Heart Visualization from MRI

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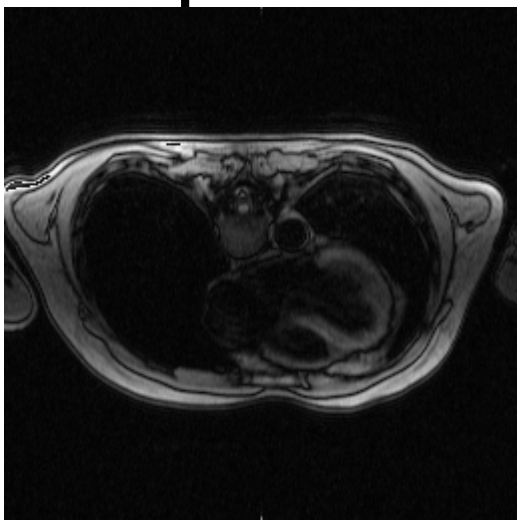
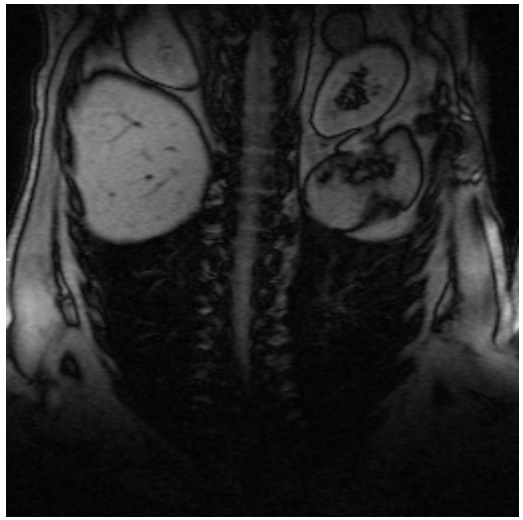
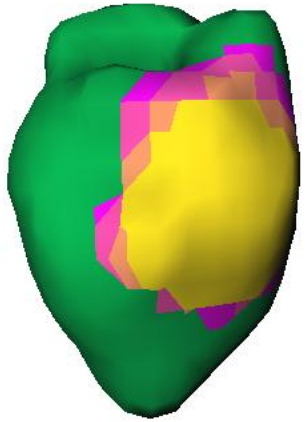
Goal of this work

- Input MRI data set



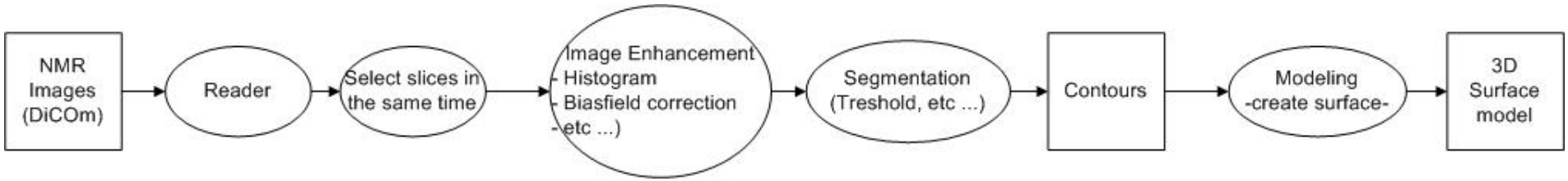


- Create Heart surface model from MRI data set



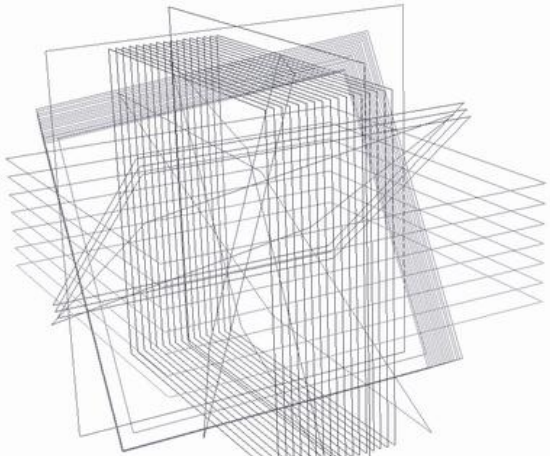
Three main problems:

- MRI Image Enhancement
- Heart segmentation
- Surface modeling from contours



Load DICOM Data

- Data
  - MRI – Dicom FILES (not parallel too)
- Loading using DCMTK
- Computing time period for every slice and group slices with the same period value



