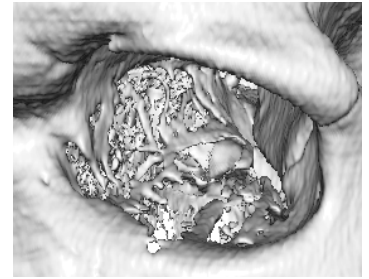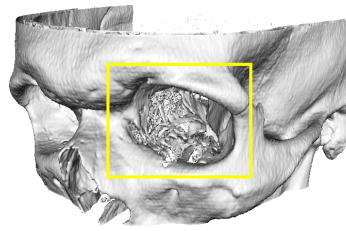**Soft thresholding of thin bone structures in 3D CT images**

Johan Nysjö
Centre for Image analysis
Swedish University of Agricultural Sciences
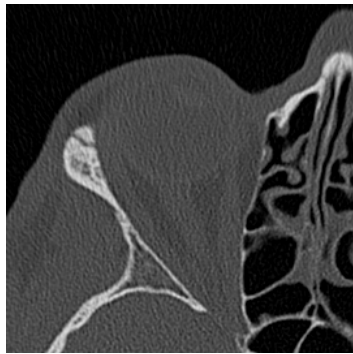Uppsala University

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Background

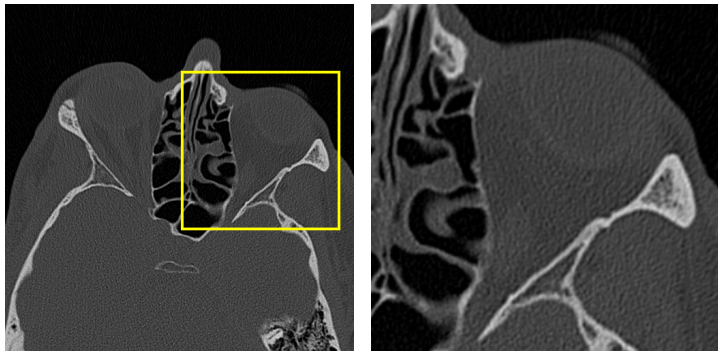# Why is bone segmentation a difficult task?

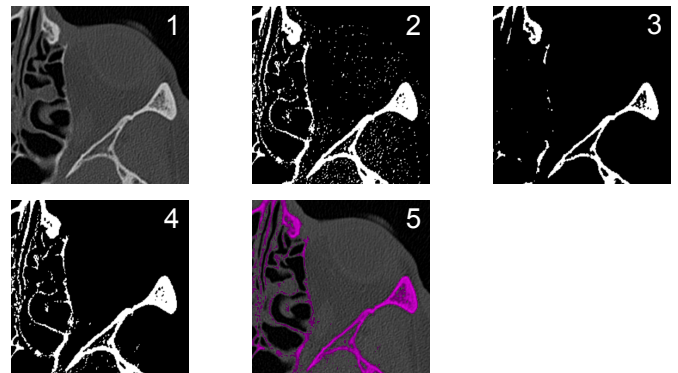- Noise
- Partial volume effects
- Density variations

Segmentation methods evaluated in this project

- Hysteresis thresholding
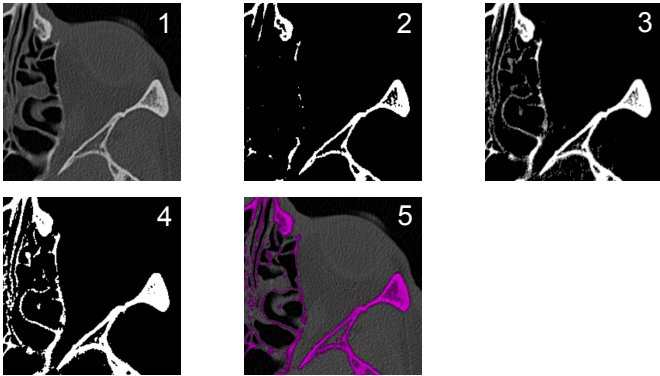- Multi-seeded fuzzy connectedness
- Soft thresholding

