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Texture Classification of 3D Mr Color Images using 3D Orthogonal 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. 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.

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Texture Classification of 3D Mr Color Images using 3D Orthogonal 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. 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.

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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 al the three orthogonal axes of a 3D rectangular discrete coordinate system in which 3D digital image is displayed.

II. Liteerature 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.

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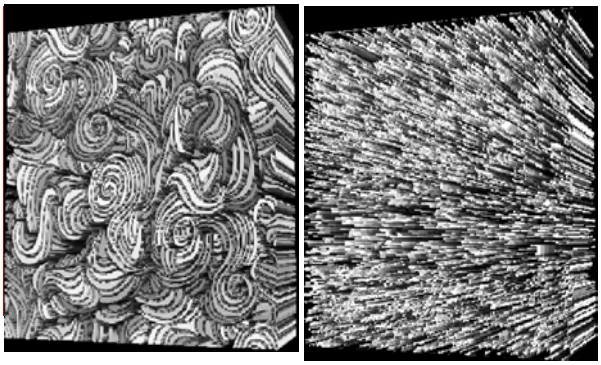
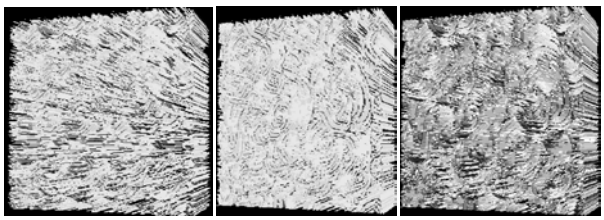


(a) Image 1 (b) Image 2

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 the expression $\frac{|\{p|Mag(p) > T\}|}{N}$ 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 2nd moment = $\sum_i \sum_j p[i,j]^2$

Contrast = $\sum_{i=1}^{Ng} \sum_{j=1}^{Ng} n^2 p[i,j]$, where $|i-j| = n$

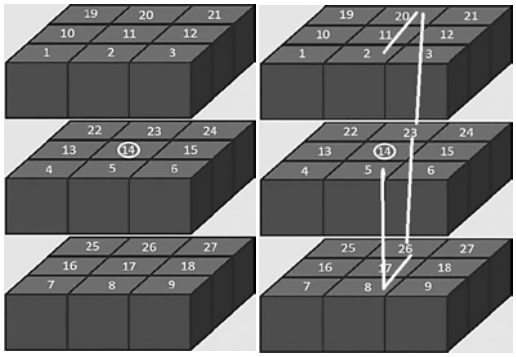
Correlation = $\frac{\sum_{i=1}^{Ng} \sum_{j=1}^{Ng} (ij)p[i,j] - \mu_x \mu_y}{\sigma_x \sigma_y}$

Entropy = $-\sum_i \sum_j p[i,j] ln(p[i,j])$

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.

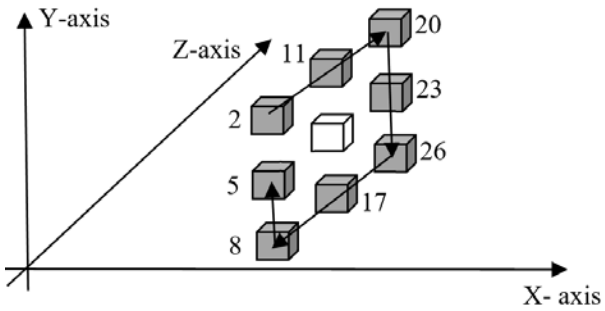


Figure 4: 3D coordinate axes and the reading plane

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.

