HW4 Detection and Segmentation of Individual Structures of Interest

CS 4650 Digital Image Processing | Isaac Milarsky | 11/8/2022

Abstract

The tasks presented in this homework were intended to demonstrate the use of watershed segmentation and connected component algorithms to complete various image processing tasks. These tasks included, using kmeans to segment the background from the foreground, using dilation and erosion techniques to extract foreground and background markers, using watershed segmentation with the aforementioned markers to find individual segmentation, and using connected component algorithms to find information of individual structures. I used C++ and openCV in order to accomplish these goals in one binary file designed to take an image file as input. All desired results and images were successfully obtained although there was some difficulty in getting the connected component algorithm to work correctly although I was successful in the end.

Introduction

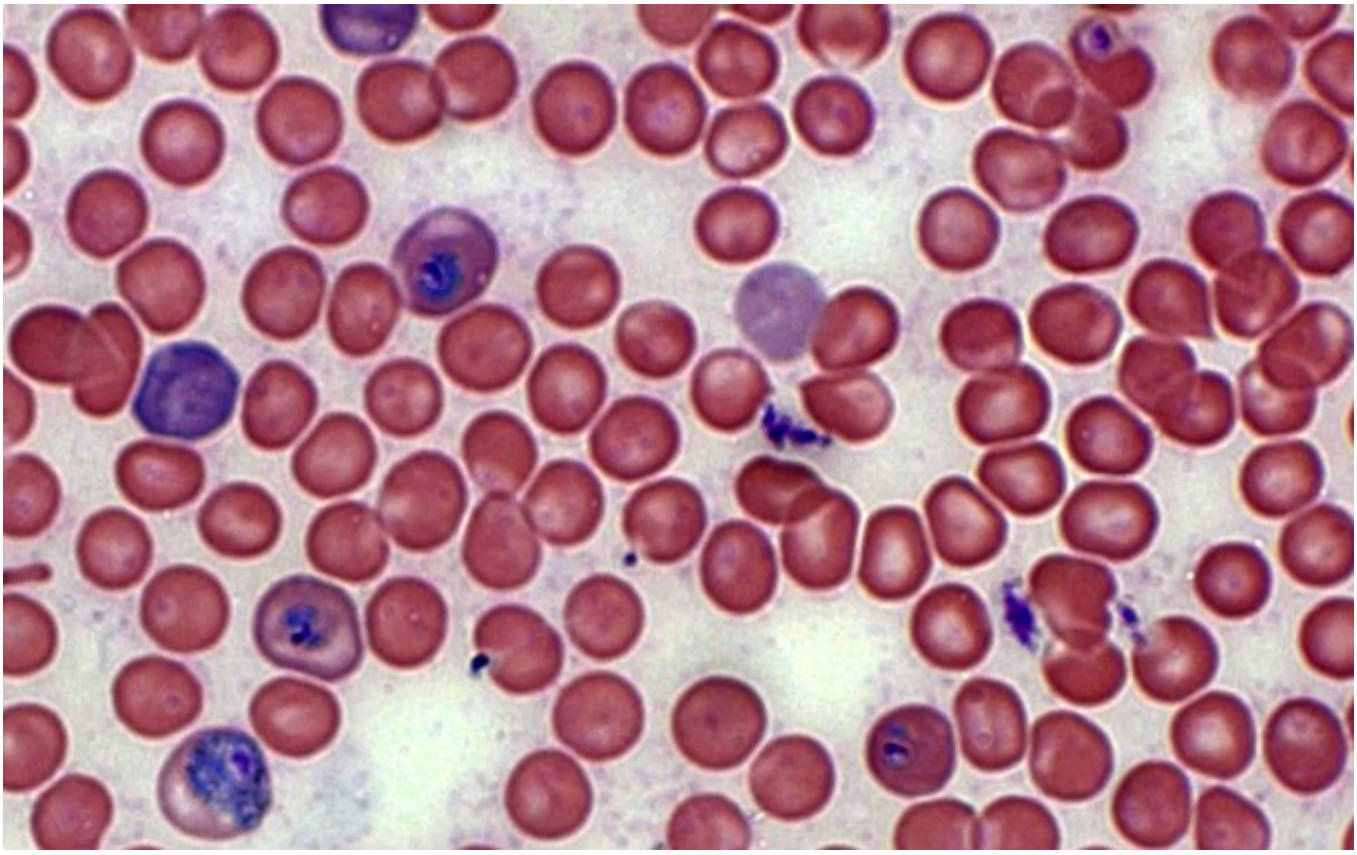
For this assignment, openCV is to be used with C++ in order to segment individual objects and find specific information about them. These tasks will be accomplished through the use of one executable file. This file will be named hw4 and will be called with the following syntax:

```
./hw4 <input image filename>
```

The goal is to be able to use connected component, erosion/dilation, and watershed algorithms used in lecture.

