

## Interactive and Automatic Segmentation of Tomographic Data

Miloš Šrámek

<http://www.cg.tuwien.ac.at/courses/MedVis/VU.html>

## Tomographic Data and Segmentation

- Large number of anatomically distinct objects
- Variability of object shapes
- Variability of scanner parameter settings
- 3D nature of objects
- Not well defined surfaces
- High demands on segmentation precision

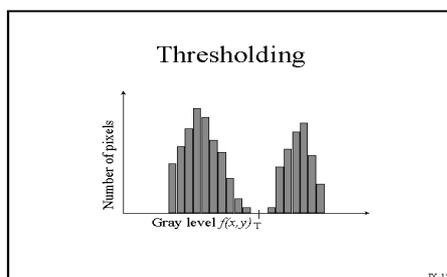
## Overview

- Thresholding
- Interactive segmentation
- Segmentation by watersheds
- Segmentation by deformable surfaces

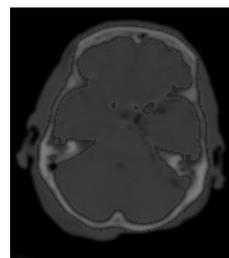
## Thresholding

- Labeling operation on a gray scale image that distinguishes pixels of a higher intensity from pixels with a lower intensity value
- The output is usually a binary image.
- Works well when the image histogram is bi-modal.

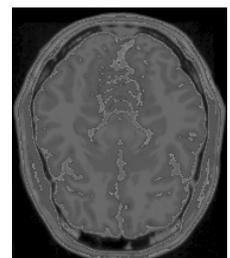
## Thresholding



## Thresholding



CT data



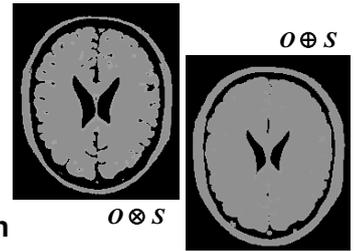
MRI data

## Interactive Segmentation (The ISEG Tool)

- Anatomic organs are connected and homogeneous:
  - Objects identification by
    - Thresholding (classification)
    - Connected component analysis (CCA)
- Objects are sometimes interconnected
  - Objects separation by morphological operations (erosion)

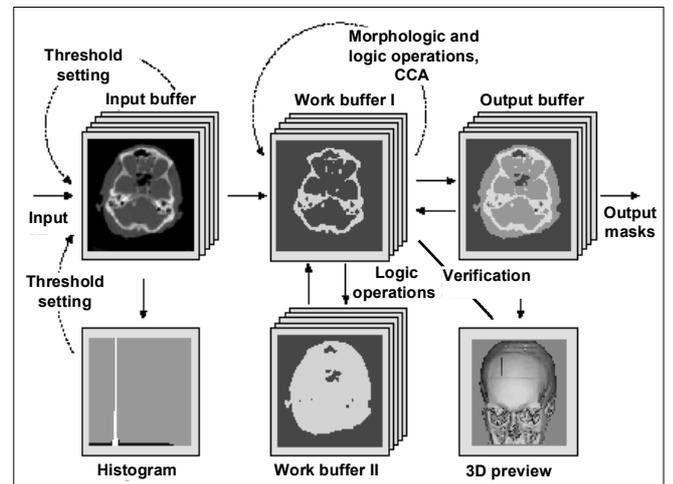
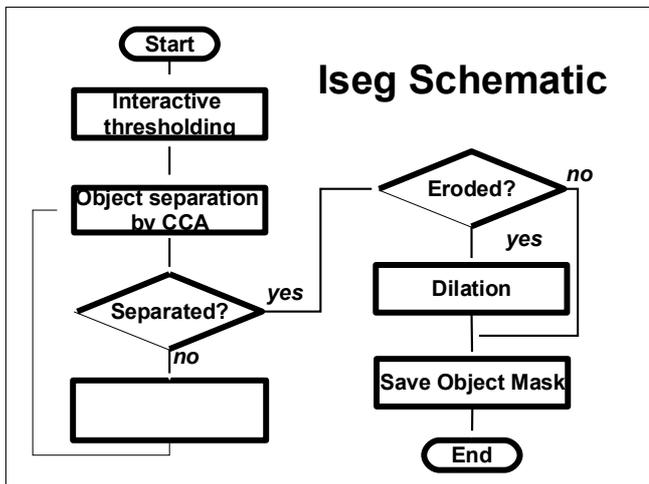
## Morphologic Operations

- Erosion  $O \otimes S$ 
  - Peeling the outer layer off
- Dilation  $O \oplus S$ 
  - Thickening by adding a layer
- Erosion + Dilation  $\neq$  Original !!



