

Stochastic Inference Method for Automated Segmentation

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Manual Segmentation is Variable

During diagnosis, radiologists segment, or paint, different parts of the human body like glioblastomas multiforme (GBM) in magnetic resonance images (MRI). Manual segmentation is:

- * radiologist dependent 3 - 5 hours †
- * radiologist variable DICE score = 61% ‡
- * requires threshold adjustment

Accuracy Sensitivity Specificity

	Accuracy	Sensitivity	Specificity
Manual	80%	*	*
AGU-Net	85%	90%	80%
nnU-Net	50%	70%	30%

Table 1: The accuracy rates noted here† represent the balance between sensitivity and specificity rates. Gray values were interpolated.

U-Net Automatic Segmentation

U-Net artificial intelligence (AI) is faster than manual segmentation.† No new U-Nets (nnU-Nets) utilize different image resolutions to identify regions of interest (ROI). Attention gates U-Nets (AGU-Nets) search using additive attention weights‡. Both U-Nets are inherently deterministic processes.

- * radiologist time 5-10 minutes †
- * validation (best mode) DICE score = 61% ‡
- * nnU-Net requires requires image pre- and post-processing.
- * nnU-Net is much less precise by consensus ground truth than AGU-Net.
- * nnU-Net lacks the minimum specificity for a robust statistical test (30% << 80% min).
- * On average, AGU-Net meets the minimum sensitivity (90%) and minimum specificity (80%) for a robust statistical test.

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Stochastic Methods are More Precise and Minimize the Need for Training

In contrast, *stochastic* methods (random, natural & normal) work mostly opposite to *deterministic* methods (weighted, forced, biased).

