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White Matter Hyperintensities Segmentation in MRI Image

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目录

1. Background

White matter hyperintensities (WMHs) in the brain are the consequence of cerebral small vessel disease, which can easily be detected on MRI. WMH's are also referred to as Leukoaraiosis and are often found in CT or MRI's of older patients. The prevailing view is that these intensities are a marker of small-vessel vascular disease and in clinical practice, are indicative of cognitive and emotional dysfunction, particularly in the ageing population. So BMH segmentation in MRI Image have vital importance in early diagnosis of related diseases. In this task, we design three automatic segmentation methods and apply them in three groups of data.

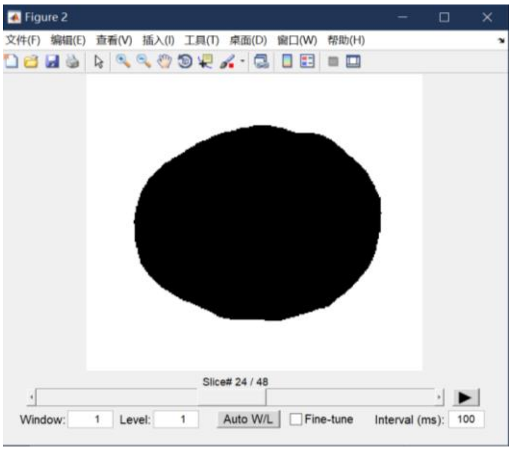
2. Methods

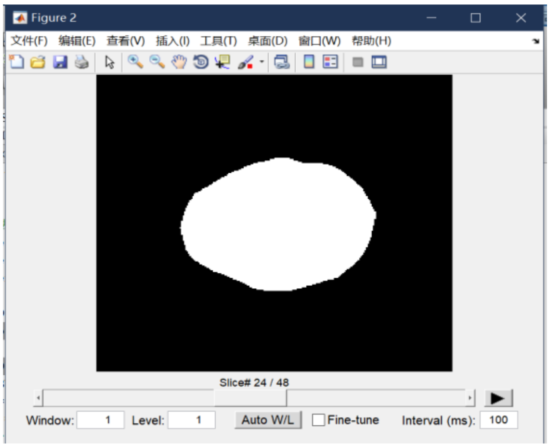
2.1 Otsu's method

We find that WMH only occurs in some particular areas of the brain and it is confirmed in some papers that WMH always occurs in paracele[2].So we choose the 20-40th slices to execute the segmentation process.

Before performing Otsu's method,we remove the undesired parts through morphological process. By using opening and erosion function,we get a window that can remove the outer parts including the skull.Then we use smaller SE to remove the undesired parts in the middle.

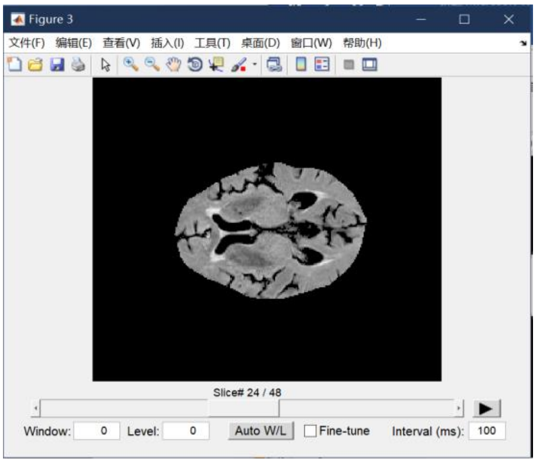
Otsu's method, in general, is used to perform optimum global thresholding.The algorithm returns a single intensity threshold that separate pixels into two classes, foreground and background. This threshold is determined by minimizing intra-class intensity variance. However, in our case, the images are mostly black, so the global threshold is not quite effective. Instead of operating on all the pixels, we separate the nonzero pixels into two classes and then pick out the threshold which can minimize intra-class intensity variance. By repeating the process, we can finally separate WMH apart. (Most of the time,3 replications can get valid results.)We also design an interactive interface in GUI, in which the user can determine how many times the process will repeat.

