**3a.**

Consider pixel P1 (438, 300) with intensity 156 on image\_1

and its corresponding pixel P2 (102, 548) with intensity 123 on image\_2

Let A be the 16 X 16 block around pixel P1

82 118 210 236 70 139 26 99 160 60 87 57 122 147 78 229

163 181 118 166 255 31 56 135 165 243 154 24 137 249 185 167

24 23 139 118 182 180 47 58 121 152 201 159 74 27 39 120

107 53 110 195 198 161 104 242 133 27 70 30 242 70 143 234

49 196 81 196 33 250 54 76 181 218 253 252 191 179 38 160

232 133 180 148 71 214 155 139 39 54 55 233 130 112 72 235

182 221 54 178 246 98 185 133 214 149 144 191 179 83 31 160

83 56 98 100 148 208 165 53 36 78 22 67 179 127 39 32

171 65 35 197 90 111 228 162 179 128 128 97 127 201 39 235

239 85 60 55 212 201 244 199 81 229 86 225 85 142 62 116

84 111 115 117 40 63 202 108 61 83 132 158 253 130 63 244

199 203 204 176 99 124 131 70 81 162 236 20 110 28 70 118

46 114 109 226 74 192 148 100 162 95 75 168 240 126 207 208

175 157 191 67 94 203 139 61 163 178 199 179 238 142 32 233

218 211 238 32 111 142 195 154 167 255 80 224 198 112 135 75

229 216 129 116 86 186 94 205 245 213 195 166 83 185 38 241

Calculating orientation of each pixel:

Y1

X1 p X2

Y2

Orientation of the pixel p = tan-1((Y1-Y2)/(X2-X1))

Rounding the orientations to the nearest angles corresponding to the 8 directions i.e, 0, 45, 90, 135,….., 360 degrees.

The orientations of all the pixels in the above A block are

246 215 91 84 226 92 99 84 131 199 236 165 173 64 236 30

90 190 181 102 115 192 114 191 69 96 242 114 31 55 250 251

74 206 117 136 23 58 84 243 130 172 30 46 226 238 23 191

40 33 199 160 218 130 200 242 38 177 138 57 185 184 43 234

56 201 96 173 230 66 198 235 236 62 141 54 160 214 52 37

61 117 214 110 50 223 255 206 113 143 139 90 134 68 58 184

99 237 76 212 217 126 105 144 43 85 65 220 71 195 88 150

27 244 234 97 45 222 110 45 196 235 198 102 148 100 134 145

240 40 192 97 173 167 215 254 64 92 207 117 161 130 67 163

66 198 233 251 109 105 24 27 158 191 112 220 129 232 46 93

66 213 175 255 201 192 26 39 102 174 116 139 198 177 128 122

214 174 58 207 217 191 247 39 52 24 137 234 99 242 25 165

158 83 188 149 117 106 52 159 95 97 216 161 249 119 145 143

252 212 175 108 152 95 212 152 53 62 245 22 30 58 139 122

203 94 146 215 62 22 73 216 231 236 219 84 105 208 84 26

243 107 54 223 193 187 254 180 41 151 196 146 31 40 218 148

Dividing this orientation matrix O1 into sixteen 4X4 blocks and calculating the frequencies of each of the 8 directions.

So, from each 4 X 4 block, we will get a histogram of frequencies in all the 8 directions

If we combine the frequencies from all the sixteen 4 X 4 blocks the we will get a 128 size vector which is called SIFT feature. ( 8 \* 16 = 128 )

SIFT feature for the pixel P1 is

S1 = [ 4, 3, 2, 3, 4, 8, 8, 8, 2, 2, 5, 8, 2, 8, 4, 6, 6, 5, 2, 5, 1, 3, 8, 3, 2, 6, 7, 8, 4, 2, 7, 2, 1, 2, 2, 4, 6, 8, 3, 4, 3, 7, 3, 5, 2, 1, 3, 6, 2, 6, 8, 5, 3, 5, 3, 6, 2, 6, 2, 5, 3, 5, 6, 1, 3, 1, 8, 5, 6, 5, 5, 6, 6, 7, 7, 7, 6, 1, 7, 8, 5, 2, 3, 3, 2, 4, 7, 4, 1, 5, 7, 2, 3, 1, 8, 1, 1, 7, 2, 8, 5, 7, 5, 2, 5, 2, 7, 8, 1, 1, 2, 7, 8, 2, 2, 5, 1, 8, 2, 1, 3, 5, 1, 4, 5, 8, 3, 5 ]