Structuring elements

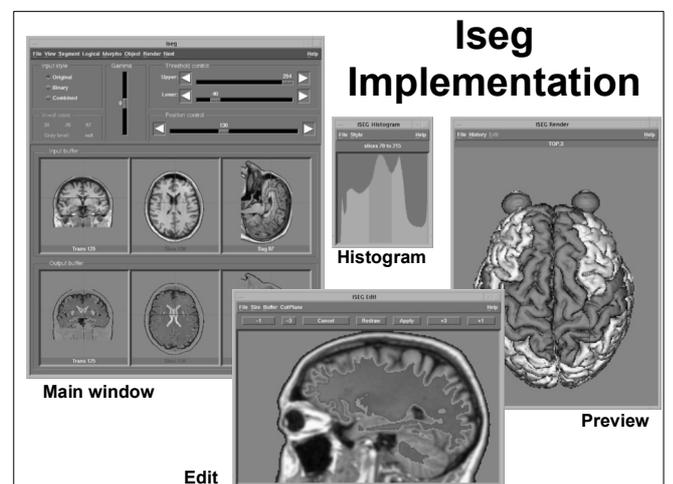
## Iseg Schematic



## Iseg Data Structures

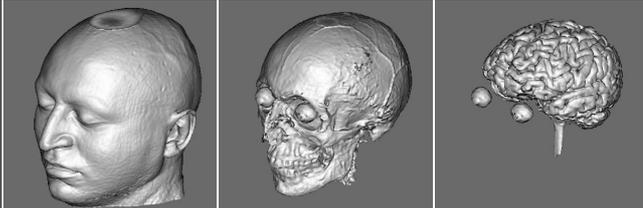
- Input buffer
  - gray level data
  - Histogram & thresholding
- Work buffer I & II
  - Morphologic, logic (AND, OR, XOR) operations
  - Manual editing of masks
- Output buffer
  - Up to 256 objects
  - Preview (6 orthographic views)

## Iseg Implementation



## Iseg Results

MRI head data segmented  
in 15 tissues and objects



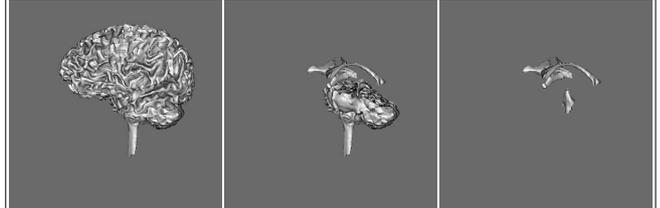
Head

Skull

Brain & eyes

## Iseg Results

MRI head data segmented  
in 15 tissues and objects

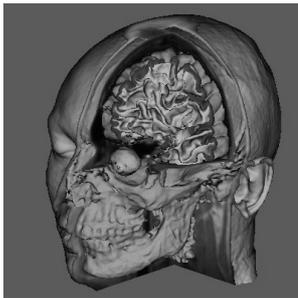


White matter

Cerebellum

Ventricles

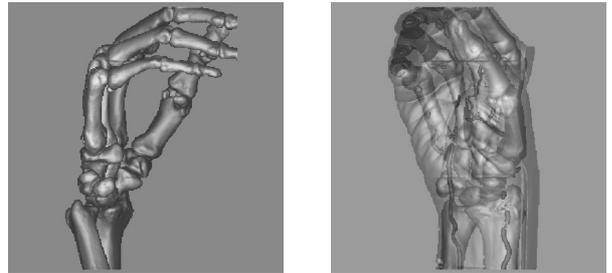
## Iseg Results



MRI head data

## Iseg Results

CT hand data



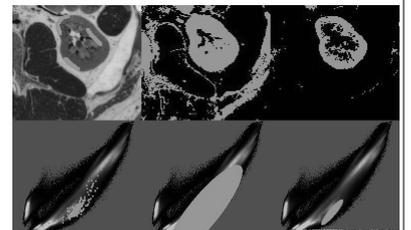
## Iseg Summary

- Segmentation of arbitrary objects
- Data and parameter independent
- Quite fast
- Feeling of result fidelity
  