Test image

Hysteresis thresholding

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Multi-seeded fuzzy connectedness

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Slide 8

Soft thresholding

High-Precision Boundary Length Estimation by Utilizing Gray-Level Information

N. Sladoje, J. Lindblad

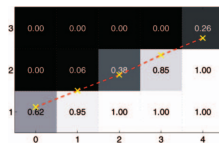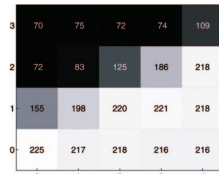**IEEE Transactions on Pattern Analysis and Machine Intelligence**, Vol. 31, No. 2, 2009

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Soft thresholding

Algorithm 1 Pixel coverage segmentation

1: $b = 0; \ f = 0$
2: **for** each gray-level b' **do**
3:    $F' = \{p \mid [\epsilon I(p) > b'\}$
4:    **if** $F' \neq \emptyset$ **then**
5:      $f' = min_{p \in F'}[\epsilon \delta I](p)$
6:      **if** $f' - b' > f - b$ **then**
7:        $f = f'; \ b = b'$
8:      **end if**
9:    **end if**
10: **end for**
11: $n = f - b$
12: $J(p) = \begin{cases} 0, & [\delta \epsilon I](p) \leq b, \\ 1, & [\epsilon \delta I](p) \geq f, \\ \frac{I(p)-b}{n}, & \text{otherwise.} \end{cases}$

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Soft thresholding

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Slide 11

Soft thresholding

Algorithm 1 Pixel coverage segmentation
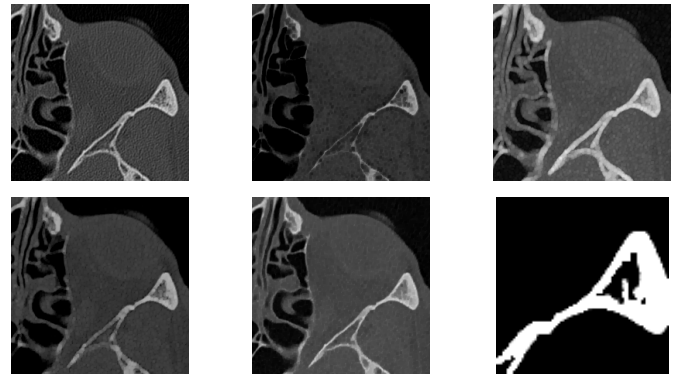
1: $b = 0; \ f = 0$
2: **for** each gray-level b' **do**
3:    $F' = \{p \mid [\epsilon I(p) > b'\}$
4:    **if** $F' \neq \emptyset$ **then**
5:      $f' = min_{p \in F'}[\epsilon \delta I](p)$
6:      **if** $f' - b' > f - b$ **then**
7:        $f = f'; \ b = b'$
8:      **end if**
9:    **end if**
10: **end for**
11: $n = f - b$
12: $J(p) = \begin{cases} 0, & [\delta \epsilon I](p) \leq b, \\ 1, & [\epsilon \delta I](p) \geq f, \\ \frac{I(p)-b}{n}, & \text{otherwise.} \end{cases}$

b = 0, f = 0
b = 0, f = 1
b = 3, f = 7
b = 4, f = 9
b = 5, f = 11
b = 6, f = 15
b = 10, f = 22
b = 13, f = 27
b = 16, f = 33
b = 195, f = 217
b = 199, f = 225

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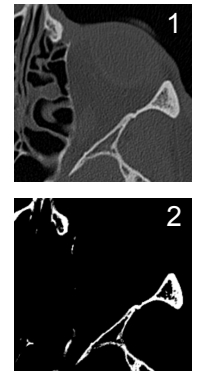Swedish University of Agricultural Sciences   johan.nysjo@cb.uu.se
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Soft thresholding