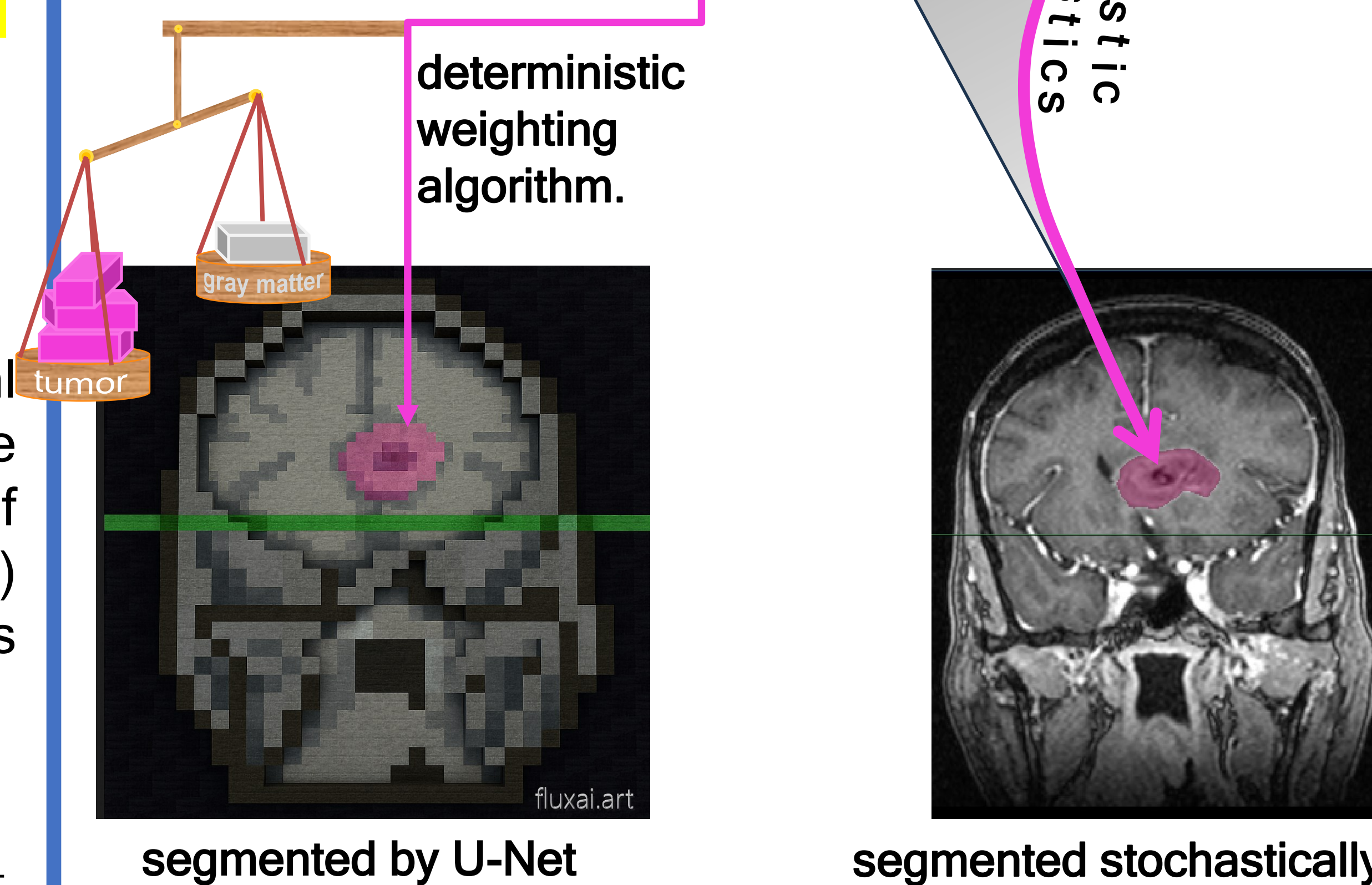
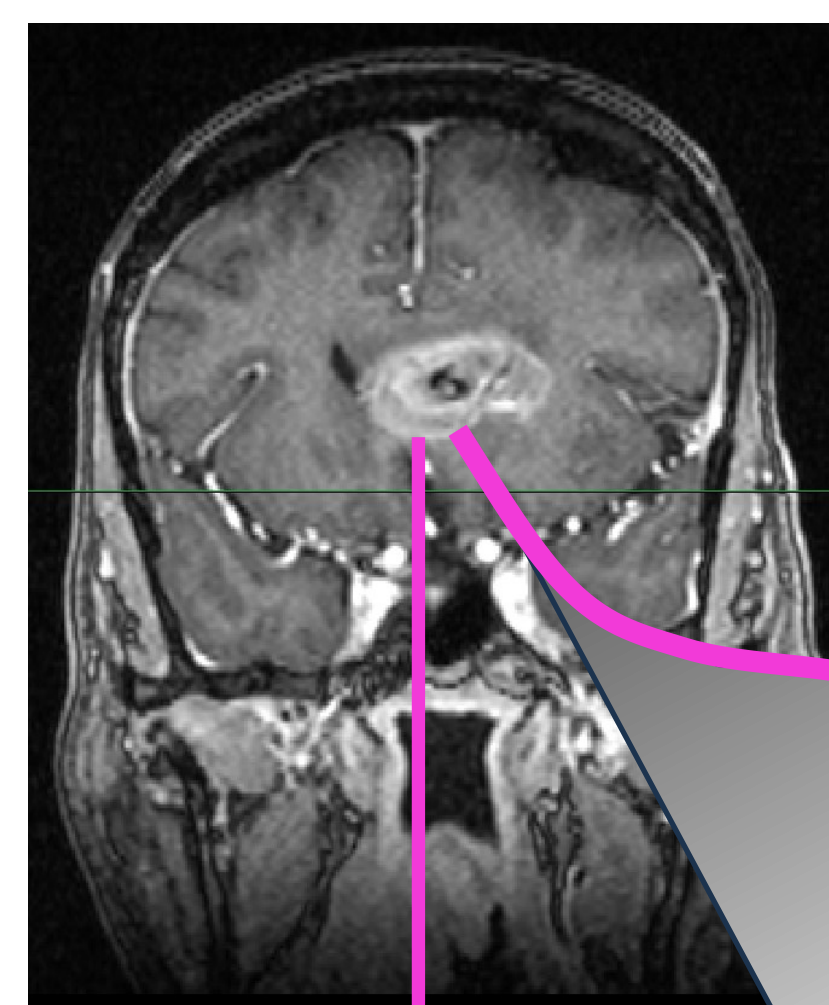


Figure 1: Which method would you want for your brain tumour ?