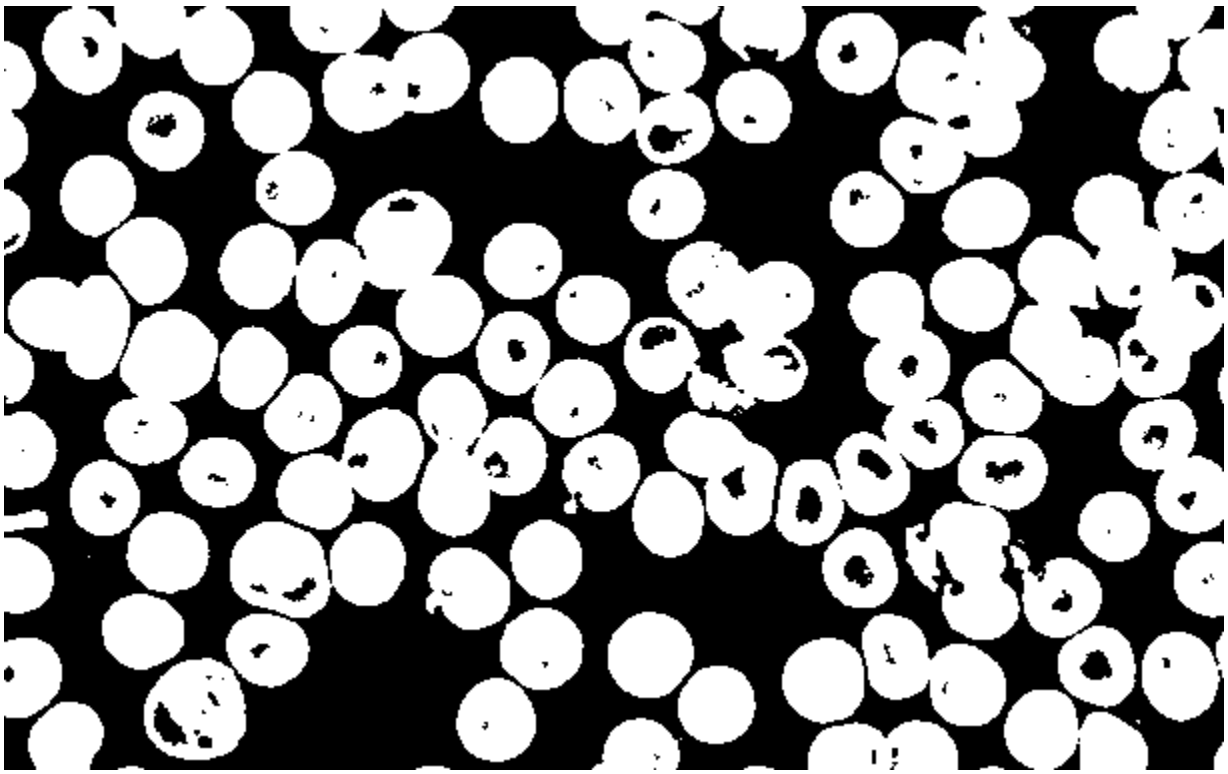
Experiments and Results

a. Input/Given Image

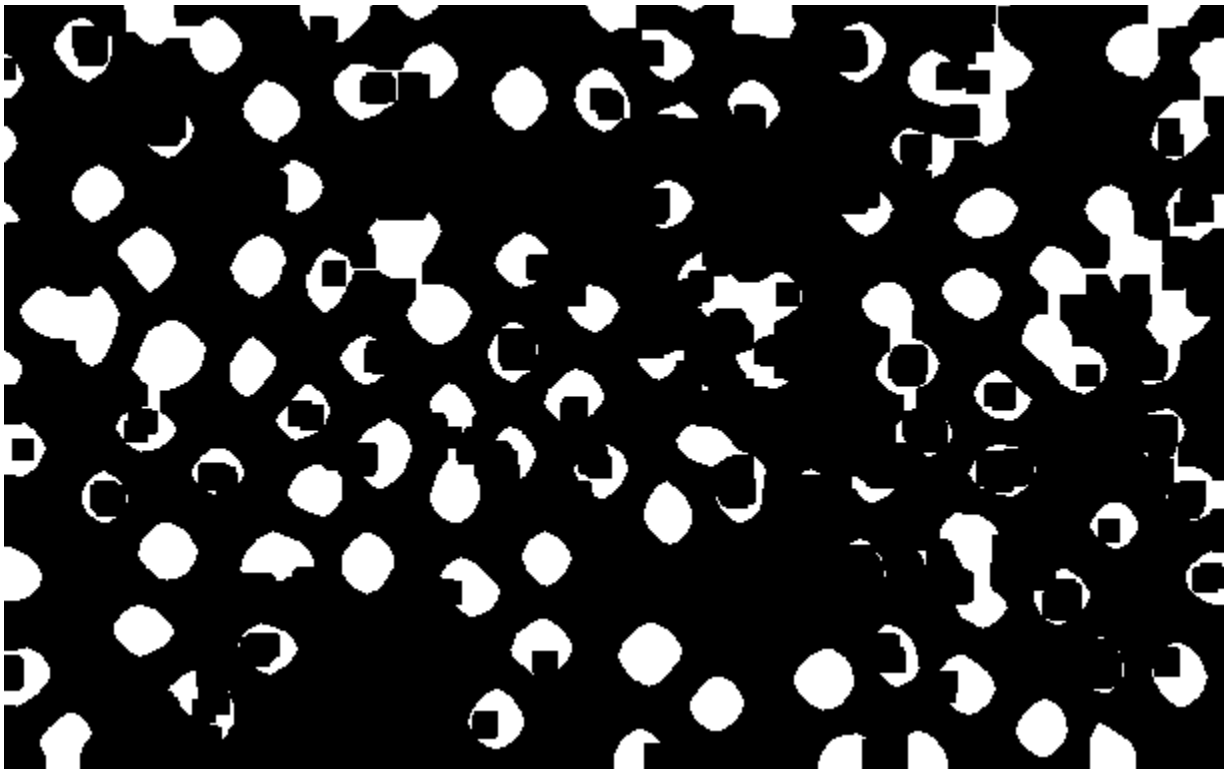


b. Results Obtained

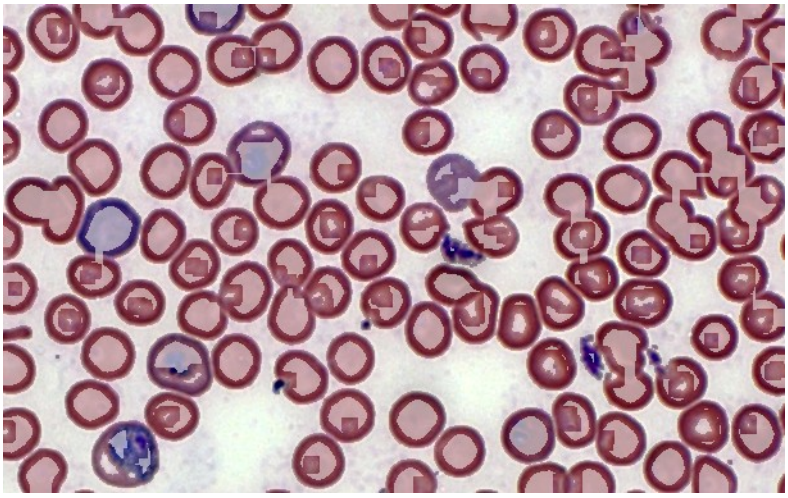