Algorithm 1 Pixel coverage segmentation

1: $b = 0; \ f = 0$
2: **for** each gray-level b' **do**
3:    $F' = \{p \mid [\epsilon I(p) > b'\}$
4:    **if** $F' \neq \emptyset$ **then**
5:      $f' = min_{p \in F'}[\epsilon \delta I](p)$
6:      **if** $f' - b' > f - b$ **then**
7:        $f = f'; \ b = b'$
8:      **end if**
9:    **end if**
10: **end for**
11: $n = f - b$
12: $J(p) = \begin{cases} 0, & [\delta \epsilon I](p) \leq b, \\ 1, & [\epsilon \delta I](p) \geq f, \\ \frac{I(p)-b}{n}, & \text{otherwise.} \end{cases}$

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Soft thresholding

Algorithm 1 Pixel coverage segmentation
1: $b = 0; \ f = 0$
2: **for** each gray-level b' **do**
3: $\quad F' = \{p \mid [\epsilon I(p) > b'\}$
4: $\quad$ **if** $F' \neq \emptyset$ **then**
5: $\quad\quad f' = min_{p \in F'}[\epsilon \delta I](p)$
6: $\quad\quad$ **if** $f' - b' > f - b$ **then**
7: $\quad\quad\quad f = f'; \ b = b'$
8: $\quad\quad$ **end if**
9: $\quad$ **end if**
10: **end for**
11: $n = f - b$
12: $J(p) = \begin{cases} 0, & [\delta \epsilon I](p) \leq b, \\ 1, & [\epsilon \delta I](p) \geq f, \\ \frac{I(p)-b}{n}, & \text{otherwise.} \end{cases}$

b = 0, f = 0
b = 0, f = 7
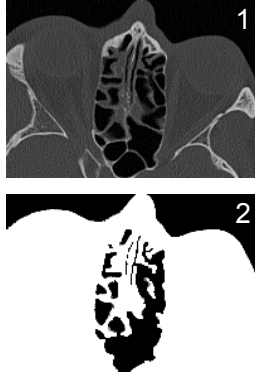b = 1, f = 10
b = 3, f = 16
b = 5, f = 22
b = 6, f = 29
b = 10, f = 35
b = 17, f = 43
b = 18, f = 45

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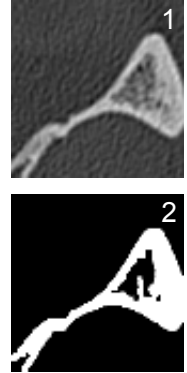johan.nysjo@cb.uu.se

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Soft thresholding

Algorithm 1 Pixel coverage segmentation
1: $b = 0; \ f = 0$
2: **for** each gray-level b' **do**
3: $\quad F' = \{p \mid [\epsilon I(p) > b'\}$
4: $\quad$ **if** $F' \neq \emptyset$ **then**
5: $\quad\quad f' = min_{p \in F'}[\epsilon \delta I](p)$
6: $\quad\quad$ **if** $f' - b' > f - b$ **then**
7: $\quad\quad\quad f = f'; \ b = b'$
8: $\quad\quad$ **end if**
9: $\quad$ **end if**
10: **end for**
11: $n = f - b$
12: $J(p) = \begin{cases} 0, & [\delta \epsilon I](p) \leq b, \\ 1, & [\epsilon \delta I](p) \geq f, \\ \frac{I(p)-b}{n}, & \text{otherwise.} \end{cases}$
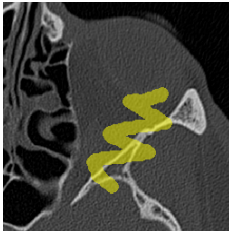
b = 30, f = 30
b = 30, f = 49
b = 73, f = 94
b = 80, f = 102
b = 84, f = 108
b = 97, f = 122
b = 99, f = 126

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Concluding remarks

- A more local coverage segmentation approach is required to segment the bones

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Thank you!

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