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Texture Classification of 3D MR Color Images Using 3D Diagonal Rank Filters

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Abstract:

The term 'texture' refers to patterns arranged in an order in a line or a curve. Textures allow one to make a meaningful interpretation of certain geometric regularity of spatially repeated patterns. In addition, texture also exhibits useful information about spatial distribution of color or gray intensities in an image. Correct interpretation of latent textures of various tissues in a body is an important requirement for a surgeon as a preoperative measure. Mostly, extraction of directional textures in an MR scanned 3D image is carried out in all three orthogonal axes of 3D geometry. Alternatively, this paper proposes a novel technique for extracting directional textures of a 3D MR image in all six diagonal axesseparately.

Keywords: *3D Color Images, Superficial and Volumetric Features, Texture Classification.*

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I. INTRODUCTION

This paper demonstrates a computationally efficient technique to detect various texture characteristics as directional features in a given 3D digital image in six diagonal axes. The computational tool used for this purpose is '3D Diagonal Rank Filters', which are essentially directional filters. These filters cause radical changes in the original content of a given image but precisely extract various textures. Any given 3D MR image consists of texture features of tissues corresponding to muscle fibers in almost all directions such as three orthogonal axes and six diagonal axes. One can visualize major muscle fibers of a body component with naked eye. But most of the finer textures cannot be visualized even by an expert, in which case machine vision support system becomes quite handy. The algorithms presented in this paper could be used to detect texture patterns in al the six diagonal axes of a 3D rectangular discrete coordinate system in which 3D digital image is displayed. Fig. 1 shows planes in these three orthogonalaxes.

A 3D MR image would exhibit texture features of tissues corresponding to muscle fibers in almost all directions especially in three orthogonal axes and six diagonal axes. Fig. 1 shows the three orthogonal planes x-y plane, y-z plane and z-x plane in a 3D geometry. In geometrical terms, these three orthogonal planes are called "**superficial features**".

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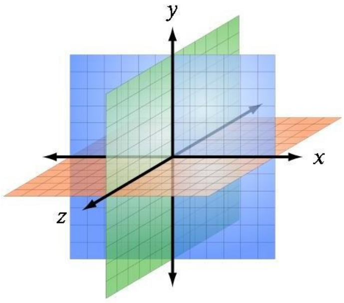


Fig. 1: Three orthogonal planes in a 3D geometry

Fig. 2 shows the six diagonal x-y-z planes in a 3D geometry.

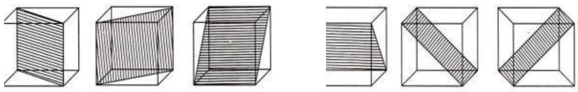
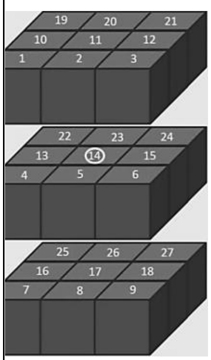


Fig. 2: Six diagonal planes in a 3D geometry

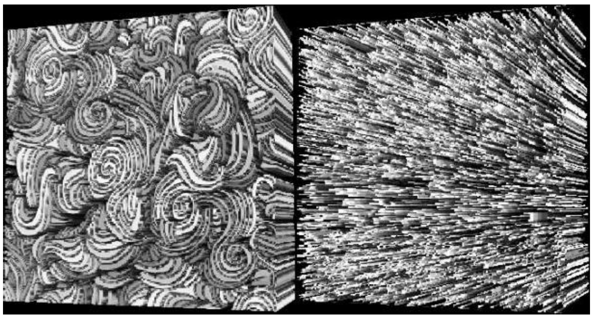
Table 1: Various diagonal planes

27-neighborhood window	Diagonal Planes	Vertices of Planes
	L Plane	1,10,19, 5,14,23, 9,18,27
	R Plane	3,12,21, 5,14,23, 7,16,25
	L Plane	1,11,21, 4,14,24, 7,17,27
	R Plane	3,11,19, 6,14,22, 9,17,25
	L Plane	1,2,3, 13,14,15, 25,26,27
	R Plane	19,20,21, 13,14,15, 7,8,9

This paper introduces a technique for detecting textures in all six x-y-z diagonal planes. In geometrical terms, these diagonal planes are called "**volumetric features**".