Output of k-means binary segmentation where k = 2.



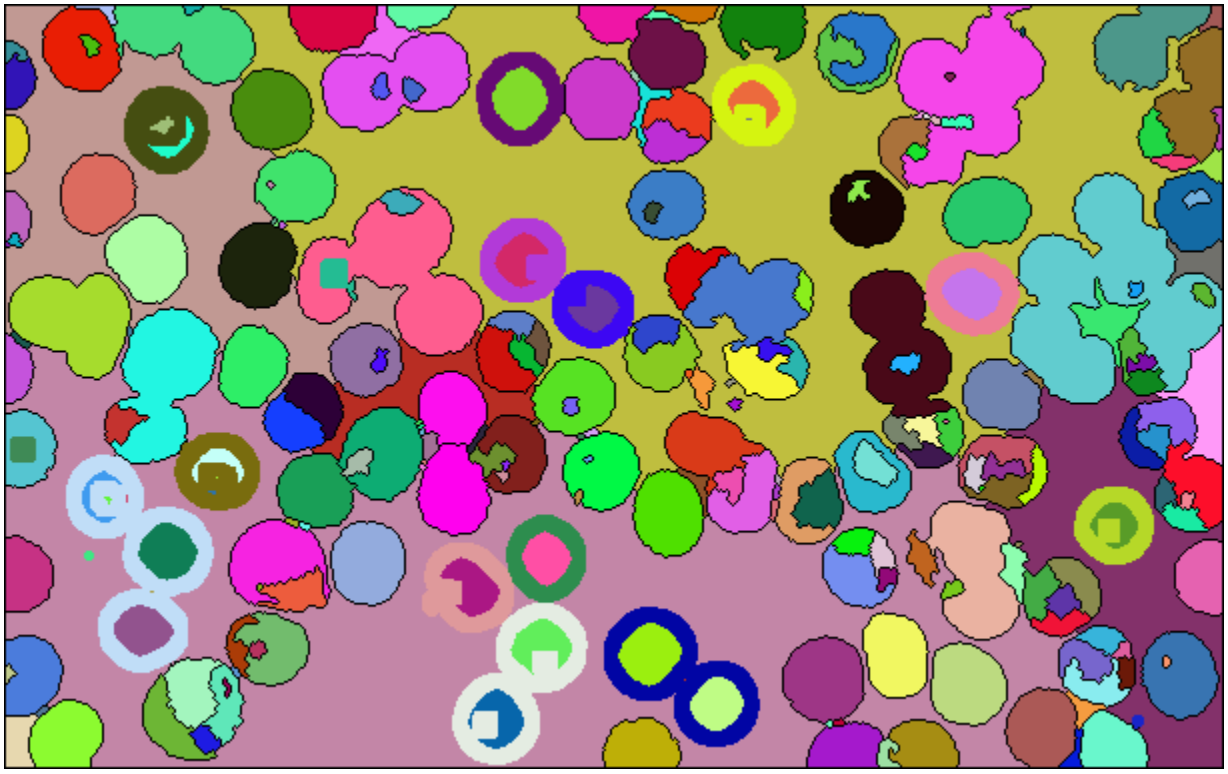
Foreground mask obtained through thresholding and erosion of distanceTransform:



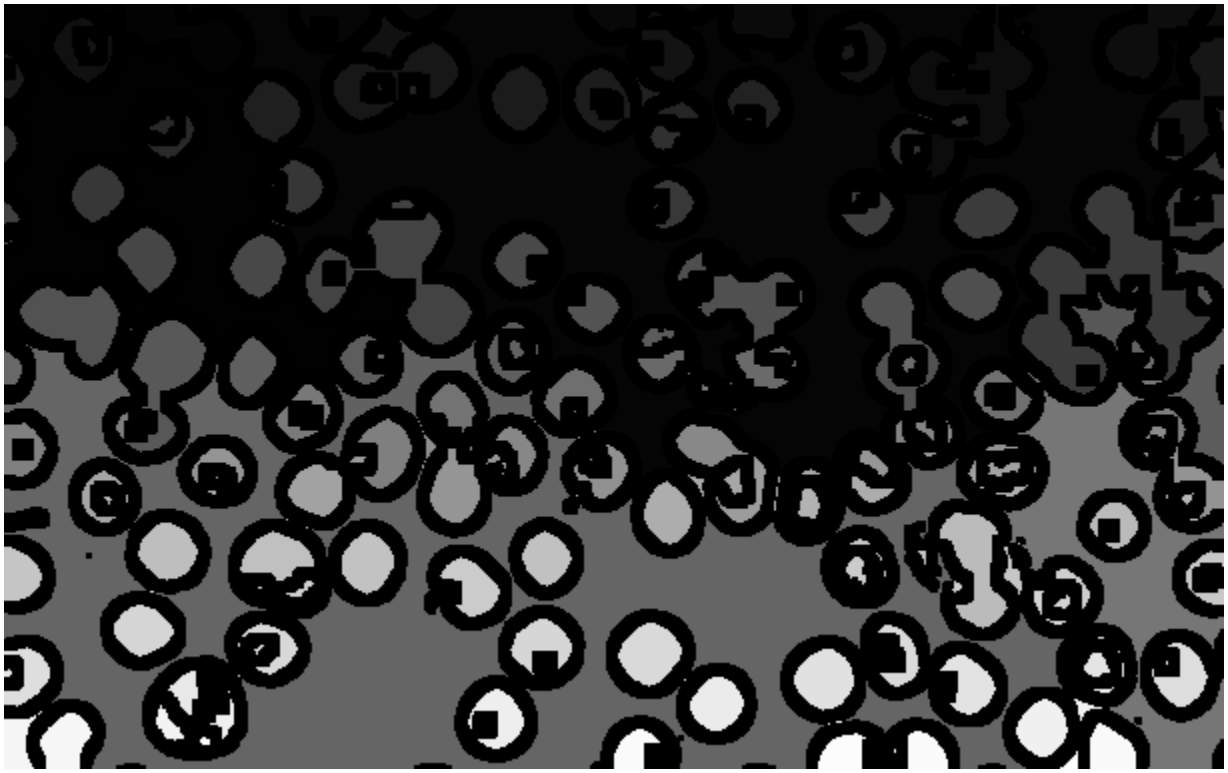
Markers shown to overlay on top of image:



Result of Watershed Segmentation (watershed boundaries):



Final Segmentation Result:



Calculated Mean Color for each connected component with infected cells identified:

```
Mean color for region 0 : (156.268, 107.832, 85.8529)
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Mean color for region 1 : (217.775, 207.183, 200.679)
Mean color for region 2 : (228.5, 213.235, 202.882)
Mean color for region 3 : (167.491, 99.8903, 81.7637)
Mean color for region 4 : (226.053, 214.053, 184.526)
Mean color for region 5 : (218.157, 207.33, 204.735)
Mean color for region 6 : (99.585, 119.014, 52.6184)
Mean color for region 7 : (156.574, 90.0833, 67.1667)
Mean color for region 8 : (162.821, 90.8097, 76.1194)
Mean color for region 9 : (153.194, 78.2903, 57.9032)
Mean color for region 10 : (159.88, 88.6498, 74.9684)
Mean color for region 11 : (149.167, 79.2069, 56.8851)
Mean color for region 12 : (157.933, 90.6626, 69.3954)
Mean color for region 13 : (216.806, 192.597, 190.016)
Mean color for region 14 : (248.818, 206, 207.545)
Mean color for region 15 : (169.73, 101.276, 83.8508)
Mean color for region 16 : (213.89, 195.785, 187.947)
Mean color for region 17 : (166.9, 91.1034, 78.6935)
Mean color for region 18 : (162.618, 88.4942, 72.6532)
Mean color for region 19 : (193, 166, 142)
Region 19 is infected with blue!
Mean color for region 20 : (215.842, 159.105, 154.105)
Mean color for region 21 : (161.413, 89.2788, 69.5183)
Mean color for region 22 : (158.017, 85.1325, 68.3065)
Mean color for region 23 : (204.853, 155.706, 149.324)
Region 23 is infected with blue!
Mean color for region 24 : (172.5, 88.8333, 79.8333)
Mean color for region 25 : (169.859, 103.6, 84.4588)
Mean color for region 26 : (164.217, 97.2743, 75.9027)
Mean color for region 27 : (160.307, 94.7593, 71.2116)
Mean color for region 28 : (214, 155, 145)
Mean color for region 29 : (253, 183, 203)
Mean color for region 30 : (173.499, 106.41, 86.5987)
Mean color for region 31 : (239.286, 208.524, 202.81)
Mean color for region 32 : (157.798, 94.6596, 66.6773)
Mean color for region 33 : (200.25, 149, 136.75)
Region 33 is infected with blue!
Mean color for region 34 : (202.167, 166, 151.5)
Region 34 is infected with blue!
Mean color for region 35 : (173.386, 98.1591, 86.2955)
Mean color for region 36 : (209.278, 188.778, 170.278)
Region 36 is infected with blue!
Mean color for region 37 : (243, 176.5, 184.5)
Mean color for region 38 : (202.055, 160.4, 142.491)
Region 38 is infected with blue!
Mean color for region 39 : (161.2, 99.4609, 73.3217)
Mean color for region 40 : (201.333, 160.667, 141)
Region 40 is infected with blue!
Mean color for region 41 : (239.5, 183, 180)
Mean color for region 42 : (249, 176, 188)
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Mean color for region 43 : (239.846, 202.5, 194.692)
Mean color for region 44 : (161.879, 112.909, 77.9394)
Mean color for region 45 : (171.938, 105.407, 88.6543)
Mean color for region 46 : (211.074, 172.102, 158.083)
Mean color for region 47 : (155.609, 88.2319, 66.2754)
Mean color for region 48 : (205.8, 153.6, 143.8)
Region 48 is infected with blue!
Mean color for region 49 : (220.218, 194.322, 185.575)
Mean color for region 50 : (131.909, 79.1818, 43)
Mean color for region 51 : (162.813, 98.3581, 71.3857)
Mean color for region 52 : (162.557, 98.035, 72.6369)
Mean color for region 53 : (169.778, 100.422, 83.56)
Mean color for region 54 : (212, 167, 147)
Mean color for region 55 : (151.325, 76.2501, 54.8097)
Mean color for region 56 : (156.846, 94.8032, 72.422)
Mean color for region 57 : (148.79, 81.4964, 55.8841)
Mean color for region 58 : (199.273, 156, 139.636)
Region 58 is infected with blue!
Mean color for region 59 : (168.156, 108.687, 89.1235)
Mean color for region 60 : (203.25, 150.5, 141.5)
Region 60 is infected with blue!
Mean color for region 61 : (158.755, 81.4528, 63.9057)
Mean color for region 62 : (187.806, 176.25, 137.028)
Region 62 is infected with blue!
Mean color for region 63 : (200, 151, 138.5)
Region 63 is infected with blue!
Mean color for region 64 : (133.359, 105.54, 64.9742)
