EVALUATION OF BREAST CANCER PROLIFERATION IN A TWO-DIMENSIONAL IMAGE USING SKELETONIZATION TECHNIQUE

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Abstract

Based on the experimental evidence available so far, most of the breast cancer proliferation evaluation methods are not reliable enough to make firm conclusions about their clinical value and use. Unfortunately, none of such recent technologies for cancer proliferation has been tried as a conventional 2D mammography technique. After confirming presence of cancer in a woman's breast, it is important to find out in which direction(s) the cancer is likely to spread. It is in this context, a novel technique to evaluate cancer proliferation using a 2D image skeletonization method is proposed.

Keywords: Breast Cancer, Lactal Carcinoma, 2D Breast Cancer Spread

1. Introduction

Fundamentally, two types of ductal carcinoma are found in women (i) Invasive Ductal Carcinoma (IDC) and (ii) Ductal Carcinoma In Situ (DCIS). DCIS is also known as 'Intraductal Carcinoma'. It is important for a radiologist to analyze 2D mammograms and evaluate the cancer status of a patient without deciding the patient as 'false positive' or 'false negative'. In this context, some kind of a technical support as to how to predict cancer spread in the breast of a patient would be a very valuable tool for a radiologist.

Conventional x-ray scanning of breast yields analog picture, and the image is visualized in an analog monitor. In such a case, the radiologist would be able to visualize the image just like one sees a photographic picture. The cancer spread with reference to the cancer seed, which is usually a calcified area, is seen as a superficial spread, and one cannot attribute directional properties to the superficial spread. This is a major disadvantage for a radiologist to judge the direction of proliferation of cancer.

This paper proposes a novel method of estimating cancer proliferation directions in a 2D mammography image. The central idea on which the method is developed is that 'skeletal form of a growing shape of a 2D digital image indicates the direction of growth'. Breast cancer spreads in all possible directions based on various physiological conditions of the surrounding areas. Purely based on the previous directional spread details, one can predict future spread directions also. This may not give very precise results because future growth not only depends on the present and past status but also on the physiological conditions of the surrounding areas, which are governed by both internal as well as external causal factors. However, for all practical purposes, present and past status based prediction would serve the purpose of predicting future spread directions.

It is in this connection, this paper proposes skeltonization of 2D images and a method of evaluating possible directions in a nine-direction based rectangular digital lattice.

Skeletonization of 2D Images

'Thinning' a 2D image is the reverse process of 2D contouring. Fig. 1 shows a square, a rhombus and an arbitrary shape. Now, operation of thinning is carried out in the respective images and results are also presented in Fig. 1. 'Skeletonization' of an image is essentially a thinning process with the exception that skeletonization retains all corner pixels. Fig. 2 shows a square, a rhombus and an arbitrary shape and the results of skeletonizing them. Given a 2D mammogram, one should be able to skeletonize it in order to detect directions in which the cancer has already grown or spread.

Thinning Based Procedure to Skeletonize a 2D digital image

Given a digital image, scan it with a 3□3 empty window, pixel wise. At each position do the following. Read the image pixels under the scanning window. Find out the largest pixel value (R,G,B) and the smallest value among the nine values. Calculate the difference between the largest and the smallest pixel values. If the difference value is less than or equal to a user defined threshold value then ***remove all boundaries other than corner pixels of the sub image*** scanned by the window and retain the central pixel value. If the difference value is greater than the threshold value then just move the scanning window to the next position. Scan the entire image and do the same

as above. This yields the image thinned by one boundary. Repeat this thinning procedure till the output image does not show up any boundary. Finally, one arrives at the completely thinned image with all boundaries removed. Fig. 3 shows a sample breast cancer image 2D slice of a 3D data, its segmented and binarized version. Fig. 4 shows the isolated skeleton version of breast cancer region and their directions, which show up the cancer proliferation.

