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ECE 4310
Lab3
Fall 2022

In this lab thinning and branchpoint and end endpoint detection techniques were used to recognize letters in an image of text.

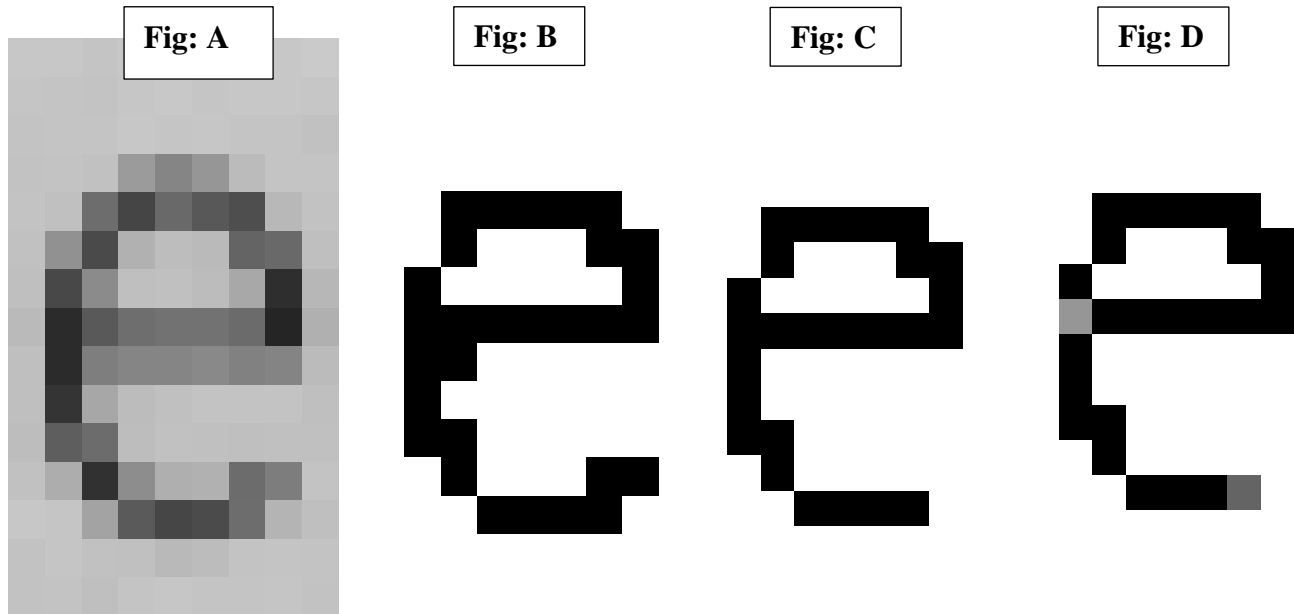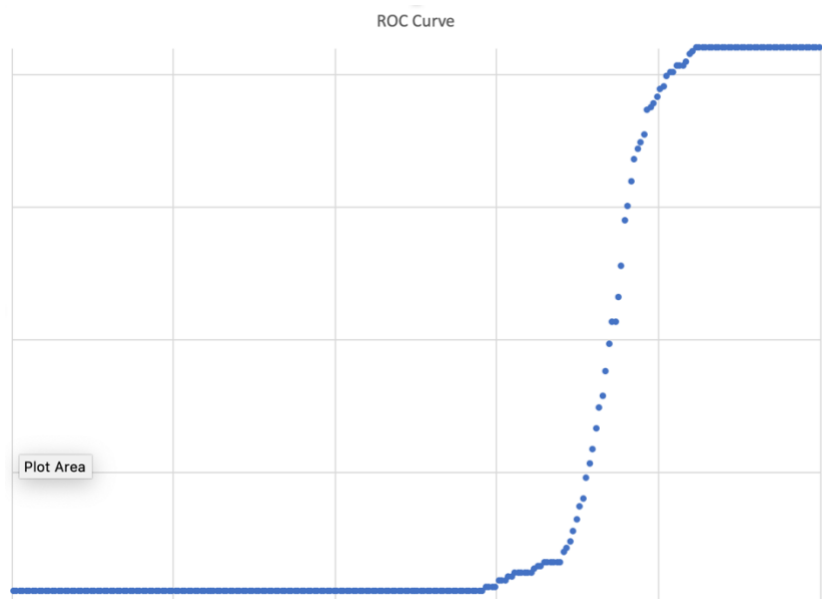**Fig: A**   **Fig: B**   **Fig: C**   **Fig: D**

Figure A shows the pixel image extracted from the original image. Figure B shows the binary extracted image (step iv). Figure C shows the image after thinning (step v) and Figure D shows the detection of branchpoints and endpoints (step vi) where the branch points are shown as lighter grey and endpoints as darker grey. Here is an output confirming the branchpoints and endpoints were equal to 1 for this letter.