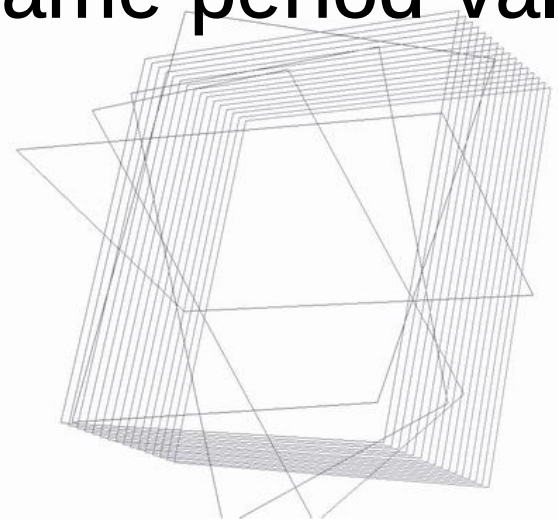
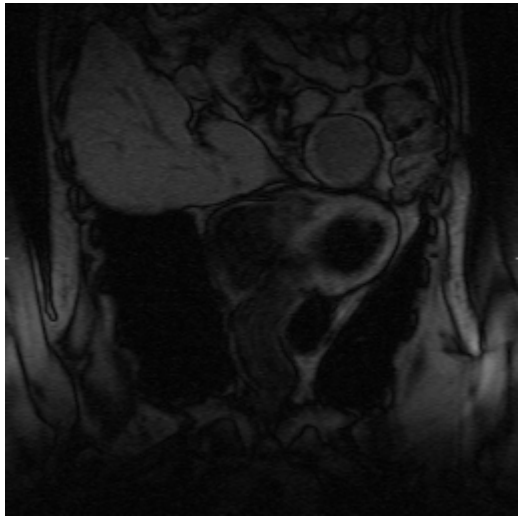


Image Enhancement

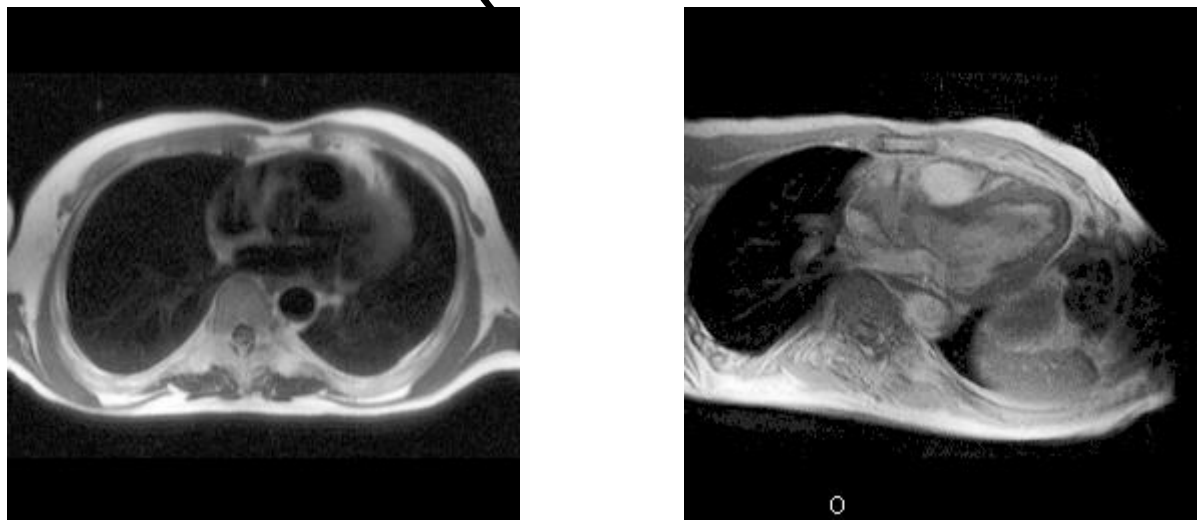
- Enhance contrast and histogram equalization

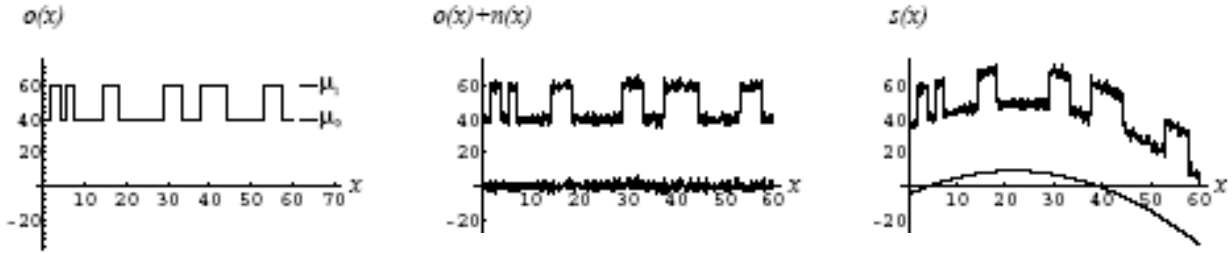


- Bias correction (Estimation of inhomogeneities)
  - Work in progress

Image Enh. - Bias correction

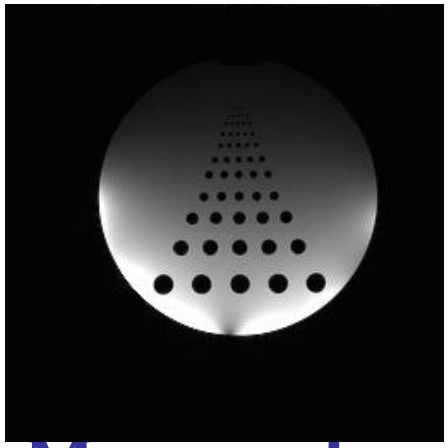
- Bias correction (Estimation of inhomogeneities)