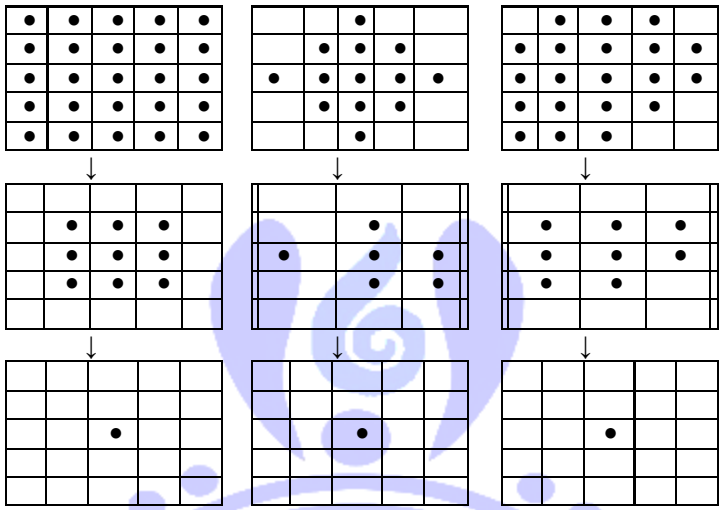


Fig. 1: Thinning process of hypothetical 2D images

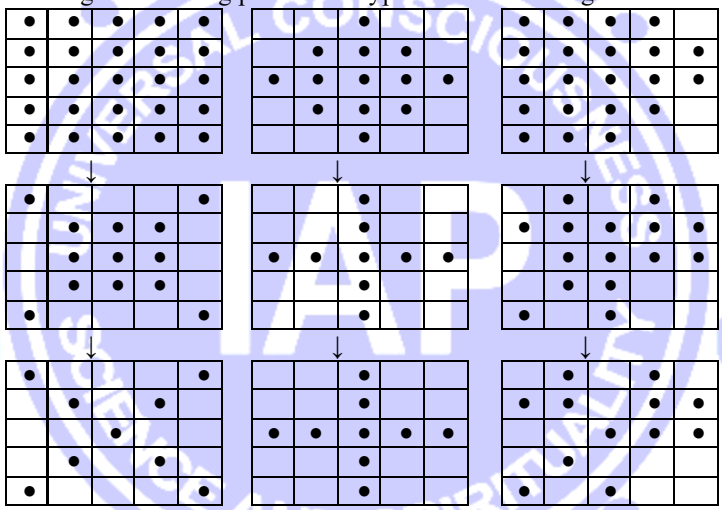
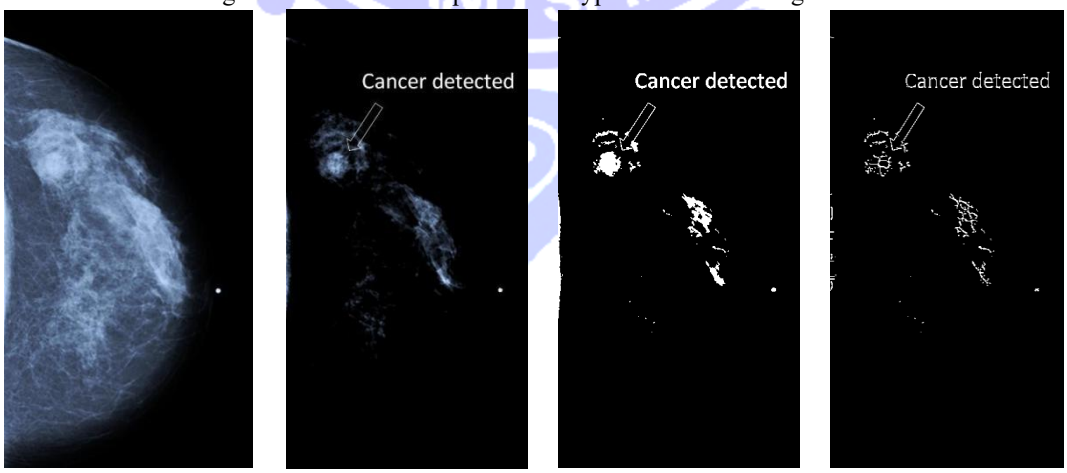
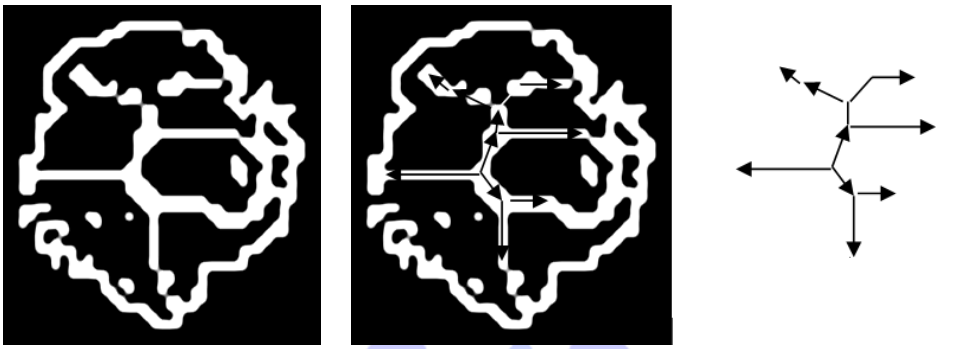


Fig. 2: Skeletonization process of hypothetical 2D images



Tomo-synthesized breast cancer image slice | Segmented image | Binarized and cancer isolated image | Skeletonized Version

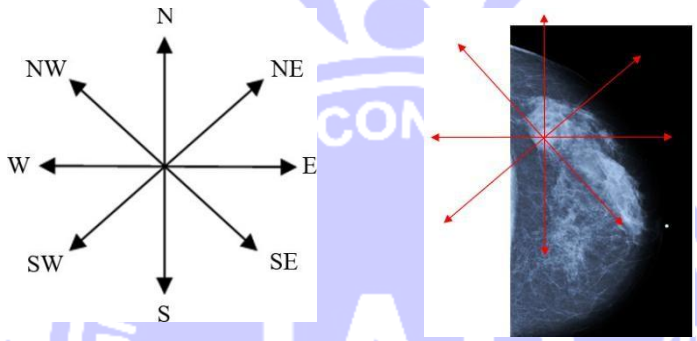
Fig. 3: Sample breast cancer image and its segmented, binarized and skeletonized versions



Cancer isolated | Directions of growth in the cancer region | Directions of growth

Fig. 4: Skeleton of breast cancer and its proliferation directions

In a two dimensional digital image, one can have eight directions from a common point, namely (i) east, (ii) south east, (iii) south, (iv) south west, (v) west, (vi) north west, (vii) north and (viii) north east. Fig. 5 shows these directions.



Eight directions in a digital plane | Possible directions of cancer proliferation

Fig. 5: Eight directions in a digital plane and directions of cancer proliferation

2. Directions of Cancer Proliferation

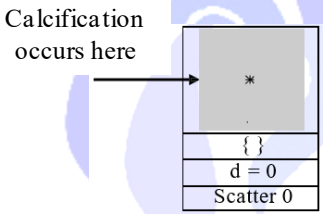
One can expect cancer proliferation in all possible combinations of eight directions.

$^8C_0 = 1$ $^8C_1 = 8$ $^8C_2 = 28$ $^8C_3 = 56$ $^8C_4 = 70$
$^8C_5 = 56$ $^8C_6 = 28$ $^8C_7 = 8$ $^8C_8 = 1$

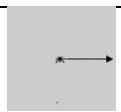
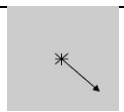
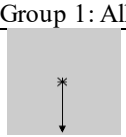
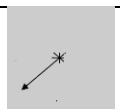
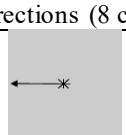
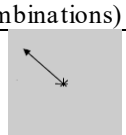
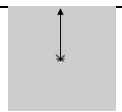
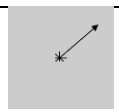
Total number of directions in a 3□3 rectangular lattice $= \sum_{i=0}^{8} {}^8C_i = 256$

All 256 direction patterns (scatters) are presented below under nine groups.

Group 0: No directions (1 combination)