Mean color for region 65 : (234, 191, 182)
Mean color for region 66 : (223, 179, 170)
Mean color for region 67 : (174.091, 104.05, 89.6958)
Mean color for region 68 : (228, 187, 176)
Mean color for region 69 : (164.108, 101.455, 82.1815)
Mean color for region 70 : (160.641, 85.4707, 68.3486)
Mean color for region 71 : (223, 169.5, 164)
Mean color for region 72 : (226, 173, 166)
Mean color for region 73 : (218.388, 200.729, 191.648)
Mean color for region 74 : (144.524, 149.988, 101.619)
Region 74 is infected with blue!
Mean color for region 75 : (156.663, 81.763, 63.0889)
Mean color for region 76 : (155.123, 109.097, 82.2005)
Mean color for region 77 : (153.2, 80.8547, 61.2617)
Mean color for region 78 : (149.445, 77.1394, 60.1834)
Mean color for region 79 : (161.171, 89.395, 70.4622)
Mean color for region 80 : (224.4, 161.8, 153.4)
Mean color for region 81 : (213.132, 163.5, 163.132)
Mean color for region 82 : (154.167, 73.3333, 59.6667)
Mean color for region 83 : (225.968, 208.768, 209.092)
Mean color for region 84 : (108.927, 125.909, 61.9268)
Region 84 is infected with blue!
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Mean color for region 85 : (158.042, 74.5417, 63.2083)
Mean color for region 86 : (219, 189, 166)
Mean color for region 87 : (209.321, 170.272, 158.074)
Region 87 is infected with blue!
Mean color for region 88 : (217.391, 199.228, 197.078)
Mean color for region 89 : (169.967, 106.686, 86.431)
Mean color for region 90 : (160.879, 93.6439, 71.9697)
Mean color for region 91 : (164.837, 101.132, 80.7516)
Mean color for region 92 : (222.017, 200.962, 194.861)
Mean color for region 93 : (200.951, 153.439, 143.463)
Region 93 is infected with blue!
Mean color for region 94 : (220.435, 186.739, 185.174)
Mean color for region 95 : (251, 191, 198)
Mean color for region 96 : (218.475, 207.902, 210.798)
Mean color for region 97 : (163.6, 85.6, 73)
Mean color for region 98 : (212.632, 157.105, 150.947)
Mean color for region 99 : (167.974, 92.1966, 82.2735)
Mean color for region 100 : (163.287, 87.1326, 70.0221)
Mean color for region 101 : (147.257, 71.5856, 52.7207)
Mean color for region 102 : (206.833, 155.333, 142.833)
Region 102 is infected with blue!
Mean color for region 103 : (203.267, 156.2, 149.767)
Region 103 is infected with blue!
Mean color for region 104 : (211.067, 158.267, 156.2)
Mean color for region 105 : (202.25, 139.5, 135.25)
Region 105 is infected with blue!
Mean color for region 106 : (164.303, 91.9223, 72.4948)
Mean color for region 107 : (158.572, 86.812, 68.36)
Mean color for region 108 : (239, 225, 194)
Mean color for region 109 : (248.571, 200.286, 200)
Mean color for region 110 : (159.618, 80.1988, 65.4098)
Mean color for region 111 : (181, 168, 156)
Region 111 is infected with blue!
Mean color for region 112 : (215.446, 202.935, 202.512)
Mean color for region 113 : (154.812, 83.9375, 62.9375)
Mean color for region 114 : (172.268, 99.7236, 87.439)
Mean color for region 115 : (14.2857, 106.857, 0)
Mean color for region 116 : (171.062, 105.429, 89.4018)
Mean color for region 117 : (205, 155, 141)
Region 117 is infected with blue!
Mean color for region 118 : (162, 166, 148)
Region 118 is infected with blue!
Mean color for region 119 : (164.78, 76.4576, 69.661)
Mean color for region 120 : (165.079, 89.5263, 75.9737)
Mean color for region 121 : (162.204, 89.2176, 72.2462)
Mean color for region 122 : (163.728, 96.9082, 78.1013)
Mean color for region 123 : (254, 210, 208)
Mean color for region 124 : (232, 194, 180)
Mean color for region 125 : (145.118, 77.9412, 57.5588)
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Mean color for region 126 : (203.436, 158.333, 147.744)
Region 126 is infected with blue!
Mean color for region 127 : (147, 56, 49)
Mean color for region 128 : (237, 200, 187)
Mean color for region 129 : (166.981, 93.5634, 79.1596)
Mean color for region 130 : (140.853, 65.8525, 52.7258)
Mean color for region 131 : (152.643, 60.8571, 51.3571)
