# Seminar: Watershed Segmentation

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Computer Integrated Surgery II

## Paper & Relevance

**Segmentation of Tumors in Brain MRI Using an Interactive Multiscale Watershed Algorithm**

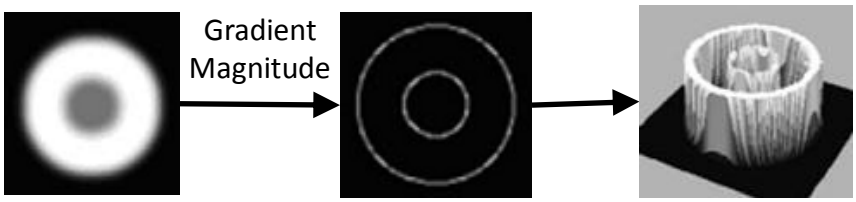
Marloes M.J. Letteboer, Ole F. Olsen, Erik B. Dam, Peter W.A. Willems, Max A. Viergever, Wiro J. Niessen. Academic Radiology 2004.

- Most recent attempt at Watershed-based segmentation of glioblastoma
- Identical user interface and experimental design

Segmentation of Tumors in Brain MRI Using an Interactive Multiscale Watershed Algorithm

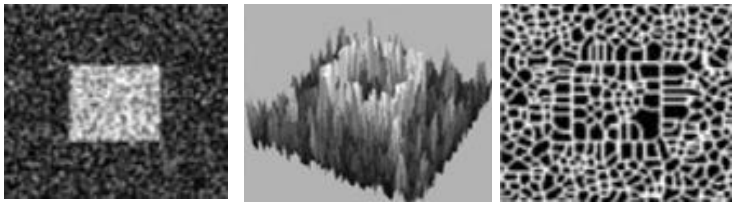
# BACKGROUND

## The Watershed Transform



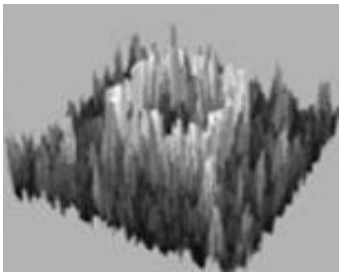

Why??

# The Watershed Transform



- Image/noise complexity produces too many **Watershed basins**
- Watershed analogy used to think about the **relevance** of each **basin**, and thus reduce over-segmentation

# The Watershed Transform



- Increasing water-level
- Global rain-based flooding
- Morphological transformations
  - Erosion/dilation

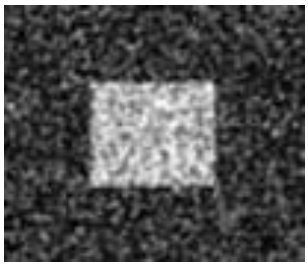
Case study: an evaluation of user-assisted hierarchical watershed segmentation.

# METHOD

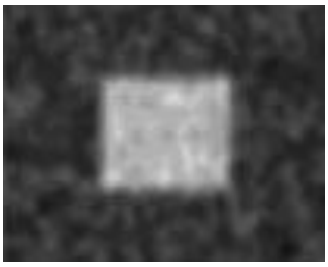
## **Multi-scale** Watershed Transform

- User can specify the **blur level σ**
  - **σ** is the number of Gaussian blur iterations

**σ = 0**



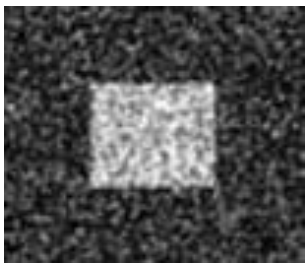
**σ = 5**



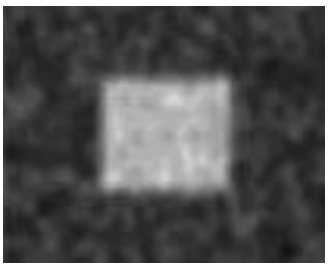
# **Multi-scale** Watershed Transform

- Computer computes original AND blurred watershed

**σ = 0**



**σ = 5**



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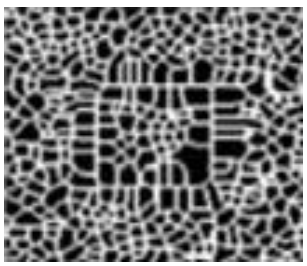

