

Texture Classification of 3D MR Color Images using 3D Orthogonal Rank Filters

Arun Kumar A ^α & E. G. Rajan ^σ

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. In this context, extraction of textures in an MR scanned 3D image would assist a medical professional in the preoperative decision making process. This paper proposes a novel technique for extracting directional textures of a 3D MR image in all three axes separately.

Keywords: 3D color images, superficial and volumetric features, texture classification.

I. INTRODUCTION

This paper describes a computationally efficient technique to detect various texture characteristics as directional features in a given 3D digital image. The computational tool used for this purpose is '3D 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.

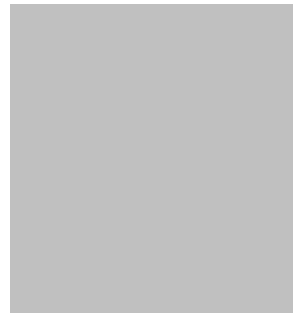
Any given 3D MR image consists of texture features of tissues corresponding to muscle fibers in almost all directions. One can visualize major muscle fibers of a body component with naked eye. But most of the finer textures cannot be visualized even by an expert, in which case machine vision support system becomes quite handy. The algorithms presented in this paper could be used to detect texture patterns in all the three orthogonal axes of a 3D rectangular discrete coordinate system in which 3D digital image is displayed.

II. LITERATURE SURVEY

Apart from detecting latent textures in a given image, one can also artificially create texture images. Fig. 1 shows a 3D texture image, which is artificially generated using a cellular automaton rule.

Author ^α: Department of Computer Science University of Mysore, Manasa Gangotri Mysore, Karnataka, India.
e-mail: arun.arigala@gmail.com

Author ^σ: Director, Rajiv Gandhi International School of Information Technology, MG-MIRSA Approved Research Centre of Mysore University. e-mail: rajaneg@yahoo.co.in



(a) Image 1

(b) Image 2

Figure 1: Texture images due to cellular automaton rules

Fig. 2 shows texture patterns extracted from image 2 shown in Fig. 1 along three axes of 3D rectangular coordinate system.

Textures along x axis Textures along y axis Textures along z axis

Figure 2: Textures along all axes of 3D coordinate system

Two texture features are usually considered for image segmentation. They are (i) spatial frequency features and (ii) average gray level features. Either 'structural approach' or 'statistical approach' could be used for developing texture detection algorithms. Mostly statistical approach is considered for texture classification because of ease in parametrization and quantification of texture features.

Edge detection is a method by which one would be able to detect edge pixels details which help determine characteristics of texture complexities. For instance, directions of edges could be treated as characteristics of textures in determining patterns in the textures.

Consider a region with N pixels in a given image. Any gradient-based edge detector algorithm could be applied to this region, which would yield two outputs for every pixel p, viz, 'gradient magnitude

Mag(p)' and 'gradient direction' Dir(p). Now, the edgeness per unit area of a given image is defined by

$$\frac{|\{p|Mag(p) > T\}|}{N}$$

the expression for some predefined

threshold T. Let $H_{mag}(R)$ be the normalized histogram of the gradient magnitudes of the region of interest R, and let $H_{dir}(R)$ be the normalized histogram of the gradient orientations of the region of interest R. Both are normalized according to the size N_R . Then, one can define a quantitative measure $F_{mag,dir} = (H_{mag}(R), H_{dir}(R))$ for describing texture of the region of interest R.

Another technique to quantify texture is 'co-occurrence matrix', which defines features of a texture using certain spatial relations of similar gray values. Such numerical features could be used for texture classification. Some of the standard features from a normalized co-occurrence matrix are given below.

Angular moment = 2^{nd}

Contrast =

Correlation =

Entropy =

where $p[i, j]$ is the $[i, j]^{th}$ entry in a gray-level spatial dependence matrix, and Ng is the number of gray-values in the quantized image. It is to be noted that the co-occurrence matrix based feature extraction will not yield comfortable visual perception.