Mean color for region 132 : (205.886, 159.371, 152.714)
Region 132 is infected with blue!
Mean color for region 133 : (227, 187, 182)
Mean color for region 134 : (238, 210, 183)
Mean color for region 135 : (225.265, 203.412, 190.235)
Mean color for region 136 : (233, 177, 169)
Mean color for region 137 : (235.5, 198, 177)
Mean color for region 138 : (157.048, 86.8406, 67.6932)
Mean color for region 139 : (156.667, 75, 63.2667)
Mean color for region 140 : (158.357, 82.1877, 67.6029)
Mean color for region 141 : (163.75, 86.2317, 74.2134)
Mean color for region 142 : (166.67, 100.041, 79.8492)
Mean color for region 143 : (209.787, 163.438, 156.27)
Region 143 is infected with blue!
Mean color for region 144 : (212.294, 165.588, 151.824)
Mean color for region 145 : (149.667, 82.1111, 61.7778)
Mean color for region 146 : (143.667, 81, 55.3333)
Mean color for region 147 : (207.632, 160, 149.105)
Region 147 is infected with blue!
Mean color for region 148 : (206, 152, 135)
Region 148 is infected with blue!
Mean color for region 149 : (158.15, 79.41, 63.93)
Mean color for region 150 : (249, 225, 211)
Mean color for region 151 : (203.5, 155.25, 142.25)
Region 151 is infected with blue!
Mean color for region 152 : (149.125, 89.75, 63.375)
Mean color for region 153 : (205.625, 169.422, 159.328)
Region 153 is infected with blue!
Mean color for region 154 : (167.917, 98.9128, 83.7384)
Mean color for region 155 : (252.5, 221, 225)
Mean color for region 156 : (152.333, 54.6667, 47.6667)
Mean color for region 157 : (169.805, 101.15, 86.5789)
Mean color for region 158 : (211.159, 162.365, 155.413)
Mean color for region 159 : (156.062, 67.5, 59)
Mean color for region 160 : (204, 152, 140)
Region 160 is infected with blue!
Mean color for region 161 : (236.259, 208.852, 201.815)
Mean color for region 162 : (203, 152, 141)
Region 162 is infected with blue!
Mean color for region 163 : (255, 222, 244.333)
Mean color for region 164 : (171.704, 99.576, 84.936)
Mean color for region 165 : (163.363, 96.5, 77.1617)
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Mean color for region 166 : (255, 215.4, 224)
Mean color for region 167 : (141.5, 75.5, 49)
Mean color for region 168 : (159.548, 96.6452, 76.0968)
Mean color for region 169 : (144.333, 77.3333, 56.5)
Mean color for region 170 : (212.076, 174.857, 170.521)
Mean color for region 171 : (162.75, 97.5, 80.25)
Mean color for region 172 : (201, 161, 156)
Region 172 is infected with blue!
Mean color for region 173 : (139.5, 83.5, 58)
Mean color for region 174 : (212.421, 163.053, 158.053)
Mean color for region 175 : (198.875, 153.375, 139.25)
Region 175 is infected with blue!
Mean color for region 176 : (237.6, 199.8, 194.8)
Mean color for region 177 : (159.336, 84.3702, 67.6489)
Mean color for region 178 : (153.728, 71.3696, 58.5288)
Mean color for region 179 : (233, 185, 191)
Mean color for region 180 : (144.25, 72.25, 48.25)
Mean color for region 181 : (168.322, 100.253, 85.7044)
Mean color for region 182 : (236, 185, 188)
Mean color for region 183 : (117.065, 123.582, 72.1788)
Region 183 is infected with blue!
Mean color for region 184 : (170.148, 102.505, 85.1786)
Mean color for region 185 : (165.48, 95.3092, 79.361)
Mean color for region 186 : (145.947, 62.2632, 49.8947)
Mean color for region 187 : (208, 197, 171)
Region 187 is infected with blue!
Mean color for region 188 : (168.571, 103.431, 92.8189)
Mean color for region 189 : (214.393, 200.155, 198.786)
Mean color for region 190 : (26.7857, 123.786, 0)
Region 190 is infected with blue!
Mean color for region 191 : (156.632, 86.8908, 68.8563)
Mean color for region 192 : (140.5, 57, 40)
Mean color for region 193 : (166.6, 97.3312, 80.9292)
Mean color for region 194 : (203.817, 167.561, 156.171)
Region 194 is infected with blue!
Mean color for region 195 : (141, 56.3333, 42.6667)
Mean color for region 196 : (149.631, 63.119, 53.0714)
Mean color for region 197 : (194.135, 167.73, 149.108)
Region 197 is infected with blue!