For letter e, the number of branch points is 1 and endpoints is 1

To the right is the ROC curve generated given the output of the program:

ROC Curve

Plot Area

For this lab, I chose the optimal threshold value to be 203. Below are the TP and FP values at this threshold

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Threshold = 203              TP = 100                    FP = 7
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Below is the output of all values for the different thresholds.

Threshold = 0	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 1	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 2	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 3	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 4	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 5	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 6	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 7	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 8	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 9	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 10	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 11	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 12	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
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Threshold = 14	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 15	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 16	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			

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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
Threshold = 31	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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Threshold = 49	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			

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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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Threshold = 70	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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Threshold = 77	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			

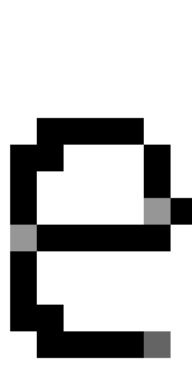|				
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
Threshold = 100	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 101	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 102	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			

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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
Threshold = 118	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 119	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
Threshold = 120	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
Threshold = 133	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			

Threshold = 134	TP = 102	FP = 154	FN = 49	TN = 957
TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.139			
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TPR = 0.675	FPR = 0.138			
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TPR = 0.675	FPR = 0.138			
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TPR = 0.675	FPR = 0.138			
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TPR = 0.675	FPR = 0.138			
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TPR = 0.675	FPR = 0.136			
Threshold = 153	TP = 102	FP = 150	FN = 49	TN = 961
TPR = 0.675	FPR = 0.135			
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TPR = 0.675	FPR = 0.134			
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TPR = 0.675	FPR = 0.134			
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TPR = 0.675	FPR = 0.134			
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TPR = 0.675	FPR = 0.134			
Threshold = 161	TP = 102	FP = 148	FN = 49	TN = 963
TPR = 0.675	FPR = 0.133			

Threshold = 162	TP = 102	FP = 147	FN = 49	TN = 964
TPR = 0.675	FPR = 0.132		
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TPR = 0.675	FPR = 0.132		
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TPR = 0.675	FPR = 0.131		
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TPR = 0.675	FPR = 0.131		
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TPR = 0.675	FPR = 0.131		
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TPR = 0.675	FPR = 0.131		
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TPR = 0.675	FPR = 0.129		
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TPR = 0.675	FPR = 0.128		
Threshold = 172	TP = 102	FP = 140	FN = 49	TN = 971
TPR = 0.675	FPR = 0.126		
Threshold = 173	TP = 102	FP = 137	FN = 49	TN = 974
TPR = 0.675	FPR = 0.123		
Threshold = 174	TP = 102	FP = 134	FN = 49	TN = 977
TPR = 0.675	FPR = 0.121		
Threshold = 175	TP = 102	FP = 130	FN = 49	TN = 981
TPR = 0.675	FPR = 0.117		
Threshold = 176	TP = 102	FP = 128	FN = 49	TN = 983
TPR = 0.675	FPR = 0.115		
Threshold = 177	TP = 102	FP = 122	FN = 49	TN = 989
TPR = 0.675	FPR = 0.110		
Threshold = 178	TP = 102	FP = 118	FN = 49	TN = 993
TPR = 0.675	FPR = 0.106		
Threshold = 179	TP = 102	FP = 114	FN = 49	TN = 997
TPR = 0.675	FPR = 0.103		
Threshold = 180	TP = 102	FP = 108	FN = 49	TN = 1003
TPR = 0.675	FPR = 0.097		
Threshold = 181	TP = 102	FP = 102	FN = 49	TN = 1009
TPR = 0.675	FPR = 0.092		
Threshold = 182	TP = 102	FP = 99	FN = 49	TN = 1012
TPR = 0.675	FPR = 0.089		
Threshold = 183	TP = 102	FP = 92	FN = 49	TN = 1019
TPR = 0.675	FPR = 0.083		
Threshold = 184	TP = 102	FP = 84	FN = 49	TN = 1027
TPR = 0.675	FPR = 0.076		
Threshold = 185	TP = 102	FP = 78	FN = 49	TN = 1033
TPR = 0.675	FPR = 0.070		
Threshold = 186	TP = 102	FP = 78	FN = 49	TN = 1033
TPR = 0.675	FPR = 0.070		
Threshold = 187	TP = 102	FP = 71	FN = 49	TN = 1040
TPR = 0.675	FPR = 0.064		
Threshold = 188	TP = 102	FP = 62	FN = 49	TN = 1049
TPR = 0.675	FPR = 0.056		
Threshold = 189	TP = 102	FP = 49	FN = 49	TN = 1062
TPR = 0.675	FPR = 0.044		