III. PROPOSED METHOD

As outlined earlier, the term 'textures' refers to 'repeated patterns' in a given image. Consider the 27-neighborhood window shown in Fig. 3. The cells 1, 2, 3, 4, 5, 6, 7, 8, 9 form the first plane, 10, 11, 12, 13, 14, 15, 16, 17, 18 the middle plane and cells 19, 20, 21, 22, 23, 24, 25, 26, 27 form the rear plane of the window. The given 3-D digital image is plane-wise raster-scanned by this window (See Fig. 3). In order to extract 3-D linear textures along an axis with a directional twist, one has to choose that particular axis and its associated rank of a particular directional twist. For example if one chooses the X axis and rank1 of zero directional twist, values in cells 2,11,20,23,26,17,8,5 would be read and stored in an array. The reading pattern is shown in Fig. 4.

(a) Labeled window (b) Reading direction

Figure 3: 27-neighborhood window in layer form and the reading direction

The values of the cells 2,11,20,23,26,17,8,5 are the boundary values corresponding to the central voxel 14. The plane formed by these cells is perpendicular to the X axis as shown in Fig. 4.

Figure 4: 3D coordinate axes and the reading plane

X-axis rank 2 consists of cells 11, 20, 23, 26, 17, 8, 5, 2 and the corresponding plane is perpendicular to X axis as given in Fig. 4 but with a directional twist of 45 degrees. One can construct four ranks in X-axis, four in Y-axis and another four in Z-axis as shown in Table 1. A total of 12 rank filters could be constructed in three axes which are called "3D Orthogonal Rank Filters".

Table 1: Ranks filters in all three 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	4,13,22,23,24,15,6,5
	Y2	13,22,23,24,15,6,5,4
	Y3	22,23,24,15,6,5,4,13
	Y4	23,24,15,6,5,4,13,22
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

IV. TEXTURE CLASSIFICATION OF 3D MEDICAL IMAGES

Textures of a medical image play an important role in support of a surgeon to decide the angle at which the surgical blade should be used to make incision so that the loss of blood due to surgery is kept minimum. A case study was carried out to verify the validity of the algorithm and the result of the study presented in Fig. 5, which is self-explanatory.



Figure 5: Sample MRI image and its colored version

Figure 6: Rank x1 filtered, sectioned (30-140) and histogram

Figure 7: Rank x2 filtered, sectioned (30-140) and histogram

Figure 8: Rank x3 filtered, sectioned (30-140) and histogram

Figure 9: Rank x4 filtered, sectioned (30-140) and histogram

Figure 10: Rank y1 filtered, sectioned (30-140) and histogram

Figure 11: Rank y2 filtered, sectioned (30-140) and histogram



Figure 12: Rank y3 filtered, sectioned (30-140) and histogram

Figure 16: Rank z3 filtered, sectioned (30-140) and histogram

Figure 13: Rank y4 filtered, sectioned (30-140) and histogram

Figure 17: Rank z4 filtered, sectioned (30-140) and histogram

Figure 14: Rank z1 filtered, sectioned (30-140) and histogram

Figure 15: Rank z2 filtered, sectioned (30-140) and histogram

V. STATISTICAL RESULTS

Original 3D image statistics

Pixels Count	568089
Pixels without black	449360
Red Min	0
Red Max	252
Red Mean	90.0212677943069
Red Standard Deviation	65.4300367403954
Red Median	92
Red Total Count	568089
Green Min	0
Green Max	249
Green Mean	48.2296154299766
Green Standard Deviation	56.6653938791041
Green Median	33
Green Total Count	568089
Blue Min	0
Blue Max	249
Blue Mean	48.2296154299766
Blue Standard Deviation	56.6653938791041
Blue Median	33
Blue Total Count	568089
Saturation Min	0
Saturation Max	1
Saturation Mean	0.347210377454758

