Unsupervised Learning for Analyzing Brain Tumors

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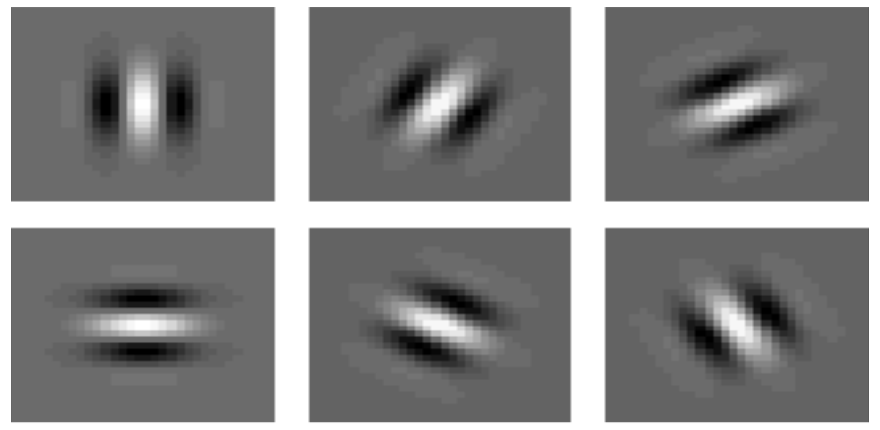
Motivation

Early diagnosis and better understanding of the specific types of tumors of brain cancer patients can significantly increase brain cancer survival rates. We used unsupervised learning algorithms to directly analyze brain images in order to discover spatial regions correlated to different types of brain tumors.

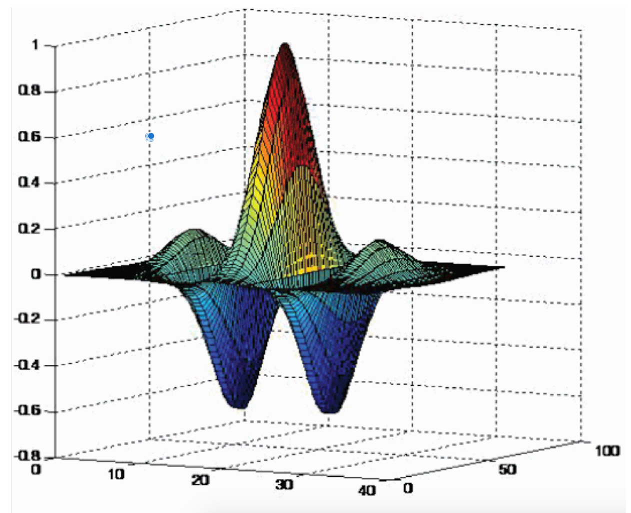
Dataset

We use a dataset containing four types of magnetic resonance (MR) 3D images of the brain of each cancer patient. Each image has four modalities (FLAIR, T1 pre-contrast, T1 post-contrast, and T2 weighted). Each modality provides different imaging contrasts and delineations that differentiate parts of the tumor from normal adjacent cells.

Gabor Filters



Gabor filters with different spatial orientations



2D Gabor Filter in 3D view

We preprocess the image with Gabor filtering. A Gabor filter is a complex sinusoid modulated by a 3D Gaussian function:

$$h(x, y, z) = g(x', y', z')s(x, y, z)$$

where

$$g(x', y', z') = g(\bar{q}) = \frac{1}{(2\pi)^{3/2}|\Sigma|^{1/2}} \exp\left(-\frac{1}{2}\bar{q}^T \Sigma^{-1} \bar{q}\right)$$

Here, Σ is diagonal and

$$s(x, y, z) = \exp(-j2\pi(vx + uy + wz))$$

We generate multiple Gabor filter banks in order to decompose 3D images into relevant texture features for the purpose of classification. The 3D image is then convolved in the time domain with each Gabor filter. In addition, Gabor filters can be tuned into various orientations and spatial-frequencies, which enable us to extract view-invariant and rotationally-invariant features.

