3D Image Segmentation based on Unsupervised Grow Cut

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We aim to tackle the task of 3D image segmentation and labeling using a flavor of cellular automata called the Unsupervised Grow Cut algorithm (UGC). As the title states, it is an unsupervised method and we wish to reinforce the fact that our approach requires no prior training or knowledge of the input data, meaning that one simply loads the 3D image and performs a run of our algorithm yielding the resulting output. We have chosen cellular automata for the main reason that they are easy to parallelize on the CPU/GPU, ensuring that we get the desired result in a matter of seconds, compared to non-parallel approaches. This is vital in our context since we mainly focus on segmenting medical images, where having a diagnostic in short time is vital.

Since we are dealing with a cellular automaton, we must define the triplet (S, N, ρ), where S is the set of states, N is the neighborhood for each voxel and ρ is the transition function. S, for each voxel is a number between 0 and 1 signifying how strongly voxels are related with each other based on the difference in adjacent voxel intensity (grayscale value for medical images). In our experiments, N is a 3*3*3 Moore neighborhood. Lastly, ρ is where our original contribution comes to life. In its initial form, the UGC algorithm takes into account a global threshold parameter which governs the granularity of the segmentation. For example, a threshold closer to 1 yields more distinct segments at the cost of increased noise, while a threshold closer to 0 has the effect of merging segments together, up to the point where there is only background. We have discovered that by dynamically altering the threshold parameter we are able to significantly increase the Dice coefficient computed versus the ground truth.

Concretely this is done in two ways: firstly we implemented adaptive thresholding, which decrements the threshold after a fixed number of iterations, effectively relaxing the threshold as the algorithm unfolds. Secondly, we treat unlabeled pixels with a higher priority over labeled ones, aiming to speed the process of label acquisition. In the end we conclude that, from extensive benchmarking, a hybrid, combined approach provides a significant boost with regard to the Dice metric over the classical UGC algorithm, while still retaining the "unsupervised" trait.

References

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