USER-INTERACTION FOR MEDICAL IMAGING SEGMENTATION

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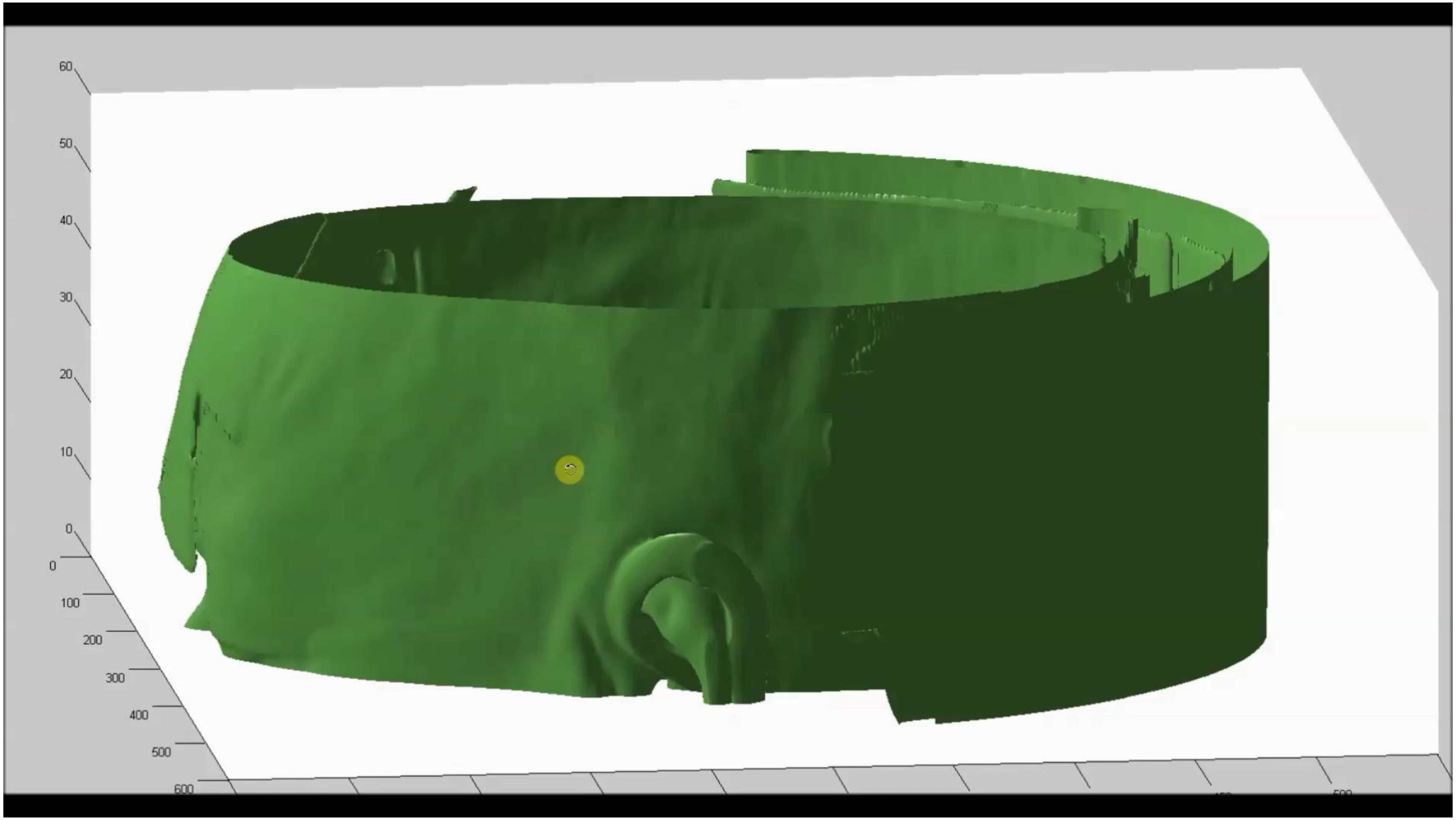
Electrical and Computer Engineering
Ben-Gurion University

Ilan Shelef, Soroka Medical Center
Ben-Gurion University

SOROKA
MEDICAL CENTER

CEREBRAL HEMORRHAGE SEGMENTATION



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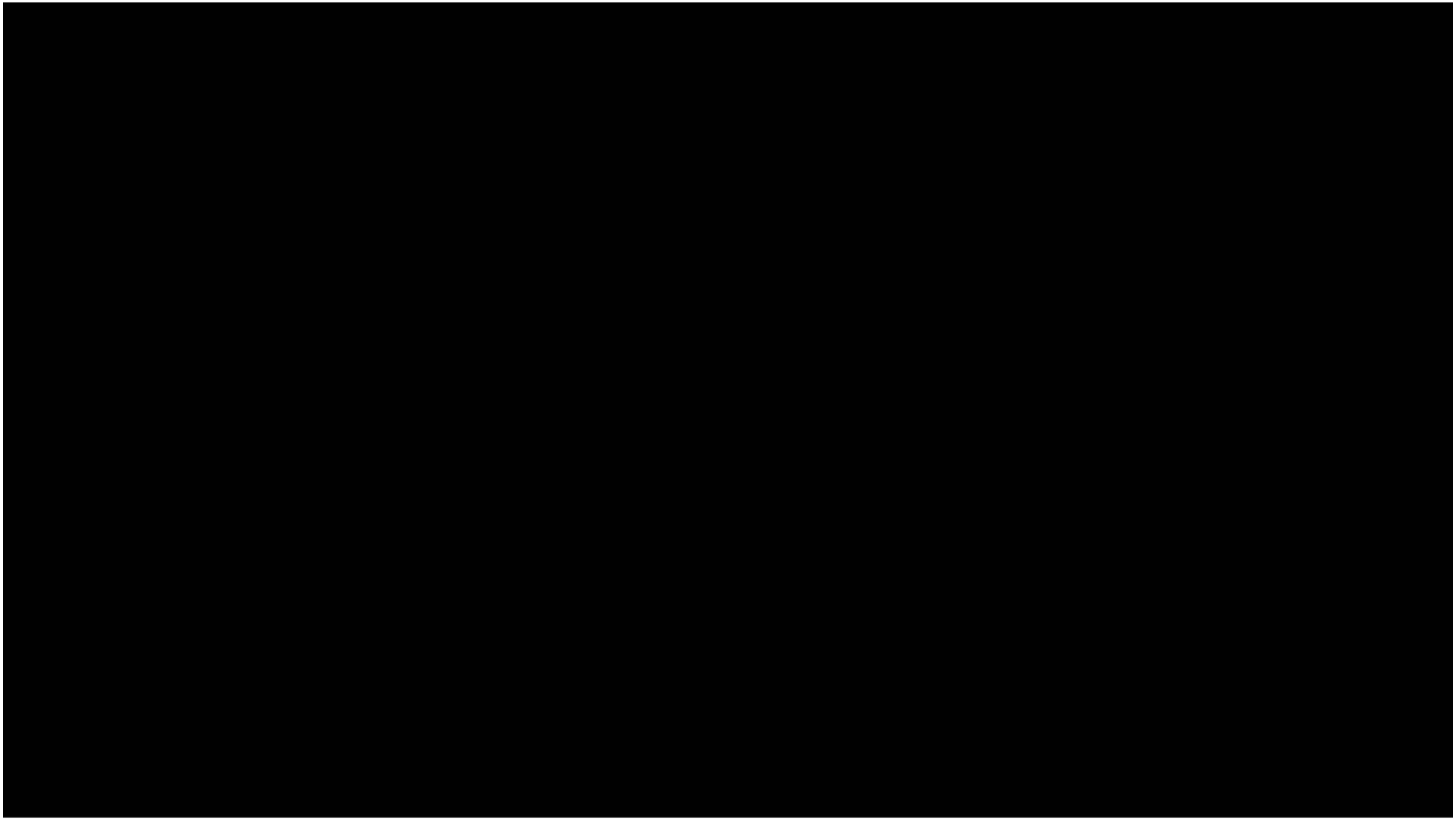

RATIONALE

- Time is critical !

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  - Image acquisition should be fast →
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Physician's knowhow and expertise are 'a Must'

OBJECTIVE

- Develop a computational platform
  - to allow machine – user dialogue
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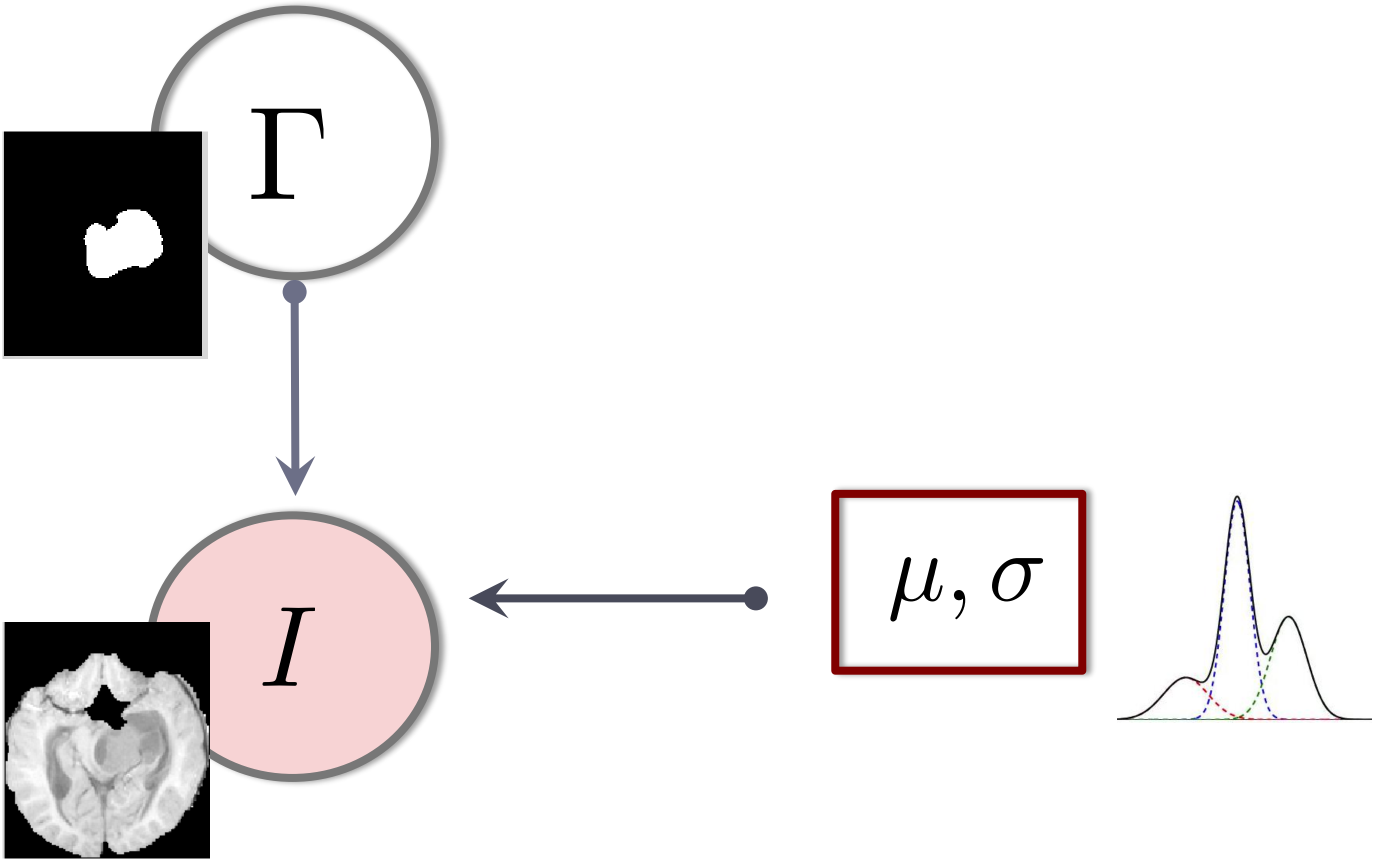
  - **Accurate**
  - **Fast**

SIMPLE GENERATIVE SEGMENTATION MODEL



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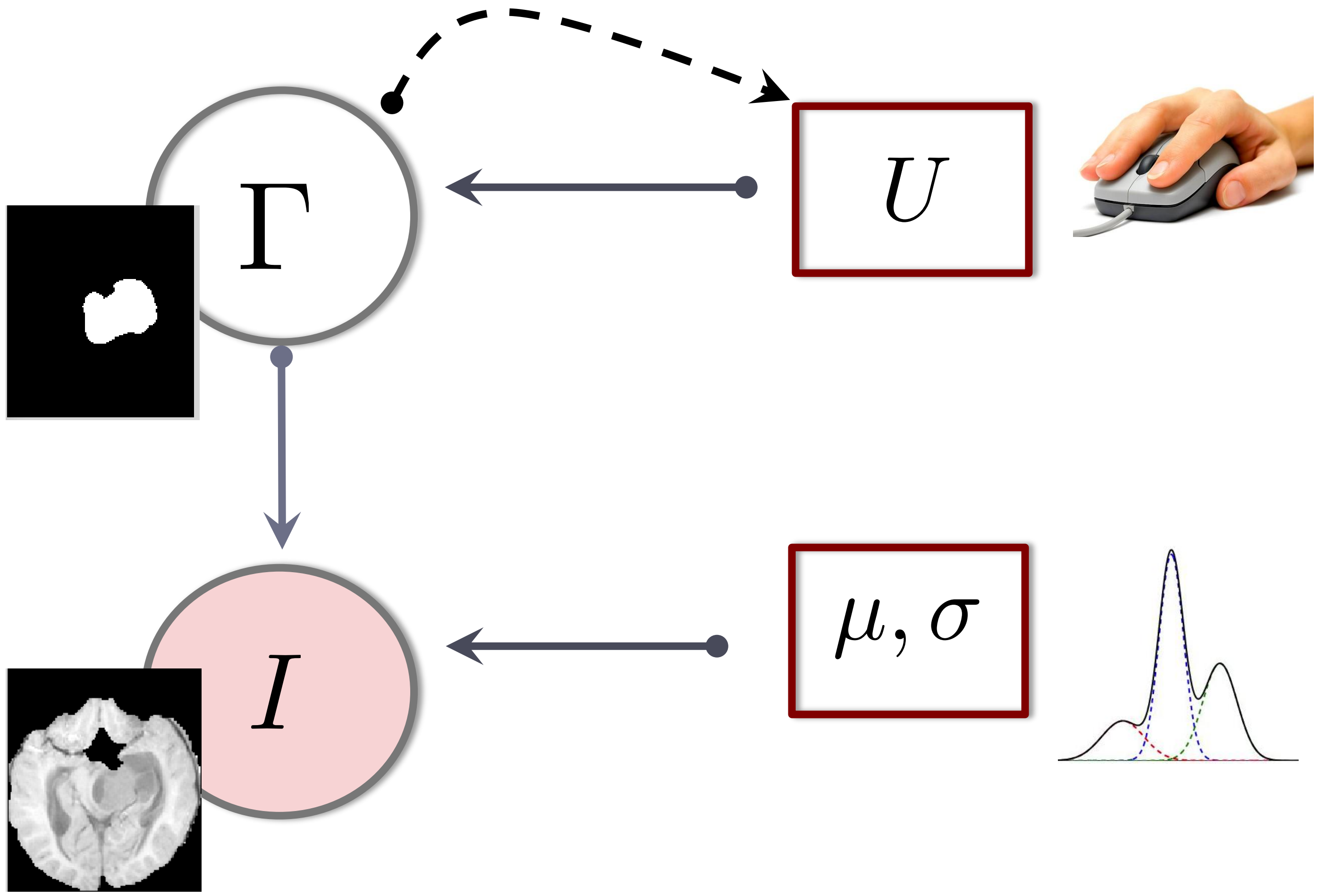