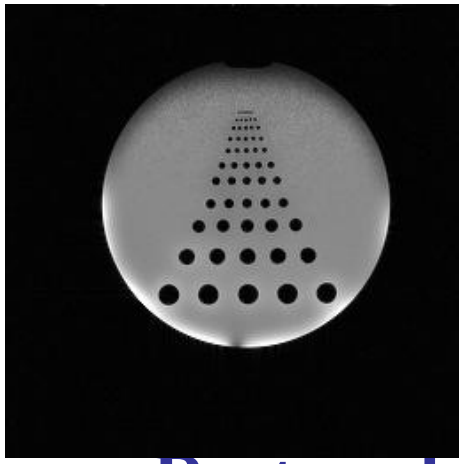


$$\tilde{s}(\underline{x}) = o(\underline{x}) + b(\underline{x}) + n(\underline{x})$$

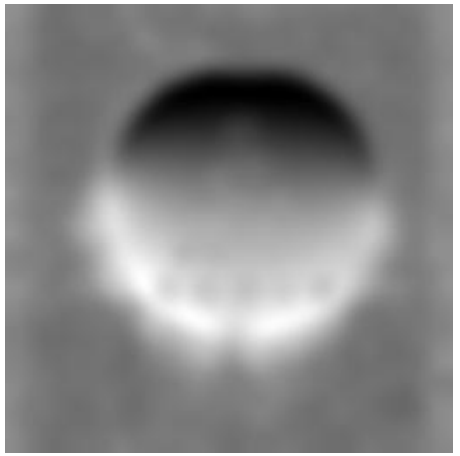
Image Enh. - Bias correction



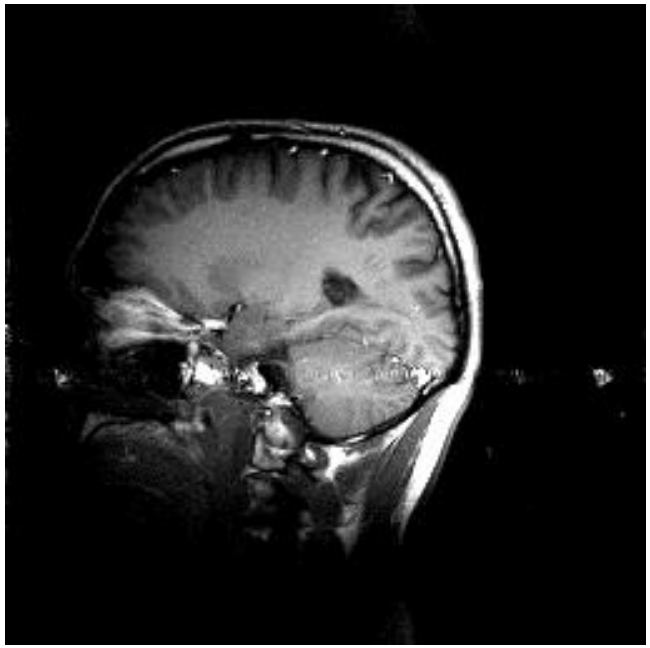
Measured

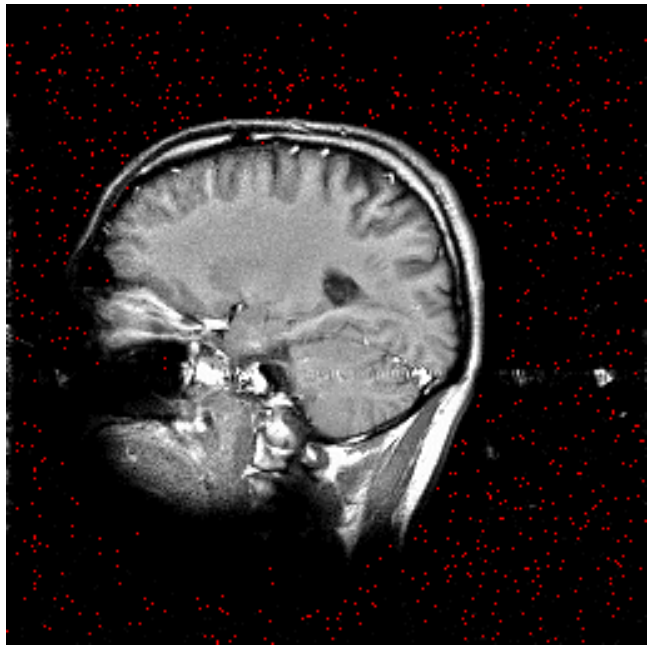


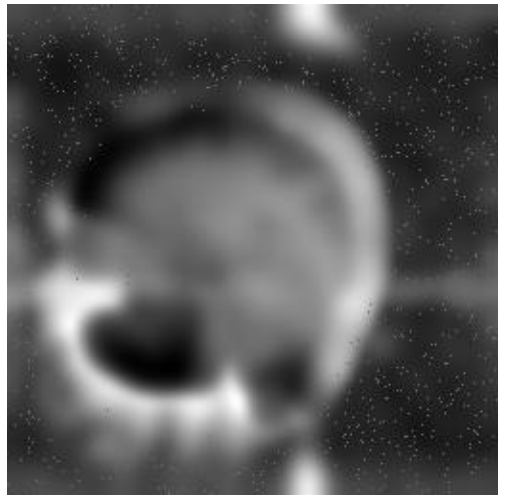
Restored



Bias field





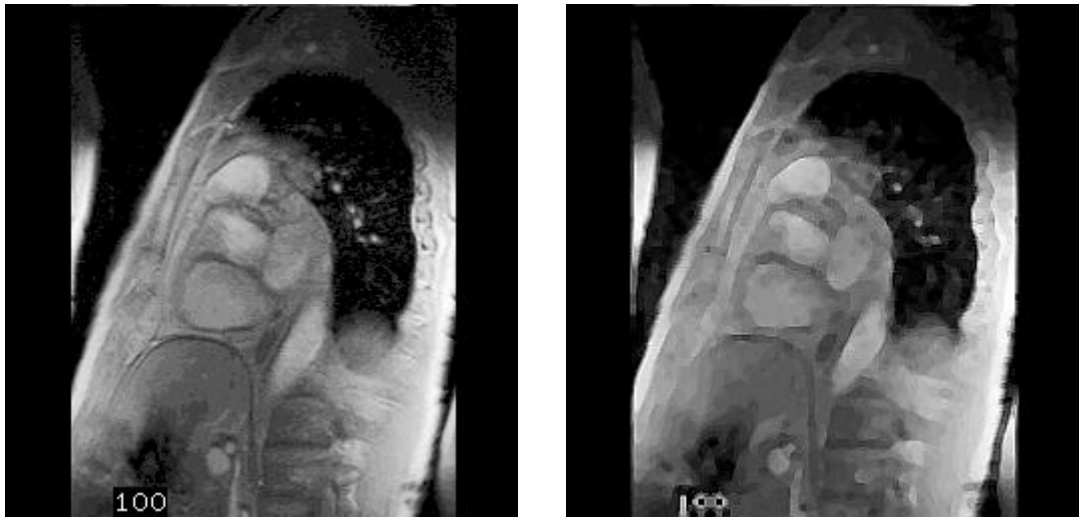


POSSIBLE USE SENARIOS

- Image Preprocessing
  - original image -> IntensityCorrector -> preprocessed image
- Bias Field Estimation