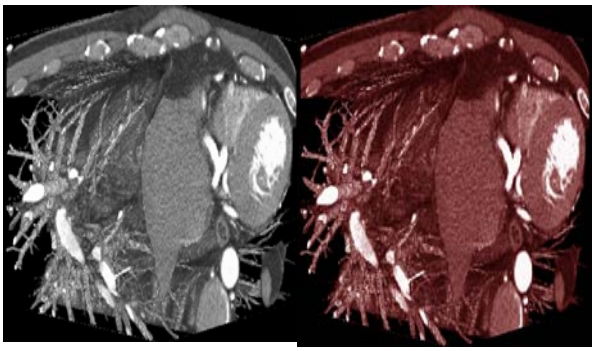


Figure 5: Sample MRI image and its colored version

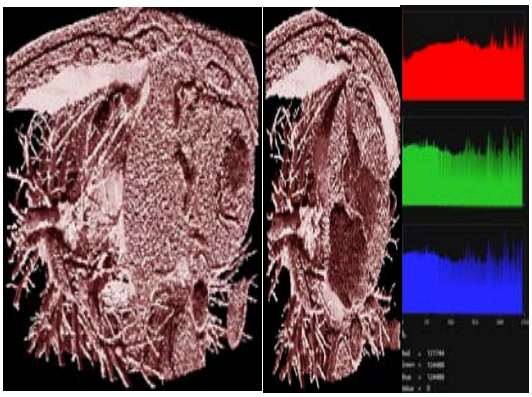


Figure 6: Rank x1 filtered, sectioned (30-140) and histogram

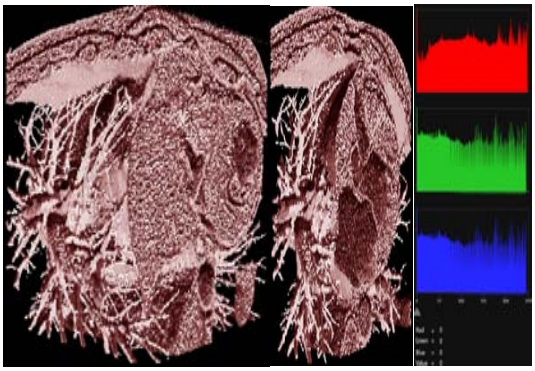


Figure 7: Rank x2 filtered, sectioned (30-140) and histogram

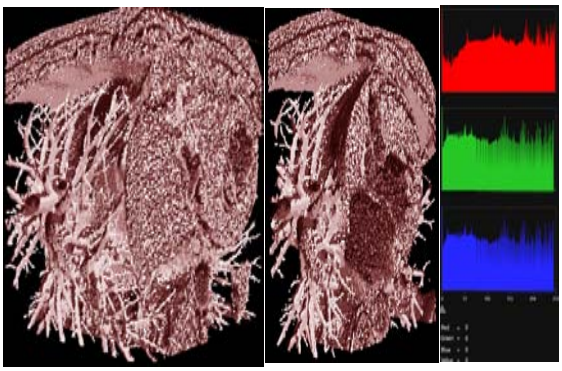


Figure 8: Rank x3 filtered, sectioned (30-140) and histogram

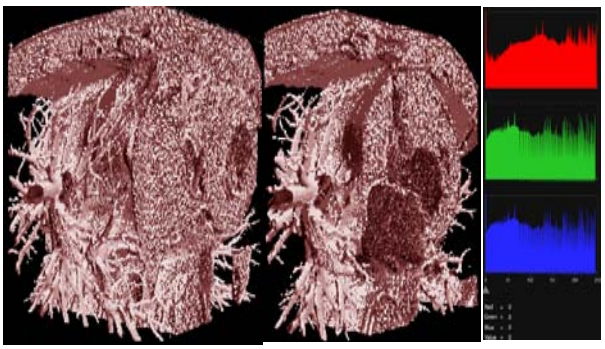


Figure 9: Rank x4 filtered, sectioned (30-140) and histogram

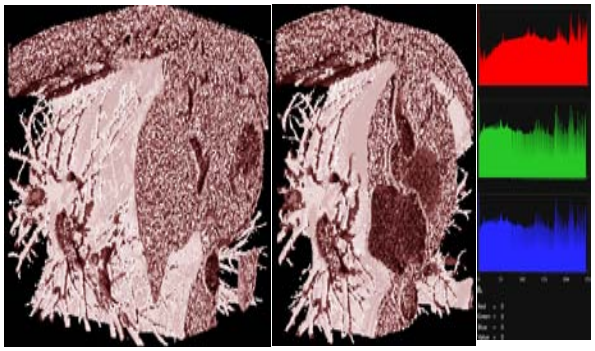


Figure 10: Rank y1 filtered, sectioned (30-140) and histogram

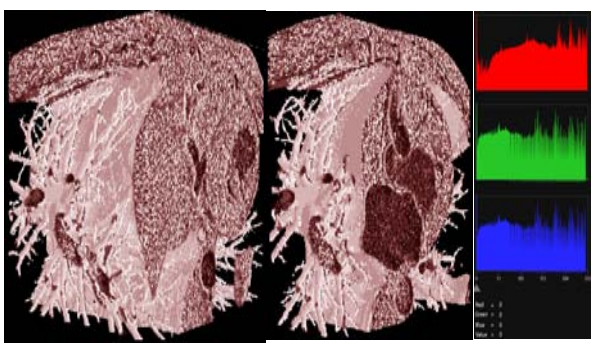


Figure 11: Rank y2 filtered, sectioned (30-140) and histogram

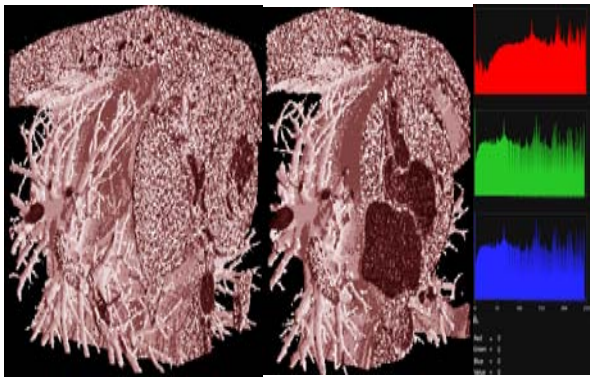


Figure 12: Rank y3 filtered, sectioned (30-140) and histogram

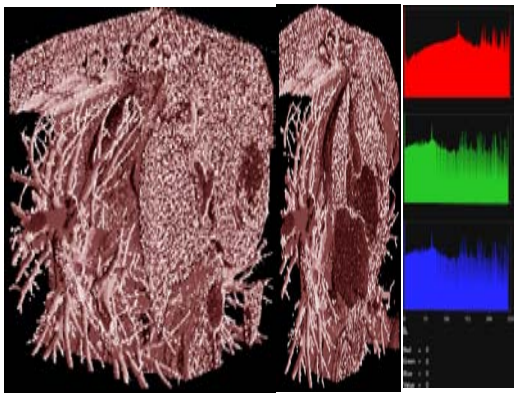


Figure 13: Rank y4 filtered, sectioned (30-140) and histogram

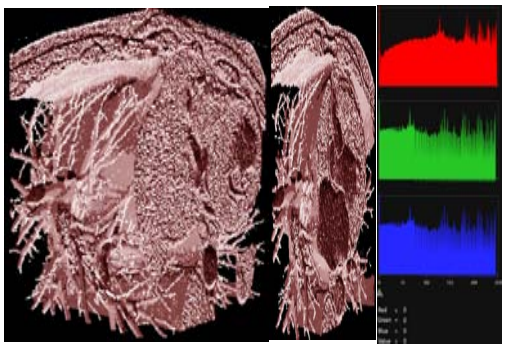


Figure 14: Rank z1 filtered, sectioned (30-140) and histogram

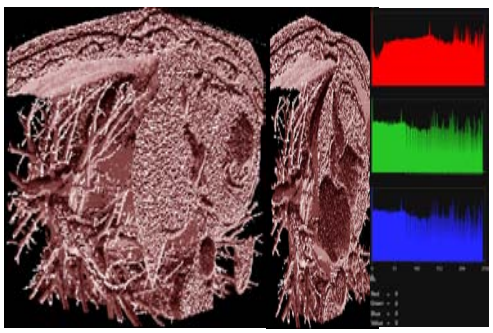


Figure 15: Rank z2 filtered, sectioned (30-140) and histogram

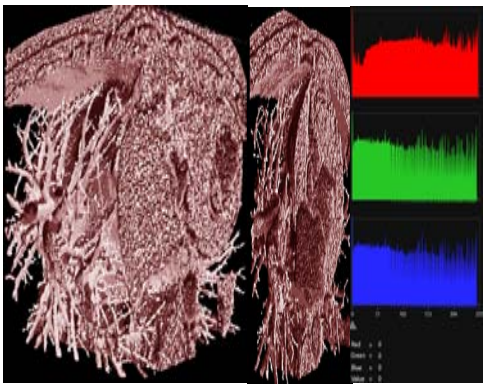


Figure 16: Rank z3 filtered, sectioned (30-140) and histogram

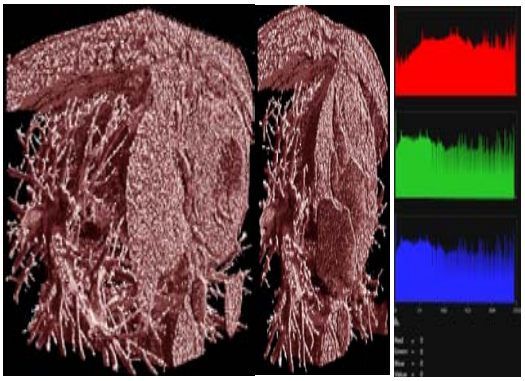


Figure 17: Rank z4 filtered, sectioned (30-140) and histogram

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
Saturation Median	0.341176480054855
Luminance Min	0
Luminance Max	0.980392158031464