GUIDING PRINCIPLES

Find the segmentation Γ by solving the following MAP:

$$\hat{\Gamma} = \arg\max_{\Gamma} \left[\log p(I|\Gamma, \{\mu, \sigma\}) \right.$$

$$+ \log p(\Gamma)$$

$$\left. + \log p(U; \Gamma)\right]$$

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Image likelihood

$$+ \log p(\Gamma)$$

Prior

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User input

GUIDING PRINCIPLES

Use: $E \propto -\log p$

Find the segmentation Γ **by minimizing the following cost functional:**

$E = \int \alpha$ Image likelihood term

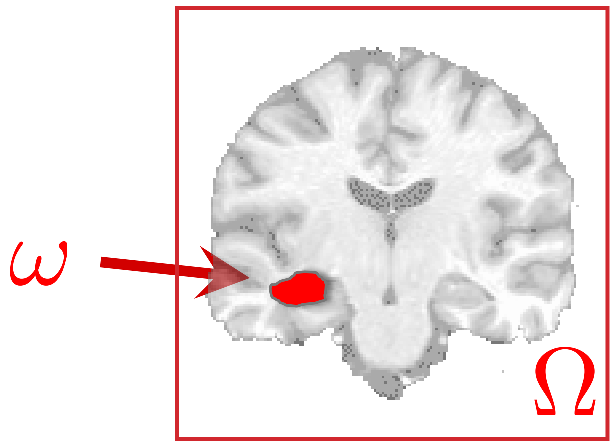
$+\beta$ Regularization

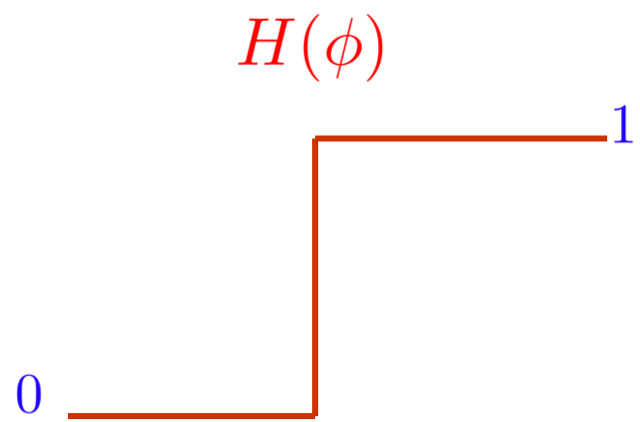
$+\gamma$ User input term dx

LEVEL-SET MODEL

Level-set function $\phi \colon \Omega \rightarrow \mathbb{R}$

Segmentation boundary $C = \{\mathbf{x} \in \Omega | \phi(\mathbf{x}) = 0\}$





$\Gamma \triangleq H(\phi)$

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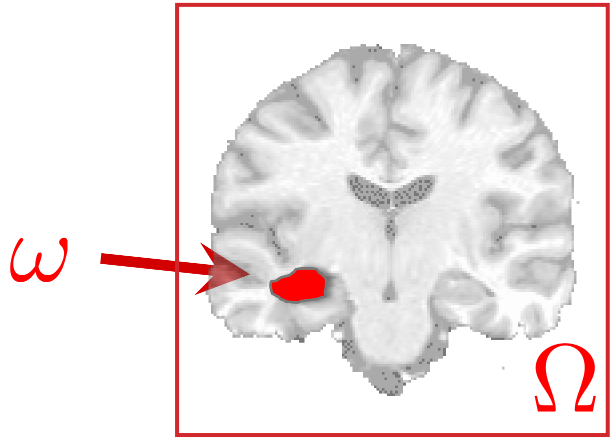

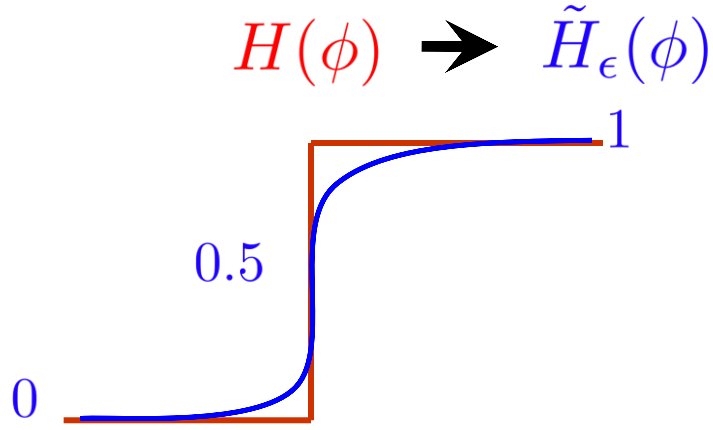

Riklin Raviv, Van Leemput, Menze, Wells, Golland, Medical Image Analysis, 2011

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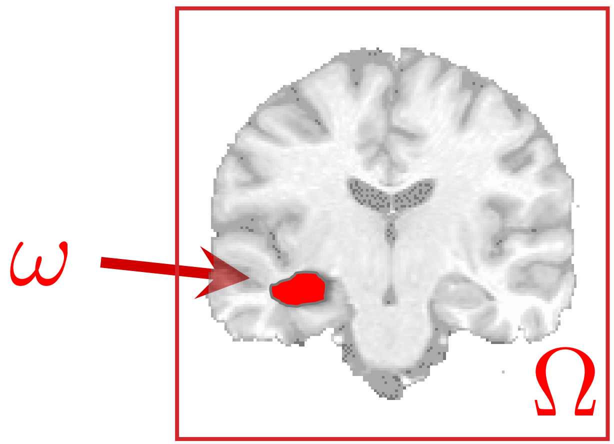

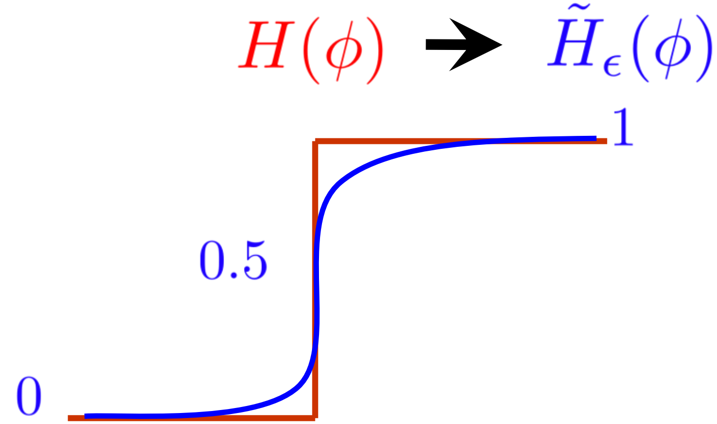

$$\phi(\mathbf{x}) \triangleq \epsilon \ \mathrm{logit}(p) = \epsilon \log \frac{p(\mathbf{x} \in \Omega_i)}{1 - p(\mathbf{x} \in \Omega_i)} = \epsilon \ \log \frac{p(\mathbf{x} \in \Omega_i)}{p(\mathbf{x} \in \Omega_o)}$$

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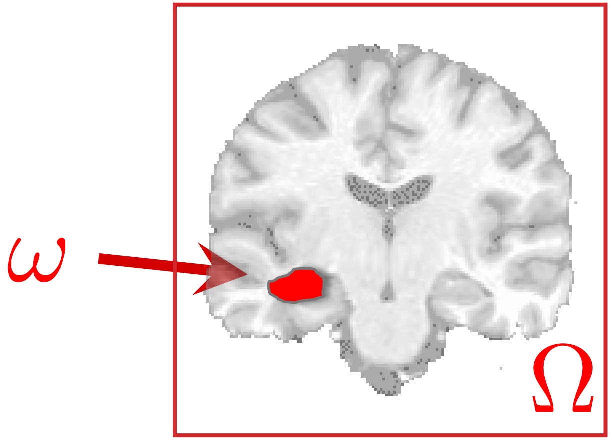

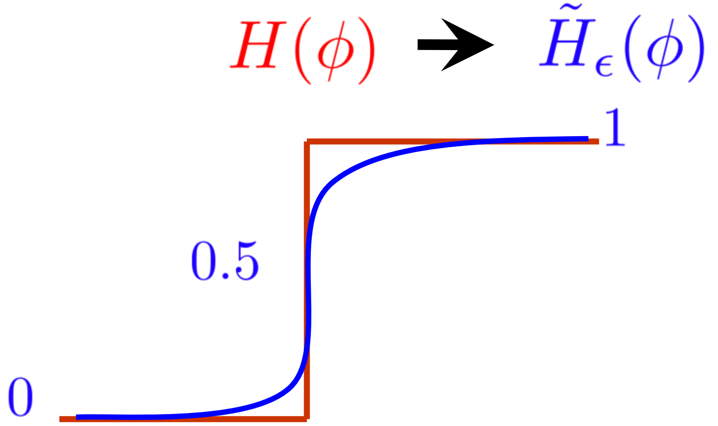

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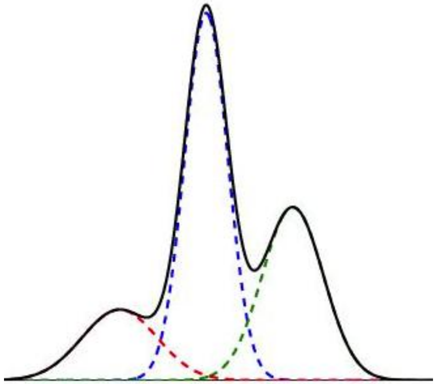
$$\tilde{H}_\epsilon(\phi) \triangleq \frac{1}{1 + e^{-\phi/\epsilon}} \quad \rightarrow \tilde{H}(\phi(\mathbf{x})) \triangleq p(\mathbf{x} \in \Omega_i)$$

CHAN-VESE AND BYHOND

$$E_I(\phi; \{\mu, \sigma\}) = -\int_\Omega \Big[\log p_{\text{in}}(I; \{\mu_{\text{in}}, \sigma_{\text{in}}\})\tilde{H}_\epsilon(\phi)$$

Image likelihood term

$$+ \log p_{\text{out}}(I; \{\mu_{\text{out}}, \sigma_{\text{out}}\})(1 - \tilde{H}_\epsilon(\phi))\Big]$$



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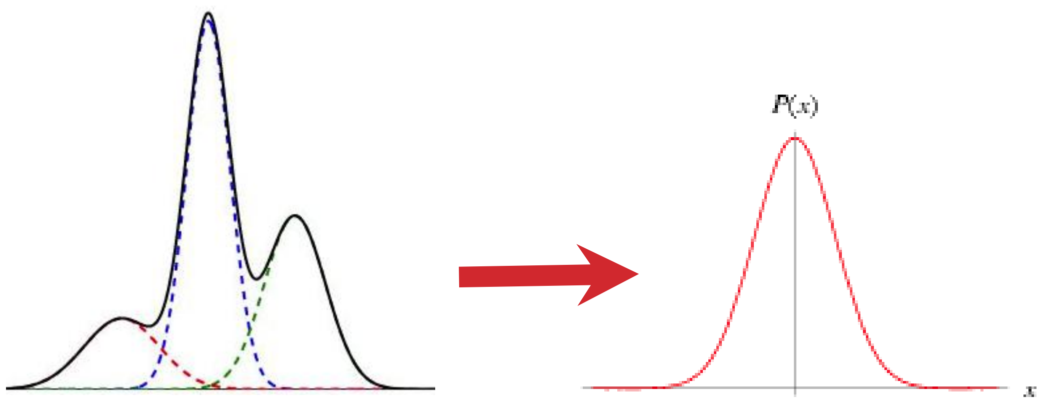

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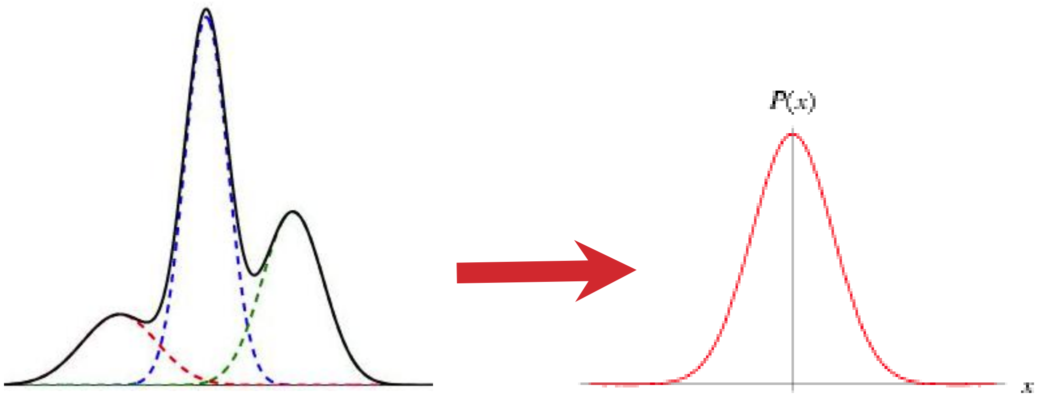


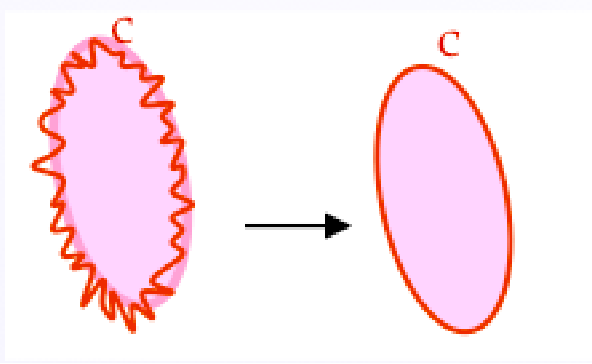
$$E_{\text{IL}}(\phi) = \int_\Omega \tilde{H}_\epsilon(\phi)\frac{(I_{\mathbf{x}} - \mu_{in})^2}{\sigma_{in}^2} + (1 - \tilde{H}_\epsilon(\phi))\frac{(I_{\mathbf{x}} - \mu_{out})^2}{\sigma_{out}^2} d\mathbf{x}$$