Threshold = 190   TP = 102   FP = 45   FN = 49   TN = 1066
        TPR = 0.675   FPR = 0.041
Threshold = 191   TP = 102   FP = 38   FN = 49   TN = 1073
        TPR = 0.675   FPR = 0.034
Threshold = 192   TP = 102   FP = 32   FN = 49   TN = 1079
        TPR = 0.675   FPR = 0.029
Threshold = 193   TP = 102   FP = 29   FN = 49   TN = 1082
        TPR = 0.675   FPR = 0.026
Threshold = 194   TP = 102   FP = 27   FN = 49   TN = 1084
        TPR = 0.675   FPR = 0.024
Threshold = 195   TP = 102   FP = 25   FN = 49   TN = 1086
        TPR = 0.675   FPR = 0.023
Threshold = 196   TP = 102   FP = 18   FN = 49   TN = 1093
        TPR = 0.675   FPR = 0.016
Threshold = 197   TP = 102   FP = 17   FN = 49   TN = 1094
        TPR = 0.675   FPR = 0.015
Threshold = 198   TP = 102   FP = 16   FN = 49   TN = 1095
        TPR = 0.675   FPR = 0.014
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        TPR = 0.675   FPR = 0.013
Threshold = 200   TP = 101   FP = 12   FN = 50   TN = 1099
        TPR = 0.669   FPR = 0.011
Threshold = 201   TP = 101   FP = 11   FN = 50   TN = 1100
        TPR = 0.669   FPR = 0.010
Threshold = 202   TP = 101   FP = 8   FN = 50   TN = 1103
        TPR = 0.669   FPR = 0.007
Threshold = 203   TP = 100   FP = 7   FN = 51   TN = 1104
        TPR = 0.662   FPR = 0.006
Threshold = 204   TP = 99   FP = 7   FN = 52   TN = 1104   TPR = 0.656   FPR = 0.006
Threshold = 205   TP = 98   FP = 5   FN = 53   TN = 1106   TPR = 0.649   FPR = 0.005
Threshold = 206   TP = 98   FP = 5   FN = 53   TN = 1106   TPR = 0.649   FPR = 0.005
Threshold = 207   TP = 97   FP = 5   FN = 54   TN = 1106   TPR = 0.642   FPR = 0.005
Threshold = 208   TP = 96   FP = 4   FN = 55   TN = 1107   TPR = 0.636   FPR = 0.004
Threshold = 209   TP = 95   FP = 2   FN = 56   TN = 1109   TPR = 0.629   FPR = 0.002
Threshold = 210   TP = 95   FP = 1   FN = 56   TN = 1110   TPR = 0.629   FPR = 0.001
Threshold = 211   TP = 95   FP = 0   FN = 56   TN = 1111   TPR = 0.629   FPR = 0.000
Threshold = 212   TP = 94   FP = 0   FN = 57   TN = 1111   TPR = 0.623   FPR = 0.000
Threshold = 213   TP = 93   FP = 0   FN = 58   TN = 1111   TPR = 0.616   FPR = 0.000
Threshold = 214   TP = 90   FP = 0   FN = 61   TN = 1111   TPR = 0.596   FPR = 0.000
Threshold = 215   TP = 90   FP = 0   FN = 61   TN = 1111   TPR = 0.596   FPR = 0.000
Threshold = 216   TP = 88   FP = 0   FN = 63   TN = 1111   TPR = 0.583   FPR = 0.000
Threshold = 217   TP = 86   FP = 0   FN = 65   TN = 1111   TPR = 0.570   FPR = 0.000