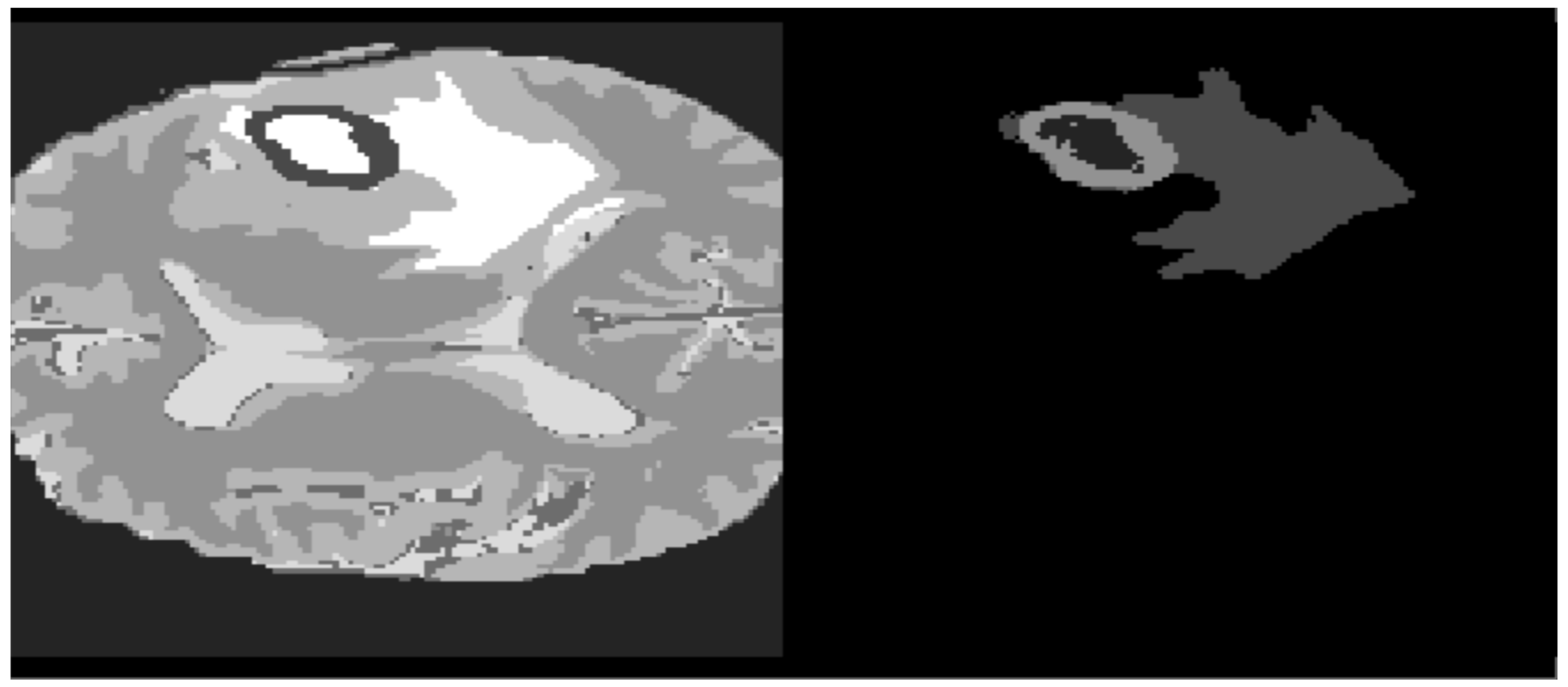
Gaussian Blur

The clustering algorithms by themselves essentially ignore any kind of spatial information when run directly on the voxel values, so we pre-process the voxels using a Gaussian convolution kernel. Gaussian Blur image processing introduces spatial correlations between each voxel and its neighboring counterparts, and reduces details and image noise. Thus, we convolve our 3D image with a 3D Gaussian function:

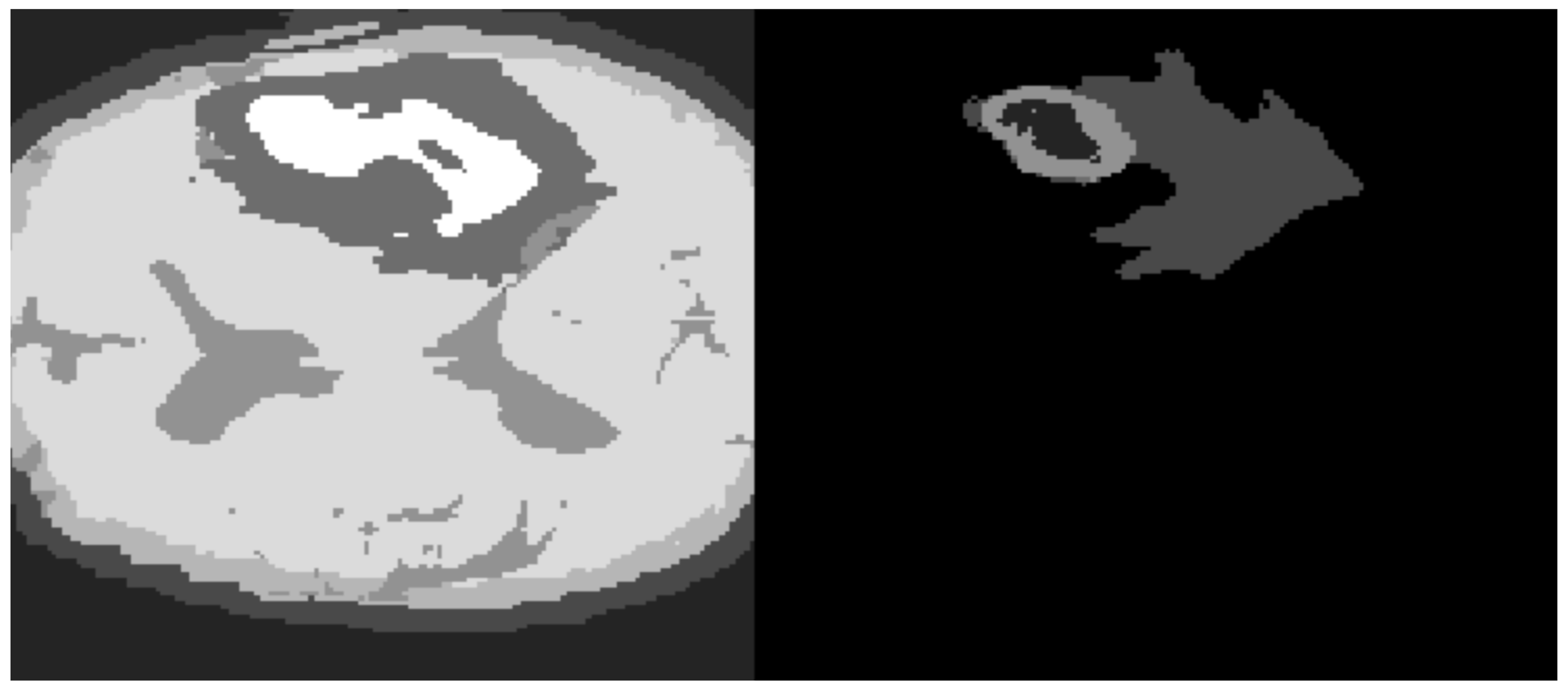
$$\hat{g}(x, y, z) = \frac{1}{(2\pi)^{3/2}\sigma^3} \exp\left(-\frac{x^2 + y^2 + z^2}{2\sigma^2}\right)$$

where we decay by the euclidean norm, measured from the center pixel of the Kernel in question. Additionally, the bandwidth of the Gaussian convolution kernel was empirically found using cross-validation.