[Chan & Vese, IEEE IP 01]

REGULARIZATION

$$E_{LEN}(\phi) = \int_{\Omega} |\nabla \tilde{H}_\epsilon(\phi)| d\mathbf{x}$$

length term



USER INPUT TERM

$$U = \{X_i\}_{i=1,\ldots N}$$ User input

$$L = \sum_{i=1}^{N} \delta(\mathbf{x} - \mathbf{x}_i)$$

$$L \colon \Omega \to \{0, 1\}$$

[Ben-Zadok, Riklin Raviv & Kiryati ISBI 09]

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$$M = \begin{cases} \Gamma & \text{if} \quad L = 0 \\ 1 - \Gamma & \text{if} \quad L = 1 \end{cases}$$

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$$\tilde{L} = L \circ \mathcal{K}(\Sigma_u) \qquad \tilde{L} : \Omega \to (0, 1)$$

USER INPUT TERM

Bernoulli distribution

$$f(\tilde{L};\phi) = \tilde{H}_\epsilon(\phi)^{(1-\tilde{L})}(1-\tilde{H}_\epsilon(\phi))^{\tilde{L}}$$

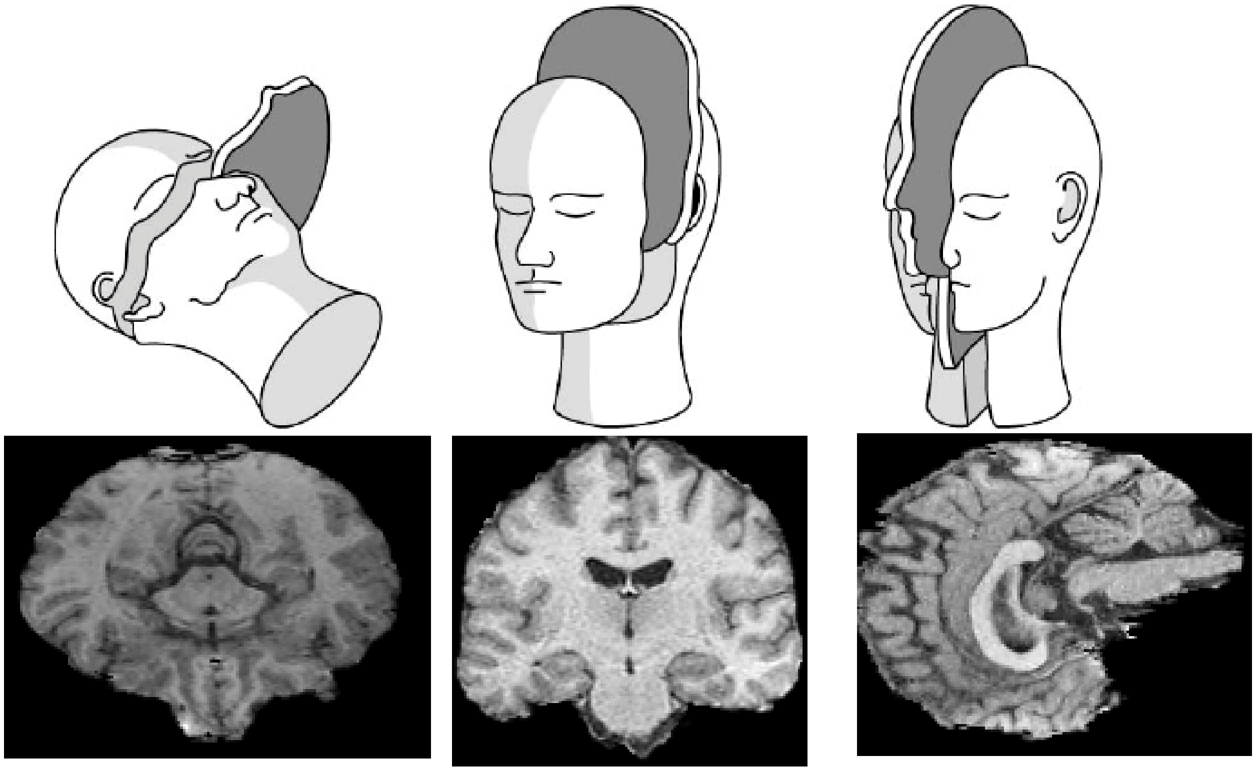
$$E_{\mathrm{UI}} = -\int_\Omega (1-\tilde{L})\log\tilde{H}_\epsilon(\phi) + \tilde{L}\log(1-\tilde{H}_\epsilon(\phi))d\mathbf{x}$$

UNIFIED ENERGY FUNCTIONAL

$$E(\phi) = E_{LEN} + E_{IL}$$

$$E(\phi) = E_{LEN} + E_{IL} + E_{UI}$$

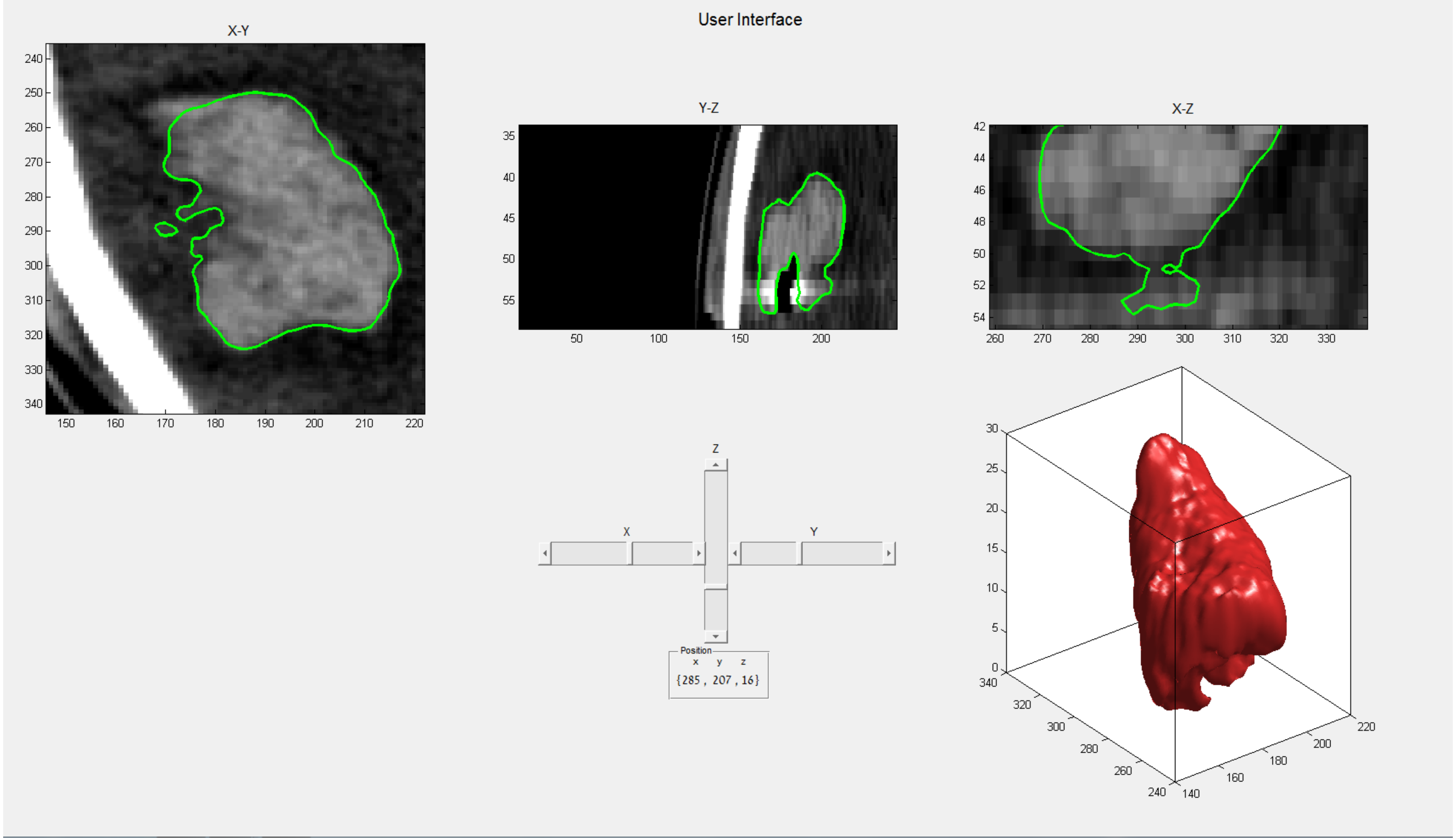
A NOTE ABOUT 3D



axial coronal sagittal

3D UI SEGMENTATION

INITIAL FULLY AUTOMATIC SEGMENTATION



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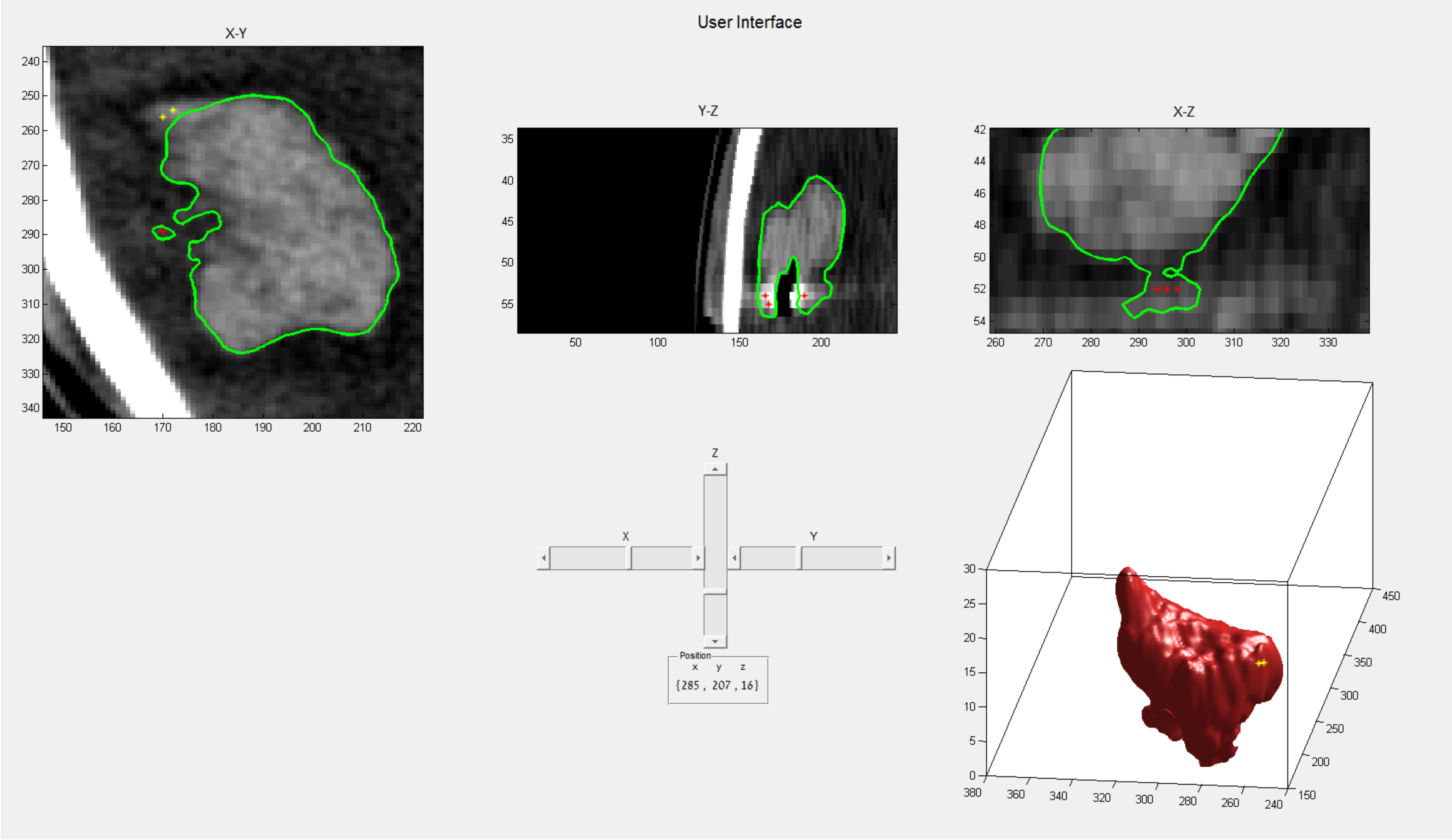
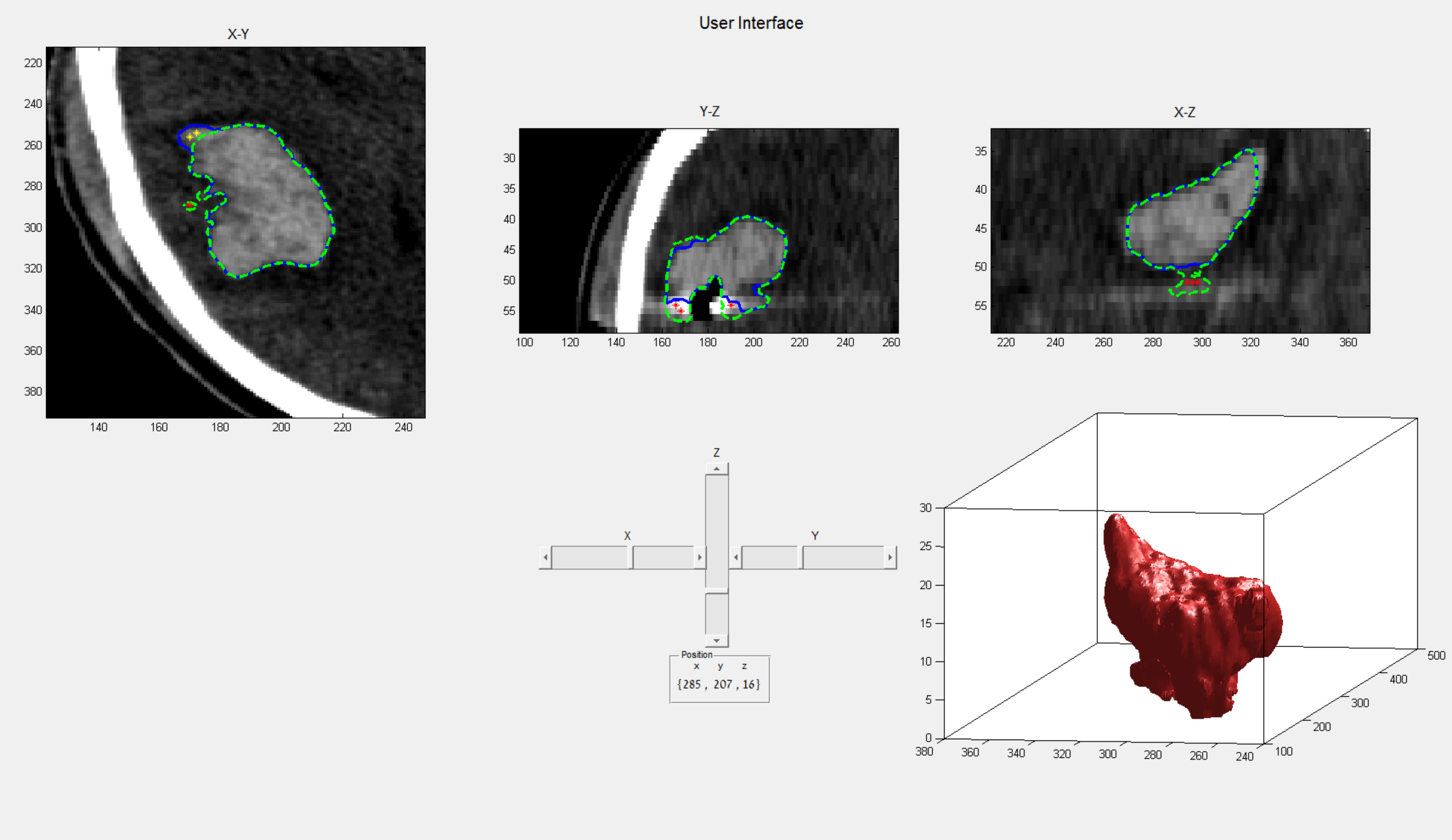