II. Proposed Method

Apart from detecting latent textures in a given image, one can also artificially create texture images. Fig. 3 shows 3D texture images, which are artificially generated using cellular automata rules.



(a) Image 1 (b) Image2

Fig. 3: Texture images due to cellular automata rules

Texture detection in six diagonal x-y-z planes

To begin with, the directional texture detection concept is explained with the help of planes perpendicular to X, Y and Z axes. The given 3-D image is plane-wise raster-scanned by the 27-neighborhood window shown in Fig. 4. Now, the 3-D linear textures are extracted along a desired axis with a directional twist by choosing the plane which is perpendicular to that axis and its associated rank of a particular directional twist. Rank is decided by the reading pattern. For instance, the Y-Z plane is perpendicular to the X-axis and rank1 of zero directional twist denoted by X1 is obtained by reading the values of the cells of 2,11,20,23,26,17,8,5 in the Y-Z central plane. Fig. 4 shows the Y-Z planes and their cellnumbering.

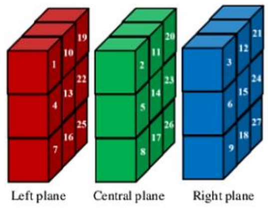


Fig. 4: Y-Z Planes perpendicular to X-axis with cell numbering in 3x3x3 neighborhood

Processing is carried out using the values in the cells and computed value placed in the central cell, that is, in the 14th cell. Texture detection algorithm is used for the processing. Table 2 shows the reading patterns for various ranks in terms of cellsequences

Table 2: Cell sequences for ranks in X, Y and Z axes

Axes	Ranks	Cell sequences
X	X1	2,11,20,23,26,17,8,5
	X2	11,20,23,26,17,8,5,2
	X3	20,23,26,17,8,5,2,11
	X4	23,26,17,8,5,2,11,20
Y	Y1	4,5,6,15,24,23,22,13
	Y2	5,6,15,24,23,22,13,4
	Y3	6,15,24,23,22,13,4,5
	Y4	15,24,23,22,13,4,5,6
Z	Z1	10,11,12,15,18,17,16,13
	Z2	11,12,15,18,17,16,13,10
	Z3	12,15,18,17,16,13,10,11
	Z4	15,18,17,16,13,10,11,12

III. The Algorithm

On every move, the sub image covered by the 3X3X3 scanning window is checked and values of the boundary cells stored as an array of numbers based on the preferredrank. For instance, the cell sequence 2,11,20,23,26,17,8,5 corresponds to the rank filter X1. Let us symbolize the cell sequence of rank X1 as $c_2,c_{11},c_{20},c_{23},c_{26},c_{17},c_8,c_5$. The central cell value is symbolized as c_{14}. Now eachvalue of the boundary cell c_i (i=2,11,20,23,26,17,8,5) is compared with the value of the central cell c_{14}. If $c_i \geq c_{14}$ then the value 1 is assigned to c_i, elsethe value 0 is assigned.Now the computed configuration of the cell sequence $c_2,c_{11},c_{20},c_{23},c_{26},c_{17},c_8,c_5$ would be a binary string. The decimal equivalent of this binary string is computed and the resulting decimal value is assigned to the central cell c_{14}. This procedure is repeated until entire image is scanned. The overall effect is that all textures present in the given image in the chosen axis are detected. There are a total of 36 rank filters, 12 in the X, Y, Z axes and 24 in XL, XR, YL, YR, ZL and ZR axes. Table 3 presents 24 rank filter cell sequences in XL, XR, YL, YR, ZL, ZR axes.

Table 3: Cell sequences in six diagonalaxes.