- Alternatives of thresholding:
  - Any segmentation technique

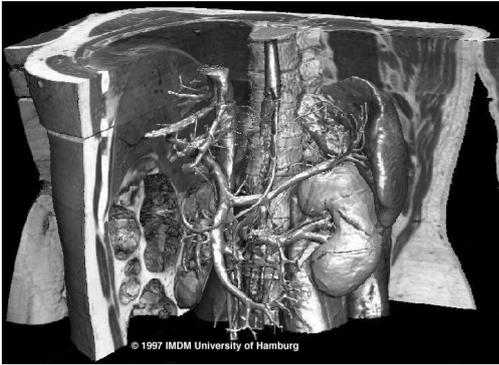
Subversion: <http://bender.dam.fmph.uniba.sk/svn/f3d/iseg/trunk>

## Interactive Segmentation of RGB Data

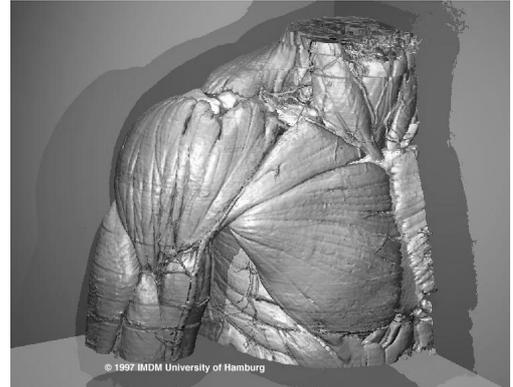
- The Visual Human Project
  - Physical slices(photographs)
  - CT & MRI data
- Thresholding replaced by data classification
  - 3D scatter plot analysis