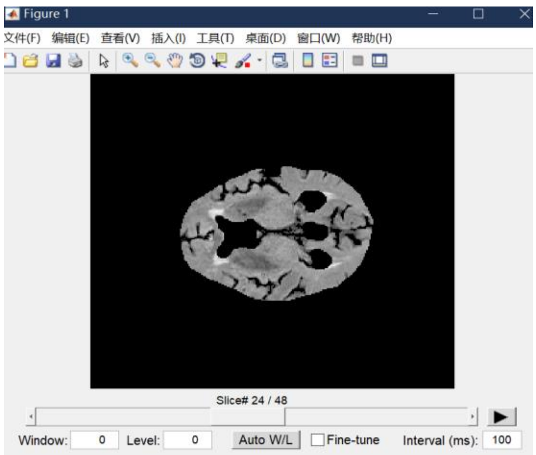




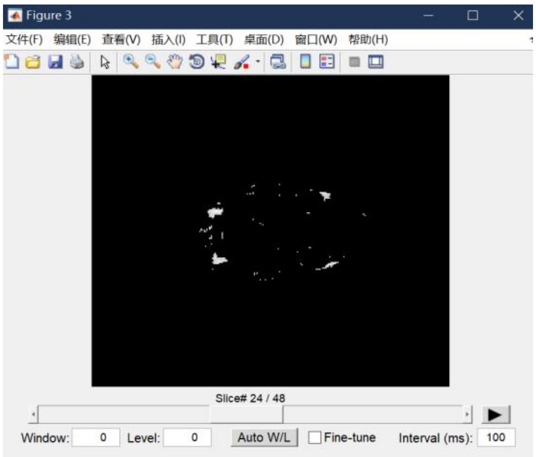
Opening

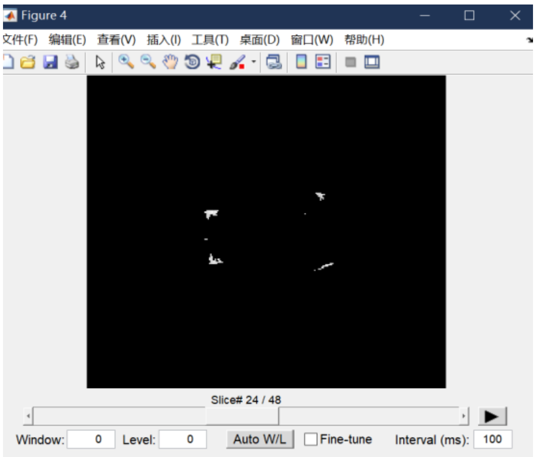
Erosion





Operate on the image Use of smaller SE





two replications three replications

2.2 Gradient related spatial methods

The hyperintensities in the given MRI images have the following features: 1 The grey level is rather high (generally higher than the grey matter region); 2. Located within the grey matter region; 3. The edge of area of hyperintensity is surrounded by pixels with lower grey level. Since these features exist, Gradient related spatial methods might come to use.

For preprocessing part, skulls are to removed. Instead of using opening, which might damage the wanted area, I used my own algorithm as follows:

We know that our skull is almost a sphere. Spheres are convex polyhedrons, and within the skull is our brain which is shown as foreground. This indicates that for those pixels showing skull, the neighbored pixels (in both 2D and 3D) should contain more background pixels than foreground pixels: an interesting property. Segmentation of the skull can be made according to the property described previously.

As a preliminary work on filter design, I used the gradient itself: Laplacian operator and Sobel operator as the filter. According to the preliminary outcome and to further obtain a better result, enhancement filters are used.

2.3 Region-growing method

The most important thing in Region-growing method is how to obtain the seeds. After observing the characteristics of ground truth image, we find most of BMH lies in four parts in Flair. So we divide the image into four equal parts and choose the brightest point (namely, its gray level is bigger than any other) in the four parts respectively. Another key point is the choose of threshold. While the seed is growing with its 8-neighbor, we need to set the threshold to decide whether we will take the neighbor in current set. In this regard, we choose a semi-automatic method. User can manually input the threshold via GUI.