Axes	Ranks	Cell sequences
XL	XL1	1,10,19,23,27,18,9,5
	XL2	10,19,23,27,18,9,5,1
	XL3	19,23,27,18,9,5,1,10
	XL4	23,27,18,9,5,1,10,19
XR	XR1	3,12,21,23,25,16,7,5
	XR2	12,21,23,25,16,7,5,3
	XR3	21,23,25,16,7,5,3,12
	XR4	23,25,16,7,5,3,12,21
YL	YL1	1,11,21,24,27,17,7,4
	YL2	11,21,24,27,17,7,4,1
	YL3	21,24,27,17,7,4,1,11
	YL4	24,27,17,7,4,1,11,21
YR	YR1	3,11,19,22,25,17,9,6
	YR2	11,19,22,25,17,9,6,3
	YR3	19,22,25,17,9,6,3,11
	YR4	22,25,17,9,6,3,11,19
ZL	ZL1	1,13,25,26,27,15,3,2
	ZL2	13,25,26,27,15,3,2,1
	ZL3	25,26,27,15,3,2,1,13
	ZL4	26,27,15,3,2,1,13,25
ZR	ZR1	7,13,19,20,21,15,9,8
	ZR2	13,19,20,21,15,9,8,7
	ZR3	19,20,21,15,9,8,7,13
	ZR4	20,21,15,9,8,7,13,19

The Pseudocode [ ]

Directional Texture Detection

***Input**: 3-D image, threshold*

***Output**: 3-D Direction Textures **Steps**:*

Read 3-D data and place voxel values in aninput_array.

Copy contents of input_array to yet anotheroutput_array

Repeat sliding the chosen plane over the image; read values(input_array)

{

If Pi >=P9 then Pi=1 else Pi=0

Place decimal equivalent (boundary values of central voxel) of binary values in the central voxel(write in output_array)

}

Until the structuring element periods whole of the image

Pass the output_arrayto VolumeRenderer().

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As an example, consider XL plane and rank XL1. The values in the cells 1,10,19,23,27,18,9,5 are read. Apply the algorithm and evaluate the decimal value corresponding to the texture and place the decimal value in central cell 14. The XL refers to the left cut plane which is oblique to X axis by 45 degrees. Fig. 5 shows the planar view of thissurface.

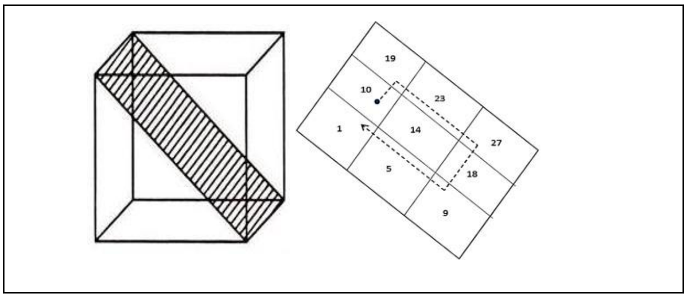
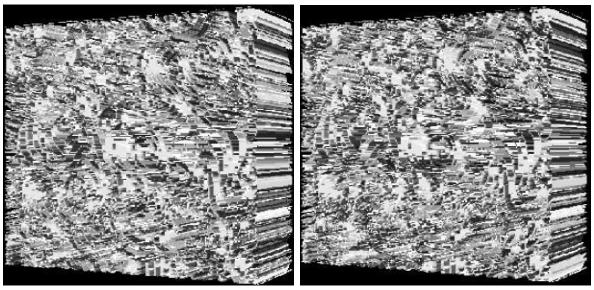


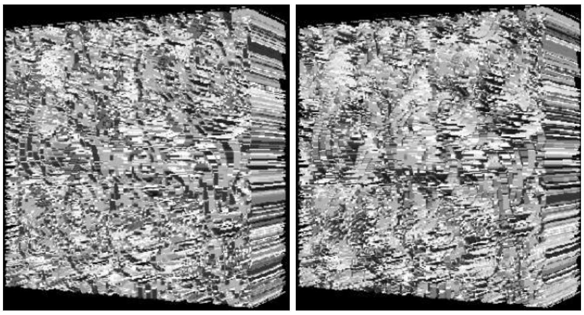
Fig. 5: XL plane perpendicular to X-axis and tilted by 45 degrees