  - original image (or preprocessed image) -> BiasFieldEstimator -> coefficients of the bias field estimate
- Bias Correction
  - original image + the coefficients of the bias field estimate (from BiasFieldEstimator) -> BiasCorrector -> bias field corrected image
- Bias Image Generation
  - the coefficients of the bias field estimate + result image dimension and size -> BiasImageGenerator -> bias image

Heart Segmentation

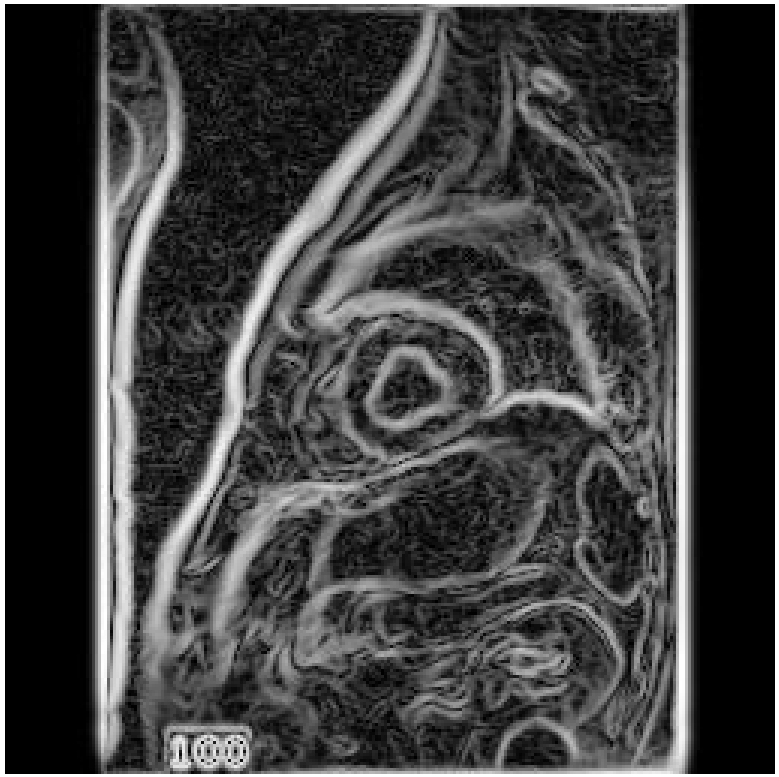
- Small changes – median filter, sharpen etc ...