3. Results

The evaluation metrics includes *Accuracy* (*Acc* in brief), *DICE*, *VOE* and *Sensitivity* (*Stv* in brief).

Acc shows the overall accuracy of the segmentation result. It is obtained using the following equation:

$$Acc = \frac{TP + TN}{TP + TN + FP + FN}$$

In which *TP* represents for the number of true positive pixels in the segmentation result, *TN* represents for the number of true negative pixels in the segmentation result, *FP* represents for the number of false positive pixels in the segmentation result and *FN* represents for the number of false negative pixels in the segmentation result. The higher *Acc* is, the better the result.

DICE (or *DSI*) shows the quality of the segmentation result by observing 2 multiplies the extracted wanted pixels over the sum of the number of positive pixels in the conference and result, thus showing both the rate of undetected wanted pixels and false results. It is obtained using the following equation:

$$DICE = \frac{2 * TP}{2 * TP + FP + FN}$$

The higher *DICE* is, the better the result.

VOE is the opposite of DICE. It is obtained using the following equation:

$$VOE = \frac{2 * (FN + FP)}{2 * TP + FP + FN}$$

The lower *VOE* is, the better the result.

Stv shows the accuracy of the segmentation results by observing the extraction rate of the wanted pixels. It is obtained using the following equation:

$$Stv = \frac{TP}{TP + FN}$$

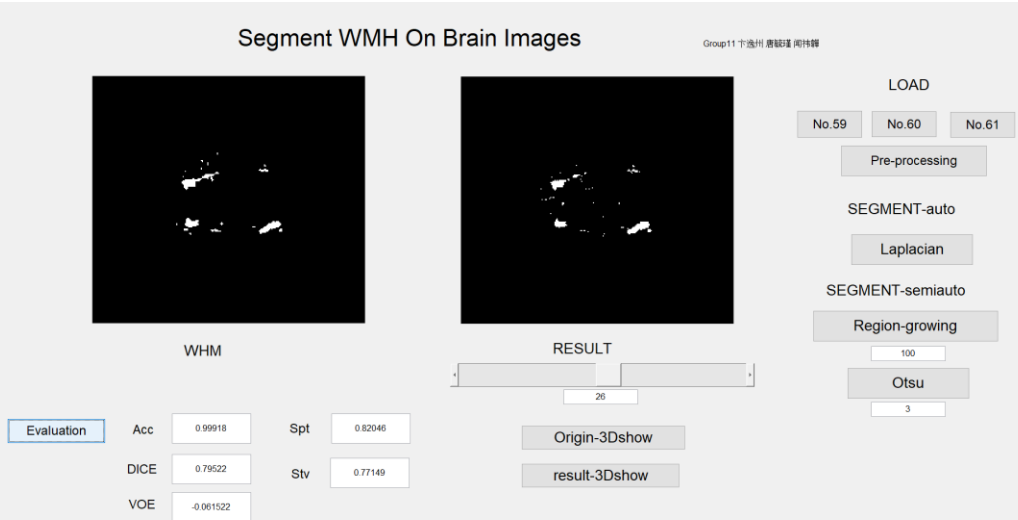
The higher *Stv* is, the better the result.