Fig. 5 shows the reading sequence 10,19,23,27,18, 9,5,1 XL2. Choosing XL plane and rank XL2, a given 3-D image is scanned by 3X3X3 empty window. As mentioned earlier, sub image scanned by XL plane is considered and the boundary values stored in a linear array according to the cell sequence 10,19,23,27,18,9,5,1, defined by the rank XL2. The texture value is computed as stipulated by the algorithm and assigned to central cell 14. Fig. 6 shows texture patterns extracted from image 2 using XL1 and XR1 rank filters. Fig. 6 shows texture patterns extracted from image 2 using XL1 and XR1 rank filters. Fig. 7 shows texture patterns extracted from image 2 using YL1 and YR1 rank filters. Fig. 8 shows texture patterns extracted from image 2 using ZL1 and ZR1 rank filters.



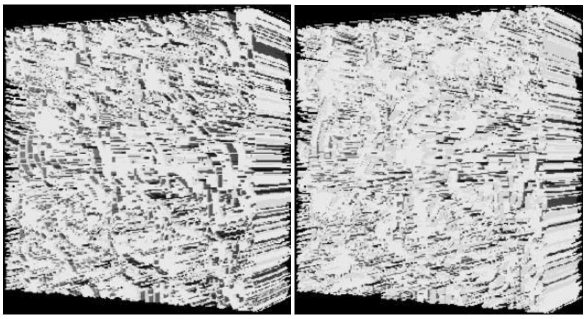
Textures obtained using XL1 rank filter Textures obtained using XR1 rank filter

Fig. 6: Textures along XL and XR planes



Textures obtained using YL1 rank filter Textures obtained using YR1 rank filter

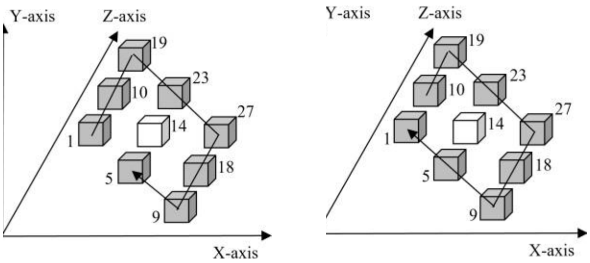
Fig. 7: Textures along YL and YR planes



Textures obtained using ZL1 rank filter Textures obtained using ZR1 rank filter

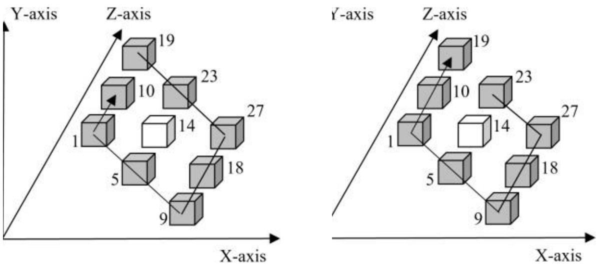
Fig. 8: Textures along ZL and ZR planes

The reading patterns for all 24 rank filters are given in Figs. 9 to 20.