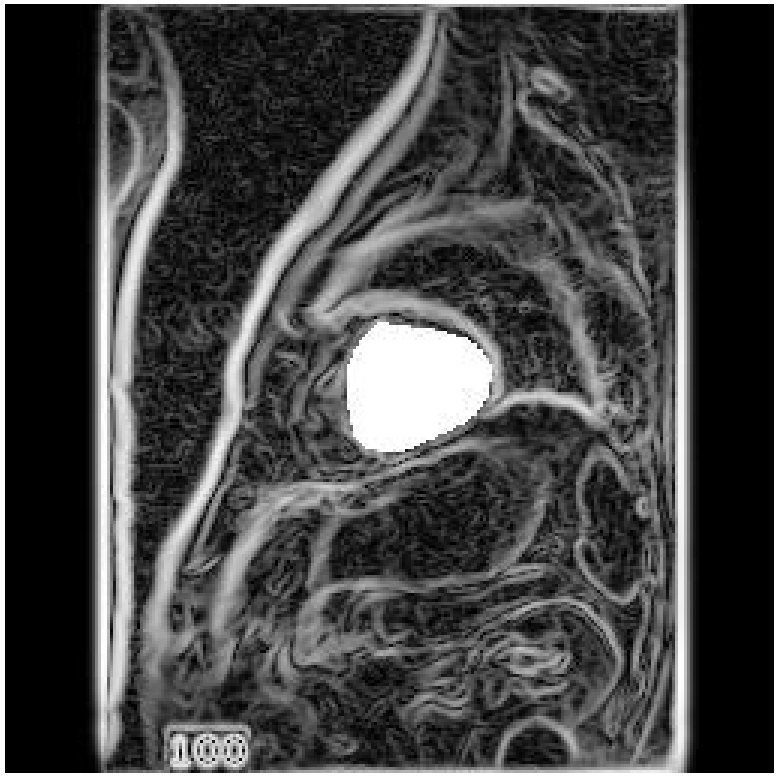


- Then segmentation

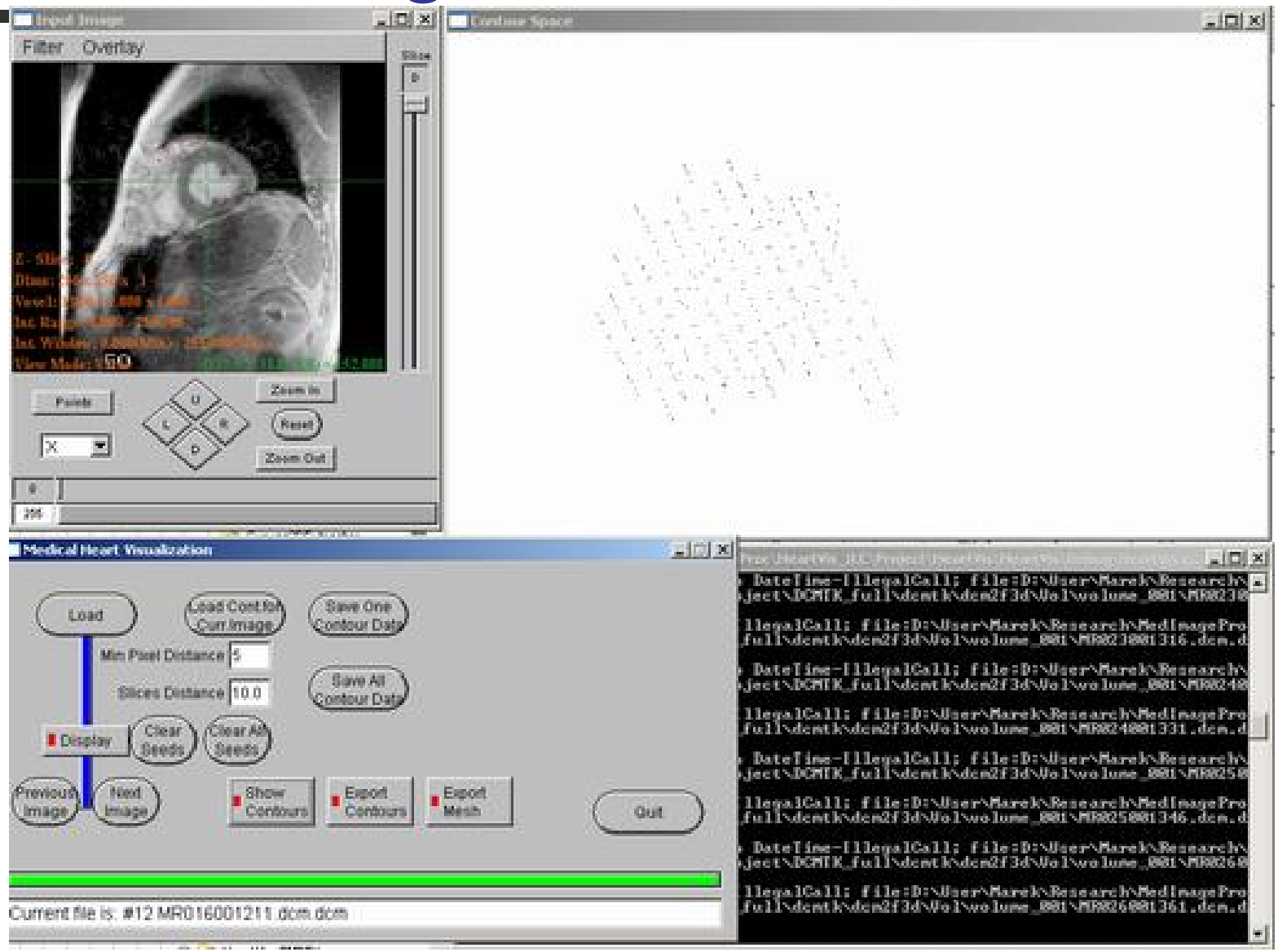
Heart Segmentation

- Canny/Deriche
- than Snake





Heart Segmentation



Heart Segmentation - next

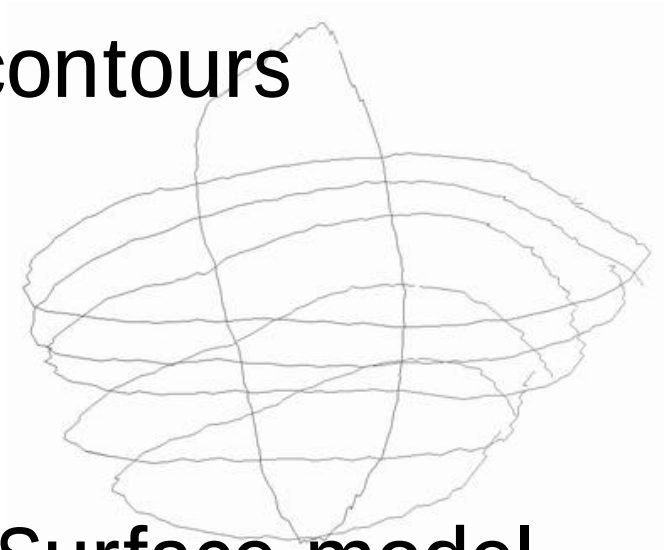
- Automatic segmentation
- Create heart contour when ventricle(s) contour is known

Heart Segmentation

- Our added value:
  - Add value for extracted pixel of contour, “how sure we are that it is a contour point”
  - Segmetation of heart when ventricles is known

Heart Modeling

- Input: contours



- Ouput: Surface model

Heart Modeling by Implicit Surfaces

- Set of points $\{c_1, c_2, \ldots c_k\}$ - contour
- Set of constraints $\{h_1, h_2, \ldots h_k\}$
- $f(c_i) = h_i$,

- Minimization of energy:

$$E = \int_{\Omega} f_{xx}^2(\mathbf{x}) + 2f_{xy}^2(\mathbf{x}) + f_{yy}^2(\mathbf{x})$$

Heart Modeling by Implicit Surfaces

- Equestion E can be solved using radial basis functions

$$E = \int_{\Omega} f_{xx}^2(\mathbf{x}) + 2f_{xy}^2(\mathbf{x}) + f_{yy}^2(\mathbf{x})$$

$$\phi(\mathbf{x}) = |\mathbf{x}|^2 \log(|\mathbf{x}|).$$

- c_i is localization of points, d_i are weights and P(x) if polynomial of deg 1

$$f(\mathbf{x}) = \sum_{j=1}^{n} d_j \phi(\mathbf{x} - \mathbf{c}_j) + P(\mathbf{x})$$

Heart Modeling by Implicit Surfaces

$$f(\mathbf{x}) = \sum_{j=1}^{n} d_j \phi(\mathbf{x} - \mathbf{c}_j) + P(\mathbf{x})$$

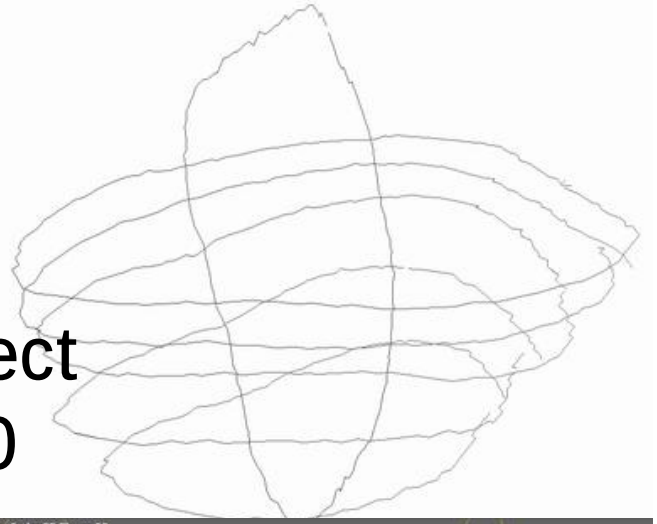
- f(c_i)= h_i, than $$h_i = \sum_{j=1}^{k} d_j \phi(\mathbf{c_i} - \mathbf{c_j}) + P(\mathbf{c_i})$$