3D UI SEGMENTATION

SEMI-SUPERVISED SEGMENTATION



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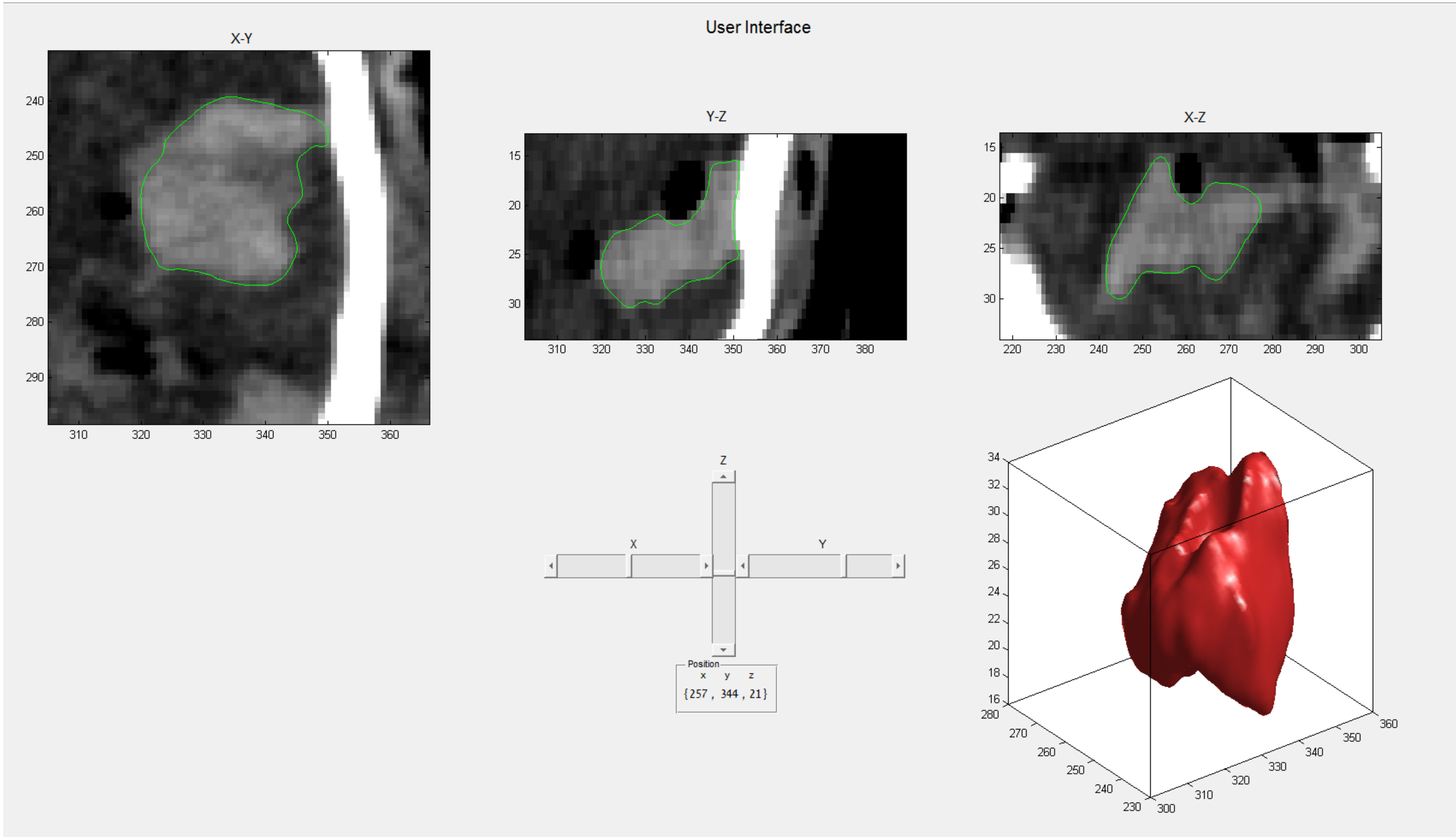

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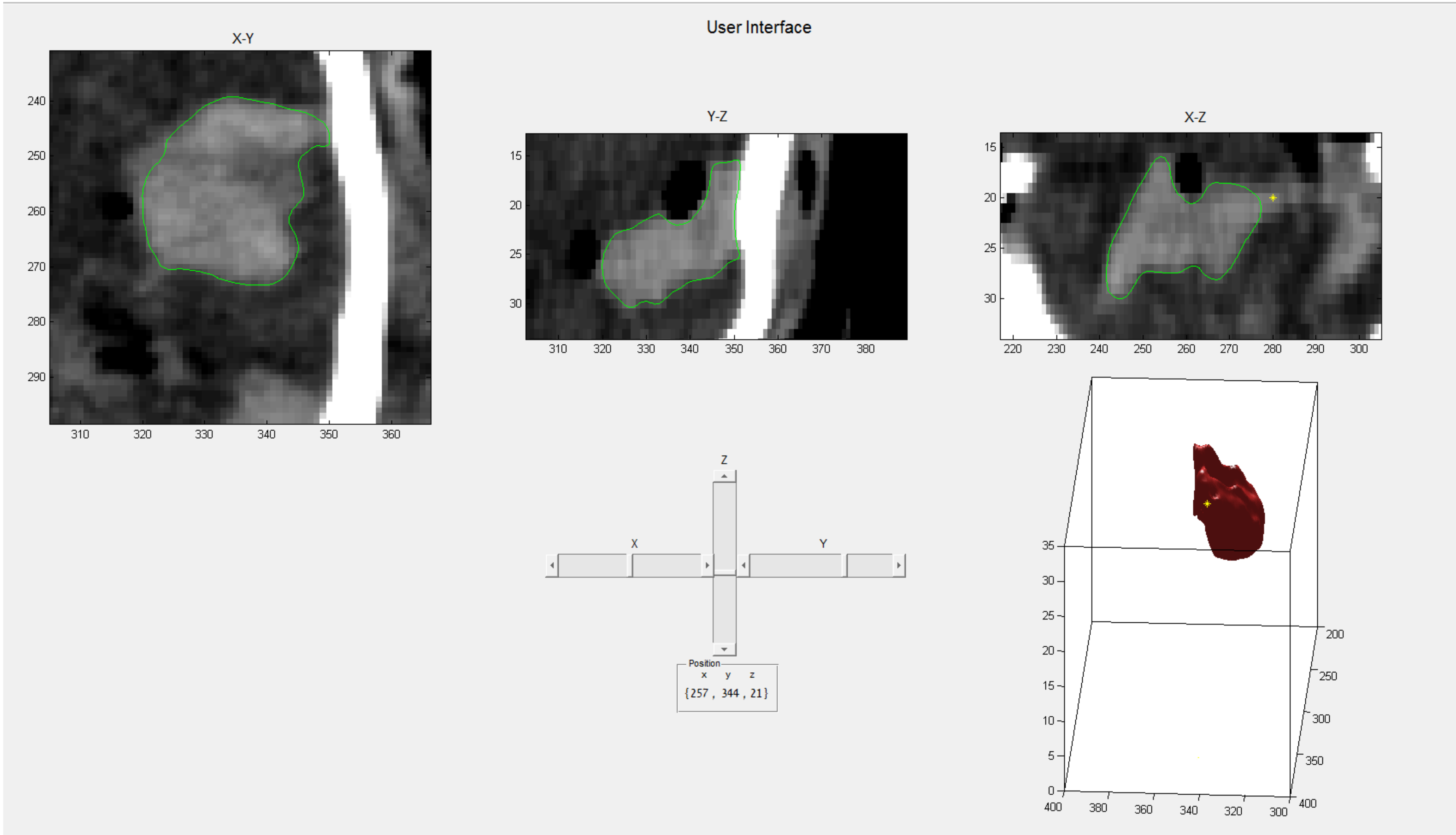

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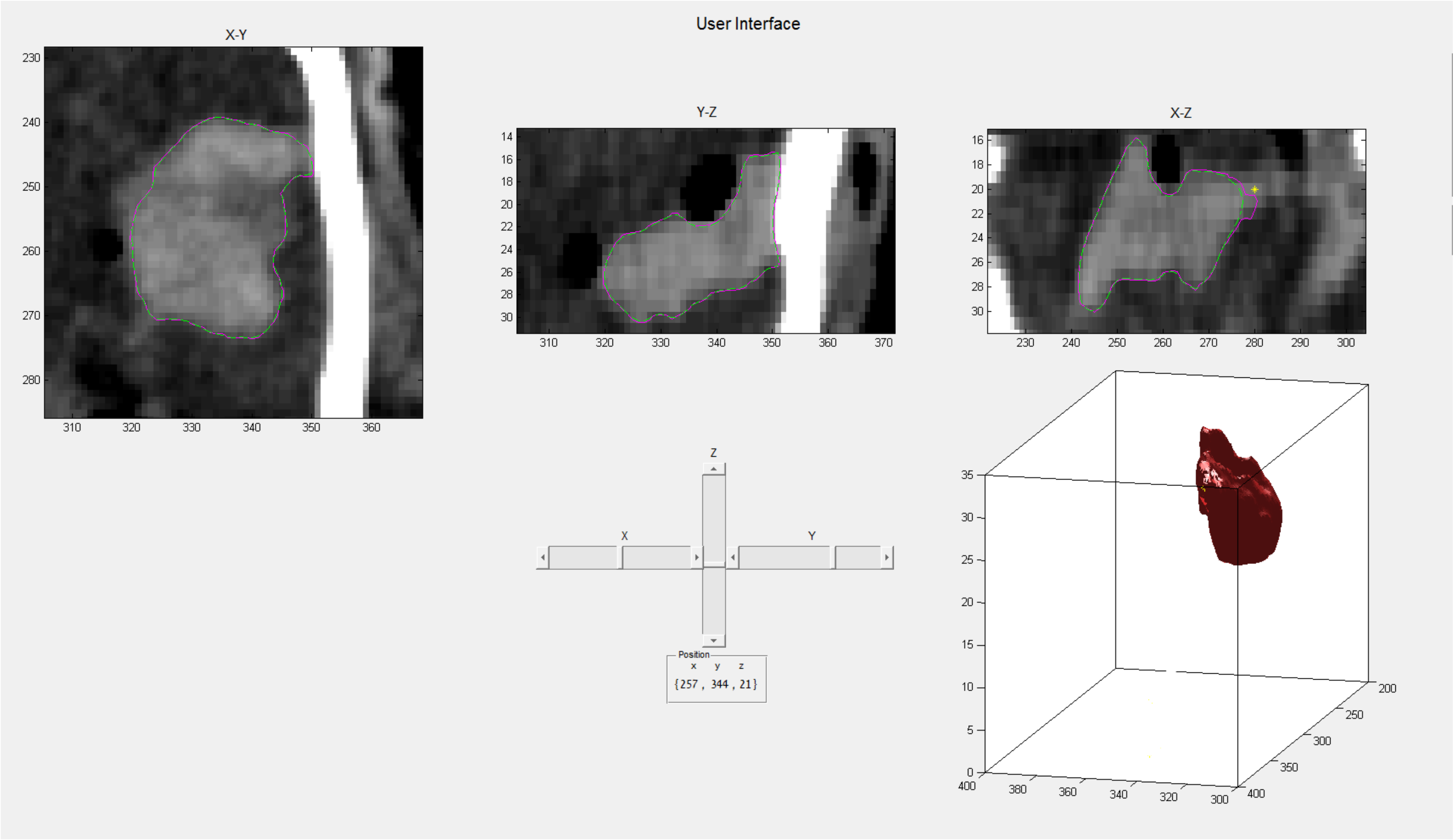