Luminance Mean	0.270397782325745
Luminance Standard Deviation	0.234511524438858
Luminance Median	0.243137255311012
Y Min	0
Y Max	0.976470589637756
Y Mean	0.236716106534004
Y Standard Deviation	0.227980986237526
Y Median	0.196078434586525
Cb Min	-0.0450980365276337
Cb Max	-0.00196078419685364
Cb Mean	-0.0298237334936857
Cb Standard Deviation	0.0168844126164913
Cb Median	-0.0372548997402191
Cr Min	-0.00196078419685364
Cr Max	0.123529434204102
Cr Mean	0.0804557129740715
Cr Standard Deviation	0.0502428002655506
Cr Median	0.103921592235565
Red Min WB	1
Red Max WB	252
Red Mean WB	113.806507032224
Red Standard Deviation WB	52.0126491068468
Red Median WB	111
Red Total Count WB	449360
Green Min WB	0
Green Max WB	249
Green Mean WB	60.972747908136
Green Standard Deviation WB	57.2920439382876
Green Median WB	48
Green Total Count WB	449360
Blue Min WB	0
Blue Max WB	249
Blue Mean WB	60.972747908136
Blue Standard Deviation WB	57.2920439382876
Blue Median WB	48
Blue Total Count WB	449360
Saturation Min WB	0.235294118523598
Saturation Max WB	1
Saturation Mean WB	0.43894961476326
Saturation Standard Deviation WB	0.154169782996178
Saturation Median WB	0.396078437566757
Luminance Min WB	0
Luminance Max WB	0.980392158031464
Luminance Mean WB	0.341841757297516
Luminance Standard Deviation WB	0.212376952171326
Luminance Median WB	0.309803932905197
Y Min WB	0
Y Max WB	0.976470589637756
Y Mean WB	0.299260765314102
Y Standard Deviation WB	0.216774046421051
Y Median WB	0.258823543787003
Cb Min WB	-0.0450980365276337
