Assessed Coursework 2

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Abstract. Medical images are limited by low signal-to-noise ratio (SNR) or contrast-to-noise ratio (CNR). Traditional method like linear filter can smooth noise but reduce SNR or CNR. High speed filtering and high quality image are difficult to obtain for traditional method. For this case, we evaluate non-linear filter on resliced image. Implementation of a re-slicing algorithm that obtains an image slice in an oblique plane, reasonable for viewing abdominal organs in 2D images. Implement a Nonlinear anisotropic filtering and analyse impact of varying values. Finally, compare differences between filtering before re-slice and filter after re-slice in theory and clinical practice. In clinical practice, these two approaches show different performance in different situations.

Keywords: Nonlinear anisotropic filter, Reslice

1 Introduction

Anatomical planes are used to transect the body. When researcher or doctor want to view or describe an oblique plane, reslice is needed in this case. However, reslice may not capture accurate points in spatial space. Sometimes, we need to interpolate the image to obtain result and evaluate the influence that interpolation cause for next step. The second part is analysis of nonlinear anisotropic filter. Previous clinical images, such as MRI or CBCT, are limited by low signal-to-noise (SNR) or contrast-to-noise ratio (CNR). For clinical therapy, high quality of image and fast speed of acquisition of image are important. Linear filter may not solve both these problem in a single algorithm. Nonlinear anisotropic filter was designed to tackle the problem. The third part is analysis of differences between 3D nonlinear filter after re-slicing and 2D nonlinear filter after re-slicing. The sequence of filter and slice may have different effect on results. And 2D filter lack information in the third dimension and as plane resliced from specific angle, the nearest 6 voxels may change for each voxel. All above problems could be analysed in this coursework.

1.1 Re-slice method

Re-slice is to obtain an oblique plane that can be any type of angle other than a horizontal or vertical angle. Use three points to determine a plane in a spatial space. Then calculate plane equation by using points. Use ‘gridmesh’ in x and y axis as index to calculate z value by using plane equation. The obtained z coordinates may not locate in image grid. Then use trilinear interpolation to obtain values of point.

1.2 Non-linear Filter Method

Perona and Malik developed a smoothing and edge detection method. Their anisotropic diffusion filtering method is mathematically formulated as a diffusion process. Their process can be formulated as follow:

$$\frac{\partial}{\partial t} I(\bar{x}, t) = div(c(\bar{x}, t) \nabla I(\bar{x}, t))$$

Here, diffusion strength is controlled by $c(\bar{x}, t)$, vector $\bar{x}$ represents spatial coordinate(s). The variable t is the process of iteration step. The function $I(\bar{x}, t)$ is image intensity.

Actual work(2D) use discrete formulation as follows:

$$I(t + \Delta t) \approx I(t) + \Delta t * (\Phi_c - \Phi_w + \Phi_n - \Phi_s)$$

Formulation in 3D is shown below:

$$I(t + \Delta t) \approx I(t) + \Delta t * (\Phi_c - \Phi_w + \Phi_n - \Phi_s + \Phi_u - \Phi_d)$$

κ and Δt are parameters which are used to control amplitude of $c(\bar{x}, t)$ and iteration.

2 Experiments

2.1 Reslice

Select three reasonable points (‘reasonable’ means following specific angle) and use ‘reslice’ function to obtain oblique plane coordinates. Display slice in 2D and 3D.

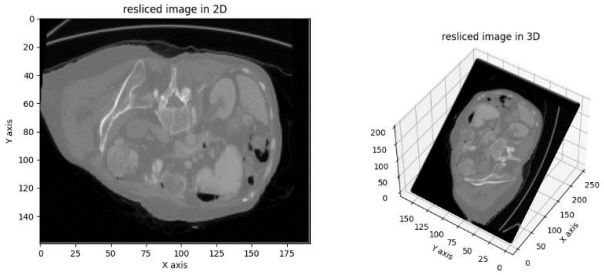


Figure 3.1.1 slice plane in 2D and 3D. Point: (0,0,0), (50,0,40), (50,200,40)

2.2 Nonlinear filtering

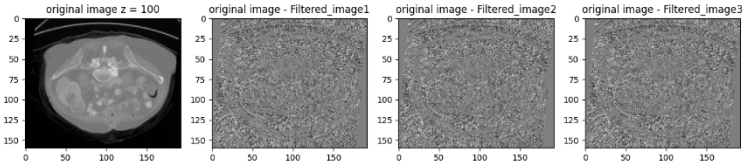


Figure3.2.1 Original image and filtered images. Filtered images from left to right use iteration = 3, K = 10, iteration = 1, K = 10, iteration = 3, K = 20 as parameters.