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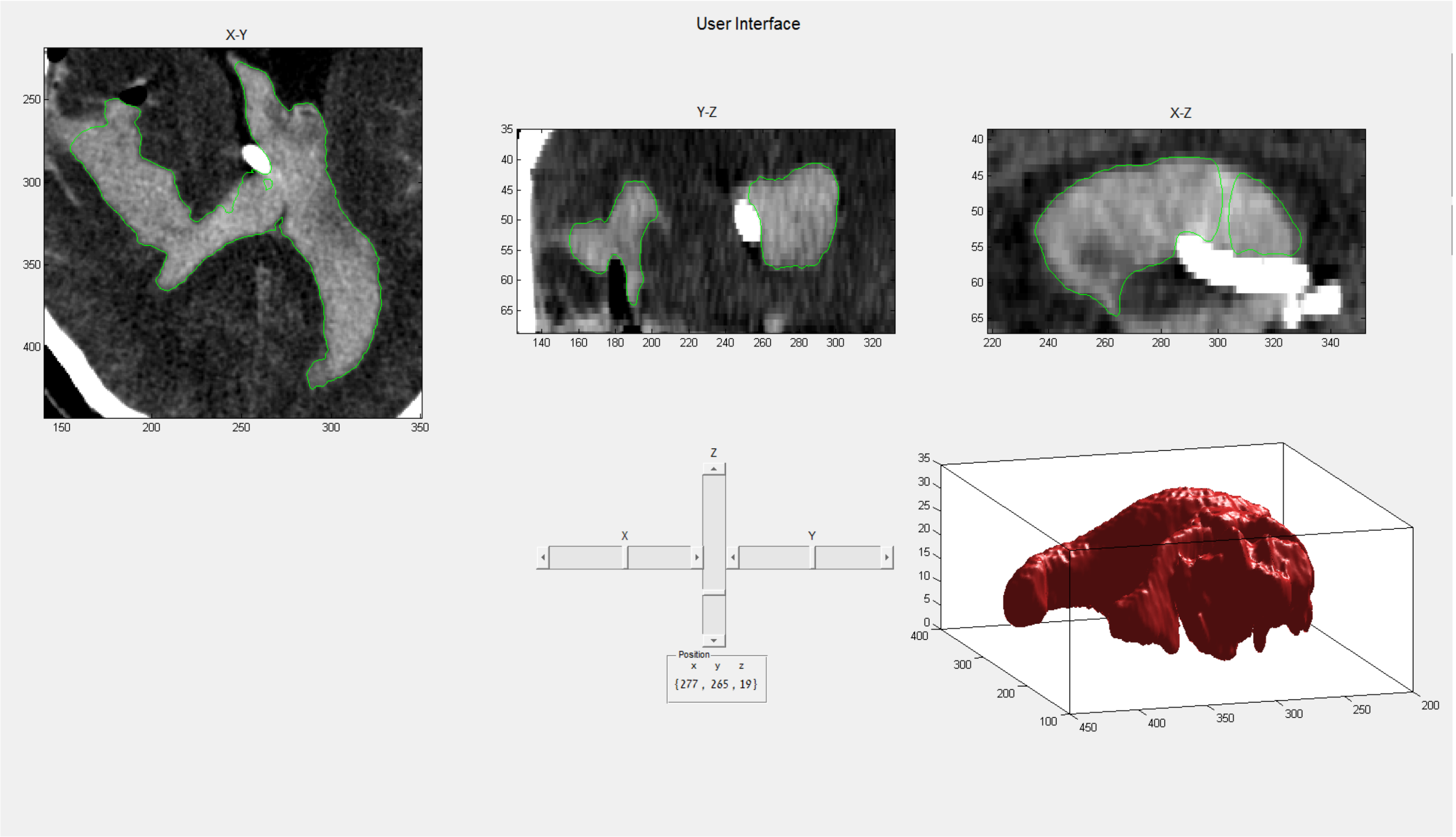

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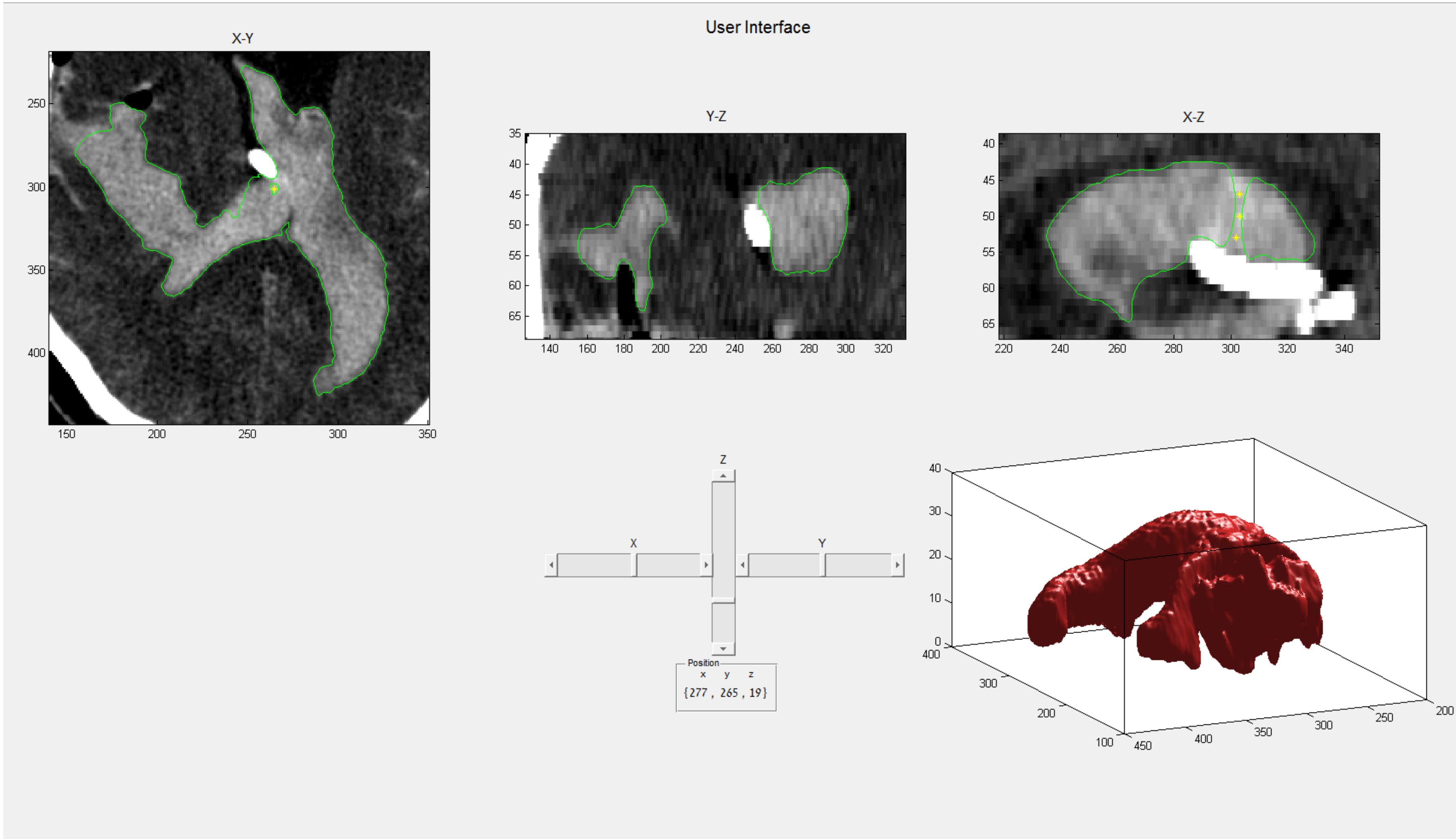

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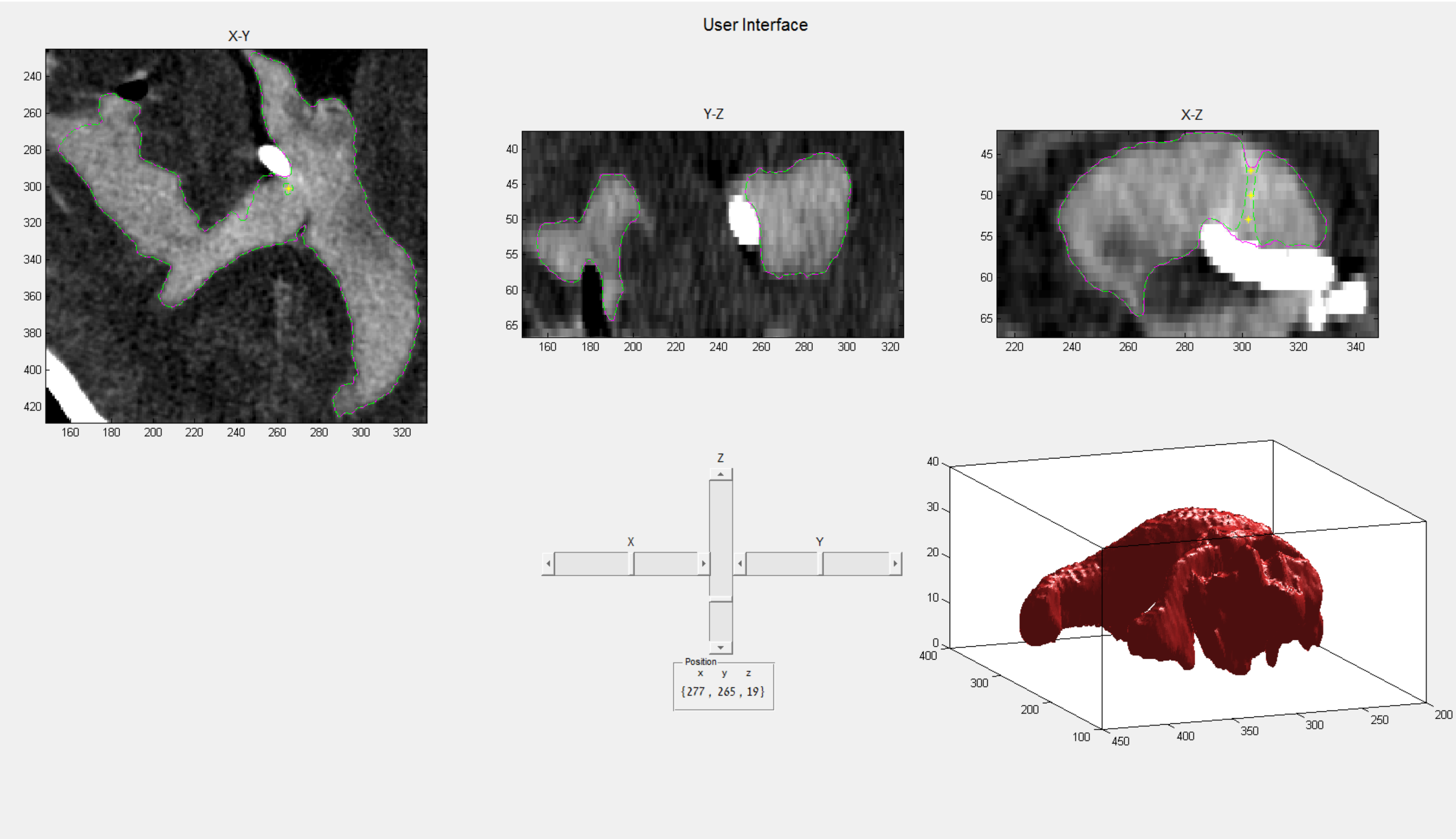

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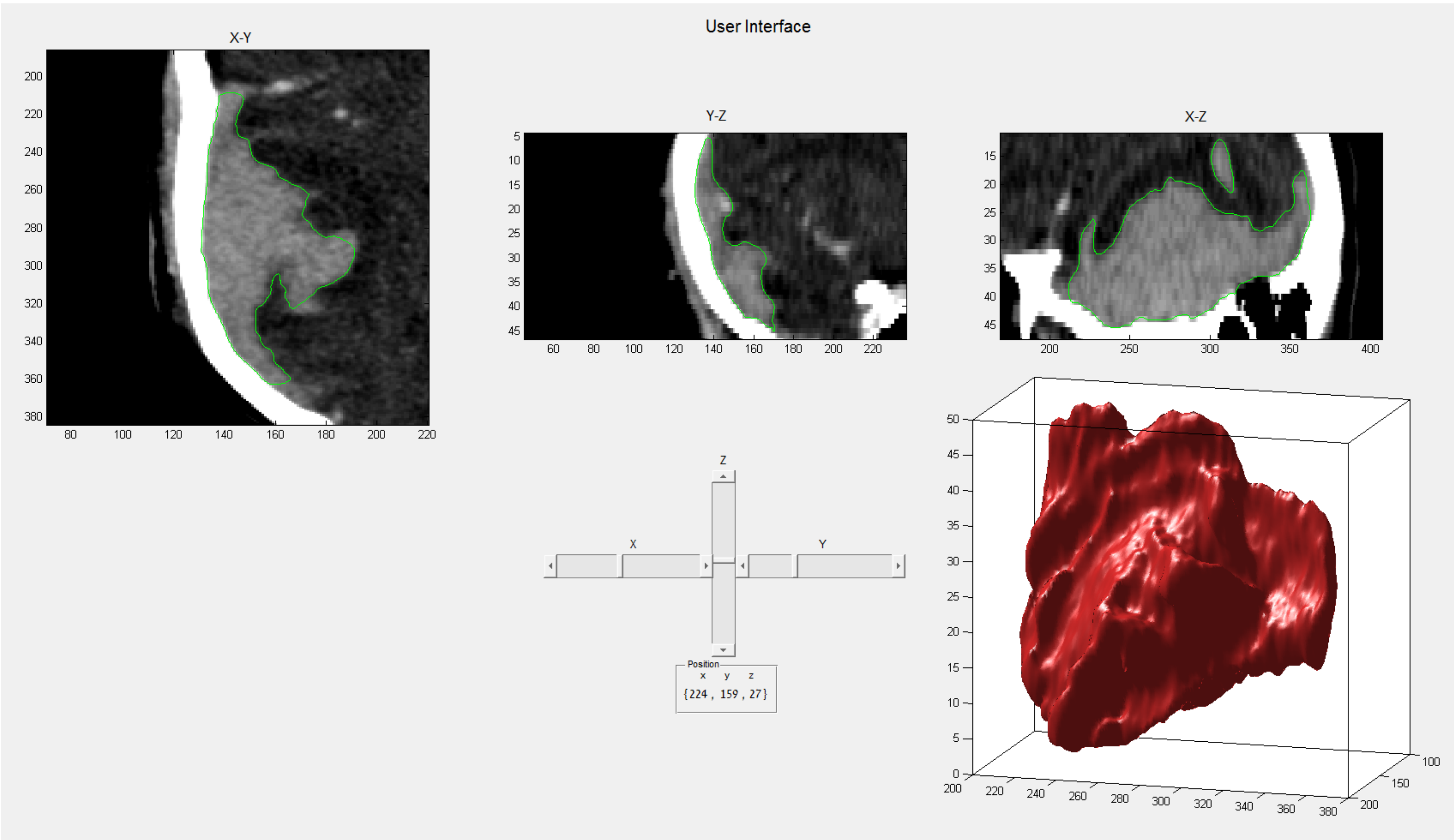