3.1 Otsu's method

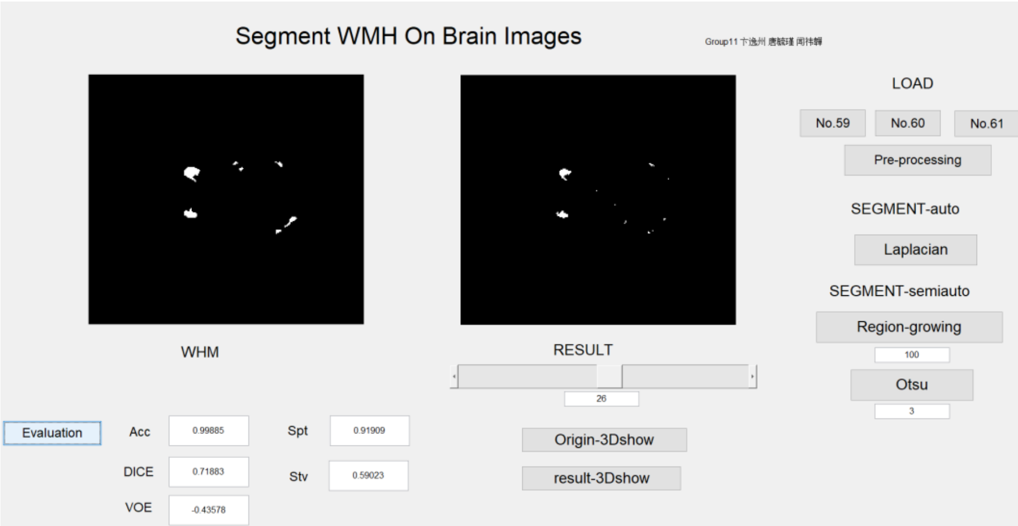
Otsu’s method is a stable method and especially when the intensities of WMH are distinguished from those of other areas, it can work well. In essensial, the key of Otsu’s method is threshold. After one or two replications,the number of nonzero pixels shrinks, and then over-segmentation occurs. Another disadvantage of this method is the time cost.Further effort is needed to improve the algorithm to reduce the time cost and try to combine the algorithm with other method.

The evaluation index and result images are shown as followed.

Num	Replication times	Acc	DICE	VOE	Stv
59	3	0.99918	0.79522	-0.0615	0.7715
60	3	0.99885	0.71883	-0.4358	0.5902
60	2	0.99834	0.7279	0.36176	0.88864
61	3	0.99831	0.6209	0.471	0.8122
61	4	0.99874	0.52012	-0.6019	0.39979



3 replications for No.59



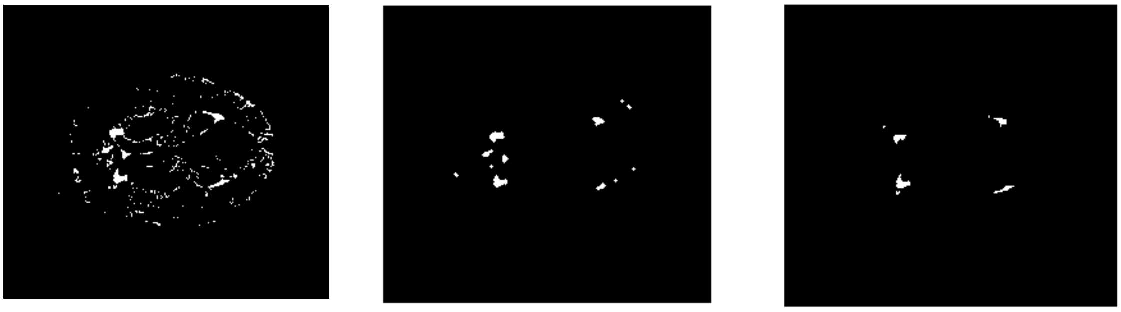
3 replications for No.60

3 replications for No.61

3.2 Gradient related spatial methods

The following figure (a) is the filtering result of the 24th image of data group No.59, (b) is the opening result of (a), and (c)is the conference

As we can see, the result resembles the reference, but not satisfying enough.



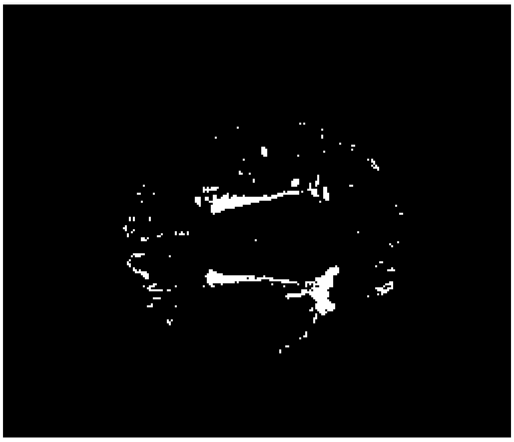
(a) (b) (c)

Sobel and LoG algorithm was only used for testing. The output of there cannot be used as criteria of the hyperintensity. The code of these two processing are in the code of mine.