Let B be the 16 X 16 block around pixel P1

158 145 240 132 142 245 150 45 99 191 105 71 103 27 238 75

175 185 190 155 111 65 199 215 71 219 69 115 83 75 71 110

100 103 164 242 229 169 197 51 25 143 64 45 84 134 78 73

215 85 85 194 201 55 32 68 192 241 81 234 77 50 175 119

89 184 224 121 120 71 203 206 129 122 228 245 215 100 220 87

113 51 144 105 35 84 137 203 193 171 47 194 83 46 154 110

144 172 208 214 213 199 80 43 35 131 162 164 152 242 249 160

51 197 33 239 180 48 36 224 110 54 204 132 59 134 248 239

249 25 146 214 31 159 24 175 131 236 111 242 193 157 235 205

249 139 139 235 141 164 239 135 110 29 131 161 34 112 81 121

41 216 200 109 229 105 87 196 46 210 255 237 132 172 65 71

143 251 24 223 232 171 188 236 95 222 133 150 131 79 139 40

227 161 111 99 68 160 56 190 76 28 98 222 58 126 82 226

96 239 163 111 29 92 181 132 207 217 134 151 190 80 188 132

86 154 193 228 120 80 114 76 84 29 154 191 211 228 176 170

253 125 233 75 187 90 226 101 154 254 100 126 145 177 107 82

Calculating orientation of each pixel:

Y1

X1 p X2

Y2

Orientation of the pixel p = tan-1((Y1-Y2)/(X2-X1))

Rounding the orientations to the nearest angles corresponding to the 8 directions i.e, 0, 45, 90, 135,….., 360 degrees.

The orientations of all the pixels in the above B block are

119 216 179 99 125 174 45 44 155 253 50 226 152 240 89 170

249 105 123 143 143 113 94 240 177 104 218 66 122 131 106 189

81 24 103 177 131 155 91 237 250 160 218 106 128 118 50 153

25 133 224 129 85 214 88 40 138 119 33 41 180 232 246 131

207 138 237 183 102 177 92 195 244 156 233 50 181 141 99 38

72 96 45 41 42 105 138 139 172 206 22 180 106 223 211 122

188 58 61 131 29 238 75 165 197 186 222 190 26 122 114 138

134 96 211 219 237 50 114 215 154 70 152 247 22 107 57 106

165 193 203 73 246 186 121 56 59 152 189 96 117 87 199 25

187 232 201 69 195 117 208 132 204 218 161 49 253 86 142 255

185 53 51 138 39 134 210 80 245 110 213 152 30 32 200 241

159 28 184 33 244 220 235 235 184 110 61 197 39 213 122 230

224 141 229 57 240 102 222 176 130 201 71 223 48 198 121 149

125 130 121 246 139 121 25 62 229 87 250 202 58 133 162 37

110 137 78 147 101 32 85 199 165 248 107 244 103 32 77 26

211 61 123 217 76 89 83 144 195 185 235 116 26 150 103 64

Dividing this orientation matrix O2 into sixteen 4X4 blocks and calculating the frequencies of each of the 8 directions.

So, from each 4 X 4 block, we will get a histogram of frequencies in all the 8 directions

If we combine the frequencies from all the sixteen 4 X 4 blocks the we will get a 128 size vector which is called SIFT feature. ( 8 \* 16 = 128 )

SIFT feature for the pixel P2 is

S2 = [ 3, 3, 1, 7, 2, 1, 4, 2, 1, 5, 6, 8, 3, 3, 6, 4, 6, 4, 6, 7, 4, 7, 3, 3, 6, 7, 4, 1, 8, 6, 7, 1, 6, 4, 7, 7, 1, 2, 5, 5, 8, 1, 4, 1, 8, 3, 7, 8, 3, 1, 1, 7, 8, 4, 1, 7, 2, 7, 3, 6, 6, 5, 6, 8, 2, 5, 6, 7, 4, 6, 5, 7, 6, 4, 5, 4, 5, 7, 3, 4, 6, 3, 6, 6, 1, 1, 3, 4, 3, 3, 7, 8, 3, 6, 1, 8, 5, 4, 3, 4, 4, 8, 7, 3, 7, 4, 6, 5, 5, 6, 8, 8, 7, 6, 8, 2, 4, 5, 3, 4, 3, 7, 5, 3, 7, 1, 1, 6 ]

Sum of squared difference (SSD) between the SIFT vectors (S1 & S2) for the pixels P1 and P2:

=> (4-3)(4-3) + (3-3)(3-3) + (2-1)(2-1) + ………………………………….. + (3-1)(3-1) + (5-6)(5-6)

=> 1 + 0 + 1 +………………………………….. + 4 + 1