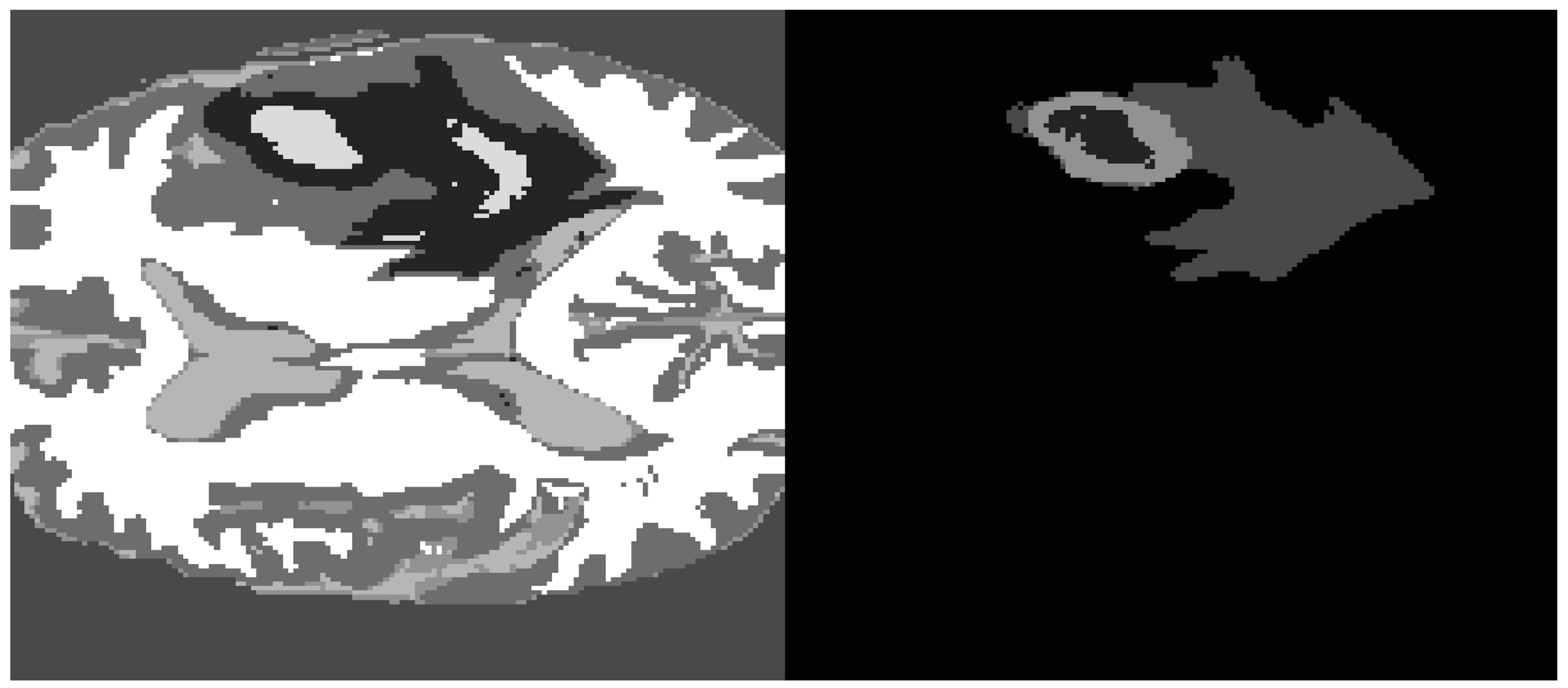
Experimental Results



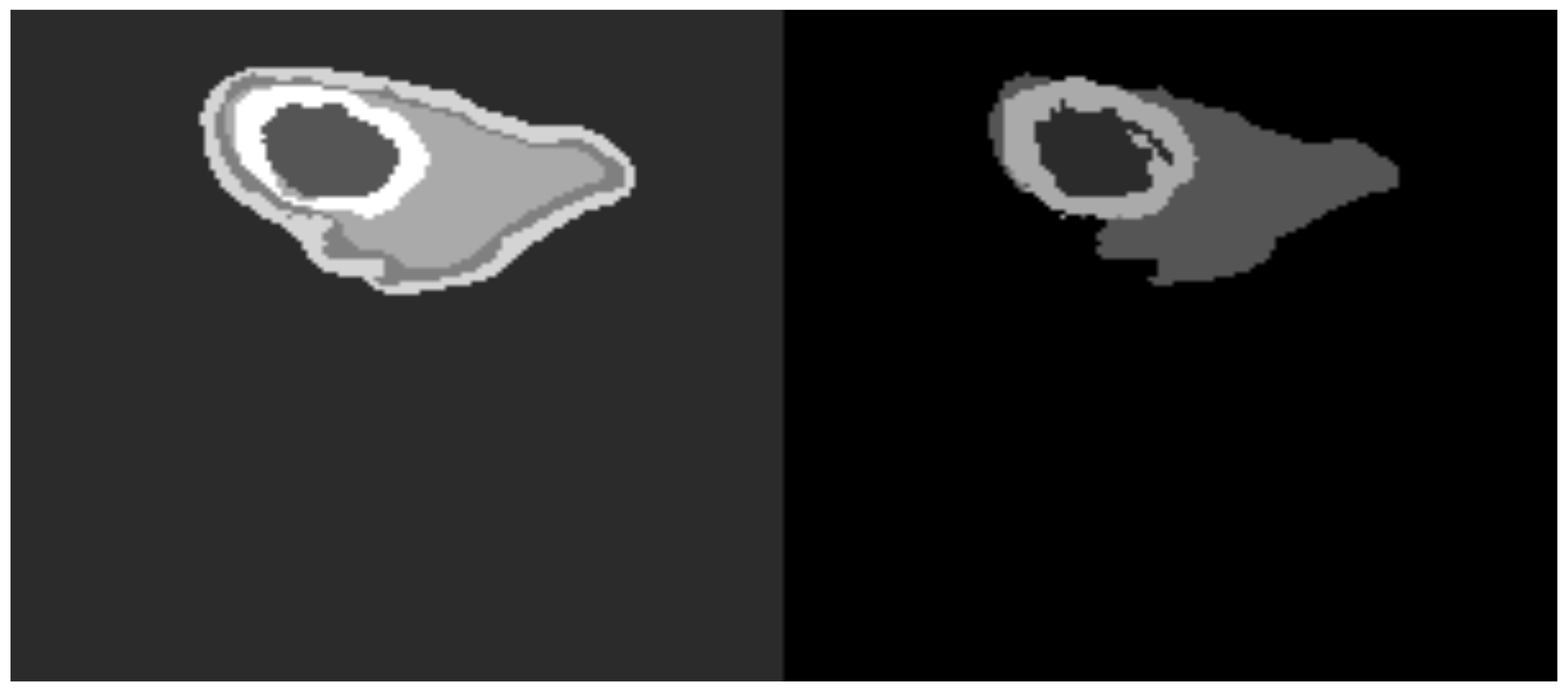
The right image shows the tumor analysis of a doctor, and the left image shows our analysis using k-means clustering with k = 7 without Gaussian blur preprocessing



The right image shows the tumor analysis of a doctor, and the left image shows our analysis using k-means clustering with k = 7 with Gaussian blur preprocessing



The right image shows the tumor analysis of a doctor, and the left image shows our analysis using k-medoids clustering with k = 7 without Gaussian blur preprocessing



The right image contains the tumor analysis of a doctor, and the left image shows our analysis using k-means clustering with k = 7 with Gabor filters (32 filters)

Conclusion

It is not difficult to imagine that there may exist several types of brain tumors each with their own idiosyncrasies regarding medical treatment (e.g. some tumors may be less responsive to specific kinds of treatments that are highly effective for other types) for which automatic classification and description will greatly help patients and doctors in treating them. Overall, our classifications may prove to be helpful not only in early detection but also in improving cancer treatment of brain tumors.

Acknowledgements

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References

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