Group 1: All possible one directions (8 combinations)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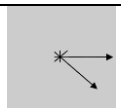
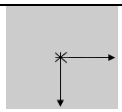
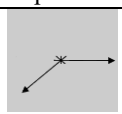
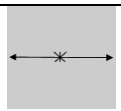
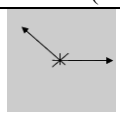
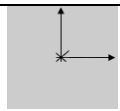
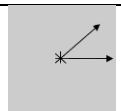
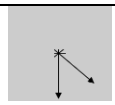
Group 2: All possible two directions (28 combinations)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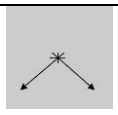	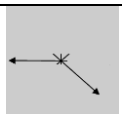	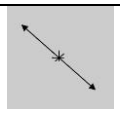	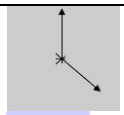	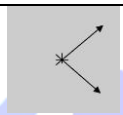	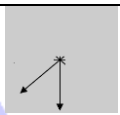	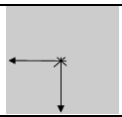	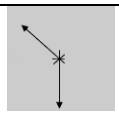
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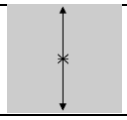	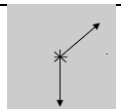	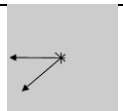	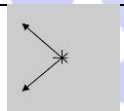	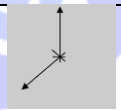	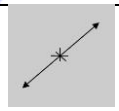	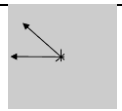	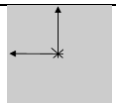
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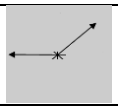	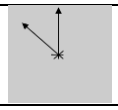	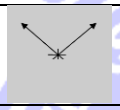	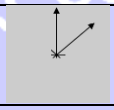				
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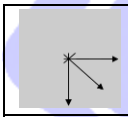
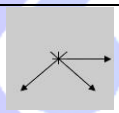
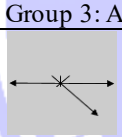
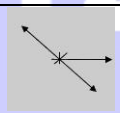
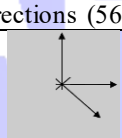
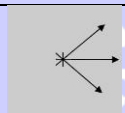
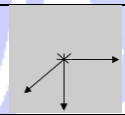
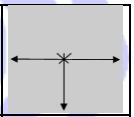
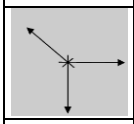
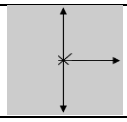
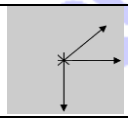
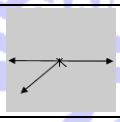
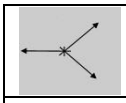
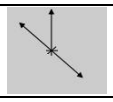
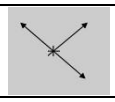
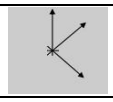
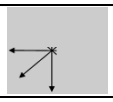
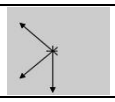
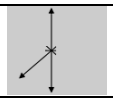
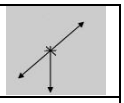
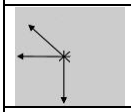
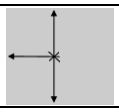
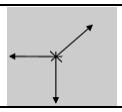
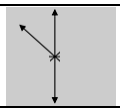
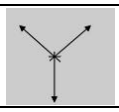
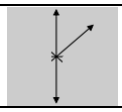
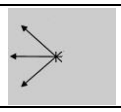
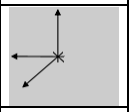
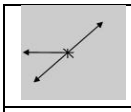
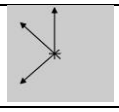
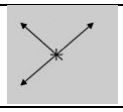
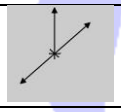
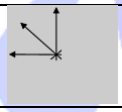
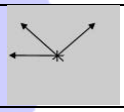
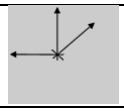
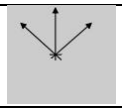
Scatter 33	Scatter 34	Scatter 35	Scatter 36				

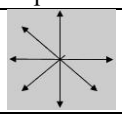
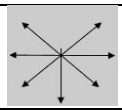
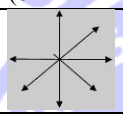
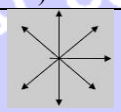
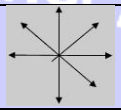
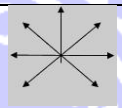
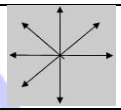
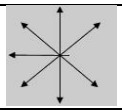
Group 3: All possible three directions (56 combinations)

							
E,SE,S	E,SE,SW	E,SE,W	E,SE,NW	E,SE,N	E,SE,NE	E,S,SW	E,S,W
d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3
Scatter 37	Scatter 38	Scatter 39	Scatter 40	Scatter 41	Scatter 42	Scatter 43	Scatter 44
							
E,S,NW	E,S,N	E,S,NE	E,SW,W	E,SW,NW	E,SW,N	E,SW,NE	E,W,NW
d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3
Scatter 45	Scatter 46	Scatter 47	Scatter 48	Scatter 49	Scatter 50	Scatter 51	Scatter 52
E,W,N	E,W,NE	E,NW,N	E,NW,NE	E,N,NE	SE,S,SW	SE,S,W	SE,S,NW
d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3
Scatter 53	Scatter 54	Scatter 55	Scatter 56	Scatter 57	Scatter 58	Scatter 59	Scatter 60
SE,S,N	SE,S,NE	SE,SW,W	SE,SW,NW	SE,SW,N	SE,SW,NE	SE,W,NW	SE,W,N
d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3
Scatter 61	Scatter 62	Scatter 63	Scatter 64	Scatter 65	Scatter 66	Scatter 67	Scatter 68

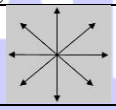
							
SE,W,NE	SE,NW,N	SE,NW,NE	SE,N,NE	S,SW,W	S,SW,NW	S,SW,N	S,SW,NE
d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3
Scatter 69	Scatter 70	Scatter 71	Scatter 72	Scatter 73	Scatter 74	Scatter 75	Scatter 76
							
S,W,NW	S,W,N	S,W,NE	S,NW,N	S,NW,NE	S,N,NE	SW,W,NW	SW,W,N
d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3
Scatter 77	Scatter 78	Scatter 79	Scatter 80	Scatter 81	Scatter 82	Scatter 83	Scatter 84

							
SW,W,NE	SW,NW,N	SW,NW,NE	SW,N,NE	W,NW,N	W,NW,NE	W,N,NE	NW,N,NE
d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3	d = 3
Scatter 85	Scatter 86	Scatter 87	Scatter 88	Scatter 89	Scatter 90	Scatter 91	Scatter 92

As presented above, one can have: Group 4: All possible four directions (70 combinations); Group 5: All possible five directions (56 combinations); Group 6: All possible six directions (28 combinations); Group 7: All possible seven directions (8 combinations)

							
E,SE,S,SW, W,NW,N	E,SE,S,SW, W,NW,NE	E,SE,S,SW, W,N,NE	E,SE,S,SW, NW,N,NE	E,SE,S,W, NW,N,NE	E,SE,SW,W, NW,N,NE	E,S,SW,W, NW,N,NE	SE,S,SW,W, NW,N,NE
d = 7	d = 7	d = 7	d = 7	d = 7	d = 7	d = 7	d = 7
Scatter 247	Scatter 248	Scatter 249	Scatter 250	Scatter 251	Scatter 252	Scatter 253	Scatter 254

Group 8: All possible eight directions (1 combination)


E,SE,S,SW, W,NW,N,NE
d = 8
Scatter 255

One can attribute quantificational measures to all 256 scatter patterns in the following manner. Presence of a direction is denoted by a '1' and absence by a '0'. Hence, one can have 256 binary patterns of length 8 and the corresponding decimal values. These are given in Table 1. Each pattern has a degree, that is number of links (directions) attached to the central node.