Saturation Standard Deviation	0.225063592195511	Cb Max WB	-0.00196078419685364
Saturation Median	0.341176480054855	Cb Mean WB	-0.0371856279671192
Luminance Min	0	Cb Standard Deviation WB	0.0100541561841965
Luminance Max	0.980392158031464	Cb Median WB	-0.0411764681339264
Luminance Mean	0.270397782325745	Cr Min WB	0.00196081399917603
Luminance Standard Deviation	0.234511524438858	Cr Max WB	0.123529434204102
Luminance Median	0.243137255311012	Cr Mean WB	0.10223163664341
Y Min	0	Cr Standard Deviation WB	0.0303715113550425
Y Max	0.976470589637756	Cr Median WB	0.115686297416687
Y Mean	0.236716106534004	Rank X1 filtered image statistics	
Y Standard Deviation	0.227980986237526	Pixels Count	563200
Y Median	0.196078434586525	Pixels without black	441456
Cb Min	-0.0450980365276337	Red Min	0
Cb Max	-0.00196078419685364	Red Max	252
Cb Mean	-0.0298237334936857	Red Mean	122.136278409091
Cb Standard Deviation	0.0168844126164913	Red Standard Deviation	87.516547830135
Cb Median	-0.0372548997402191	Red Median	121
Cr Min	-0.00196078419685364	Red Total Count	563200
Cr Max	0.123529434204102	Green Min	0
Cr Mean	0.0804557129740715	Green Max	249
Cr Standard Deviation	0.0502428002655506	Green Mean	88.18859375
Cr Median	0.103921592235565	Green Standard Deviation	85.5399836766261
Red Min WB	1	Green Median	57
Red Max WB	252	Green Total Count	563200
Red Mean WB	113.806507032224	Blue Min	0
Red Standard Deviation WB	52.0126491068468	Blue Max	249
Red Median WB	111	Blue Mean	88.18859375
Red Total Count WB	449360	Blue Standard Deviation	85.5399836766261
Green Min WB	0	Blue Median	57
Green Max WB	249	Blue Total Count	563200
Green Mean WB	60.972747908136	Saturation Min	0
Green Standard Deviation WB	57.2920439382876	Saturation Max	1
Green Median WB	48	Saturation Mean	0.30152890086174
Green Total Count WB	449360	Saturation Standard Deviation	0.202493324875832
Blue Min WB	0	Saturation Median	0.317647069692612
Blue Max WB	249	Luminance Min	0
Blue Mean WB	60.972747908136	Luminance Max	0.980392158031464
Blue Standard Deviation WB	57.2920439382876	Luminance Mean	0.411772221326828
Blue Median WB	48	Luminance Standard Deviation	0.335566163063049
Blue Total Count WB	449360	Luminance Median	0.34901961684227
Saturation Min WB	0.235294118523598	Y Min	0
Saturation Max WB	1	Y Max	0.976470589637756
Saturation Mean WB	0.43894961476326	Y Mean	0.384158581495285
Saturation Standard Deviation WB	0.154169782996178	Y Standard Deviation	0.334127157926559
Saturation Median WB	0.396078437566757	Y Median	0.298039227724075
Luminance Min WB	0	Cb Min	-0.0450980365276337
Luminance Max WB	0.980392158031464	Cb Max	-0.00196078419685364
Luminance Mean WB	0.341841757297516	Cb Mean	-0.0245320294052362
Luminance Standard Deviation WB	0.212376952171326	Cb Standard Deviation	0.0166890006512403
Luminance Median WB	0.309803932905197	Cb Median	-0.0254901945590973
Y Min WB	0	Cr Min	-0.00196078419685364
Y Max WB	0.976470589637756	Cr Max	0.123529434204102
Y Mean WB	0.299260765314102	Cr Mean	0.0646790862083435
Y Standard Deviation WB	0.216774046421051	Cr Standard Deviation	0.0495649240911007
Y Median WB	0.258823543787003	Cr Median	0.0686274766921997
Cb Min WB	-0.0450980365276337		

Red Min WB 1
 Red Max WB 252
 Red Mean WB 155.818817730419
 Red Standard Deviation WB 67.2532471235556
 Red Median WB 150
 Red Total Count WB 441456
 Green Min WB 0
 Green Max WB 249
 Green Mean WB 112.509097169367
 Green Standard Deviation WB 81.2324164509591
 Green Median WB 88
 Green Total Count WB 441456
 Blue Min WB 0
 Blue Max WB 249
 Blue Mean WB 112.509097169367
 Blue Standard Deviation WB 81.2324164509591
 Blue Median WB 88
 Blue Total Count WB 441456
 Saturation Min WB 0.235294118523598
 Saturation Max WB 1
 Saturation Mean WB 0.384684056043625
 Saturation Standard Deviation WB 0.142558693885803
 Saturation Median WB 0.329411774873734
 Luminance Min WB 0
 Luminance Max WB 0.980392158031464
 Luminance Mean WB 0.525330066680908
 Luminance Standard Deviation WB 0.289833068847656
 Luminance Median WB 0.466666668653488
 Y Min WB 0
 Y Max WB 0.976470589637756
 Y Mean WB 0.490101218223572
 Y Standard Deviation WB 0.300843000411987
 Y Median WB 0.415686279535294
 Cb Min WB -0.0450980365276337
 Cb Max WB -0.00196078419685364
 Cb Mean WB -0.0307566896080971
 Cb Standard Deviation WB 0.013269835151732
 Cb Median WB -0.0333333313465118
 Cr Min WB 0.00196081399917603
 Cr Max WB 0.123529434204102
 Cr Mean WB 0.0830569192767143
 Cr Standard Deviation WB 0.039645180106163
 Cr Median WB 0.0960784554481506
 Rank Y1 filtered image statistics
 Pixels Count 559680
 Pixels without black 440208
 Red Min 0
 Red Max 252
 Red Mean 140.256889651229
 Red Standard Deviation 91.295496046247
 Red Median 155
 Red Total Count 559680
 Green Min 0
 Green Max 249
 Green Mean 109.47983133219