## Interactive Segmentation of RGB Data



## Interactive Segmentation of RGB Data



## The Watershed Concept (1)



Štrbské pleso, Slovakia

## The Watershed Concept (1)

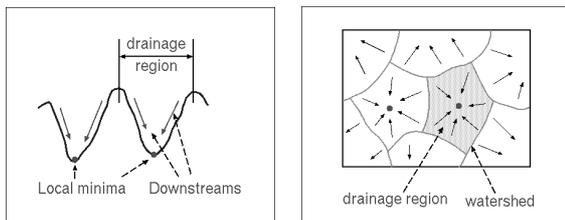


Štrbské pleso, Slovakia

## The Watershed Concept (2)

### ■ Waterflow simulation on gradient images:

#### ■ Catchment basins & watershed lines

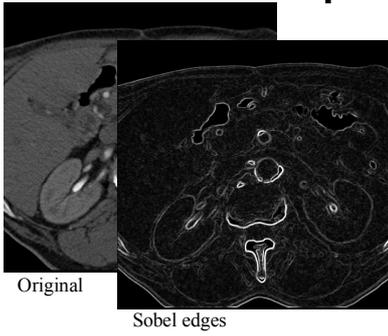


## Watershed Implementation

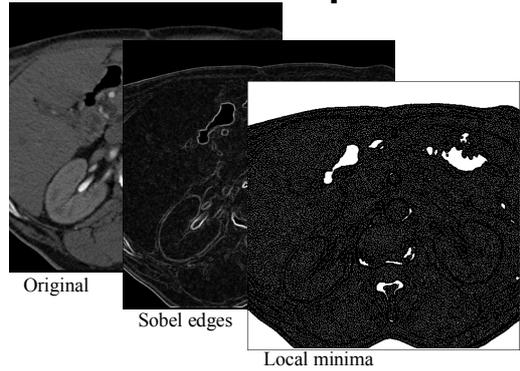


Original

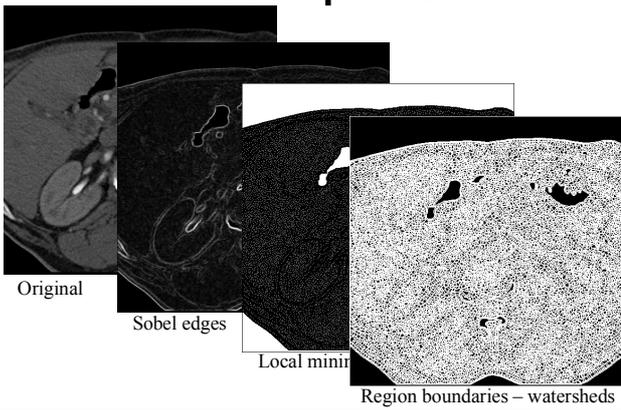
### Watershed Implementation



### Watershed Implementation



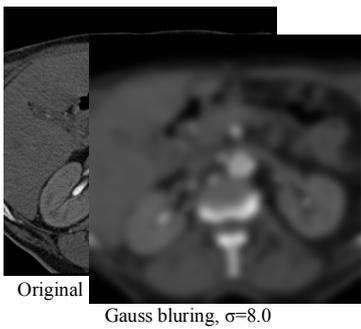
### Watershed Implementation



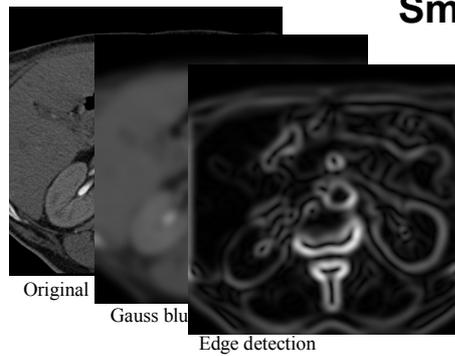
### Large Regions by Gaussian Smoothing



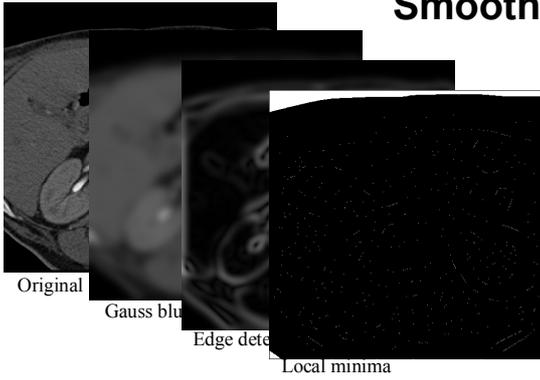
### Large Regions by Gaussian Smoothing



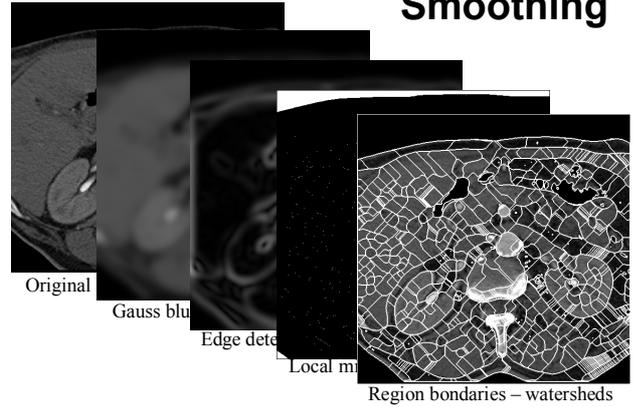
### Large Regions by Gaussian Smoothing



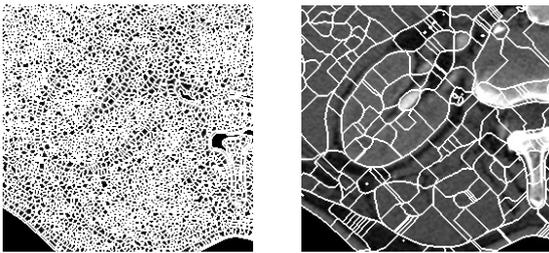
## Large Regions by Gaussian Smoothing



## Large Regions by Gaussian Smoothing



## Watersheds

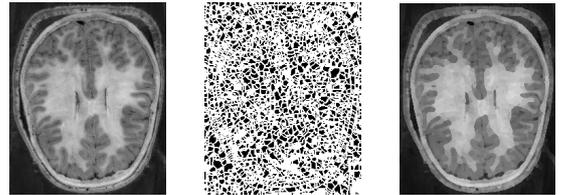


No smoothing: numerous small regions

Smoothing: fewer regions but imprecise contours

## Watersheds: postprocessing (1)

### ■ Data smoothing



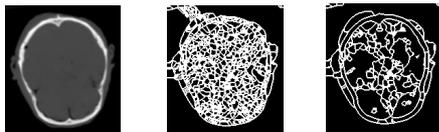
Original

Regions

Smoothed by region average

## Watersheds: postprocessing (2)

### ■ Merging of neighbors according to similarity



Original

Regions

Merged neighbors

### ■ Other possibilities

## Segmentation by Deformable Models

### ■ Parametric form

#### ■ 2D snakes & 3D balloons

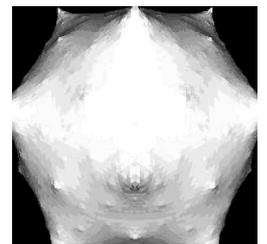
#### ■ Model and image forces govern the model to solution