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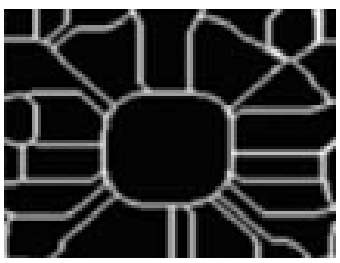
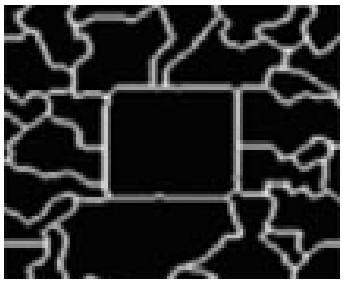
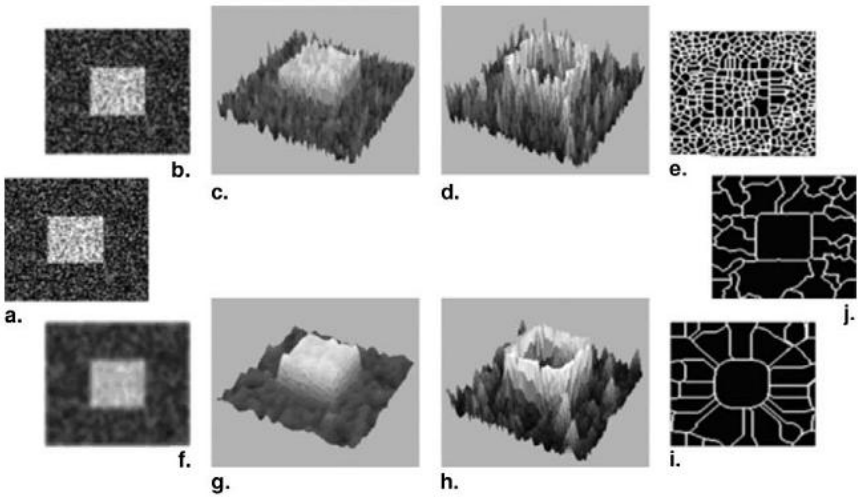


# **Multi-scale** Watershed Transform

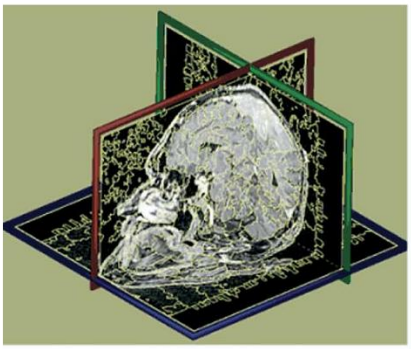
- Blurred watershed is projected onto original watershed by **% overlap**

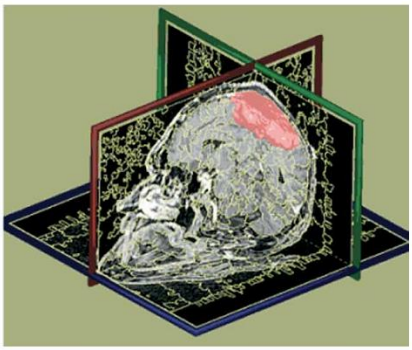


# **Multi-scale** Watershed Transform



# **Multi-scale** Watershed Transform





Segmentation of Tumors in Brain MRI Using an Interactive Multiscale Watershed Algorithm

## EXPERIMENTAL SETUP

# Test Data

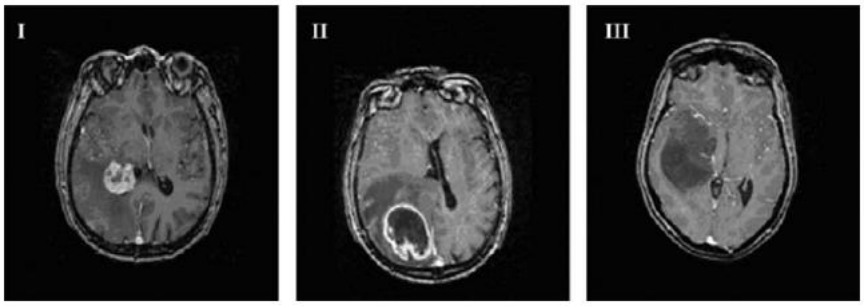



**Figure 5.** Different classes of tumor based on their pattern of contrast enhancement: **(I)** full-enhancing, **(II)** ring-enhancing, and **(III)** non-enhancing.