Table 1: Binary representations of scatter patterns along with decimal equivalents

Sl. No.	Scatter Number	Degree	North East	North	North West	West	South West	South	South East	East	Decimal Value
1	0	0	0	0	0	0	0	0	0	0	0
2	1	1	0	0	0	0	0	0	0	1	1
3	2	1	0	0	0	0	0	0	1	0	2
4	3	1	0	0	0	0	0	1	0	0	4
5	4	1	0	0	0	0	1	0	0	0	8
6	5	1	0	0	0	1	0	0	0	0	16
7	6	1	0	0	1	0	0	0	0	0	32
8	7	1	0	1	0	0	0	0	0	0	64
9	8	1	1	0	0	0	0	0	0	0	128
10	9	2	0	0	0	0	0	0	1	1	3
11	10	2	0	0	0	0	0	1	0	1	5
12	11	2	0	0	0	0	1	0	0	1	9
13	12	2	0	0	0	1	0	0	0	1	17
14	13	2	0	0	1	0	0	0	0	1	33

15	14	2	0	1	0	0	0	0	0	1	65
16	15	2	1	0	0	0	0	0	0	1	129
17	16	2	0	0	0	0	0	1	1	0	6
18	17	2	0	0	0	0	1	0	1	0	10
19	18	2	0	0	0	1	0	0	1	0	18
20	19	2	0	0	1	0	0	0	1	0	34
21	20	2	0	1	0	0	0	0	1	0	66
22	21	2	1	0	0	0	0	0	1	0	130
23	22	2	0	0	0	0	1	1	0	0	12
24	23	2	0	0	0	1	0	1	0	0	20
25	24	2	0	0	1	0	0	1	0	0	36
26	25	2	0	1	0	0	0	1	0	0	68
27	26	2	1	0	0	0	0	1	0	0	132
28	27	2	0	0	0	1	1	0	0	0	24
29	28	2	0	0	1	0	1	0	0	0	40
30	29	2	0	1	0	0	1	0	0	0	72
31	30	2	1	0	0	0	1	0	0	0	136
32	31	2	0	0	1	1	0	0	0	0	48
33	32	2	0	1	0	1	0	0	0	0	80
34	33	2	1	0	0	1	0	0	0	0	144
35	34	2	0	1	1	0	0	0	0	0	96
36	35	2	1	0	1	0	0	0	0	0	160
37	36	2	1	1	0	0	0	0	0	0	192
38	37	3	0	0	0	0	0	1	1	1	7
39	38	3	0	0	0	0	1	0	1	1	11
40	39	3	0	0	0	1	0	0	1	1	19
41	40	3	0	0	1	0	0	0	1	1	35
42	41	3	0	1	0	0	0	0	1	1	67
43	42	3	1	0	0	0	0	0	1	1	131
44	43	3	0	0	0	0	1	1	0	1	13
45	44	3	0	0	0	1	0	1	0	1	21
46	45	3	0	0	1	0	0	1	0	1	37
47	46	3	0	1	0	0	0	1	0	1	69
48	47	3	1	0	0	0	0	1	0	1	133
49	48	3	0	0	0	1	1	0	0	1	25
50	49	3	0	0	1	0	1	0	0	1	41
51	50	3	0	1	0	0	1	0	0	1	73
52	51	3	1	0	0	0	1	0	0	1	137
53	52	3	0	0	1	1	0	0	0	1	49
54	53	3	0	1	0	1	0	0	0	1	81
55	54	3	1	0	0	1	0	0	0	1	145
56	55	3	0	1	1	0	0	0	0	1	97
57	56	3	1	0	1	0	0	0	0	1	161
58	57	3	1	1	0	0	0	0	0	1	193
59	58	3	0	0	0	0	1	1	1	0	14
60	59	3	0	0	0	1	0	1	1	0	22
61	60	3	0	0	1	0	0	1	1	0	38
62	61	3	0	1	0	0	0	1	1	0	70
63	62	3	1	0	0	0	0	1	1	0	134
64	63	3	0	0	0	1	1	0	1	0	26
65	64	3	0	0	1	0	1	0	1	0	42
66	65	3	0	1	0	0	1	0	1	0	74
67	66	3	1	0	0	0	1	0	1	0	138
68	67	3	0	0	1	1	0	0	1	0	50
69	68	3	0	1	0	1	0	0	1	0	82

70	69	3	1	0	0	1	0	0	1	0	146
71	70	3	0	1	1	0	0	0	1	0	98
72	71	3	1	0	1	0	0	0	1	0	162
73	72	3	1	1	0	0	0	0	1	0	194
74	73	3	0	0	0	1	1	1	0	0	28
75	74	3	0	0	1	0	1	1	0	0	44
76	75	3	0	1	0	0	1	1	0	0	76
77	76	3	1	0	0	0	1	1	0	0	140
78	77	3	0	0	1	1	0	1	0	0	52
79	78	3	0	1	0	1	0	1	0	0	84
80	79	3	1	0	0	1	0	1	0	0	148
81	80	3	0	1	1	0	0	1	0	0	100
82	81	3	1	0	1	0	0	1	0	0	164
83	82	3	1	1	0	0	0	1	0	0	196
84	83	3	0	0	1	1	1	0	0	0	56
85	84	3	0	1	0	1	1	0	0	0	88
86	85	3	1	0	0	1	1	0	0	0	152
87	86	3	0	1	1	0	1	0	0	0	104
88	87	3	1	0	1	0	1	0	0	0	168
89	88	3	1	1	0	0	1	0	0	0	200
90	89	3	0	1	1	1	0	0	0	0	112
91	90	3	1	0	1	1	0	0	0	0	176
92	91	3	1	1	0	1	0	0	0	0	208
93	92	3	1	1	1	0	0	0	0	0	224
94	93	4	0	0	0	0	1	1	1	1	15
95	94	4	0	0	0	1	0	1	1	1	23
96	95	4	0	0	1	0	0	1	1	1	39
97	96	4	0	1	0	0	0	1	1	1	71
98	97	4	1	0	0	0	0	1	1	1	135
99	98	4	0	0	0	1	1	0	1	1	27
100	99	4	0	0	1	0	1	0	1	1	43
101	100	4	0	1	0	0	1	0	1	1	75
102	101	4	1	0	0	0	1	0	1	1	139
103	102	4	0	0	1	1	0	0	1	1	51
104	103	4	0	1	0	1	0	0	1	1	83
105	104	4	1	0	0	1	0	0	1	1	147
106	105	4	0	1	1	0	0	0	1	1	99
107	106	4	1	0	1	0	0	0	1	1	163
108	107	4	1	1	0	0	0	0	1	1	195
109	108	4	0	0	0	1	1	1	0	1	29
110	109	4	0	0	1	0	1	1	0	1	45
111	110	4	0	1	0	0	1	1	0	1	77
112	111	4	1	0	0	0	1	1	0	1	141
113	112	4	0	0	1	1	0	1	0	1	53
114	113	4	0	1	0	1	0	1	0	1	85
115	114	4	1	0	0	1	0	1	0	1	149
116	115	4	0	1	1	0	0	1	0	1	101
117	116	4	1	0	1	0	0	1	0	1	165
118	117	4	1	1	0	0	0	1	0	1	197
119	118	4	0	0	1	1	1	0	0	1	57
120	119	4	0	1	0	1	1	0	0	1	89
121	120	4	1	0	0	1	1	0	0	1	153
122	121	4	0	1	1	0	1	0	0	1	105
123	122	4	1	0	1	0	1	0	0	1	169
124	123	4	1	1	0	0	1	0	0	1	201