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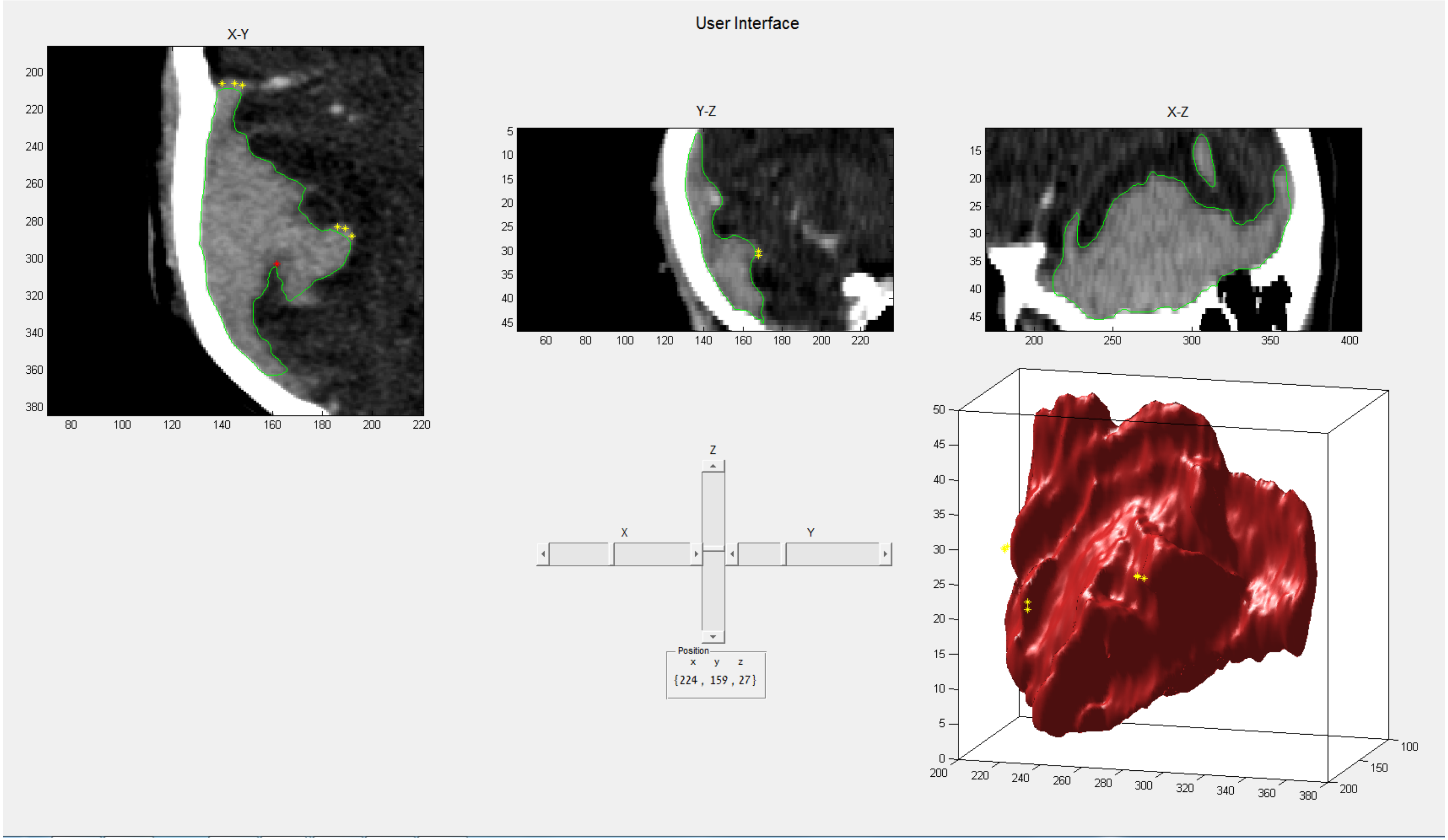

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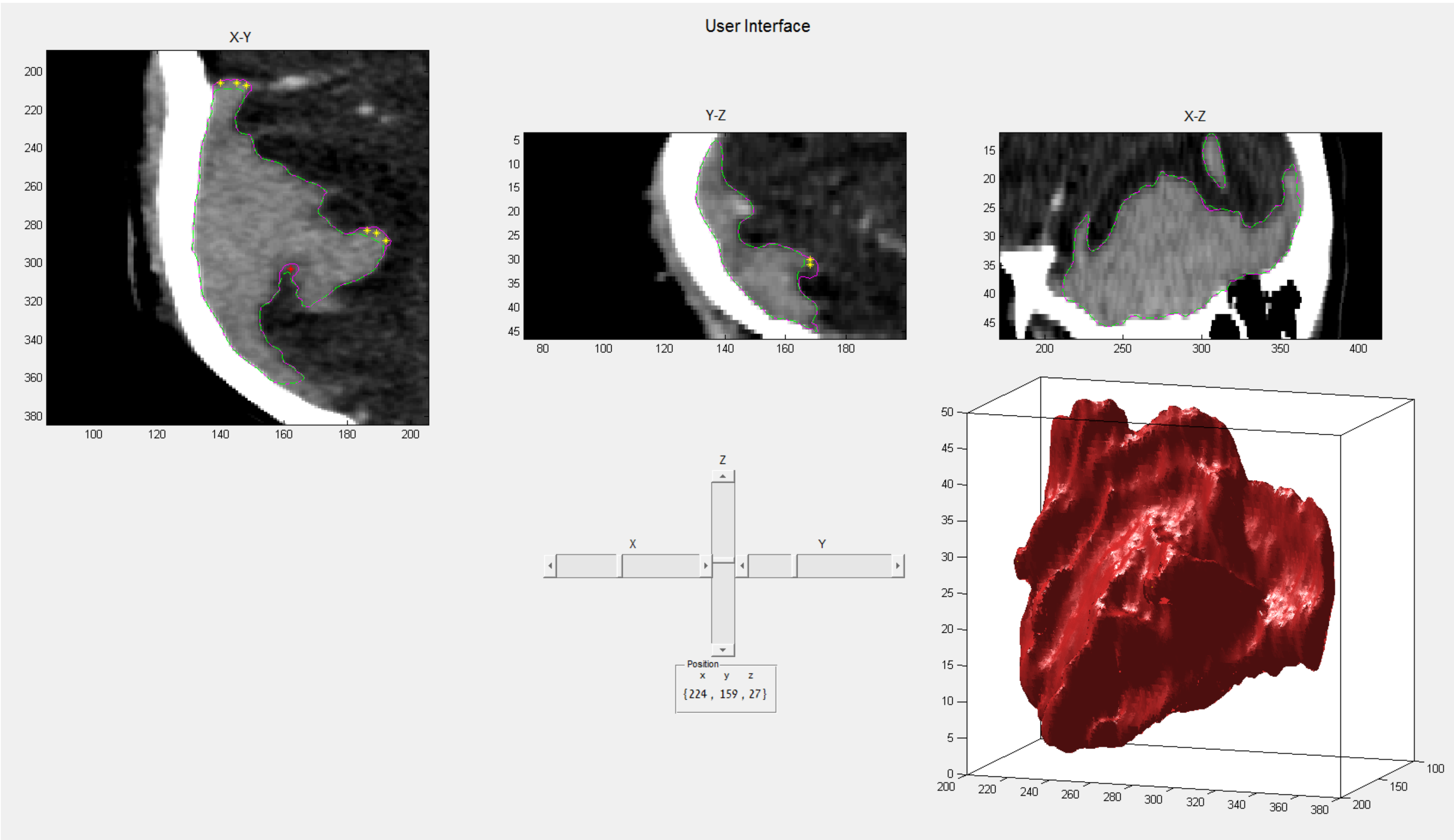

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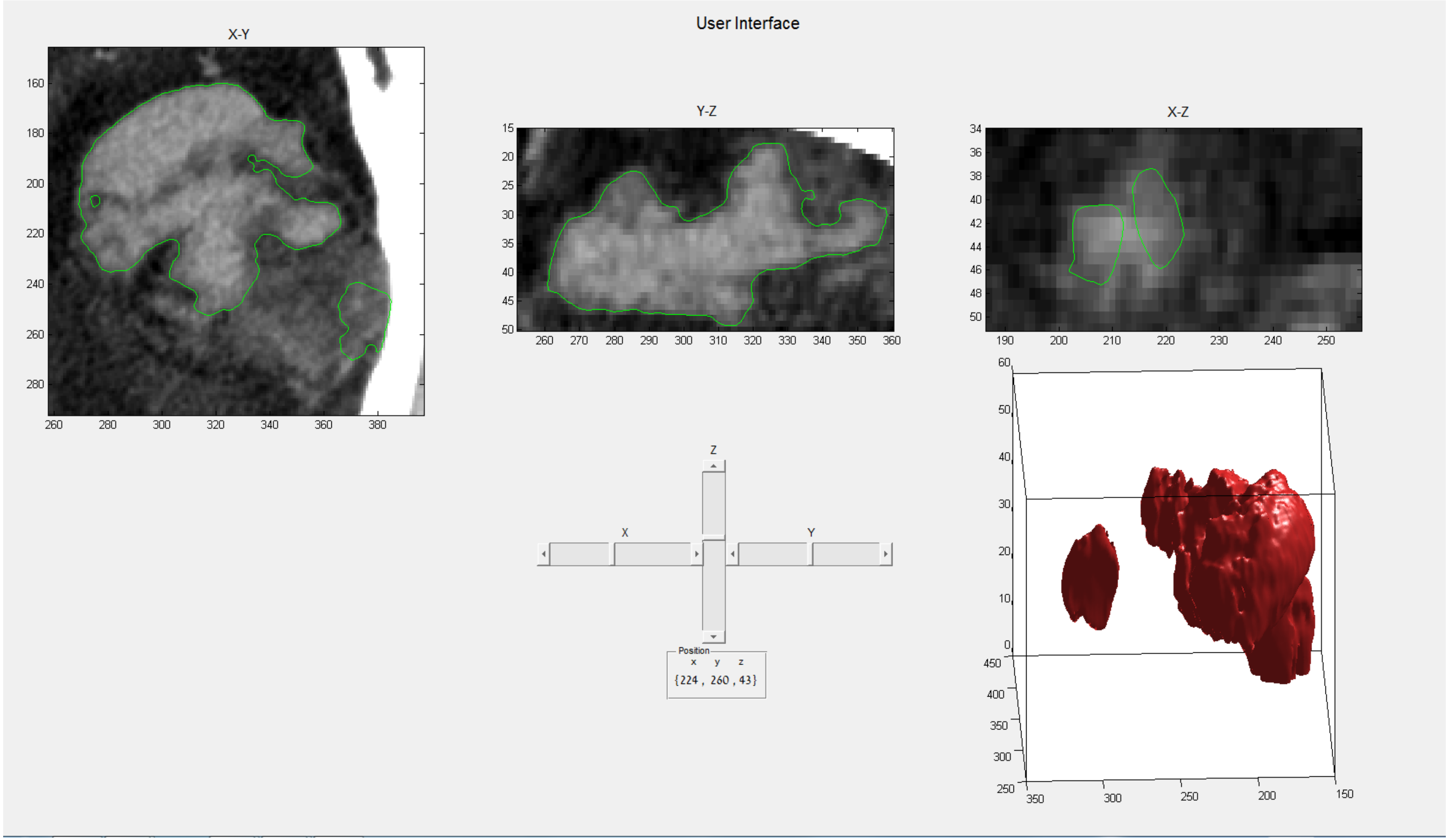

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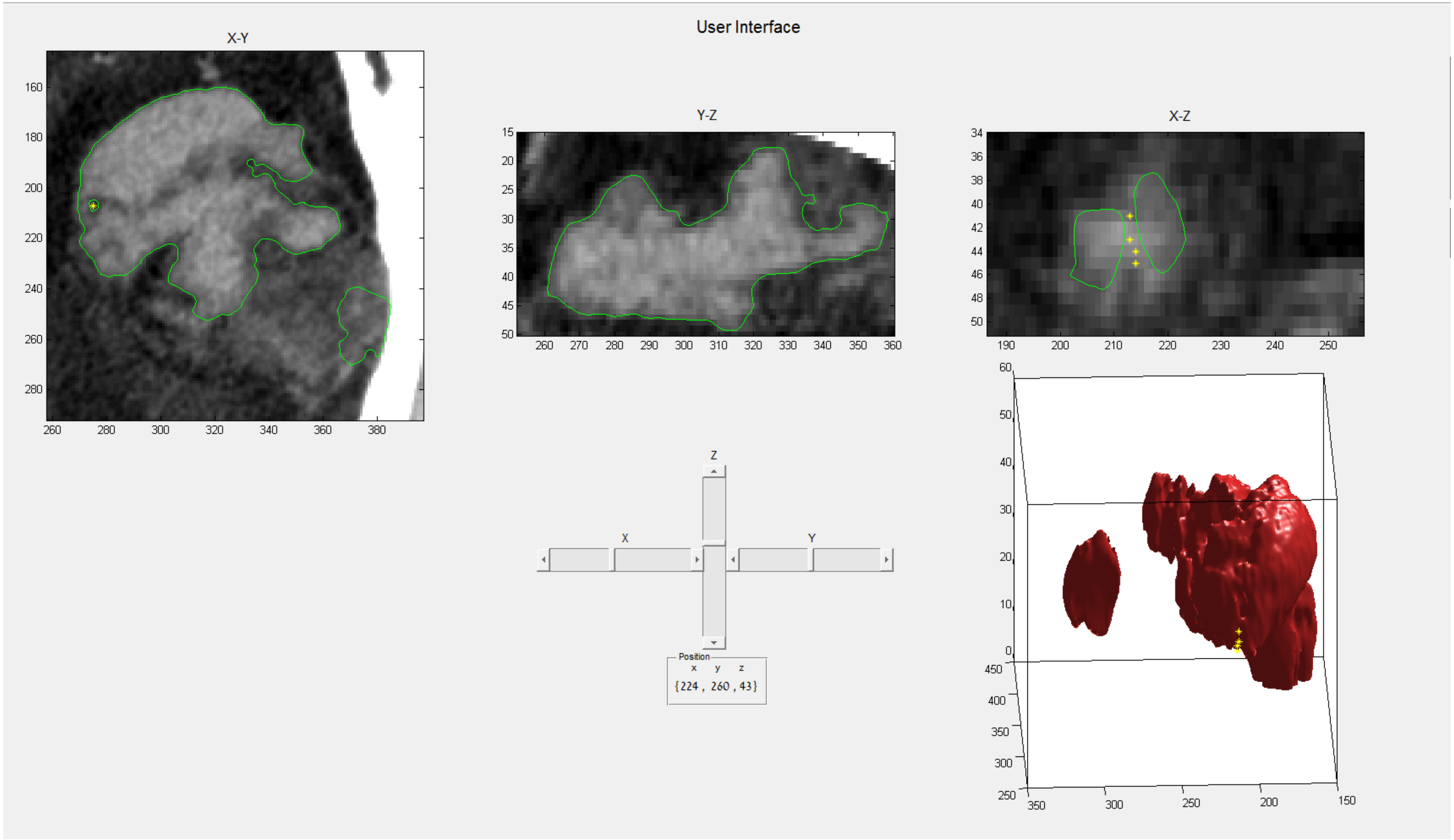