XL1=1,10,19,23,27,18,9,5 XL2=10,19,23,27,18,9,5,1

Fig. 9: Reading patterns for XL1 and XL2



XL3=19,23,27,18,9,5,1,10 XL4=23,27,18,9,5,1,10,19

Fig. 10: Reading patterns for XL3 andXL4

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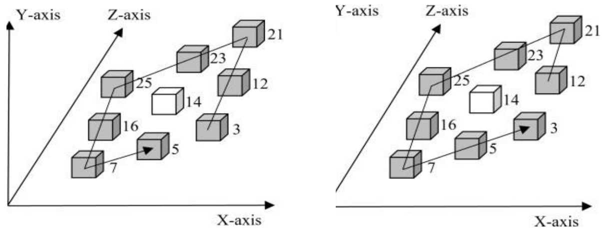

XR1=3,12,21,23,25,16,7,5 XR2=12,21,23,25,16,7,5,3

Fig. 11: Reading patterns for XR1 andXR2

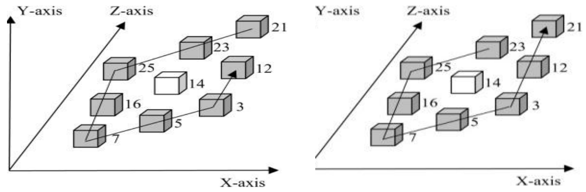

XR3=21,23,25,16,7,5,3,12 XR4=23,25,16,7,5,3,12,21

Fig. 12: Reading patterns for XR3 andXR4

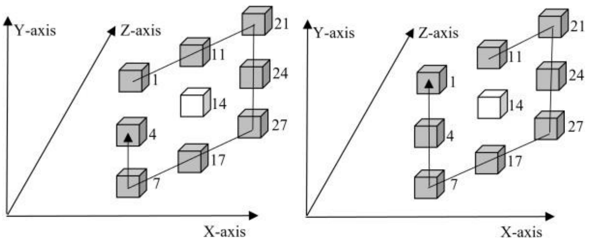


Fig. 13: Reading patterns for YL1 and YL2

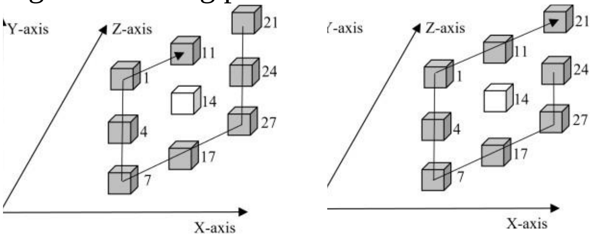

YL3=21,24,27,17,7,4,1,11 YL4=24,27,17,7,4,1,11,21

Fig. 14: Reading patterns for YL3 and YL4

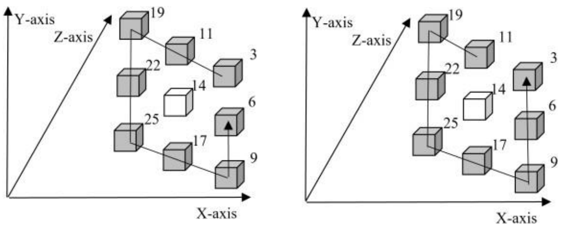


Fig. 15: Reading patterns for YR1 andYR2

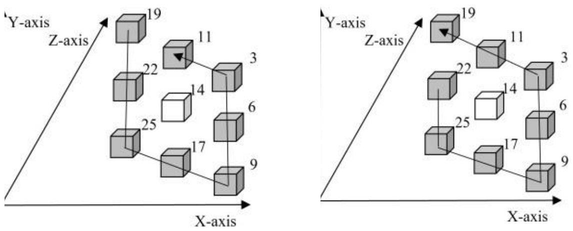

YR3=19,22,25,17,9,6,3,11 YR4=22,25,17,9,6,3,11,19

Fig. 16: Reading patterns for YR3 andYR4

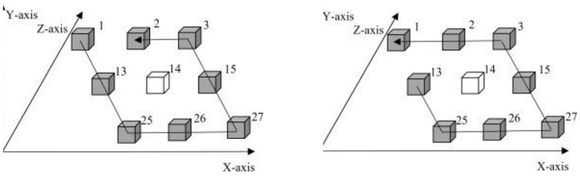

ZL1=1,13,25,26,27,15,3,2 ZL2=13,25,26,27,15,3,2,1

Fig. 17: Reading patterns for ZL1 andZL2

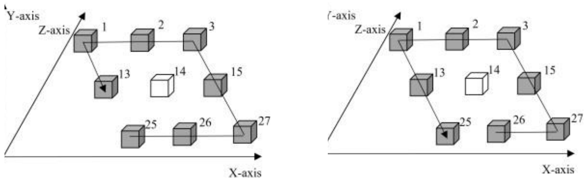

ZL3=25,26,27,15,3,2,1,13 ZL4=26,27,15,3,2,1,13,25

Fig. 18: Reading patterns for ZL3 andZL4

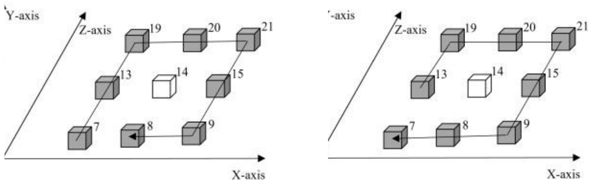

ZR1=7,13,19,20,21,15,9,8 ZR2=13,19,20,21,15,9,8,7

Fig. 19: Reading patterns for ZR1 and ZR2