125	124	4	0	1	1	1	0	0	0	1	113
126	125	4	1	0	1	1	0	0	0	1	177
127	126	4	1	1	0	1	0	0	0	1	209
128	127	4	1	1	1	0	0	0	0	1	225
129	128	4	0	0	0	1	1	1	1	0	30
130	129	4	0	0	1	0	1	1	1	0	46
131	130	4	0	1	0	0	1	1	1	0	78
132	131	4	1	0	0	0	1	1	1	0	142
133	132	4	0	0	1	1	0	1	1	0	54
134	133	4	0	1	0	1	0	1	1	0	86
135	134	4	1	0	0	1	0	1	1	0	150
136	135	4	0	1	1	0	0	1	1	0	102
137	136	4	1	0	1	0	0	1	1	0	166
138	137	4	1	1	0	0	0	1	1	0	198
139	138	4	0	0	1	1	1	0	1	0	58
140	139	4	0	1	0	1	1	0	1	0	90
141	140	4	1	0	0	1	1	0	1	0	154
142	141	4	0	1	1	0	1	0	1	0	106
143	142	4	1	0	1	0	1	0	1	0	170
144	143	4	1	1	0	0	1	0	1	0	202
145	144	4	0	1	1	1	0	0	1	0	114
146	145	4	1	0	1	1	0	0	1	0	178
147	146	4	1	1	0	1	0	0	1	0	210
148	147	4	1	1	1	0	0	0	1	0	226
149	148	4	0	0	1	1	1	1	0	0	60
150	149	4	0	1	0	1	1	1	0	0	92
151	150	4	1	0	0	1	1	1	0	0	156
152	151	4	0	1	1	0	1	1	0	0	108
153	152	4	1	0	1	0	1	1	0	0	172
154	153	4	1	1	0	0	1	1	0	0	204
155	154	4	0	1	1	1	0	1	0	0	116
156	155	4	1	0	1	1	0	1	0	0	180
157	156	4	1	1	0	1	0	1	0	0	212
158	157	4	1	1	1	0	0	1	0	0	228
159	158	4	0	1	1	1	1	0	0	0	120
160	159	4	1	0	1	1	0	0	0	0	184
161	160	4	1	1	0	1	1	0	0	0	216
162	161	4	1	1	1	0	1	0	0	0	232
163	162	4	1	1	1	1	0	0	0	0	240
164	163	5	0	0	0	1	1	1	1	1	31
165	164	5	0	0	1	0	1	1	1	1	47
166	165	5	0	1	0	0	1	1	1	1	79
167	166	5	1	0	0	0	1	1	1	1	143
168	167	5	0	0	1	1	0	1	1	1	55
169	168	5	0	1	0	1	0	1	1	1	87
170	169	5	1	0	0	1	0	1	1	1	151
171	170	5	0	1	1	0	0	1	1	1	103
172	171	5	1	0	1	0	0	1	1	1	167
173	172	5	1	1	0	0	0	1	1	1	199
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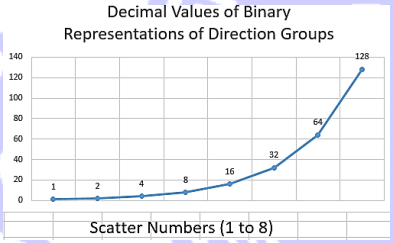
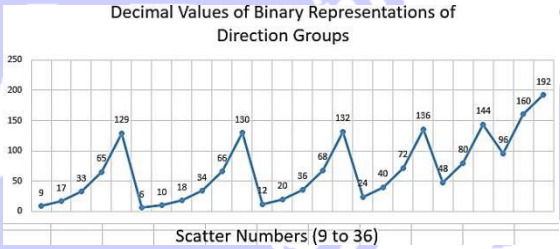
176	175	5	1	0	0	1	1	0	1	1	155
177	176	5	0	1	1	0	1	0	1	1	107