Set different parameters. Change values of iteration and K dependently.

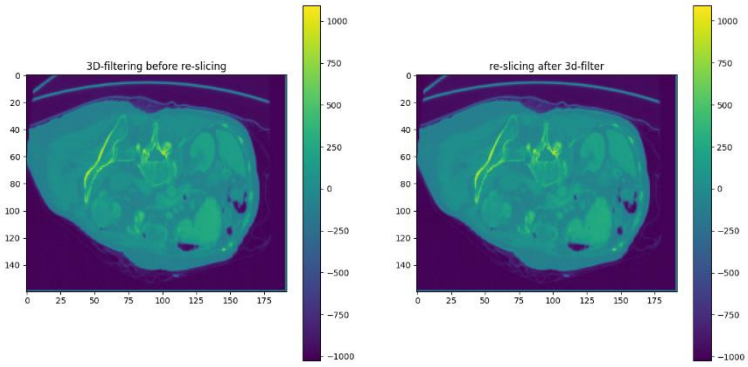
As κ increases, $c(\bar{x}, t)$ approaches 1, edge contrast is more closed to edge gradient. Standard increases and Mean decrease.

As iteration changes, there is no apparent difference among these filtered images.

2.3 Compare sequence between reslice and filter

Firstly, implement '3D-filtering before re-slicing'(result1). Execute nonlinear filter function and obtain filtered image. Then use re-slice function to slice at specific plane.

Secondly, implement '3d-filter after re-slicing'(result2). Execute re-slice function to obtain a 2D slice. Then use 'nonlinear_filter' function to filter 2D slice.



We assumed that 2D nonlinear filter only utilises information from two dimensions, while 3D nonlinear filter utilises three dimensions information. And for each voxel, its six nearest voxels change as reslice at any angle.

Collect mean and standard of each method result. Calculate mean and standard of subtraction from result1 to result2.

Point	(0,0,0),(50,0,40),(50,200,40)		(0,0,0),(50,150,0),(50,150,100)	
	mean	standard	mean	standard
Result1	-409.470	500.093	-421.514	495.917
Result2	-409.458	500.120	-421.658	495.926
Result1-Result2	0.012	2.613	-0.144	2.561

Tabel 3.3.1 Result of comparation

3 Results

Reslice can obtain 2D image from any angle according to clinical demand. Specific whole organ can be viewed in a single slice. This is useful for clinical exercise.

Nonlinear filter can decrease noise level and increase edge contrast. Meanwhile, this method can keep main part of image instead of changing.

Tabel 3.3.1 shows statistic difference between two approaches (Result1 and Result2). Small changes exist and the third axis has little influence in nonlinear filtering.

4 Discussion

We have three assumptions at the beginning. (1) Reslice could obtain image at any angle. Interpolation changes a few related image details (2) Nonlinear filter does not change the main part of image while increase SNR. (3) Nonlinear filter in 2D which lost one dimension information may affect result.

Voxels in high-quality medical image can be regarded as ‘continuous data’ and MRI and CT with high resolution are not influenced a lot by 2D and 3D. Those images with low resolution like CBCT and ultrasound might perform worse.

5 Conclusion

Reslice for viewing specific organ at a oblique plane is possible. Clinical practice for viewing liver or ribs could utilise this method.

Nonlinear filter can reduce noise while keep contrast of edge. Perona and Malik combine divergence with nonlinear filter. This method decreases noise level and keeps high resolution.

CT image has high spatial resolution which leads to little difference between 2D filter and 3D filter. If there exists obvious gradient along the third axis, ‘reslice before 2D filter’ might miss related information. But ‘reslice after 3D filter’ means more computation. The selection between these two approaches depends on our demand.