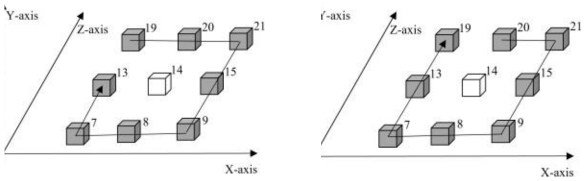

ZR3=19,20,21,15,9,8,7,13 ZR4=20,21,15,9,8,7,13,19

Fig. 20: Reading patterns for ZR3 and ZR4

III. Case Study

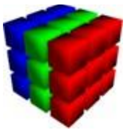
A sample MR image set called 'toutaix" is considered here for the case study. This image corresponds to a human heart and is taken from the website https://www.osirix-viewer.com/. MR images are by default gray images. A coloring scheme has been used to convert 3D gray images into 3D color images. Details about this image are given in table4

Table 4: Details of MR image 'toutatix '

Website	Details of the image	Remarks
http://pubimage.hcuge.ch:8080/	File name: Toutatix Image type: MRI Width = 256 Height = 256 Depth = 256 Max Gray level: 256	Reconstructed from a set of 2-D slices

Fig. 21 shows MR image 'toutatix' and its colored version. The color image voxels are depicted by R, G and B values and the maximum value of a color component is 255. Figs. 22 to 33 show the texture detected versions of the color image 'toutatix' using all 24 rank filters.

All these 24 rank filters are defined in a 27-neighborhood structure shown on the right. ATI Radeon HD R5970 Graphics card has been used to process 3D images.



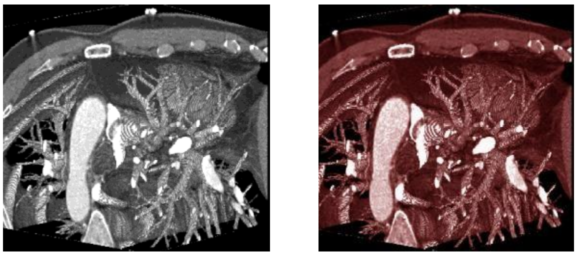
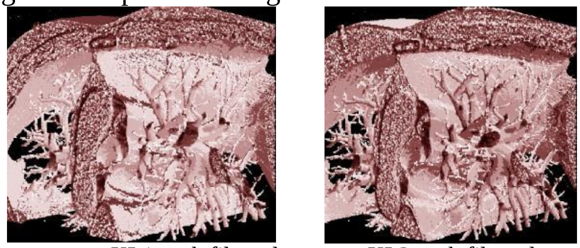
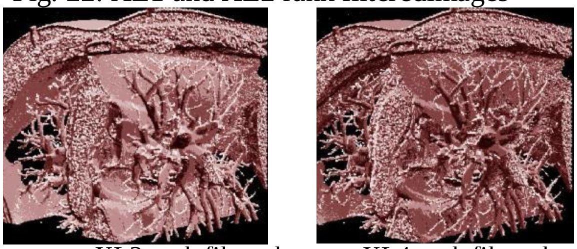