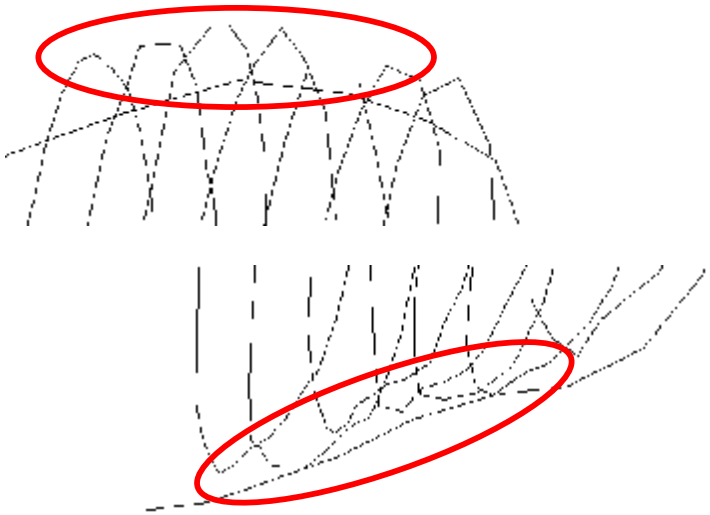
$$\begin{bmatrix} \phi_{11} & \phi_{12} & \dots & \phi_{1k} & 1 & c_1^x & c_1^y & c_1^z \\ \phi_{21} & \phi_{22} & \dots & \phi_{2k} & 1 & c_2^x & c_2^y & c_2^z \\ \vdots & \vdots & & \vdots & \vdots & \vdots & \vdots & \vdots \\ \phi_{k1} & \phi_{k2} & \dots & \phi_{kk} & 1 & c_k^x & c_k^y & c_k^z \\ 1 & 1 & \dots & 1 & 0 & 0 & 0 & 0 \\ c_1^x & c_2^x & \dots & c_k^x & 0 & 0 & 0 & 0 \\ c_1^y & c_2^y & \dots & c_k^y & 0 & 0 & 0 & 0 \\ c_1^z & c_2^z & \dots & c_k^z & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_k \\ p_0 \\ p_1 \\ p_2 \\ p_3 \end{bmatrix} = \begin{bmatrix} h_1 \\ h_2 \\ \vdots \\ h_k \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

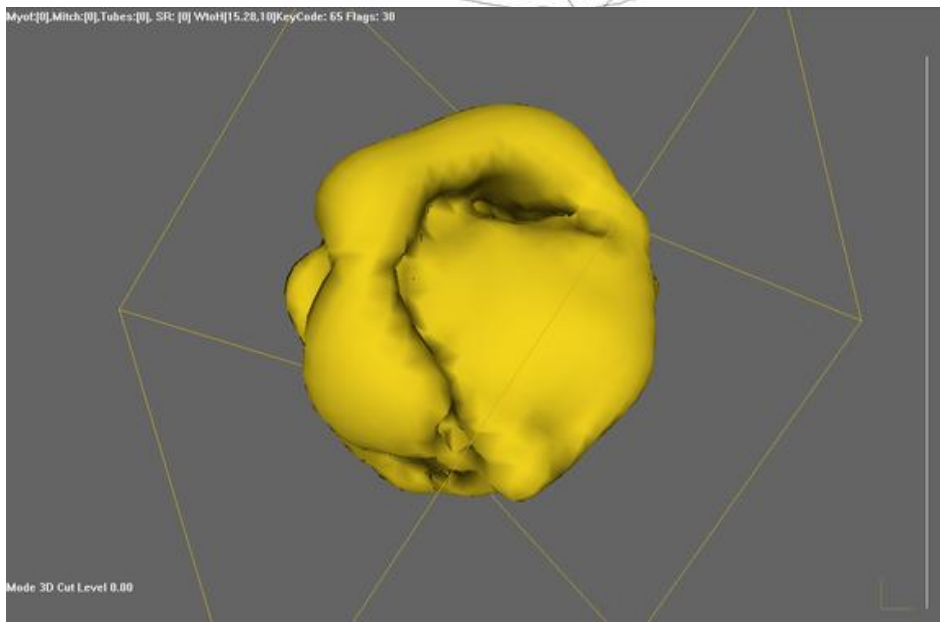
- Solving by symmetric LU decomposition

Heart Modeling by Implicit Surfaces

- Problems:
  - Correct setting of constrains
  - Contours don't have to intersect - points with constrain value 0 can be in the object