Stochastic modelling of a random variable means using statistical inference tests, like 2 sample t-tests.

Statistical inferences shall objectively render each voxel ('volume + pixel') to its most likely region of the brain.

References

- † Kaus MR, Warfield SK, Nabavi A, Black PM, Jolesz FA, Kikinis R. Automated segmentation of MR images of brain tumors. Radiology. 2001 Feb;218(2):586-91. doi: 10.1148/radiology.218.2.r01fe44586. PMID: 11161183. <https://pubmed.ncbi.nlm.nih.gov/11161183/>
- ‡ Helland, R.H., Ferles, A., Pedersen, A. et al. Segmentation of glioblastomas in early post-operative multi-modal MRI with deep neural networks. Sci Rep 13, 18897 (2023). <https://doi.org/10.1038/s41598-023-45456-x> Also, find it here: <https://www.nature.com/articles/s41598-023-45456-x>
- + Otkay, Ozan Dr., Attention Gate. Cornell University, arXiv:1804.03999 (2018). <https://paperswithcode.com/method/attention-gate>

Proof of Concept

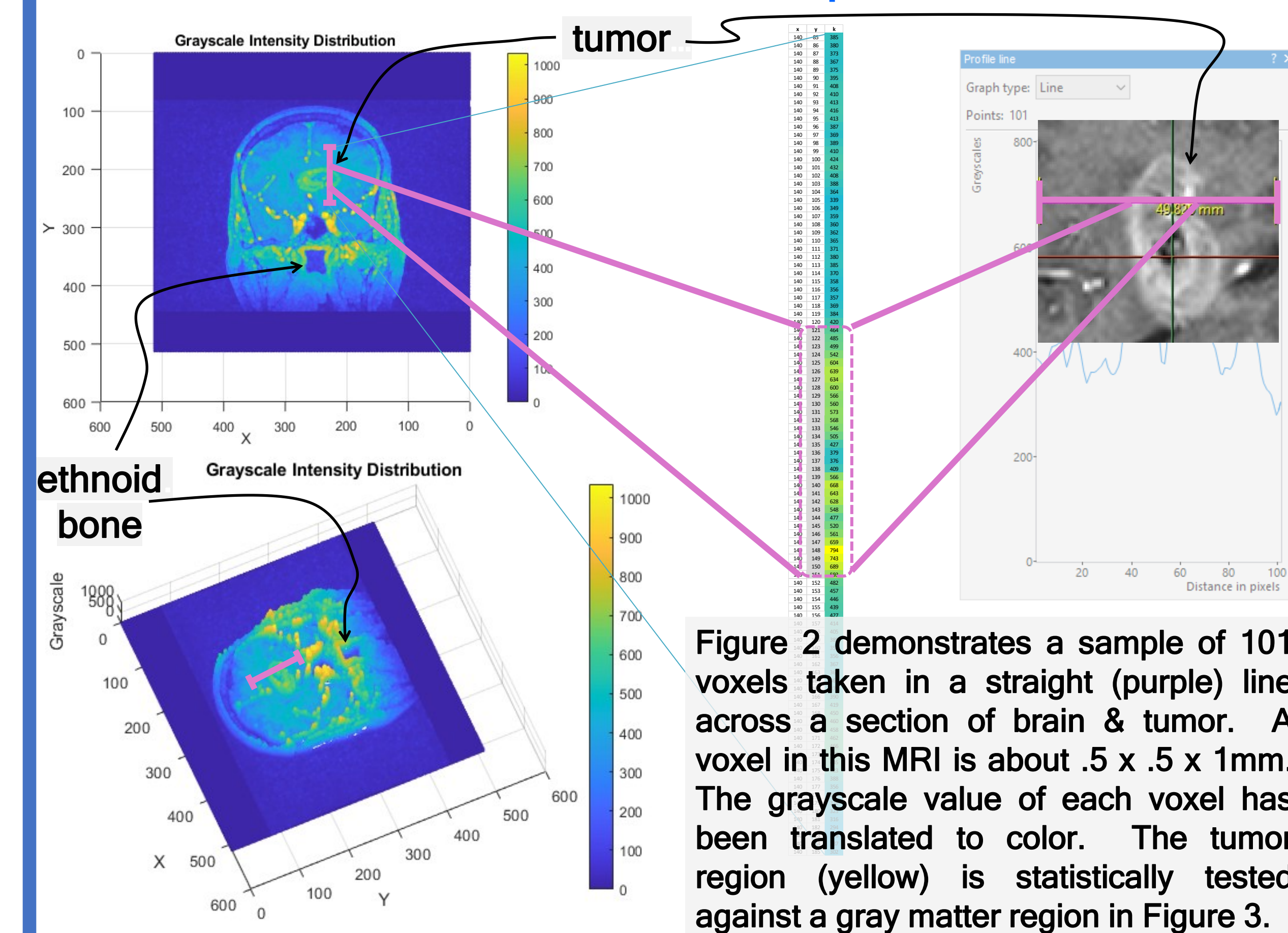


Figure 2 demonstrates a sample of 101 voxels taken in a straight (purple) line across a section of brain & tumor. A voxel in this MRI is about .5 x .5 x 1mm. The grayscale value of each voxel has been translated to color. The tumor region (yellow) is statistically tested against a gray matter region in Figure 3.