Green Standard Deviation 89.8741846221284
 Green Median 94
 Green Total Count 559680
 Blue Min 0
 Blue Max 249
 Blue Mean 109.47983133219
 Blue Standard Deviation 89.8741846221284
 Blue Median 94
 Blue Total Count 559680
 Saturation Min 0
 Saturation Max 1
 Saturation Mean 0.275802910327911
 Saturation Standard Deviation 0.171386480331421
 Saturation Median 0.30588236451149
 Luminance Min 0
 Luminance Max 0.980392158031464
 Luminance Mean 0.489122450351715
 Luminance Standard Deviation 0.351963937282562
 Luminance Median 0.486274510622025
 Y Min 0
 Y Max 0.976470589637756
 Y Mean 0.463929653167725
 Y Standard Deviation 0.35080423951149
 Y Median 0.439215689897537
 Cb Min -0.0450980365276337
 Cb Max -0.00196078419685364
 Cb Mean -0.0224275775253773
 Cb Standard Deviation 0.015973724424839
 Cb Median -0.02156862616539
 Cr Min -0.00196078419685364
 Cr Max 0.123529434204102
 Cr Mean 0.0583211965858936
 Cr Standard Deviation 0.0472652688622475
 Cr Median 0.0607843399047852
 Red Min WB 1
 Red Max WB 252
 Red Mean WB 178.322465743467
 Red Standard Deviation WB 61.7170538248096
 Red Median WB 204
 Red Total Count WB 440208
 Green Min WB 0
 Green Max WB 249
 Green Mean WB 139.192545342202
 Green Standard Deviation WB 78.318391541463
 Green Median WB 163
 Green Total Count WB 440208
 Blue Min WB 0
 Blue Max WB 249
 Blue Mean WB 139.192545342202
 Blue Standard Deviation WB 78.318391541463
 Blue Median WB 163
 Blue Total Count WB 440208
 Saturation Min WB 0.235294118523598
 Saturation Max WB 1
 Saturation Mean WB 0.350655525922775