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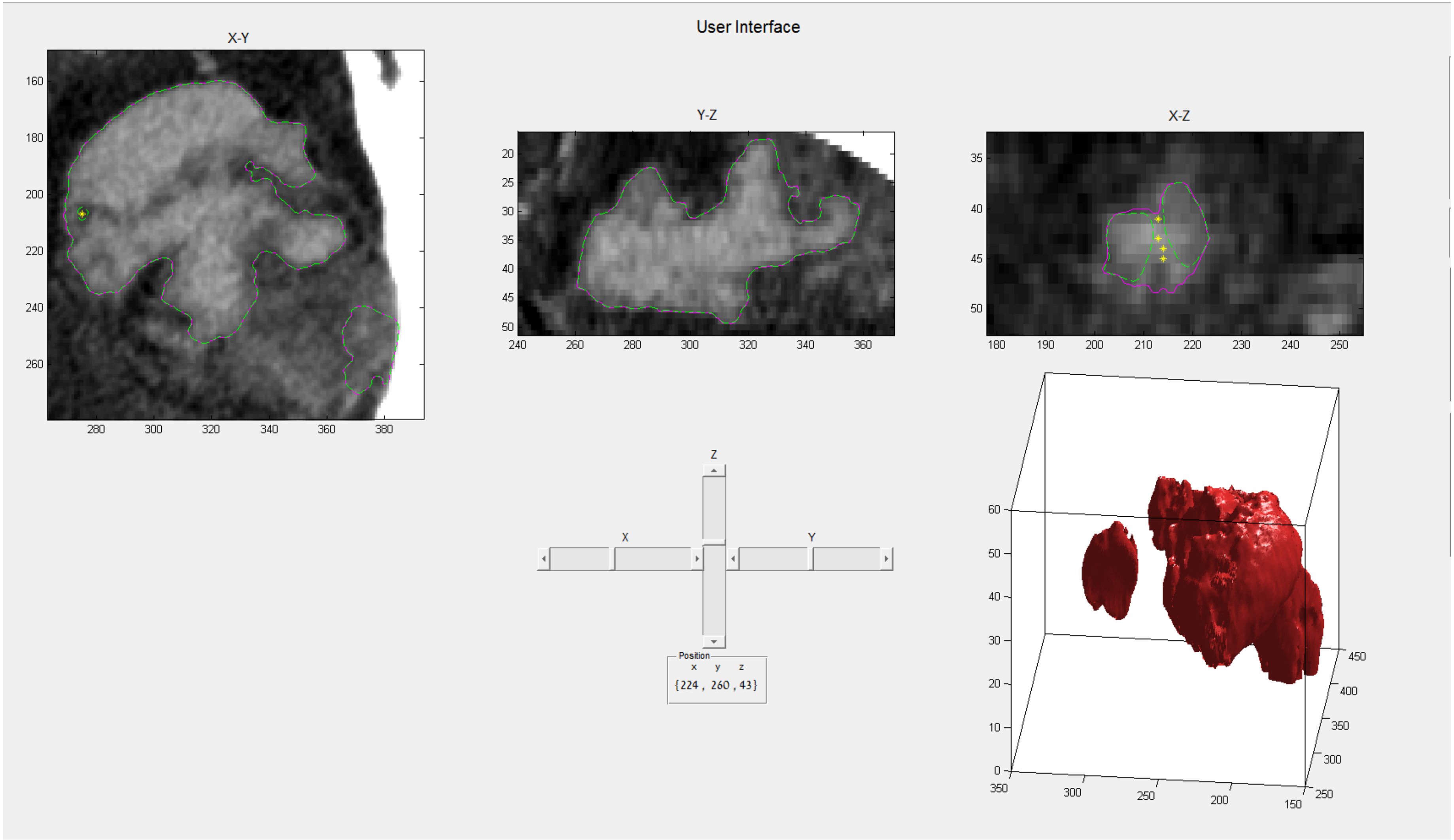

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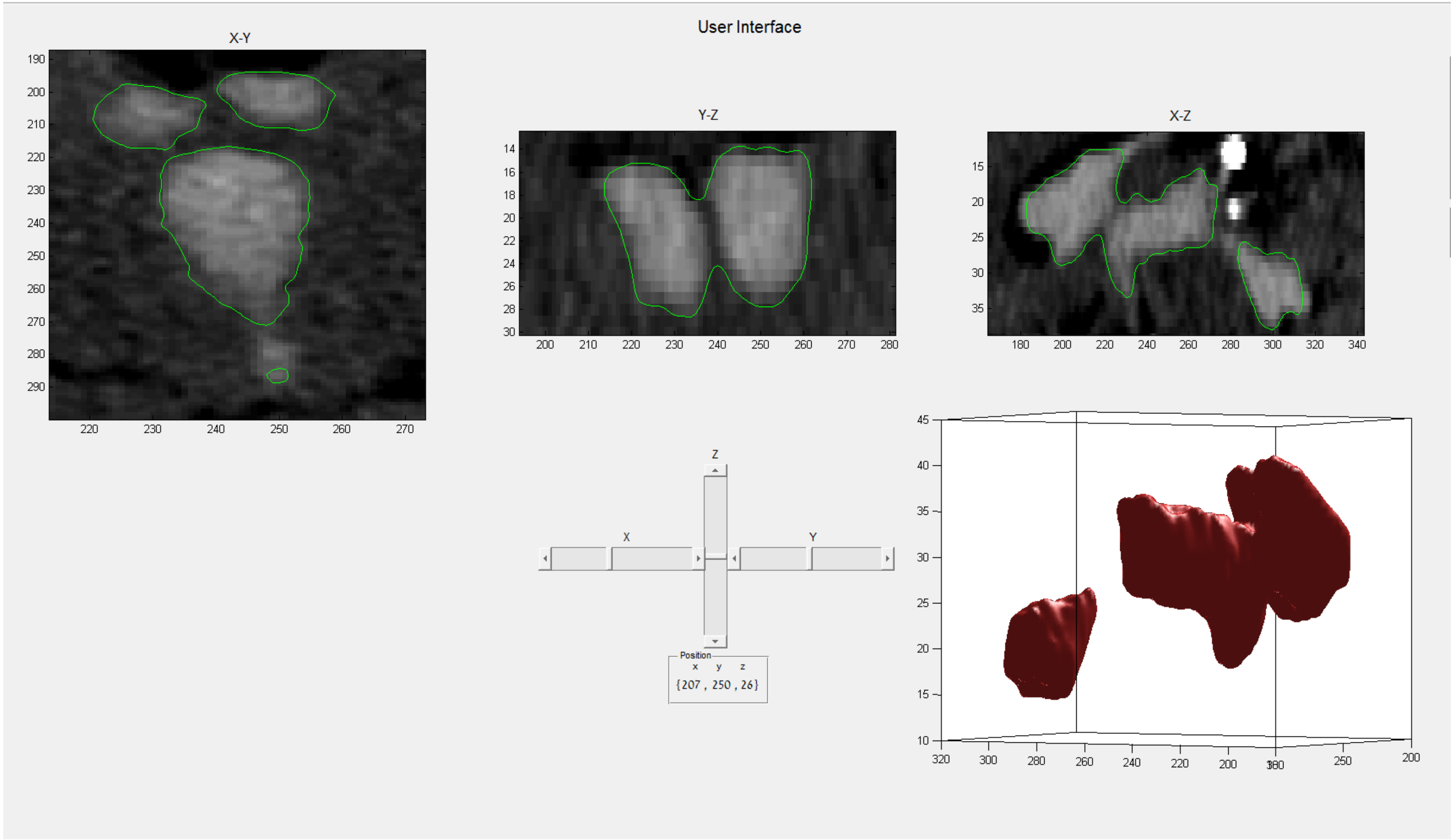

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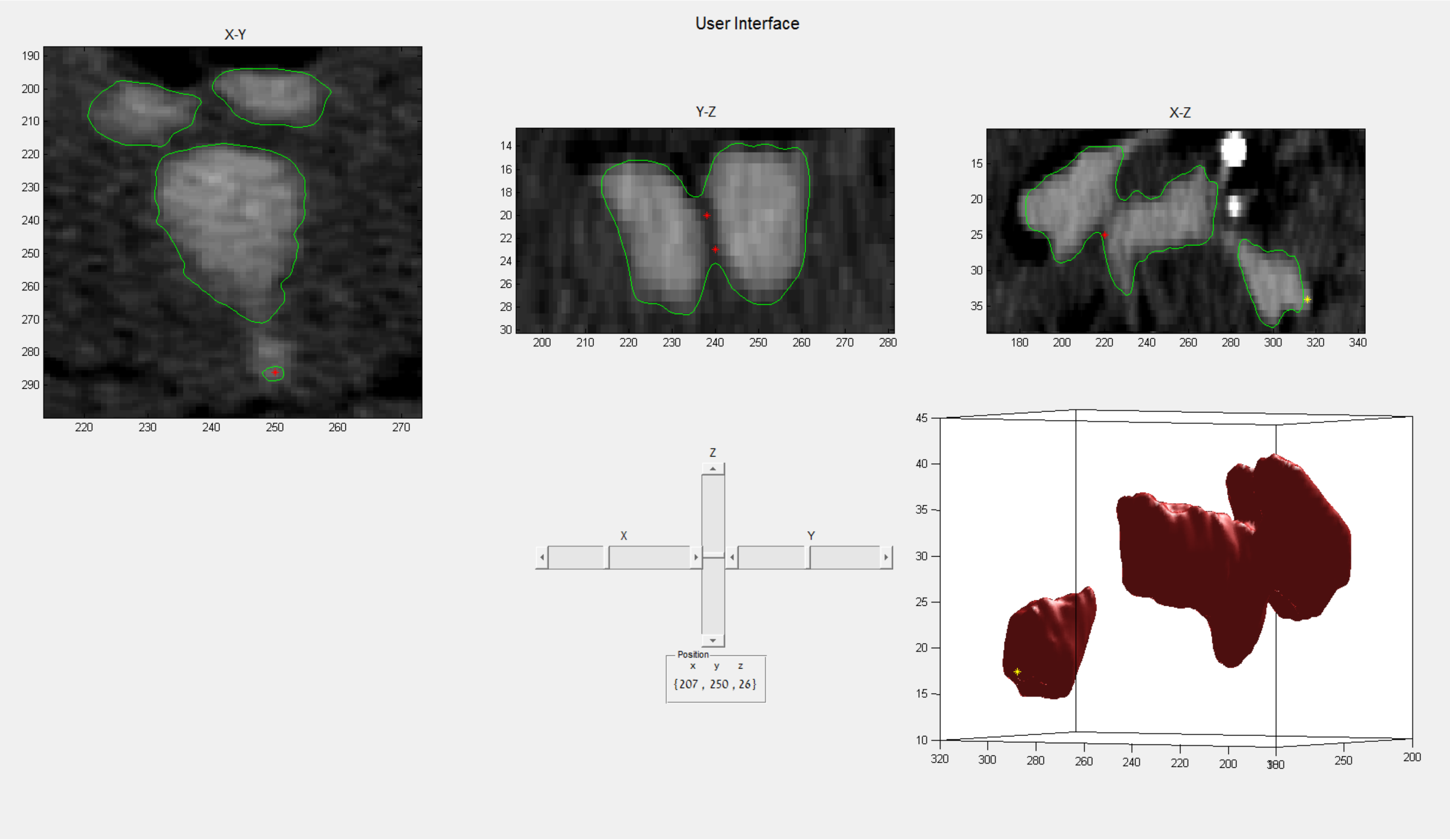

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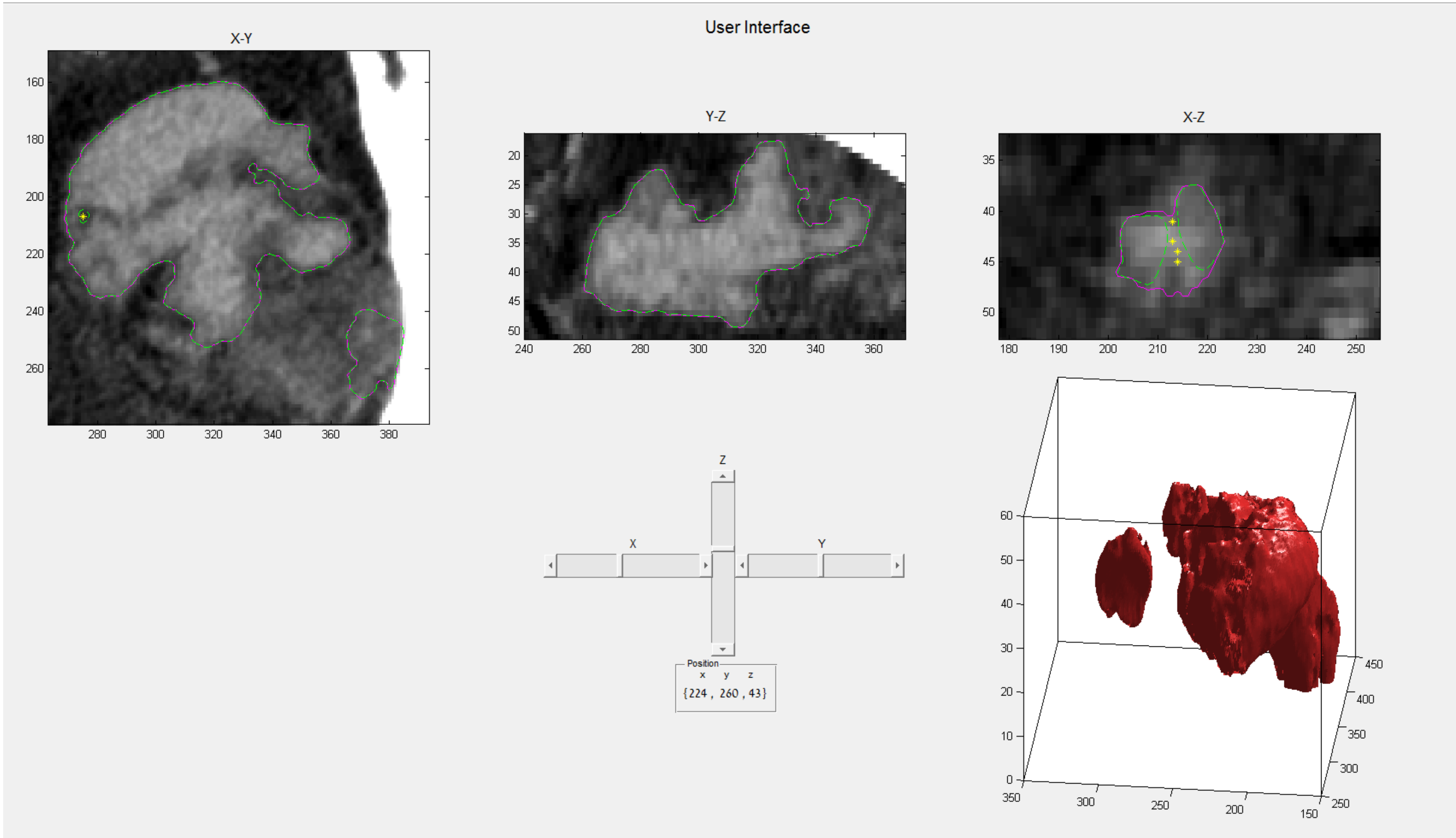