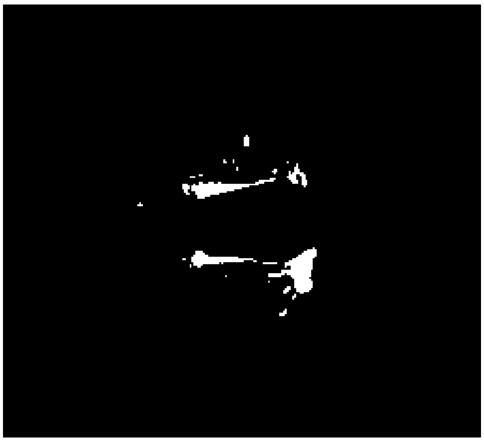
The evaluation metrics of the output after applying enhancement filter, opening and closing is shown in the following table. The results, sadly are far from satisfaction.

	Acc	DSI	VOE	Stv
No.59	0.9980	0.4400	1.1201	0.3905
No.60	0.9983	0.4668	0.8525	0.5737
N0.61	0.9984	0.3068	1.2220	0.3890

However, the reason I still chose enhancement filter as my final method is as follows. The output of the processed 24th image of data group No.59 using enhancement filter is shown in the following figure (a) and the conference in (b), which was shown in my presentation as well.



(a)



(b)

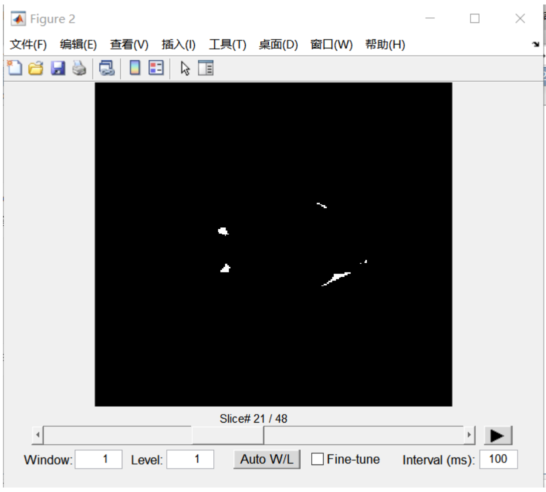
It is obvious that the wanted parts with hyperintensity is mostly included, with noises that clearly as some way to erase. It is sad that my methods of opening and closing didn't work, but I'm sure that with some other reasonable steps the result can be beautiful.

3.3 Region-growing method

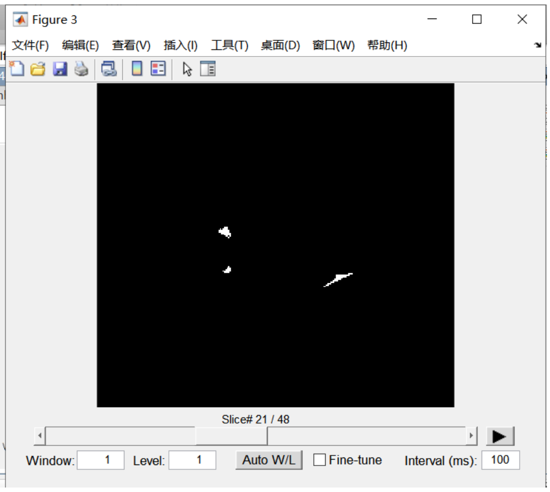
Considering not all slices have BMH, we find that if we choose slice 21 to 33(13 images) ,we can get a really beautiful result. We calculate accuracy and dice coefficient of both 1-48 slices and 21-33 slices.

