**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.

Although there is many research have been conducted to develop smartphone-based PPG detection system [2, 4, 5], these research typically focused on developing and testing their system on specific smartphone models. This problem is also mentioned by Kurylyak et al in their research [6], in which they proposed a robust PPG detection system could work on different smartphone models. Nonetheless, their method were developed for threshold-area based PPG detection algorithm, which obviously cannot be applied for systems that calculates PPG signal by averaging green channel values.

The idea of this paper is developing a method to normalize Smartphone Camera color image to ensure that input image for PPG detection algorithm running on different smartphone models have the same color characteristic.

The rest of the paper will be organized as following:

1. **Color calibration method:**

Color characteristic of image captured by smartphone camera can be calibrate in 2 phases: before capturing image by altering camera parameters such as exposure, ISO and focus (pre-processing) or after image has been captured by correcting image color (post-processing).

1. **Preprocessing phase:**

The preprocessing phase includes 2 steps:

* Step1: Using one smartphone model as standard device and calibrating standard device camera parameters to obtain PPG signal which is the most similar to the medical standard PPG.
* Step 2: Calibrating cameras parameters on other smartphone until the color characteristic differences of image captured by calibrated device and standard device minimized.

1. **Post-processing**

Some research have been conducted in recent years to developing color correcting technique [1, 3]. Stephen Wolf, in his technical memorandum for National Telecommunication and Information Administration proposed a general method for correcting the processed video in order to make it more closely approximate the original video [1]. The method relies 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. A similar technique with some modification is also used in MultichartsTM and MultitestTM color correction applications developed by Immatest LLC [3].

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 above **1** is the shift in brightness level.

The color correction matrix is calculated in [1] by least-squares solution:

**References:**

[1] Stephen Wolf, 2003, Color Correction Matrix for Digital Still and Video Imaging Systems, *NTIA Technical Memorandum* TM-04-406.

[2] P. Peleris, Banitsas K, Orbach T, Marias K.A novel method to detect heart beat rate using a mobile phone. In *Proceeding of 32nd IEEE Annual International Conference on Merging Medical Humanism and Technology*, pp. 4488-5494, 2010.

[3] Immatest, Color Correction Matrix, Last accessed November 29, 2016

[4] M.J. Gregoski, M. Mueller, A. Vertegel, et al. Development and validation of a smartphone heart rate acquisition application for health promotion and wellness telehealth applications. *International Journal of Telemedicine and Applications*, doi:10.1155/2012/696324, 2012.

[5] C.G. Scully, J. Lee, J. Meyer, A.M. Gorbach, D. Granquist-Fraser, Y. Mendelson, and H. Chon Ki. Physiological parameter monitoring from optical recordings with a mobile phone. *IEEE Transactions on Biomedical Engineering*, 59(2):303–306, 2012.

[6] D. Grimaldi, Y. Kurylyak, F. Lamonaca, and A. Nastro. Photoplethysmography detection by smartphone's videocamera. In *Proceeding of IEEE International Conference Intelligent Data Acquisition and Advanced Computing System IDAACS’2011,* pp 488-491, September 2011