Fig. 21: Sample MRI image and its colored version



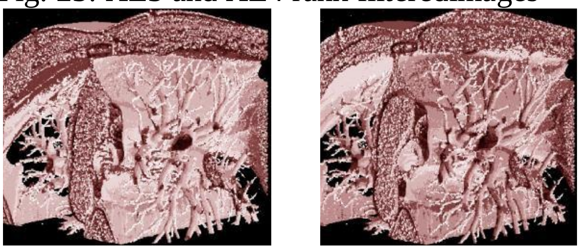
XL1 rank filtered XL2 rank filtered

Fig. 22: XL1 and XL2 rank filteredimages



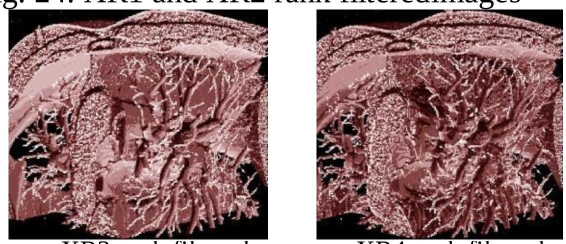
XL3 rank filtered XL4 rank filtered

Fig. 23: XL3 and XL4 rank filteredimages



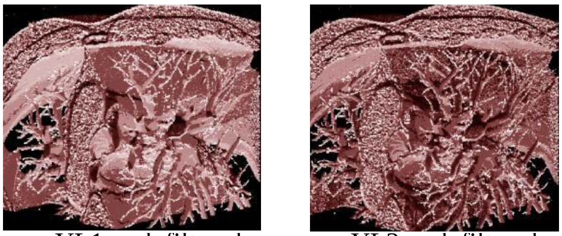
XR1 rank filtered XR2 rank filtered

Fig. 24: XR1 and XR2 rank filteredimages



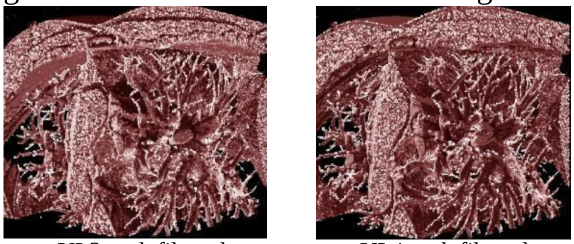
XR3 rank filtered XR4 rank filtered

Fig. 25: XR3 and XR4 rank filteredimages



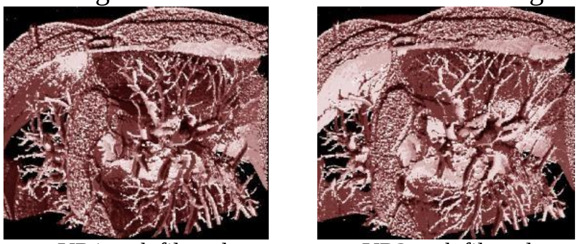
YL1 rank filtered YL2 rank filtered

Fig. 26: YL1 and YL2 rank filteredimages



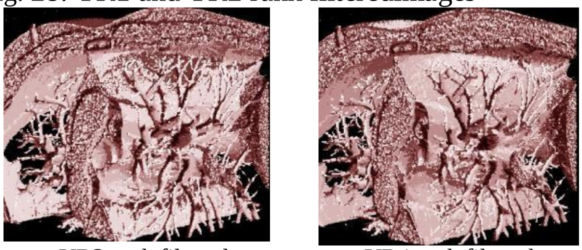
YL3 rank filtered YL4 rank filtered

Fig. 27: YL3 and YL4 rank filteredimages



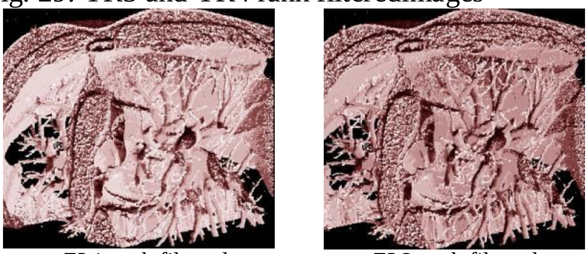
YR1 rank filtered YR2 rank filtered

Fig. 28: YR1 and YR2 rank filteredimages



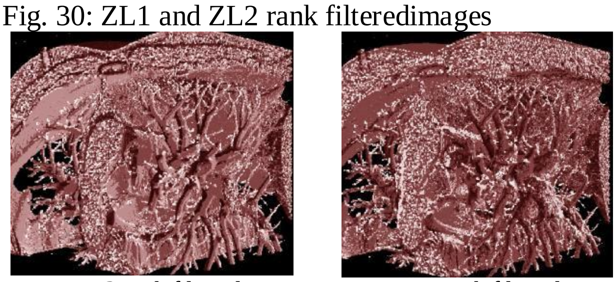
YR3 rank filtered YR4 rank filtered

Fig. 29: YR3 and YR4 rank filteredimages



ZL1 rank filtered ZL2 rank filtered