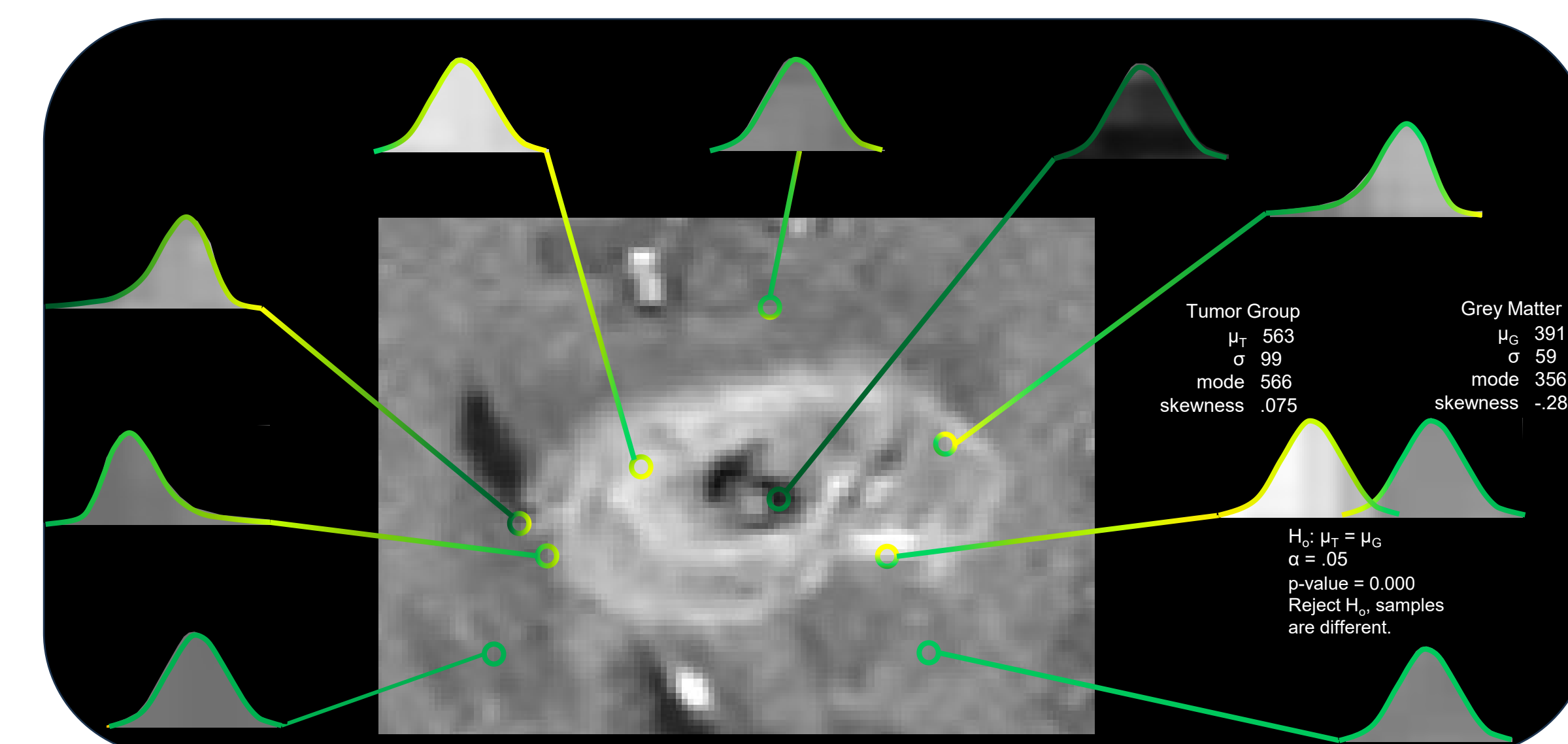
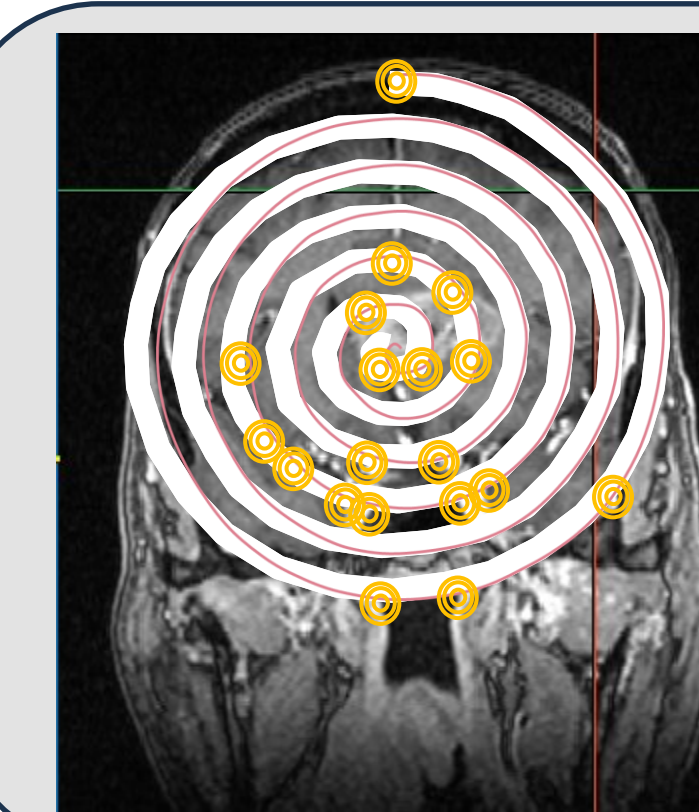


Figure 3: The circles represent voxel samples. Region samples will be more uniform, normal, with a tight standard deviation, σ . Border samples shall skew left (dark) or right (light) or, shall be bimodal.

In Figure 3, the null hypothesis ($H_0: \mu_{Tumor} = \mu_{Grey Matter}$, p-value = 0.0000, $\alpha = .05$) is rejected, displaying a clear difference between samples taken on the border edge of a cell. This, and the skewness metrics demonstrate the viability of stochastic inference to detect borders.



Next Steps

Develop code to search in a spiral pattern, sampling in concentric circles as Regions of Interest (ROI) are discovered via statistical inferences.