Saturation Standard Deviation WB0.105345770716667	Y Mean	0.391311198472977
Saturation Median WB 0.321568638086319	Y Standard Deviation	0.319555670022964
Luminance Min WB 0	Y Median	0.333333343267441
Luminance Max WB 0.980392158031464	Cb Min	-0.0450980365276337
Luminance Mean WB 0.621869742870331	Cb Max	-0.00196078419685364
LuminanceStandardDeviation WB0.273765563964844	Cb Mean	-0.0252390317618847
Luminance Median WB 0.717647075653076	Cb Standard Deviation	0.0168824307620525
Y Min WB 0	Cb Median	-0.0294117629528046
Y Max WB 0.976470589637756	Cr Min	-0.00196078419685364
Y Mean WB 0.589839696884155	Cr Max	0.123529434204102
Y Standard Deviation WB 0.286698818206787	Cr Mean	0.066443957388401
Y Median WB 0.686274528503418	Cr Standard Deviation	0.0499764792621136
Cb Min WB -0.0450980365276337	Cr Median	0.0803921818733215
Cb Max WB -0.00196078419685364	Red Min WB	1
Cb Mean WB -0.0279822442680597	Red Max WB	252
Cb Standard Deviation WB 0.0134115405380726	Red Mean WB	162.220466007254
Cb Median WB -0.0254901945590973	Red Standard Deviation WB59.5814731225976	
Cr Min WB 0.00196081399917603	Red Median WB	163
Cr Max WB 0.123529434204102	Red Total Count WB	440594
Cr Max WB 0.123529434204102	Green Min WB	0
Cr Mean WB 0.0746816620230675	Green Max WB	249
Cr Standard Deviation WB 0.0398297160863876	Green Mean WB	116.723936322328
Cr Median WB 0.0686274766921997	Green Standard Deviation WB 73.1980388120368	
Rank Z1 filtered image statistics	Green Median WB	104
Pixels Count 573516	Green Total Count WB	440594
Pixels without black 440594	Blue Min WB	0
Red Min 0	Blue Max WB	249
Red Max 252	Blue Mean WB	116.723936322328
Red Mean 124.623138674422	Blue Standard Deviation WB 73.1980388120368	
Red Standard Deviation 86.0969667214582	Blue Median WB	104
Red Median 130	Blue Total Count WB	440594
Red Total Count 573516	Saturation Min WB	0.235294118523598
Green Min 0	Saturation Max WB	1
Green Max 249	Saturation Mean WB	0.354308485984802
Green Mean 89.6711966187517	Saturation StandardDeviation WB0.123913042247295	
Green Standard Deviation 80.8826837693388	Saturation Median WB	0.317647069692612
Green Median 66	Luminance Min WB	0
Green Total Count 573516	Luminance Max WB	0.980392158031464
Blue Min 0	Luminance Mean WB	0.546131551265717
Blue Max 249	LuminanceStandardDeviationWB0.258956789970398	
Blue Mean 89.6711966187517	Luminance Median WB	0.521568655967712
Blue Standard Deviation 80.8826837693388	Y Min WB	0
Blue Median 66	Y Max WB	0.976470589637756
Blue Total Count 573516	Y Mean WB	0.509365200996399
Saturation Min 0	Y Standard Deviation WB	0.269796907901764
Saturation Max 1	Y Median WB	0.474509805440903
Saturation Mean 0.272191524505615	Cb Min WB	-0.0450980365276337
Saturation Standard Deviation 0.184789970517159	Cb Max WB	-0.00196078419685364
Saturation Median 0.298039227724075	Cb Mean WB	-0.0322618037462234
Luminance Min 0	Cb Standard Deviation WB	0.0125779723748565
Luminance Max 0.980392158031464	Cb Median WB	-0.0333333313465118
Luminance Mean 0.419556379318237	Cr Min WB	0.00196081399917603
Luminance Standard Deviation 0.323453366756439	Cr Max WB	0.123529434204102
Luminance Median 0.384313732385635	Cr Mean WB	0.0870808660984039
Y Min 0	Cr Standard Deviation WB	0.0375980846583843
Y Max 0.976470589637756	Cr Median WB	0.0960784554481506

Table 2: Comparison of selected statistical parameters

Selected Statistical Parameter	Original Image	Rank X1 Filtered Image	Rank Y1 Filtered Image	Rank Z1 Filtered Image
Red Min	0	0	0	0
Red Max	252	252	252	252
Red Mean	90.02	122.13	140.25	124.62
Red Standard Deviation	65.43	87.51	91.29	86.09
Red Median	92	121	155	130
Red Total Count	568089	563200	559680	573516
Green Min	0	0	0	0
Green Max	249	249	249	249
Green Mean	48.22	88.18	109.47	89.67
Green Standard Deviation	56.66	85.531	89.87	80.88
Green Median	33	57	94	66
Green Total Count	568089	563200	559680	573516
Blue Min	0	0	0	0
Blue Max	249	249	249	249
Blue Mean	48.22	88.18	109.47	89.67
Blue Standard Deviation	56.66	85.53	89.87	80.88
Blue Median	33	57	94	66
Blue Total Count	568089	563200	559680	573516

Red, Green and Blue values. One can infer similar behavior as far as other parameters also.

All four texture versions of the image obtained using rank filters could be seen to provide a visual proof of the fact textures in an image are direction sensitive and so they could be used for image segmentation purposes.

ACKNOWLEDGMENT

The authors thank the administration of Avatar MedVision US LLC, NC, USA and Pentagram Research Centre Private Limited, Hyderabad, India various hospitals both in India and USA for providing actual MR Images for the intended study. Technical support from Mr. Srikanth Maddikunta of Pentagram Research Centre Pvt Ltd, Hyderabad, India, is duly acknowledged.

Figure 18: Graph showing textures statistics

VI. CONCLUSION

From the experimental study, it was observed that the variations in the statistical parameter values remain almost uniform, especially standard deviations of

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