Threshold = 218   TP = 82   FP = 0   FN = 69   TN = 1111   TPR =
0.543   FPR = 0.000
Threshold = 219   TP = 82   FP = 0   FN = 69   TN = 1111   TPR =
0.543   FPR = 0.000
Threshold = 220   TP = 80   FP = 0   FN = 71   TN = 1111   TPR =
0.530   FPR = 0.000
Threshold = 221   TP = 79   FP = 0   FN = 72   TN = 1111   TPR =
0.523   FPR = 0.000
Threshold = 222   TP = 75   FP = 0   FN = 76   TN = 1111   TPR =
0.497   FPR = 0.000
Threshold = 223   TP = 72   FP = 0   FN = 79   TN = 1111   TPR =
0.477   FPR = 0.000
Threshold = 224   TP = 70   FP = 0   FN = 81   TN = 1111   TPR =
0.464   FPR = 0.000
Threshold = 225   TP = 69   FP = 0   FN = 82   TN = 1111   TPR =
0.457   FPR = 0.000
Threshold = 226   TP = 64   FP = 0   FN = 87   TN = 1111   TPR =
0.424   FPR = 0.000
Threshold = 227   TP = 61   FP = 0   FN = 90   TN = 1111   TPR =
0.404   FPR = 0.000
Threshold = 228   TP = 55   FP = 0   FN = 96   TN = 1111   TPR =
0.364   FPR = 0.000
Threshold = 229   TP = 52   FP = 0   FN = 99   TN = 1111   TPR =
0.344   FPR = 0.000
Threshold = 230   TP = 48   FP = 0   FN = 103   TN = 1111
    TPR = 0.318   FPR = 0.000
Threshold = 231   TP = 45   FP = 0   FN = 106   TN = 1111
    TPR = 0.298   FPR = 0.000
Threshold = 232   TP = 43   FP = 0   FN = 108   TN = 1111
    TPR = 0.285   FPR = 0.000
Threshold = 233   TP = 39   FP = 0   FN = 112   TN = 1111
    TPR = 0.258   FPR = 0.000
Threshold = 234   TP = 34   FP = 0   FN = 117   TN = 1111
    TPR = 0.225   FPR = 0.000
Threshold = 235   TP = 30   FP = 0   FN = 121   TN = 1111
    TPR = 0.199   FPR = 0.000
Threshold = 236   TP = 29   FP = 0   FN = 122   TN = 1111
    TPR = 0.192   FPR = 0.000
Threshold = 237   TP = 28   FP = 0   FN = 123   TN = 1111
    TPR = 0.185   FPR = 0.000
Threshold = 238   TP = 24   FP = 0   FN = 127   TN = 1111
    TPR = 0.159   FPR = 0.000
Threshold = 239   TP = 23   FP = 0   FN = 128   TN = 1111
    TPR = 0.152   FPR = 0.000
Threshold = 240   TP = 21   FP = 0   FN = 130   TN = 1111
    TPR = 0.139   FPR = 0.000
Threshold = 241   TP = 18   FP = 0   FN = 133   TN = 1111
    TPR = 0.119   FPR = 0.000
Threshold = 242   TP = 17   FP = 0   FN = 134   TN = 1111
    TPR = 0.113   FPR = 0.000
Threshold = 243   TP = 16   FP = 0   FN = 135   TN = 1111
    TPR = 0.106   FPR = 0.000
Threshold = 244   TP = 13   FP = 0   FN = 138   TN = 1111
    TPR = 0.086   FPR = 0.000
Threshold = 245   TP = 10   FP = 0   FN = 141   TN = 1111
    TPR = 0.066   FPR = 0.000

Threshold = 246	TP = 9	FP = 0	FN = 142	TN = 1111
TPR = 0.060		FPR = 0.000		
Threshold = 247	TP = 6	FP = 0	FN = 145	TN = 1111
TPR = 0.040		FPR = 0.000		
Threshold = 248	TP = 5	FP = 0	FN = 146	TN = 1111
TPR = 0.033		FPR = 0.000		
Threshold = 249	TP = 4	FP = 0	FN = 147	TN = 1111
TPR = 0.026		FPR = 0.000		
Threshold = 250	TP = 0	FP = 0	FN = 151	TN = 1111
TPR = 0.000		FPR = 0.000		
Threshold = 251	TP = 0	FP = 0	FN = 151	TN = 1111
TPR = 0.000		FPR = 0.000		
Threshold = 252	TP = 0	FP = 0	FN = 151	TN = 1111
TPR = 0.000		FPR = 0.000		
Threshold = 253	TP = 0	FP = 0	FN = 151	TN = 1111
TPR = 0.000		FPR = 0.000		
Threshold = 254	TP = 0	FP = 0	FN = 151	TN = 1111
TPR = 0.000		FPR = 0.000		
Threshold = 255	TP = 0	FP = 0	FN = 151	TN = 1111
TPR = 0.000		FPR = 0.000		

The reason for having numerous false negatives was due to the ignoring of the edge pixels which I was told to do by John Lawler. Below is an example of a false negative e.

As can be seen the reason it detected 2 branch points was because the edge cases were ignored as instructed to do.