	Acc_1-48	DSI_1-48	Acc_21-33	DSI_21-33
59	0.9992	0.7253	0.9999	0.9842
60	0.9992	0.8018	0.9996	0.9392
61	0.9995	0.5980	0.9994	0.9393

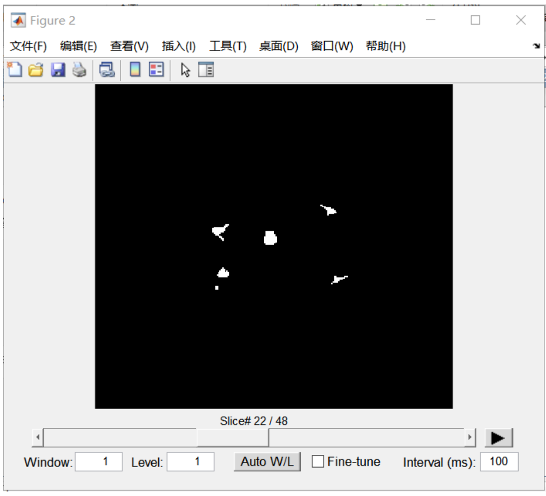
Below are some segmentation images.



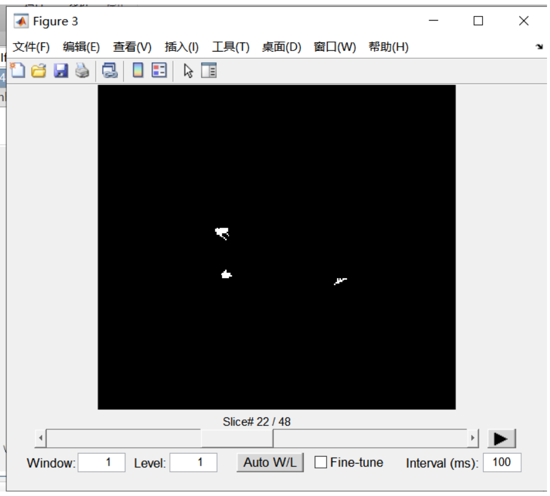
Slice 21(Origin)



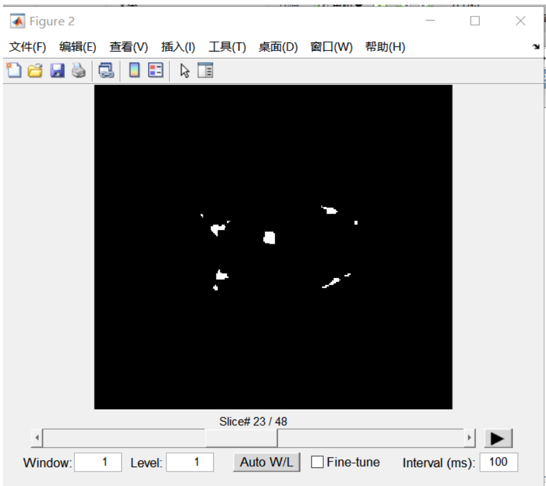
Slice 21(Segmented)



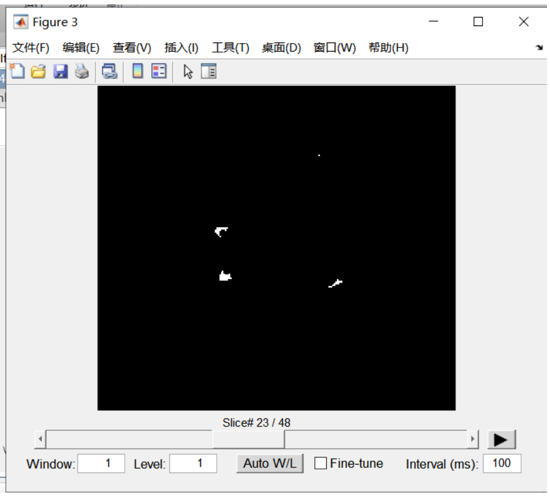
Slice 22(Origin)