Cb Max WB	-0.00196078419685364
Cb Mean WB	-0.0371856279671192
Cb Standard Deviation WB	0.0100541561841965
Cb Median WB	-0.0411764681339264
Cr Min WB	0.00196081399917603
Cr Max WB	0.123529434204102
Cr Mean WB	0.10223163664341
Cr Standard Deviation WB	0.0303715113550425
Cr Median WB	0.115686297416687

Rank X1 filtered image statistics

Pixels Count	563200
Pixels without black	441456
Red Min	0
Red Max	252
Red Mean	122.136278409091
Red Standard Deviation	87.516547830135
Red Median	121
Red Total Count	563200
Green Min	0
Green Max	249
Green Mean	88.18859375
Green Standard Deviation	85.5399836766261
Green Median	57
Green Total Count	563200
Blue Min	0
Blue Max	249
Blue Mean	88.18859375
Blue Standard Deviation	85.5399836766261
Blue Median	57
Blue Total Count	563200
Saturation Min	0
Saturation Max	1
Saturation Mean	0.30152890086174
Saturation Standard Deviation	0.202493324875832
Saturation Median	0.317647069692612
Luminance Min	0
Luminance Max	0.980392158031464
Luminance Mean	0.411772221326828
Luminance Standard Deviation	0.335566163063049
Luminance Median	0.34901961684227
Y Min	0
Y Max	0.976470589637756
Y Mean	0.384158581495285
Y Standard Deviation	0.334127157926559
Y Median	0.298039227724075
Cb Min	-0.0450980365276337
Cb Max	-0.00196078419685364
Cb Mean	-0.0245320294052362
Cb Standard Deviation	0.0166890006512403
Cb Median	-0.0254901945590973
Cr Min	-0.00196078419685364
Cr Max	0.123529434204102
Cr Mean	0.0646790862083435
Cr Standard Deviation	0.0495649240911007
Cr Median	0.0686274766921997

