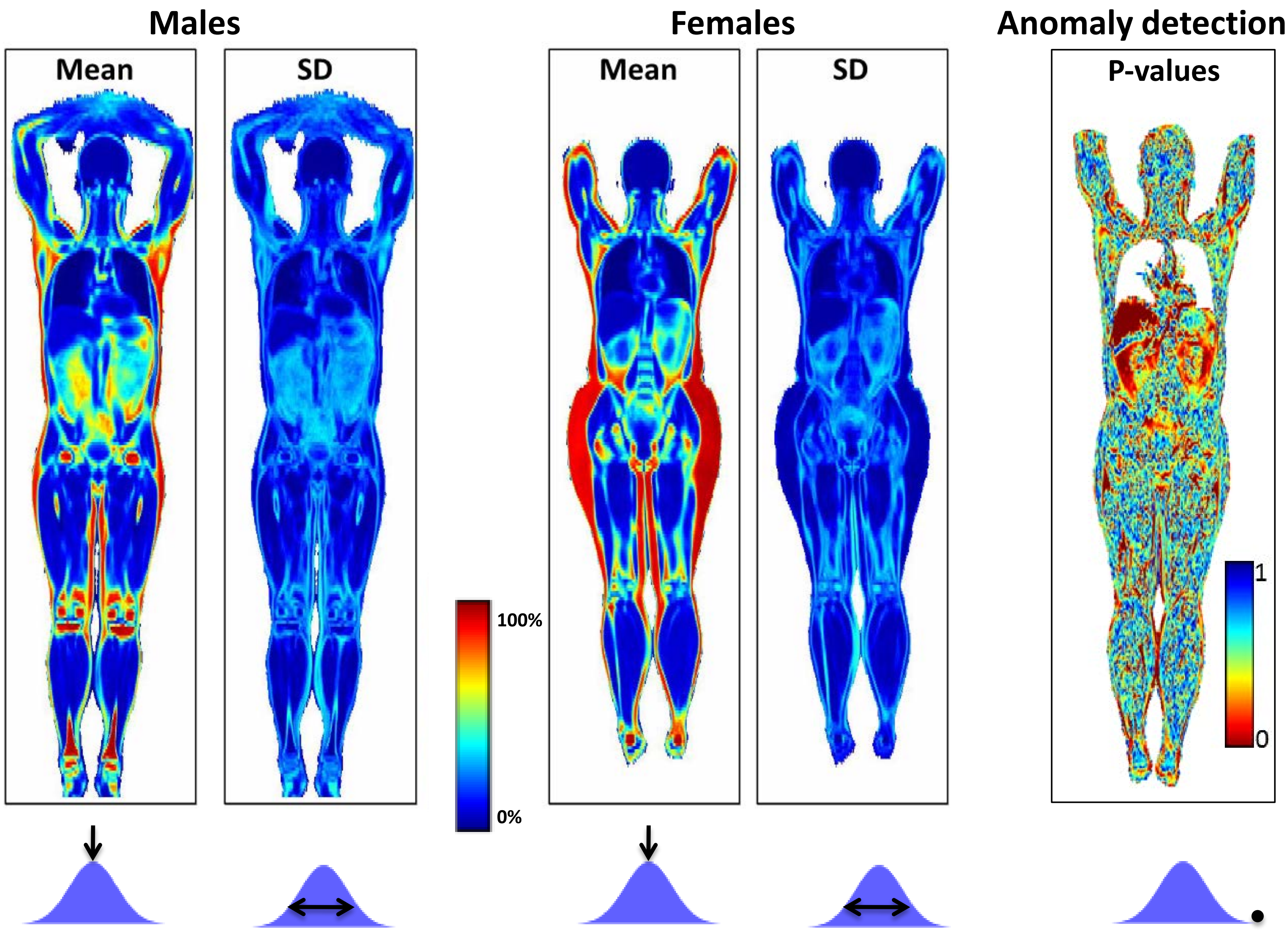


Image registration

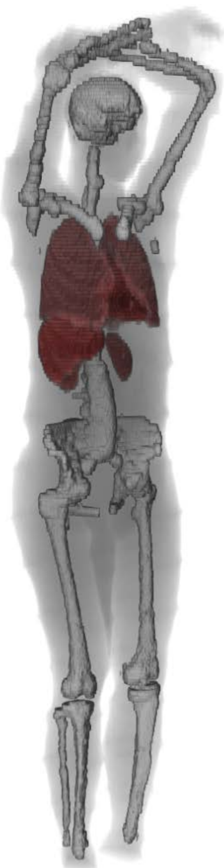


Whole Body Imaging Atlas & Anomaly detection
Fat content



Summary

- Discrete optimization is a powerful and often used approach in image processing.



Thanks for inviting me!