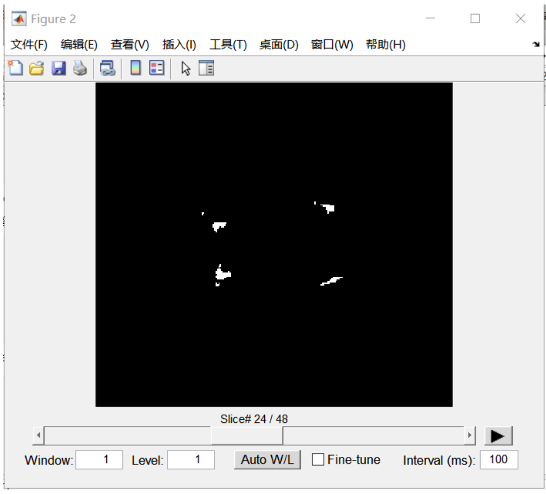
Slice 22(Segmented)

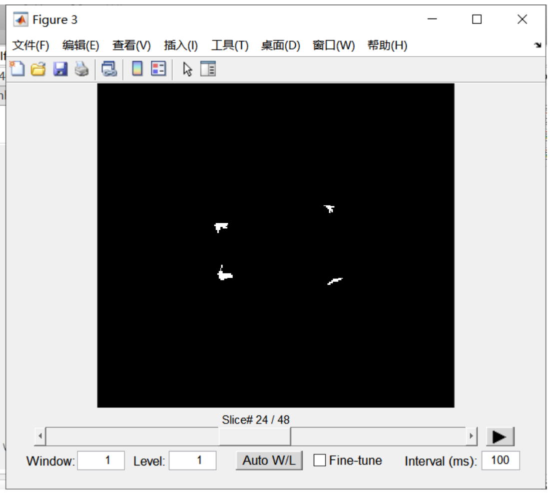


Slice 22(Origin)



Slice 22(Segmented)





Slice 22(Origin) Slice 22(Segmented)

4. Conclusion

Otsu's method is comparatively a conservative approach. It can always get valid results. However, its time cost is the largest.

Spatial filters seem to be not so effective in the hyperintensity segmentation, but it does give an interesting result where further researches can be done. Morphological procedures and different threshold algorithms might be useful.

Region growing method focus on main region and thus lose some important small information. But it could have a really good effect in images from 21 to 33. This method also provides a different angle to think about WMH's essential characteristic.

To conclude, we try three different methods to realize BMH automatic segmentation under the case that we don't have much prior knowledge about it. We do the segmentation task based on both discontinuity and similarity. And threshold method (optimal method like Outs) is the most straightforward but effective one. Spatial filter plays an important role in intermediate process. Region growing method lose some information but is efficient when considering most images.

Through this task, we have a better understanding about segmentation. Learning from the result (ground truth) is also one way to solve the problem. I believe What we learn from the task and this class will benefit us a lot in our future study and research..

5. GUI Design

The GUI has mainly four parts.The first part is ‘load’ and ‘pre-progressing’,used to load the image data and finish the pre-processing progress.The second part is to peform the three different methods——‘laplacian’ ‘Otsu’ ‘region-growing’——on brain images. For Otsu and region-growing method ,we design an additional interaction part,in which the user can enter the key parameter for better segmentation result.(we also set a default value.)The third part displays the five evaluation index, among which, ’Acc’ represents accuracy,’DICE’ represents DICE, ’VOE’ represents VOE,’Spt’ represents specificity and ‘Stv’ represents sensitivity. The fourth part provide a 3D view of the images and ‘save nii’ instruction.

We record a video to demonstrate. Please refer to the video enclosed for more details.

Appendix

References

1.Performance measure characterization for evaluating neuroimage segmentation algorithms.Herng-Hua Chang, Audrey H. Zhuang, Daniel J. Valentino, Woei-Chyn Chu.2009

2.基于多模态 MRI 的脑白质病变检测算法研究.单文强 2014

3. 图像分割评价指标模型总结 https://blog.csdn.net/qq_40677266/article/details/96106580