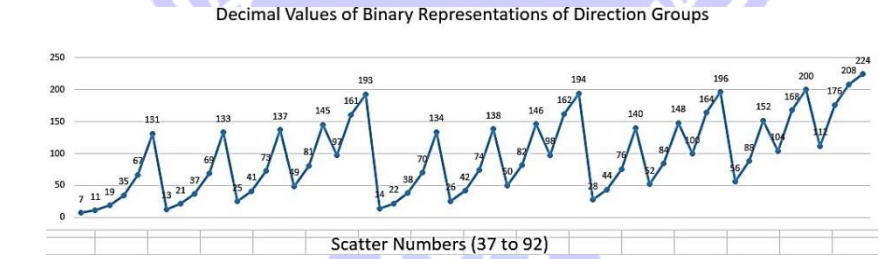
178	177	5	1	0	1	0	1	0	1	1	171
179	178	5	1	1	0	0	1	0	1	1	203
180	179	5	0	1	1	1	0	0	1	1	115
181	180	5	1	0	1	1	0	0	1	1	179
182	181	5	1	1	0	1	0	0	1	1	211
183	182	5	1	1	1	0	0	0	1	1	227
184	183	5	0	0	1	1	1	1	0	1	61
185	184	5	0	1	0	1	1	1	0	1	93
186	185	5	1	0	0	1	1	1	0	1	157
187	186	5	0	1	1	0	1	1	0	1	109
188	187	5	1	0	1	0	1	1	0	1	173
189	188	5	1	1	0	0	1	1	0	1	205
190	189	5	0	1	1	1	0	1	0	1	117
191	190	5	1	0	1	1	0	1	0	1	181
192	191	5	1	1	0	1	0	1	0	1	213
193	192	5	1	1	1	0	0	1	0	1	229
194	193	5	0	1	1	1	1	0	0	1	121
195	194	5	1	0	1	1	1	0	0	1	185
196	195	5	1	1	0	1	1	0	0	1	217
197	196	5	1	1	1	0	1	0	0	1	233
198	197	5	1	1	1	1	0	0	0	1	241
199	198	5	0	0	1	1	1	1	1	0	62
200	199	5	0	1	0	1	1	1	1	0	94
201	200	5	1	0	0	1	1	1	1	0	158
202	201	5	0	1	1	0	1	1	1	0	110
203	202	5	1	0	1	0	1	1	1	0	174
204	203	5	1	1	0	0	1	1	1	0	206
205	204	5	0	1	1	1	0	1	1	0	118
206	205	5	1	0	1	1	0	1	1	0	182
207	206	5	1	1	0	1	0	1	1	0	214
208	207	5	1	1	1	0	0	1	1	0	230
209	208	5	0	1	1	1	1	0	1	0	122
210	209	5	1	0	1	1	1	0	1	0	186
211	210	5	1	1	0	1	1	0	1	0	218
212	211	5	1	1	1	0	1	0	1	0	234
213	212	5	1	1	1	1	0	0	1	0	242
214	213	5	0	1	1	1	1	1	0	0	124
215	214	5	1	0	1	1	1	1	0	0	188
216	215	5	1	1	0	1	1	1	0	0	220
217	216	5	1	1	1	0	1	1	0	0	236
218	217	5	1	1	1	1	0	1	0	0	244
219	218	5	1	1	1	1	1	0	0	0	248
220	219	6	0	0	1	1	1	1	1	1	63
221	220	6	0	1	0	1	1	1	1	1	95
222	221	6	1	0	0	1	1	1	1	1	159
223	222	6	0	1	1	0	1	1	1	1	111
224	223	6	1	0	1	0	1	1	1	1	175
225	224	6	1	1	0	0	1	1	1	1	207
226	225	6	0	1	1	1	0	1	1	1	119
227	226	6	1	0	1	1	0	1	1	1	183
228	227	6	1	1	0	1	0	1	1	1	215
229	228	6	1	1	1	0	0	1	1	1	231
230	229	6	0	1	1	1	1	0	1	1	123
231	230	6	1	0	1	1	1	0	1	1	187
232	231	6	1	1	0	1	1	0	1	1	219
233	232	6	1	1	1	0	1	0	1	1	235

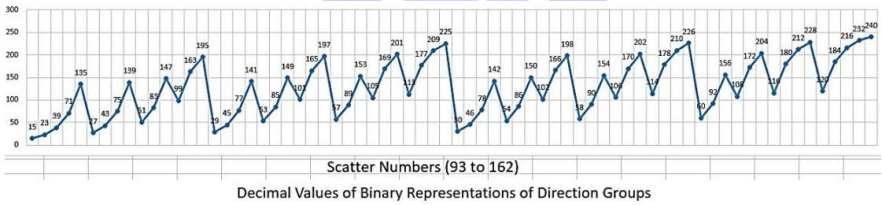
234	233	6	1	1	1	1	0	0	1	1	243
235	234	6	0	1	1	1	1	1	0	1	125
236	235	6	1	0	1	1	1	1	0	1	189
237	236	6	1	1	0	1	1	1	0	1	221
238	237	6	1	1	1	0	1	1	0	1	237
239	238	6	1	1	1	1	0	1	0	1	245
240	239	6	1	1	1	1	1	0	0	1	249
241	240	6	0	1	1	1	1	1	1	0	126
242	241	6	1	0	1	1	1	1	1	0	190
243	242	6	1	1	0	1	1	1	1	0	222
244	243	6	1	1	1	0	1	1	1	0	238
245	244	6	1	1	1	1	0	1	1	0	246
246	245	6	1	1	1	1	1	0	1	0	250
247	246	6	1	1	1	1	1	1	0	0	252
248	247	7	0	1	1	1	1	1	1	1	127
249	248	7	1	0	1	1	1	1	1	1	191
250	249	7	1	1	0	1	1	1	1	1	223
251	250	7	1	1	1	0	1	1	1	1	239
252	251	7	1	1	1	1	0	1	1	1	247
253	252	7	1	1	1	1	1	0	1	1	251
254	253	7	1	1	1	1	1	1	0	1	253
255	254	7	1	1	1	1	1	1	1	0	254
256	255	8	1	1	1	1	1	1	1	1	255

The decimal representations of scatter patterns are presented in the form of graphs.