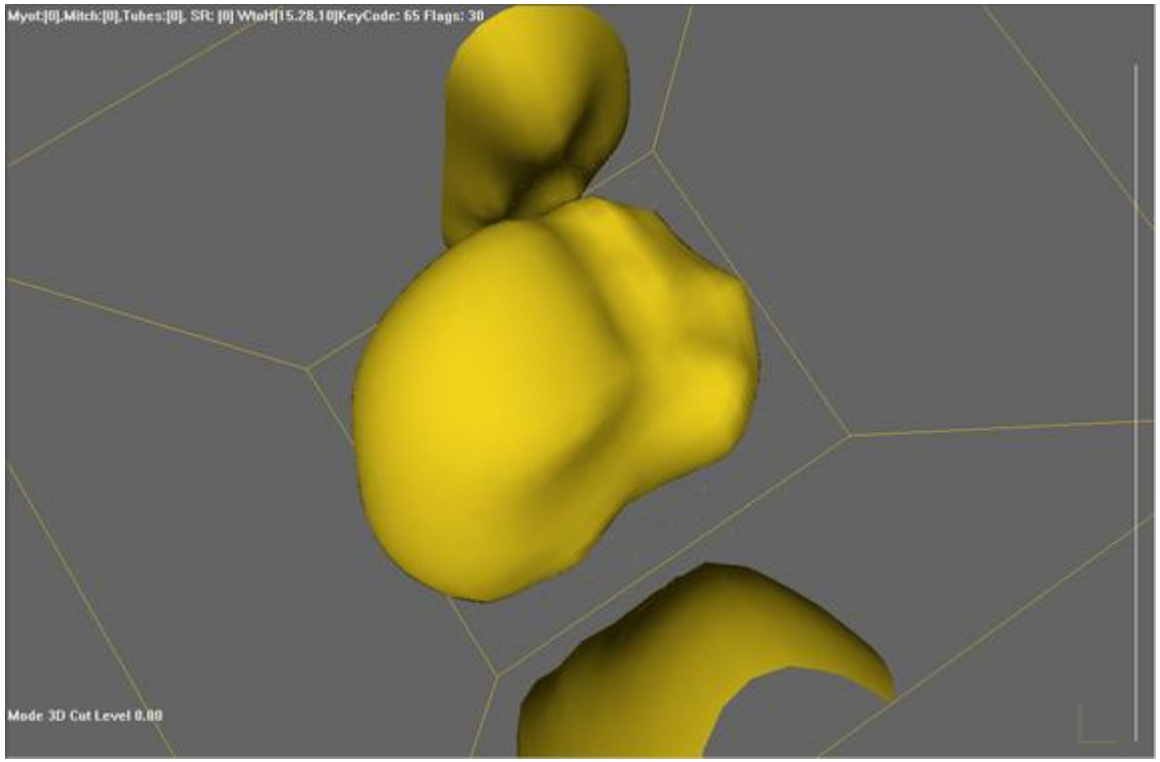


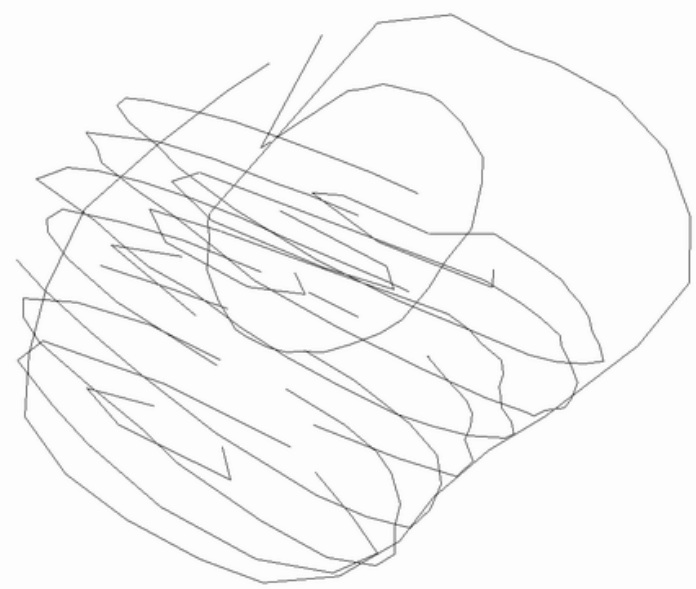




Heart Modeling by Implicit Surfaces

- Solution:
  - Add new contours of L/R ventricle as an interior of heart





Heart Modeling

- Our added value:
  - Create mechanism for creating implicit surface when points with constrain value 0 can be in the object.

Next work

- Finnish correct setting of constrains fo implicit surface generation
- (Semi)Automatic segmentation of heart
- Add motion info to segmentation

Literature

- Jorgen Ahlberg, *Active Contours in Three Dimension*, research report, 1996
- Zhukov et al, *Dynamic Deformable Models for 3D MRI Heart Segmentation*
- Sorgel W., Vaerman V., *Automatic heart localization from a 4D MRI dataset*
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- M-P Jolly, N.Duta, G F-Lea, *Segmentation of Left Ventricle in Cardiac MR Images,* ICCV 01
- Greg Turk, J F O'Brien, *Shape Transformation Using Variatonal Implicit Functions,* Siggraph'99