**Abstract:**

In this paper we propose a methodology to normalize the biological signal measured by camera of various smartphone models. Our method provides the ability for different mobile camera system to capture images with color characteristic as close as possible to the same standard.

1. **Introduction:**

In recent years, smartphone has become one of the most popular device. Powerful computational power as well as high resolution camera allow their usage in very wide sphere especially in health monitoring. Blood pressure, photoplethysmogram (PPG) measurement, stress index and heart rate detection all of them are prominent medical applications for smartphone.

However, there is huge number of smartphone brands in the market equipped with cameras and flash modules with different qualities and having various camera parameters settings. This difference lead to an issue with algorithms that depends on color images such as PPG detection, which might give different results when working on images having different color profile. As showed in our test, color characteristic of image captured by smartphone is not only varies with difference smart phone models but also with difference camera parameters settings.

The idea of this paper is applying color correction method to normalize Smartphone Camera color image to ensure that output image of different smartphone models have the same color characteristic.

The rest of the paper will be organized as following: Section II shows the color correction scheme, Section II shows the camera color respond experiment, Section III presents our attempt in correcting color output, and Section IV concludes.

1. **Camera color response experiment:**

In order to define typical color properties of captured image, a number of experiments with different smartphone models was carried out. In this experiments R, G, B values of center pixels and 8 boundary pixels was recorded.

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The obtained tested result are illustrated in below figures:

1. **Applying color correction for smartphone captured image:**
   * + 1. **Color correction method:**

Some research have been conducted in recent years to developing color correcting technique [1, 3]. In this paper, we use the general method for correcting color response proposed by Stephen Wolf, in his technical memorandum for National Telecommunication and Information Administration [1]. The method relies on using a least-square solution for estimating the color correcting matrix, which will later be use to calibrate the processed video frames color to the original ones.

In this technique, an *m x n x 3* (m row, n column, 3 color layers – R, G, B) color image are reorganized as a *k x 3* array with *k = m x n* [3]. In Wolf’s paper, k is reduced to the number of color patch in reference image.

The uncorrected image O and the reference image P can be represented as:

The relation of uncorrected image O, references image P and color correction matrix A could be described in below equations:

(\*)

In above equation, 1 is the shift in brightness level.

The color correction matrix is calculated in (\*) by least-squares solution:

* + - 1. **Applying color correction method for smartphone captured image:**

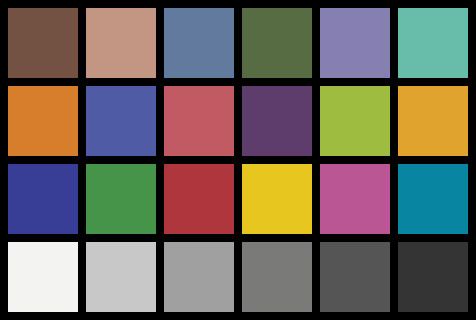
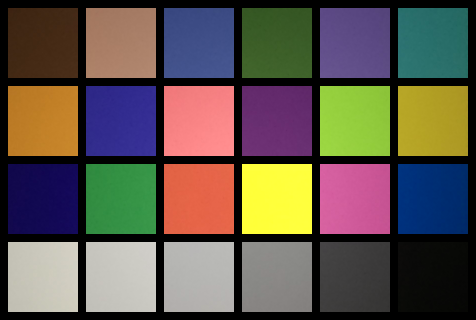
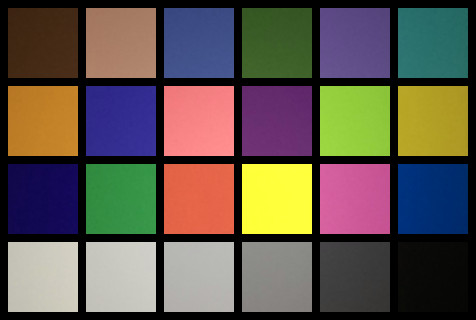
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Figure 1 – From left to right: Reference color chart-Xrite Color checker classic, Test chart captured by Samsung Galaxy S6 Edge, Mototola G4

Figure 2 – Corrected color chart of image captured by Samsung Galaxy S6 Edge and Motorola G4

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| --- | --- | --- | --- | --- | --- |
| **Color Patch** | **Reference color values**  **R G B** | **Captured values**  **(Samsung S6)**  **R G B** | **Color corrected values**  **(Samsung S6)**  **R G B** | **Captured values**  **(Motorola G4)**  **R G B** | **Color corrected values**  **(Motorola G4)**  **R G B** |
| **1** | 115 82 68 | 107 67 58 | 103 69 48 | 67 41 21 | 94 65 49 |
| **2** | 194 150 130 | 211 160 160 | 187 144 124 | 169 127 103 | 169 125 108 |
| **3** | 98 122 157 | 109 113 179 | 104 130 165 | 64 79 136 | 89 127 170 |
| **4** | 87 108 67 | 92 113 79 | 98 119 62 | 59 93 39 | 95 122 70 |
| **5** | 133 128 177 | 148 119 186 | 133 125 167 | 93 75 133 | 108 111 160 |
| **6** | 103 189 170 | 91 162 179 | 100 180 157 | 41 111 106 | 81 159 144 |
| **7** | 214 126 44 | 228 145 74 | 203 112 36 | 193 127 39 | 190 104 36 |
| **8** | 80 91 166 | 84 64 180 | 77 91 179 | 50 44 143 | 74 100 181 |
| **9** | 193 90 99 | 246 134 160 | 208 110 126 | 249 132 133 | 221 106 120 |
| **10** | 94 60 108 | 124 53 132 | 107 62 127 | 103 45 111 | 112 74 134 |
| **11** | 157 188 64 | 178 215 120 | 176 198 76 | 148 205 61 | 171 199 70 |
| **12** | 224 163 46 | 231 191 81 | 213 155 34 | 178 159 37 | 185 139 37 |
| **13** | 56 61 150 | 38 14 133 | 38 49 144 | 18 8 83 | 51 66 126 |
| **14** | 70 148 73 | 54 142 108 | 74 160 92 | 53 145 69 | 97 180 102 |
| **15** | 175 54 60 | 228 90 79 | 193 61 52 | 229 100 72 | 207 71 61 |
| **16** | 231 199 31 | 252 244 125 | 234 206 67 | 255 255 59 | 250 205 41 |
| **17** | 187 86 149 | 234 112 187 | 193 97 160 | 207 90 154 | 185 86 152 |
| **18** | 8 133 161 | 7 98 173 | 28 142 173 | 0 46 116 | 43 115 165 |
| **19** | 243 243 242 | 225 218 235 | 203 206 190 | 202 200 187 | 197 199 187 |
| **20** | 200 200 200 | 211 204 222 | 191 194 181 | 200 199 192 | 195 200 193 |
| **21** | 160 160 160 | 186 176 201 | 170 172 167 | 182 181 178 | 181 187 183 |
| **22** | 122 122 121 | 144 132 160 | 134 135 137 | 137 136 133 | 147 152 148 |
| **23** | 85 85 85 | 76 69 90 | 78 83 84 | 61 60 60 | 90 94 92 |
| **24** | 52 52 52 | 21 18 25 | 34 41 32 | 8 9 7 | 50 54 50 |

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