#### ■ Energy minimization

$$E = E_{\text{ext}} + E_{\text{int}}$$

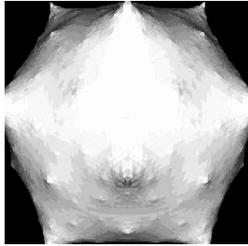
### ■ Implicit form

#### ■ Embedding in $\mathcal{R}^{n+1}$ space



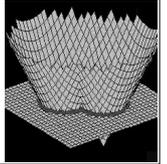
## Segmentation by Deformable Models

- Parametric form
  - 2D snakes & 3D balloons
  - Model and image forces govern the model to solution
  - Energy minimization
    - $E = E_{ext} + E_{int}$
- Implicit form
  - Embedding in  $\mathfrak{R}^{n+1}$  space



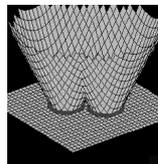
## Deformable Models in Implicit Form

- Snakes: problems with splitting and merging.
- Solution: implicit form
  - sharp corners, break apart, merge together.
- Two types:
  - Fast Marching Methods
    - Interface moving in one direction
  - Level Set Methods
    - Interface moving in both directions



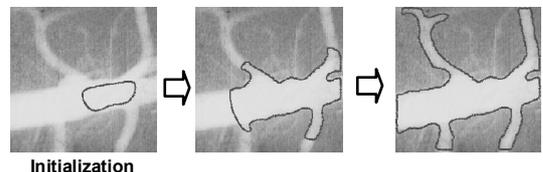
## Deformable Models in Implicit Form

- Snakes: problems with splitting and merging.
- Solution: implicit form
  - sharp corners, break apart, merge together.
- Two types:
  - Fast Marching Methods
    - Interface moving in one direction
  - Level Set Methods
    - Interface moving in both directions



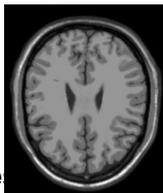
## Level Set Example

- Segmentation of a vessel from Digital Subtraction Angiogram (DSA)
- Speed depends on gradient magnitude



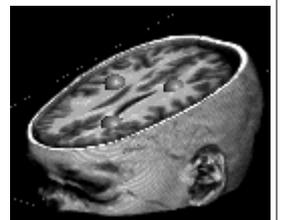
## LS Application - Coupled Surfaces Propagation

- Brain cortex is bounded by two surfaces:
  - white - gray - CSF
  - Gradient at surface
  - Homogeneous in between
- Cortex thickness - about 3mm
- A model coupling both surface
  - Automatic & robust technique
  - Problems at one boundary (unsharp edge) can be solved by the second boundary



## Coupled Surfaces

- Initialization
- Interface speed:
  - Interface White-Gray (W/G)
    - W/G presence probability
    - Distance to G/CSF interface
  - Interface Gray/CSF (G/CSF)
    - G/CSF presence probability
    - Distance to W/G interface



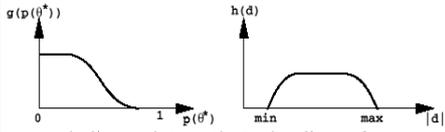
## Interface speed

### ■ Interface W/G

$$F_{in} = g(\rho_{w/g}) * h(\Phi_{out})$$

### ■ Interface G/CSF

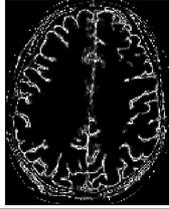
$$F_{out} = g(\rho_{g/csf}) * h(\Phi_{in})$$



$d$ : distance between the two bounding surfaces  
 $|d|$ : absolute value of the distance  
min: minimal distance allowed  
max: maximal distance allowed

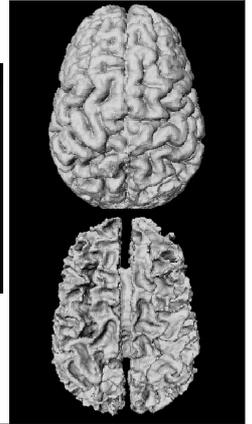
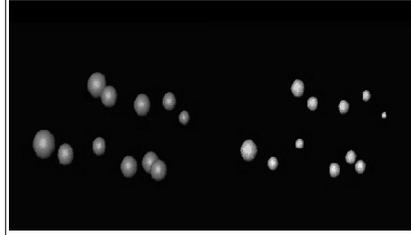


$\rho_{w/g}$



$\rho_{g/csf}$

## Interface Evolution and Results



## Interface Evolution and Results