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 WB	0.105345770716667
Saturation Median WB	0.321568638086319
Luminance Min WB	0
Luminance Max WB	0.980392158031464
Luminance Mean WB	0.621869742870331
LuminanceStandardDeviation WB	0.273765563964844
Luminance Median WB	0.717647075653076
Y Min WB	0
Y Max WB	0.976470589637756
Y Mean WB	0.589839696884155
Y Standard Deviation WB	0.286698818206787
Y Median WB	0.686274528503418
Cb Min WB	-0.0450980365276337
Cb Max WB	-0.00196078419685364
Cb Mean WB	-0.0279822442680597
Cb Standard Deviation WB	0.0134115405380726
Cb Median WB	-0.0254901945590973
Cr Min WB	0.00196081399917603
Cr Max WB	0.123529434204102
Cr Max WB	0.123529434204102
Cr Mean WB	0.0746816620230675
Cr Standard Deviation WB	0.0398297160863876
Cr Median WB	0.0686274766921997
Rank Z1 filtered image statistics	
Pixels Count	573516
Pixels without black	440594
Red Min	0
Red Max	252
Red Mean	124.623138674422
Red Standard Deviation	86.0969667214582
Red Median	130
Red Total Count	573516
Green Min	0
Green Max	249
Green Mean	89.6711966187517
Green Standard Deviation	80.8826837693388
Green Median	66
Green Total Count	573516
Blue Min	0
Blue Max	249
Blue Mean	89.6711966187517
Blue Standard Deviation	80.8826837693388
Blue Median	66
Blue Total Count	573516
Saturation Min	0
Saturation Max	1
Saturation Mean	0.272191524505615
Saturation Standard Deviation	0.184789970517159
Saturation Median	0.298039227724075
Luminance Min	0
Luminance Max	0.980392158031464
Luminance Mean	0.419556379318237
Luminance Standard Deviation	0.323453366756439
Luminance Median	0.384313732385635
Y Min	0
Y Max	0.976470589637756
Y Mean	0.391311198472977
Y Standard Deviation	0.319555670022964
Y Median	0.333333343267441
Cb Min	-0.0450980365276337
Cb Max	-0.00196078419685364
Cb Mean	-0.0252390317618847
Cb Standard Deviation	0.0168824307620525
Cb Median	-0.0294117629528046
Cr Min	-0.00196078419685364
Cr Max	0.123529434204102
Cr Mean	0.066443957388401
Cr Standard Deviation	0.0499764792621136
Cr Median	0.0803921818733215
Red Min WB	1
Red Max WB	252
Red Mean WB	162.220466007254
Red Standard Deviation WB	59.5814731225976
Red Median WB	163
Red Total Count WB	440594
Green Min WB	0
Green Max WB	249
Green Mean WB	116.723936322328
Green Standard Deviation WB	73.1980388120368
Green Median WB	104
Green Total Count WB	440594
Blue Min WB	0
Blue Max WB	249
Blue Mean WB	116.723936322328
Blue Standard Deviation WB	73.1980388120368
Blue Median WB	104
Blue Total Count WB	440594
Saturation Min WB	0.235294118523598
Saturation Max WB	1
Saturation Mean WB	0.354308485984802
Saturation StandardDeviation WB	0.123913042247295
Saturation Median WB	0.317647069692612
Luminance Min WB	0
Luminance Max WB	0.980392158031464
Luminance Mean WB	0.546131551265717
LuminanceStandardDeviationWB	0.258956789970398
Luminance Median WB	0.521568655967712
Y Min WB	0
Y Max WB	0.976470589637756
Y Mean WB	0.509365200996399
Y Standard Deviation WB	0.269796907901764
Y Median WB	0.474509805440903
Cb Min WB	-0.0450980365276337
Cb Max WB	-0.00196078419685364
Cb Mean WB	-0.0322618037462234
Cb Standard Deviation WB	0.0125779723748565
Cb Median WB	-0.0333333313465118
Cr Min WB	0.00196081399917603
Cr Max WB	0.123529434204102
Cr Mean WB	0.0870808660984039
Cr Standard Deviation WB	0.0375980846583843
Cr Median WB	0.0960784554481506

Table 2: Comparison og 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

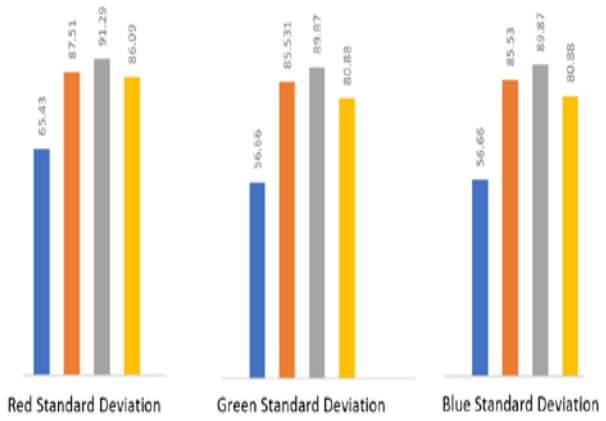


Figure 18: Graph showing textures statistics

VI. Conclusion

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

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