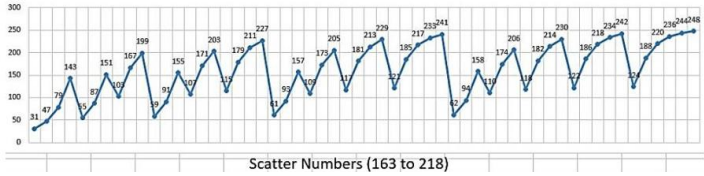








Decimal Values of Binary Representations of Direction Groups



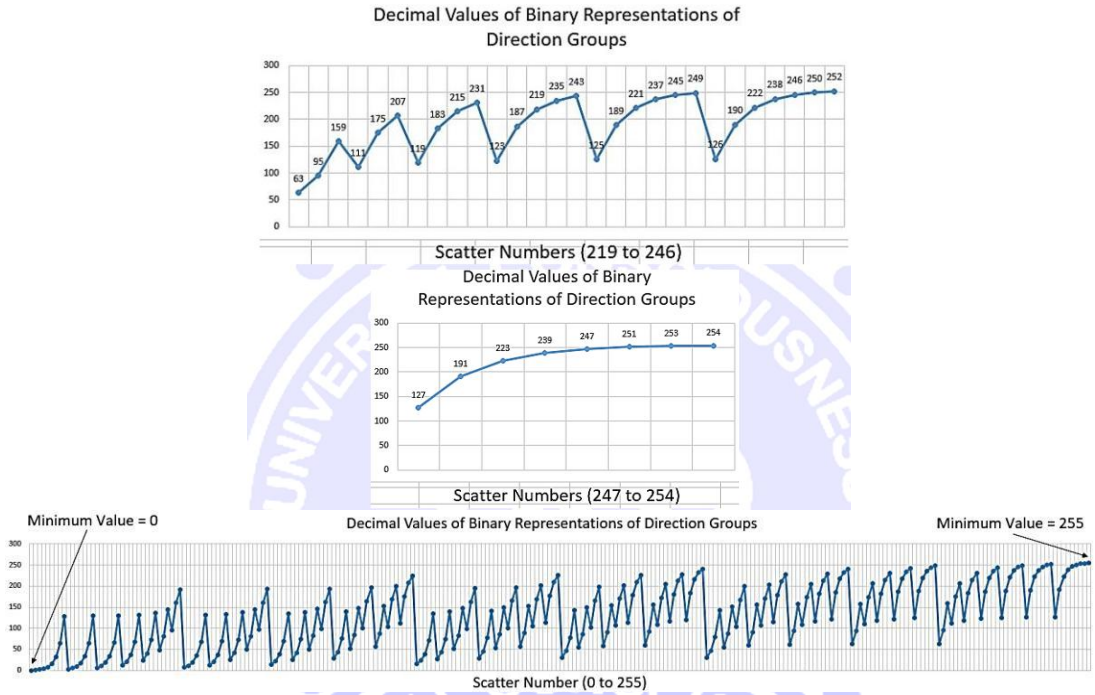


Fig. 6: Graph showing all decimal equivalents of scatter patterns 1 to 254

Scatter Number	Decimal Representation	Maximum Angle Between Adjacent Directions	Degree	Maximum Angle Between Adjacent Directions (in a segment)	Proliferation Direction	Lactal Carcinoma Stage
0	0	0°	0	0°	No Proliferation	0
1	1	360°	1	360°	East Spread	I
2	2	360°	1	360°	South East Spread	I
3	4	360°	1	360°	South Spread	I
4	8	360°	1	360°	South West Spread	I
5	16	360°	1	360°	West Spread	I
6	32	360°	1	360°	North West Spread	I
7	64	360°	1	360°	North Spread	I
8	128	360°	1	360°	North East Spread	I
9	3	315°	2	315°	East - South East Spread	IA
10	5	270°	2			
11	9	225°	2			
12	17	180°	2			
13	33	225°	2			
14	65	270°	2			
15	129	315°	2	315°	North East – East Spread	IA
16	6	315°	2	315°	South East – South Spread	IA
17	10	270°	2			
18	18	225°	2			
19	34	180°	2			
20	66	225°	2			
21	130	270°	2			
22	12	315°	2	315°	South – South West Spread	IA
23	20	270°	2			
24	36	225°	2			
25	68	180°	2			
26	132	225°	2			
27	24	315°	2	315°	South West – West Spread	IA
28	40	270°	2			
29	72	225°	2			
30	136	180°	2			
31	48	315°	2	315°	West – North West Spread	IA
32	80	270°	2			
33	144	225°	2			
34	96	315°	2	315°	North West – North Spread	IA
35	160	270°	2			IA
36	192	315°	2	315°	North – North East Spread	IA
37	7	270°	3	270°	East – South Spread	II

38	11	225°	3			
39	19	180°	3			
40	35	180°	3			
41	67	225°	3			
42	131	270°	3	270°	North East – South East Spread	II
43	13	225°	3			
44	21	180°	3			
45	37	135°	3			
46	69	180°	3			
47	133	225°	3			
48	25	180°	3			
49	41	135°	3			
50	73	135°	3			
51	137	180°	3			
52	49	180°	3			
53	81	180°	3			
54	145	180°	3			
55	97	225°	3			
56	161	225°	3			
57	193	270°	3	270°	North – East Spread	II
58	14	270°	3	270°	South East – South West Spread	II
59	22	225°	3			
60	38	180°	3			
61	70	180°	3			
62	134	225°	3			
63	26	225°	3			
64	42	180°	3			
65	74	135°	3			
66	138	180°	3			
67	50	180°	3			
68	82	135°	3			
69	146	135°	3			
70	98	180°	3			
71	162	180°	3			
72	194	225°	3			
73	28	270°	3	270°	South – West Spread	II
74	44	225°	3			
75	76	180°	3			
76	140	180°	3			
77	52	225°	3			
78	84	180°	3			
79	148	135°	3			
80	100	180°	3			
81	164	135°	3			
82	196	180°	3			
83	56	270°	3	270°	South West – North West Spread	II
84	88	225°	3			
85	152	180°	3			
86	104	225°	3			
87	168	180°	3			
88	200	180°	3			
89	112	270°	3	270°	West - North Spread	II
90	176	225°	3			
91	208	225°	3			
92	224	270°	3	270°	North West – North East Spread	II
93	15	225°	4	225°	East – South West Spread	**IIA**
94	23	180°				
95	39	135°	4			
96	71	180°	4			
97	135	225°	4	225°	North East – South Spread	**IIA**
98	27	180°	4			
99	43	135°	4			
100	75	135°	4			
101	139	180°	4			
102	51	135°	4			
103	83	135°	4			

104	147	135°	4			
105	99	180°	4			
106	163	180°	4			
107	195	225°	4	225°	North – South East Spread	IIA
108	29	180°	4			
109	45	135°	4			
110	77	135°	4			
111	141	180°	4			
112	53	135°	4			
113	85	90°	4			
114	149	135°	4			
115	101	135°	4			
116	165	135°	4			
117	197	180°	4			
118	57	135°	4			
119	89	135°	4			
120	153	135°	4			
121	105	135°	4			
122	169	135°	4			
123	201	135°	4			
124	113	180°	4			
125	177	180°	4			
126	209	180°	4			
127	225	225°	4	225°	North West – East Spread	IIA
128	30	225°	4	225°	South East – West Spread	IIA
129	46	180°	4			
130	78	135°	4			
131	142	180°	4			
132	54	180°	4			
133	86	135°	4			
134	150	135°	4			
135	102	135°	4			
136	166	135°	4			
137	198	180°	4			
138	58	180°	4			
139	90	135°	4			
140	154	135°	4			
141	106	135°	4			
142	170	90°	4			
143	202	135°	4			
144	114	135°	4			
145	178	135°	4			
146	210	135°	4			
147	226	180°	4			
148	60	225°	4	225°	South – North West Spread	IIA
149	92	180°	4			
150	156	135°	4			
151	108	180°	4			
152	172	135°	4			
153	204	135°	4			
154	116	180°	4			
155	180	135°	4			
156	212	135°	4			
157	228	135°	4			
158	120	225°	4	225°	South West – North Spread	IIA
159	184	180°	4			
160	216	180°	4			
161	232	180°	4			
162	240	225°	4	225°	West – North East Spread	IIA
163	31	180°	5	180°	East – West Spread	IIB
164	47	135°	5			
165	79	135°	5			
166	143	180°	5	180°	North East – South West Spread	IIB
167	55	135°	5			
168	87	90°	5			
169	151	135°	5			
170	103	135°	5			
171	167	135°	5			
172	199	180°	5	180°	North – South Spread	IIB