Fig. 30: ZL1 and ZL2 rank filteredimages



ZL3 rank filtered ZL4 rank filtered

Fig. 31: ZL3 and ZL4 rank filteredimages

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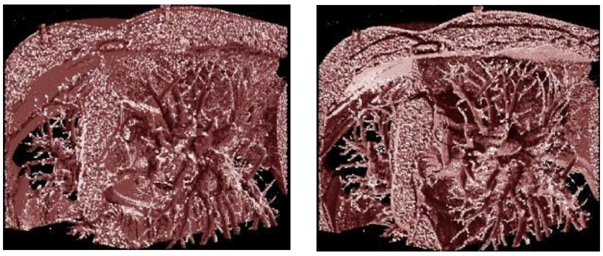
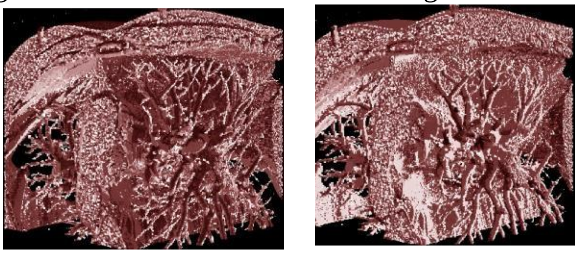


ZR1rankfiltered filtered ZR2 rank

Fig. 32: ZR1 and ZR2 rank filteredimages



ZR3 rank filtered ZR4 rank filtered

Fig. 33: ZR3 and ZR4 rank filteredimages

IV. Observations

1. The rank filters XL1, XL2, XR1, XR2, YR3, YR4, ZL1 and ZL2 extract texture regions where the blood vessels areembedded.
2. The structure and form of the blood vessels could be clearly seen in such filteredimages.

IV. Conclusion

All twenty four texture patterns of the image are obtained using diagonal rank filters. This provides a solid visual proof of the fact that textures in an image are essentially direction sensitive and so they could be used for segmenting images.

V. Acknowledgment

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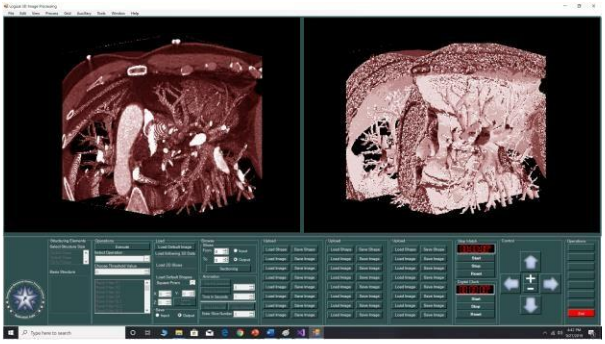

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