Mean color for region 198 : (231.588, 186.412, 188.941)
Mean color for region 199 : (188, 155.5, 140)
Region 199 is infected with blue!
Mean color for region 200 : (236.5, 197.5, 188.5)
Mean color for region 201 : (142.486, 83.1622, 58.8378)
Mean color for region 202 : (213.233, 171.767, 168.033)
Mean color for region 203 : (167.936, 100.367, 85.0414)
Mean color for region 204 : (169.604, 100.619, 86.0173)
Mean color for region 205 : (142.143, 71.1429, 51.2857)
Mean color for region 206 : (167.387, 95.7883, 83.0766)
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Mean color for region 207 : (153.114, 86.4957, 71.8333)
Mean color for region 208 : (168.03, 101.746, 87.2288)
Mean color for region 209 : (143, 59.6667, 45.6667)
Mean color for region 210 : (158, 89.5, 73)
Mean color for region 211 : (150.156, 81.4308, 63.1824)
Mean color for region 212 : (163.447, 92.5731, 78.1977)
Mean color for region 213 : (209, 159.444, 146.333)
Region 213 is infected with blue!
Mean color for region 214 : (118.837, 90.7706, 50.5502)
Mean color for region 215 : (151, 65, 50)
Mean color for region 216 : (160.673, 82.1474, 68.2628)
Mean color for region 217 : (202.302, 167.472, 161.17)
Region 217 is infected with blue!
Mean color for region 218 : (146.857, 68, 50.8571)
Mean color for region 219 : (197, 154, 143.5)
Region 219 is infected with blue!
Mean color for region 220 : (206, 162.167, 155.75)
Region 220 is infected with blue!
Mean color for region 221 : (76.2597, 150.204, 69.8287)
Region 221 is infected with blue!
Mean color for region 222 : (218, 170, 164)
Mean color for region 223 : (231, 188, 183)
Mean color for region 224 : (164.638, 94.96, 81.3276)
Mean color for region 225 : (149.067, 73, 56)
Mean color for region 226 : (102, 163, 70)
Region 226 is infected with blue!
Mean color for region 227 : (162.429, 93.6098, 77.2366)
Mean color for region 228 : (72.5529, 135.894, 65.9412)
Region 228 is infected with blue!
Mean color for region 229 : (155.487, 90.1377, 68.3415)
Mean color for region 230 : (223.208, 202.688, 193.354)
Mean color for region 231 : (205.795, 188.265, 175.641)
Region 231 is infected with blue!
Mean color for region 232 : (238, 196, 183)
Mean color for region 233 : (219.826, 207.688, 214.122)
Mean color for region 234 : (164.687, 101.548, 80.8826)
Mean color for region 235 : (228, 197, 185)
Mean color for region 236 : (242.333, 217, 204)
Mean color for region 237 : (162.248, 97.8321, 77.4282)
Mean color for region 238 : (163.863, 99.7906, 81.5126)
Mean color for region 239 : (161.765, 84.0261, 71)
Mean color for region 240 : (161.994, 87.6293, 74.352)
Mean color for region 241 : (197.312, 190.25, 171.875)
Region 241 is infected with blue!
Mean color for region 242 : (194, 163, 139)
Region 242 is infected with blue!
Mean color for region 243 : (220.553, 194.947, 194.579)
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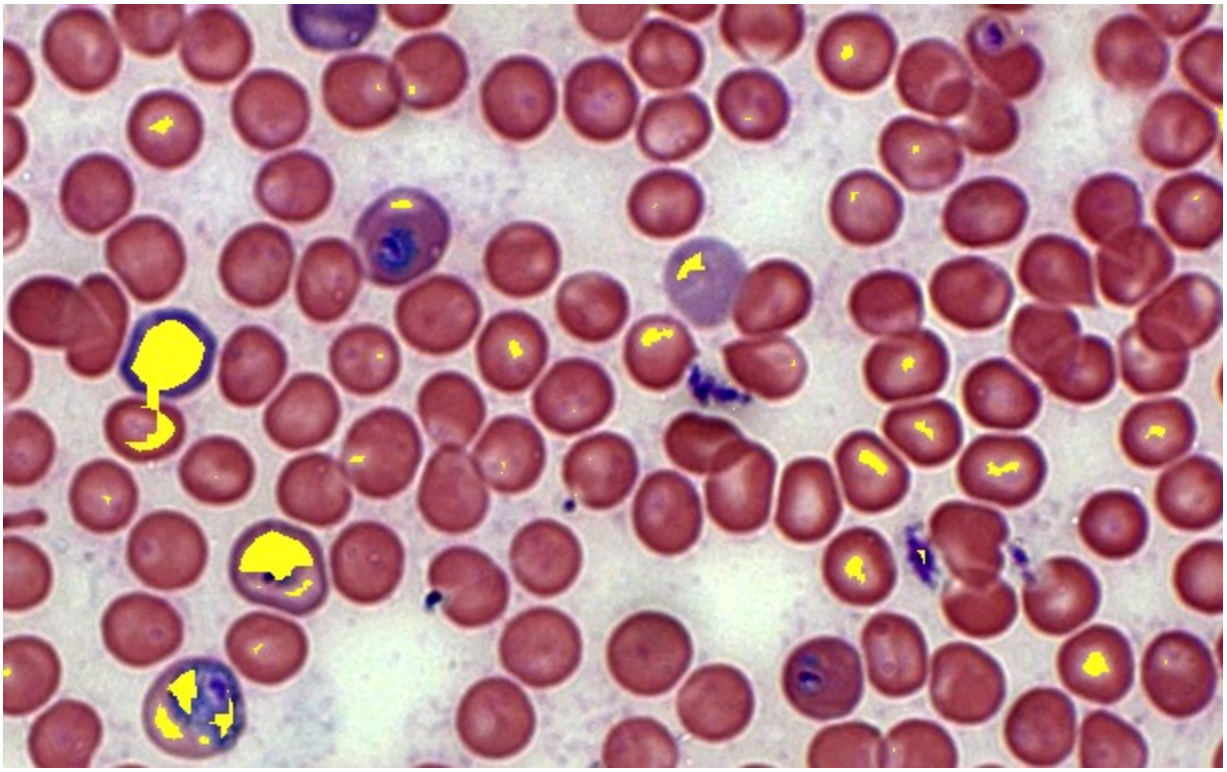
Segmentation of the infected cells (blue regions are highlighted yellow):



Total number of regions and infected regions:

There are 244 regions and 49 infected regions.

Task Discussion

The results obtained were satisfactory in detecting and segmenting the input image. The markers were obtained through distance transform in addition to erosion/dilation of the image. The foreground and background were found with the help of the k-means algorithm. The utility of the watershed algorithm is entirely up to the quality of the markers obtained. Details and amount of segmentation varied based on the amount of erosion of the foreground as well as other variables that determined the mask. This shows how the choice of markers in the watershed algorithm is very important.

Conclusions

I was able to successfully use openCV with C++ to create a program that processed an image in the required way for the assignment. This assignment was very challenging, mainly because of the having to create the markers and get it to work with the connected component algorithm.