173	59	135°	5			
174	91	90°	5			
175	155	135°	5			
176	107	90°	5			
177	171	90°	5			
178	203	135°	5			
179	115	135°	5			
180	179	135°	5			
181	211	135°	5			
182	227	180°	5	180°	North West – South East Spread	IIB
183	61	135°	5			
184	93	90°	5			
185	157	135°	5			
186	109	90°	5			
187	173	90°	5			
188	205	135°	5			
189	117	90°	5			
190	181	90°	5			
191	213	90°	5			
192	229	135°	5			
193	121	135°	5			
194	185	135°	5			
195	217	135°	5			
196	233	135°	5			
197	241	180°	5	180°	West - East Spread	IIB
198	62	180°	5	180°	South East – North West Spread	IIB
199	94	135°	5			
200	158	135°	5			
201	110	135°	5			
202	174	90°	5			
203	206	135°	5			
204	118	135°	5			
205	182	90°	5			
206	214	90°	5			
207	230	135°	5			
208	122	135°	5			
209	186	90°	5			
210	218	90°	5			
211	234	90°	5			
212	242	135°	5			
213	124	180°	5	180°	South – North Spread	IIB
214	188	135°	5			
215	220	135°	5			
216	236	135°	5			
217	244	135°	5			
218	248	180°	5	180°	South West – North East Spread	IIB
219	63	135°	6	135°	East – North West Spread	III
220	95	90°	6			
221	159	90°	6			
222	111	90°	6			
223	175	90°	6			
224	207	135°	6	135°	North – South West Spread	III
225	119	90°	6			
226	183	90°	6			
227	215	90°	6			
228	231	135°	6	135°	North West – South Spread	III
229	123	90°	6			
230	187	90°	6			
231	219	90°	6			
232	235	90°	6			
233	243	135°	6	135°	West – North East Spread	III
234	125	90°	6			
235	189	90°	6			
236	221	90°	6			
237	237	90°	6			
238	245	90°	6			
239	249	135°	6	135°	South West – East Spread	III

240	126	135°	6	135°	South East – North Spread	III
241	190	90°	6			
242	222	90°	6			
243	238	90°	6			
244	246	90°	6			
245	250	90°	6			
246	252	135°	6	135°	South – North East Spread	III
247	127	90°	7	90°	East – North Spread	IIIA
248	191	90°	7	90°	North East – North West Spread	IIIA
249	223	90°	7	90°	North – West Spread	IIIA
250	239	90°	7	90°	North West – South West Spread	IIIA
251	247	90°	7	90°	West – South Spread	IIIA
252	251	90°	7	90°	South West – South East Spread	IIIA
253	253	90°	7	90°	South - East Spread	IIIA
254	254	90°	7	90°	South East – North East Spread	IIIA
255	255	45°	8	45°	All Directions	IV

3. Conclusions

Given a two-dimensional scanned image of female breast, one can evaluate the present cancer proliferation status using the novel technique introduced in this chapter. Skeletonization algorithm is used for this purpose. Unfortunately, this technique is not enough to precisely evaluate cancer proliferation since this technique deals with two dimensional images only. Alternatively, if one uses the same technique for evaluating cancer proliferation in a **three-dimensional image**, then the study would be highly fruitful.

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References

1. A. J. Mendez, P. G. Tahoces, M. J. Lado, M. Souto, and J. J. Vidal, “Computer-aided diagnosis: Automatic detection of malignant masses in digitized mammograms,” Med Phys., vol. 25, pp. 957–64, Jun. 1998.
2. J. Tang, R. Rangayyan, J. Xu, I. E. Naqa, and Y. Yang, “Computer aided detection and diagnosis of breast cancer with mammography: Recent advances,” IEEE Trans. Inf. Technol. Biomed., vol. 13, no. 2, pp. 236–251, Mar. 2009.
3. M. Ladekarl, “Objective malignancy grading: A review emphasizing unbiased stereology applied to breast tumors,” APMIS Suppl., vol. 79, pp. 1–34, 1998.
4. T. M. Haygood, G. J. Whitman, E. N. Atkinson, R. G. Nikolova, S. Y. Sandoval, and P. J. Dempsey, “Results of a survey on digital screening mammography: Prevalence, efficiency, and use of ancillary diagnostic AIDS,” J. Amer. Coll. Radiol., vol. 5, pp. 585–92, Apr. 2008.
5. R. Schulz-Wendtland, K. P. Hermann, T.Wacker, and W. Bautz, “Current situation and future perspectives of digital mammography,” Radiologe, vol. 48, pp. 324–34, Apr. 2008.

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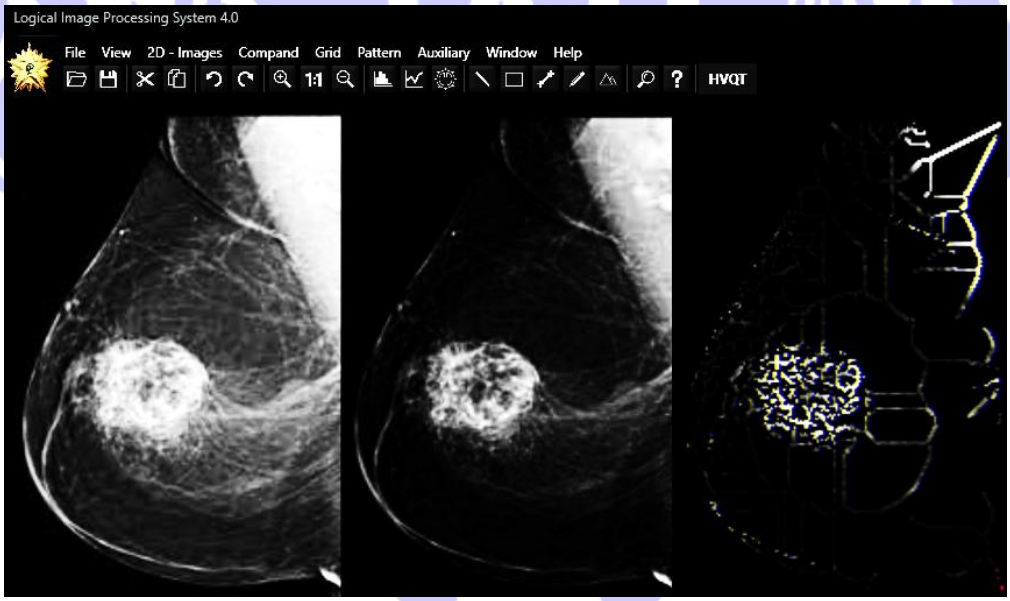

Breast cancer detected Cancer regions isolated Cancer proliferation detected