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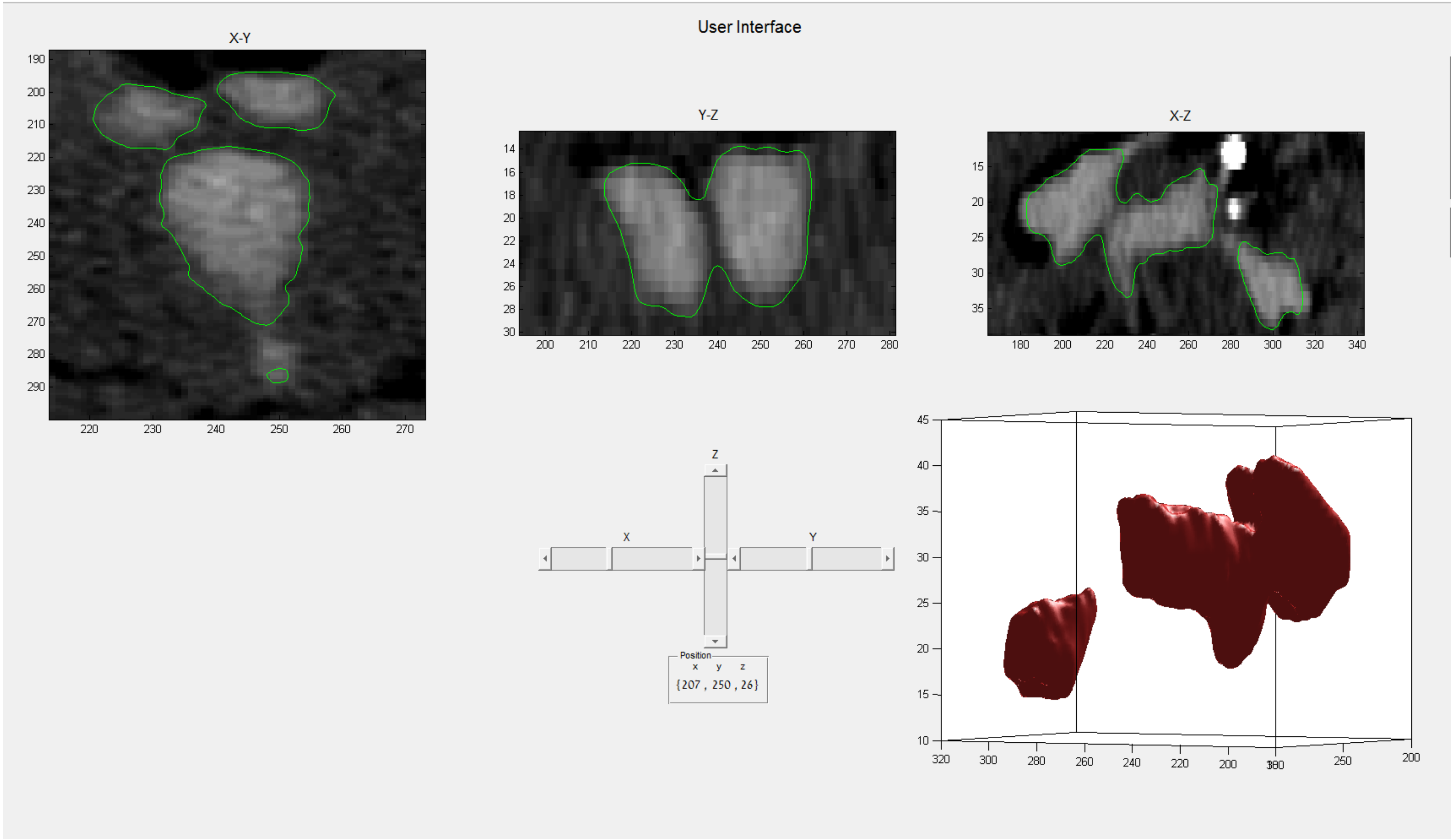

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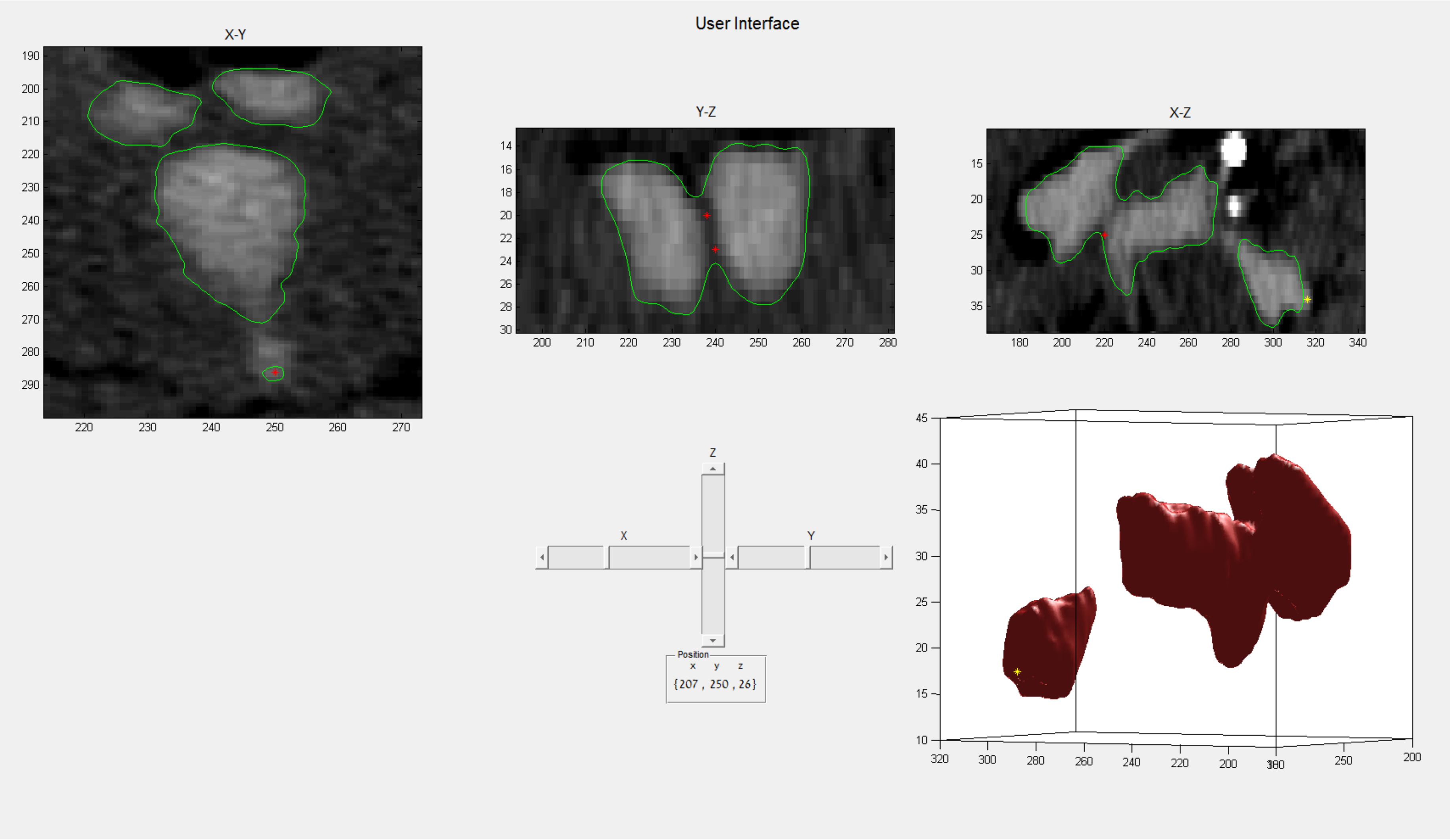
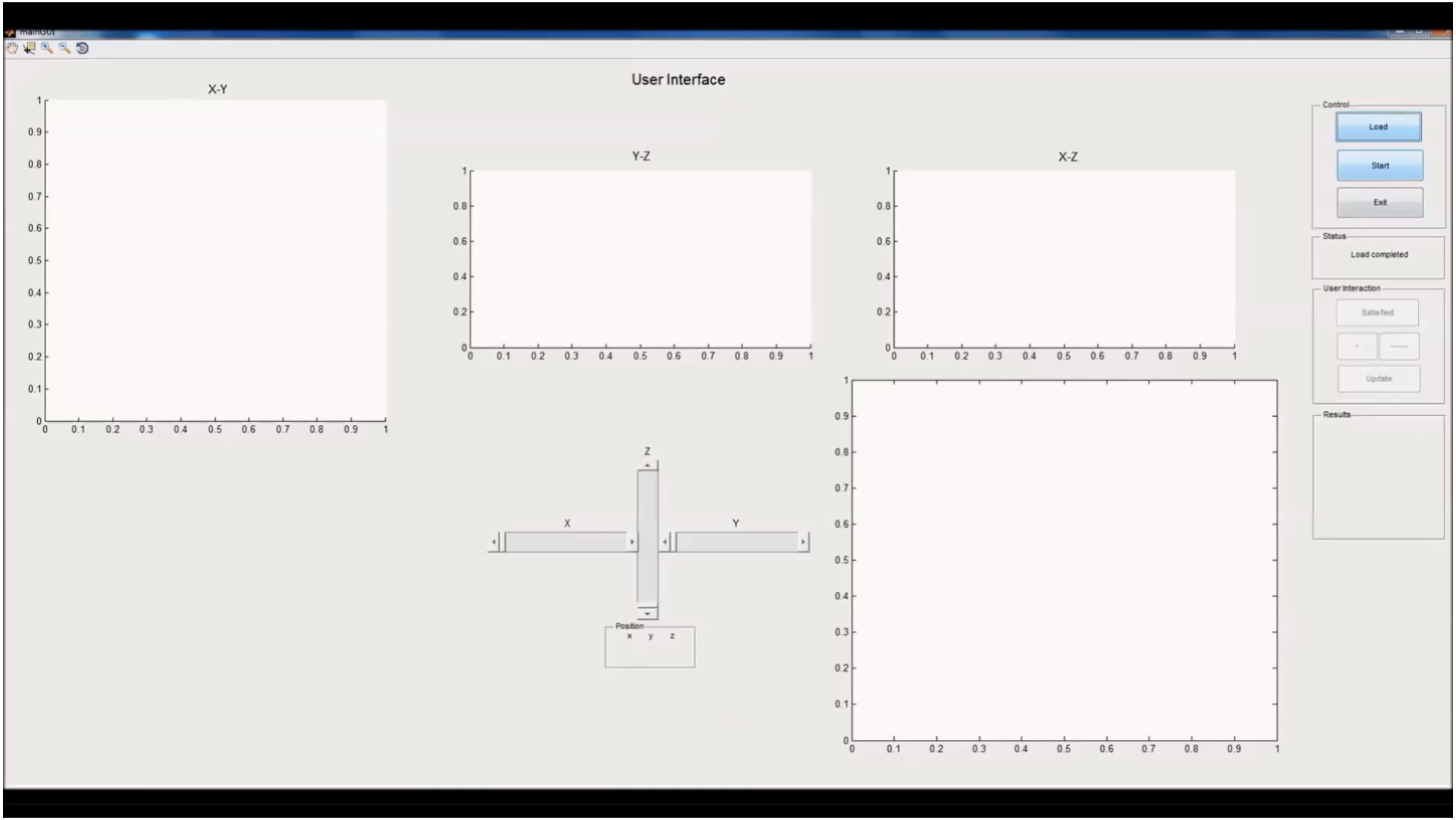


ONE MORE SHORT DEMO



UP TILL NOW & THE FUTURE

- Fast and reliable segmentation
- User-Machine Dialogue
- Friendly
- 3D Segmentation and visualization

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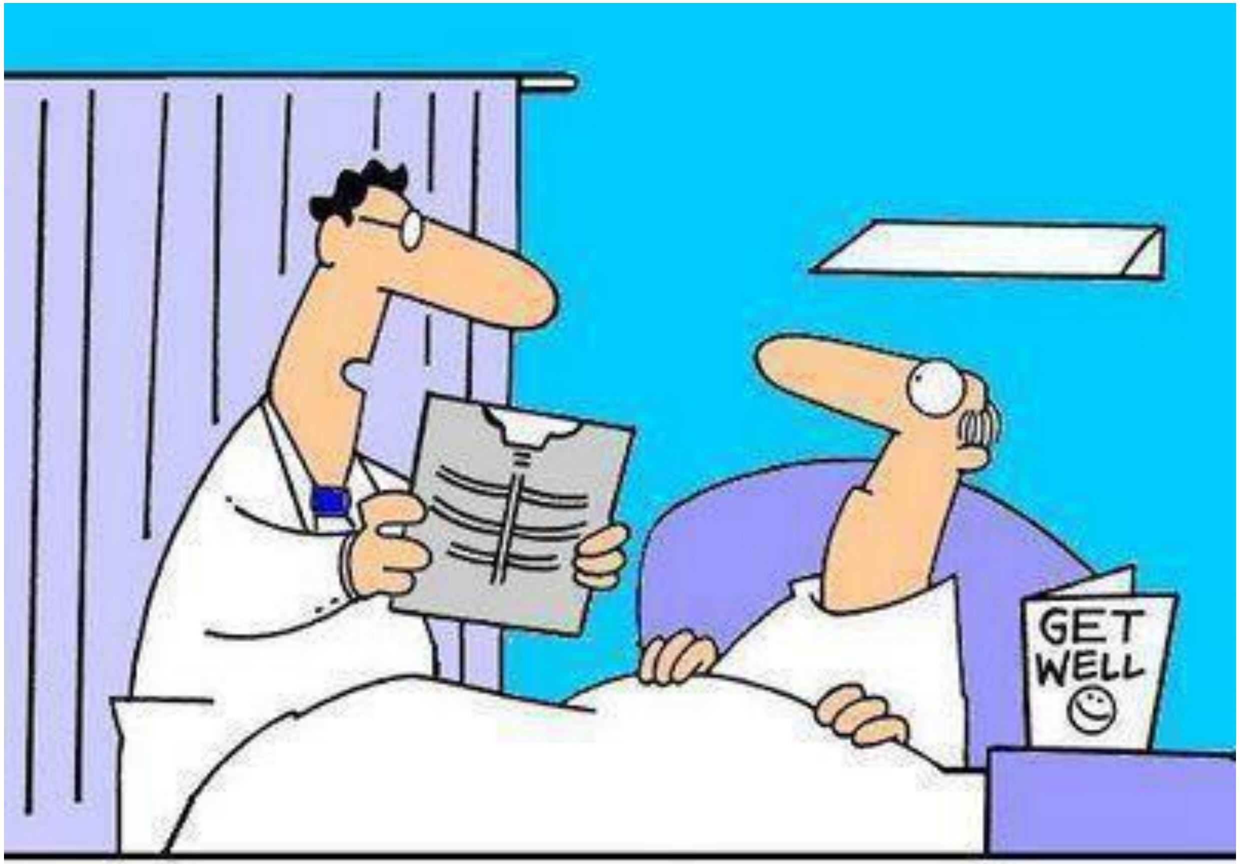
THANK YOU!

QUESTIONS?



"Your x-ray showed a broken rib,
but we fixed it with Photoshop."