# Test Data

- N=20 patients
- Standard pre-operative MRI scan
- Doesn't specify:
  - Same scanner?
  - Types of brain tumors?

# Experiment

- 3 operators segment each tumor twice
  - At least one week between segmentations
  - Once manually, once using Watershed
- Each observer completed 2 training scans
  - Doesn't specify expertise of observers
- Compare average manual segmentations to average Watershed segmentations

# Evaluation Metrics

$$Volume\ Difference = 2 \cdot \frac{|V_1 - V_2|}{(V_1 + V_2)}$$

$$Similarity = 2 \cdot \frac{V_1 \cap V_2}{(V_1 + V_2)}$$

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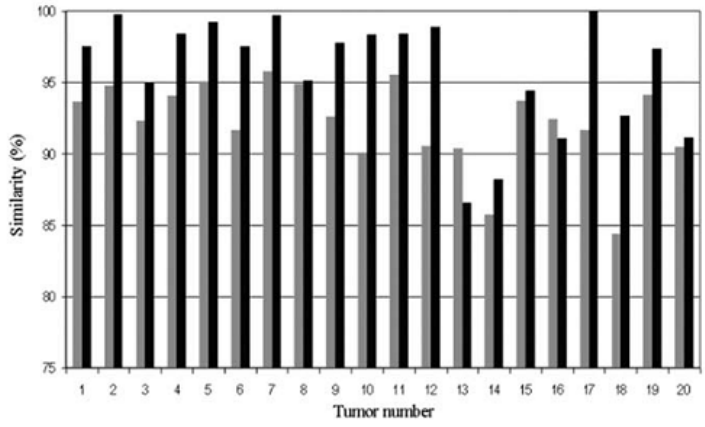
# RESULTS

**Table 1**
**Difference Between Watershed and Manual Segmentation Methods, and Intraobserver and Interobserver Variability for Both Methods (Both Volume Difference and Similarity Are Compared)**

| | | Manual Segmentation | | | | Watershed Segmentation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Volume Difference (%) | | Overlap (%) | | Volume Difference (%) | | Overlap (%) | | Difference Watershed vs Manual | |
| Tumor No. | Volume (cm3) | Intra | Inter | Intra | Inter | Intra | Inter | Intra | Inter | Volume Difference (%) | Overlap (%) |
| Non-enhancing | 1.8 | 6 | 94.7 | 93.1 | 2.2 | 3.6 | 98.5 | 97.9 | | 6.7 | 91.7 |
| Ring-enhancing | 3.7 | 10.5 | 93.7 | 91.1 | 4.9 | 6.3 | 96.5 | 95.2 | | 11.5 | 89.8 |
| Full-enhancing | 4.1 | 12.8 | 92.1 | 88.6 | 7.6 | 10.7 | 94.1 | 92.9 | | 9.9 | 86.7 |
| TOTAL | 4.2 | 9.7 | 93.5 | 90.9 | 4.9 | 6.5 | 96.4 | 95.3 | | 9.3 | 89.4 |

# Segmentation Similarity

Manual – Gray Watershed – Black




# Segmentation Time

**Table 2**
**Comparison of Operator Interaction Time of Manual and Watershed Segmentation Method**

| Tumor Type | Manual Time (min) | Watershed Time (min) |
|---|---|---|
| Non-enhancing | 21 | 5 |
| Ring-enhancing | 20 | 8 |
| Full-enhancing | 25 | 9 |
| Total | 22 | 7 |

# Conclusions

- Multiscale Watershed useful
  - Increased Similarity
  - Less operator time required
- Critiques:
  - No detailed comparisons of manual vs Watershed segmentations
  - Accuracy only defined by volume (in ccs), which discards the detail of the 3D object
  - Small sample size

# Questions?

# Accuracy

"We used the method of Bland and Altman to show that the tumor segments obtained with the watershed method are as accurate as the segments obtained by manual delineation, and hence the two methods can be used interchangeably. The Bland and Altman evaluations also show that the volume segmented with the watershed method is slightly smaller than the volume segmented with the manual method. Visual inspections of the segmented volumes show that the watershed segmentation method places the boundary of the segmented volume at the edge of the tumor, while with manual segmentation the observers tend to draw the tumor boundary slightly outside the real tumor boundary, thus segmenting a larger volume."