Automated, accurate and fast segmentation of 4D cardiac images

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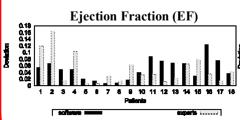
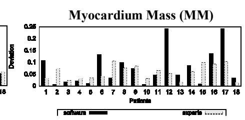
Accuracy

• **Point to surface** measurement (P2S) from automated and manual segmentations

	Endocardial Border	Epicardial Border
Lötjönen *et al* (2004)	2.01 ± 0.31 mm	2.77 ± 0.49 mm
Mitchel *et al* (2001)	2.75 ± 0.86 mm	2.63 ± 0.76 mm
Kaus *et al* (2004)	2.28 ± 0.93 mm	2.62 ± 0.75 mm
Lorenzo-Valdés *et al* (2006)	1.88 ± 2.00 mm	2.75 ± 2.62 mm
van Assen *et al* (2006)	1.97 ± 0.54 mm	2.23 ± 0.46 mm
ours	1.51 ± 0.38 mm	1.81 ± 0.43 mm

• **Left ventricular critical parameters**

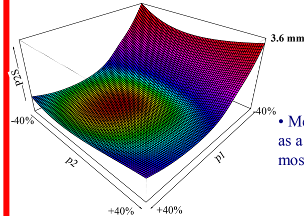




EF Mean error: 0.03 (automated) and 0.05 (manual)
MM Mean error: 0.05 (automated) and 0.05 (manual)

Robustness

with respect to parameters of the method

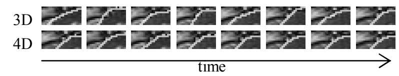


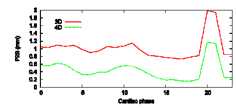
• Mean P2S (18 patients) as a function of the 2 most sensitive parameters

• Robustness with respect to small variations on the other parameters has been qualitatively verified during experimentation.

Temporal consistency

• 3D version as accurate as 4D version
• But, 4D contours are more regular along cardiac cycle



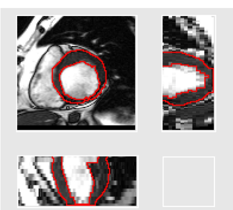


Mean P2S (18 patients) from successive segmentations along cardiac cycle

• **18 patients from routine clinical practice**
• 1,5 T MR scanner (Magnetom Symphony R, Siemens)
• 3D+t representations of the LV
• **Manual segmentation** of the myocardium
  • at end-diastole and end-systole
  • **by two cardiologists**

Time efficiency

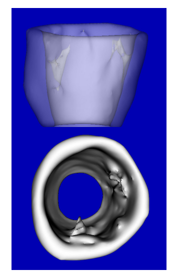
• Computation time: 3 mn (Pentium 4, 3.06 GHz, 512MB)
• One unique mouse click per 3D+t sequence
• Training the method on a new MR device: 1 hour of work



Why yet another approach ?

Mathematical morphology also provides **efficient tools** for clinical routine

• **4D watershed**
• Homotopic transforms
• Euclidean dilation/Closing/Openning



Left ventricular chamber (LVC)

Prior knowledge

• **Topology**: connected object.

• **Brightness**: it is a bright object surrounded by a significatively darker object

• **Geometry**: endocardial border is irregular

Operators

Geodesic dilation of:

• a marker (component of a high threshold) in
• a mask (low threshold)

Illustration

Marker: inside of epicardial border

Prior knowledge

• **Topology**: connected object.

• **Brightness**: very bright and dark objects (right ventricular chamber or lungs) in the complementary set.

• **Geometry**: non null myocardial thickness.

Operators

Euclidean dilation of LVC **repulsed** by:

• background landmarks.

Epicardial border

Prior knowledge

•**Brightness**: very low contrasted

•**Geometry**: smooth surface, consistent over time

Operators

• **4D watershed** from markers

• Morphological smoothing filters (Euclidean alternating sequential filers)

Marker: outside of epicardial border

Prior knowledge

• **Topology**: connected object with one cavity

• **Brightness**: contains very bright and dark objects (right ventricular chamber or lungs)

• **Geometry**: bounded myocardial thickness.

Operators

Homotopic skeleton constrained by:

• background landmark
• maximal myocardial thickness