Human Skin Darkness Comparison Using Digital Image Analysis

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Abstract. People generally wish to have a lighter or a darker skin. Based on this wish, they regularly compare their skins regarding darkness while there is no simple and accessible system to perform that. This research proposes an algorithm and implements the algorithm in a simple and accessible computerized system that is capable to compare skins of two persons regarding darkness. The system uses digital image processing that accepts an image containing forearms of two persons who are under comparison, then displays some message that expresses the darker skin and the lighter skin. The system uses different techniques such as greyscaling through average method, partitioning and sampling. The system was implemented on an ordinary PC having Linux Ubuntu as operating system, ImageLab as library, and C++ as programming language. The results regarding accuracy are presented in different tables. Based on the results, the system has minimum accuracy of 98%.

1. Introduction
The skin is considered as the largest organ of our body [1] [2] [3]. In fact, skin is the outer-most body tissue that covers almost entire body [4] [5]. There are many organs and parts related to appearance of human such as eyes, nose, ears, lips, hairs and skin. Although shape (or size) are important parameters regarding some organs such as eyes, nose and lips, about skin the importance is tone or darkness (or lightness) [6] [7] [8]. In other words, one parameter in appearance comparison of two persons is to compare their skin colors or skin darkness.

Regardless of matter of skin, people generally are used to compare their skins regarding darkness (or lightness) [9] [10], since people want to know how light (or dark) their skins are, as they wish to have lighter (or darker) skin. Skin color is very important for some people who are after on their outside look. Some person wants a darker skin and other wants a lighter skin [1]. The skin is like the shield of our body that guards the body against high temperatures, sunlight with ultraviolet-radiation and chemicals that are dangerous to us [2]. Most of the people are not contented of what color of the skin they have so they find alternative solution for a change. That is why people try different ways to have the perfect color of the skin for them and for a change of their skin color. With the help of our modern technology today there are many ways on how to select the proper outlook of each person. For those who want to darken their skin specially the Europeans and Americans, during summertime, they stay in the beach hours and hours for sunbathing and applying some lotions to the skin excessive ultraviolet-radiations due to the sunlight [3].
2. Related studies

There are numerous researches and studies regarding comparison of human skin. We consider these studies.

There is an interesting research that compares different skin models that can be used as replacements for human skin in in-vitro penetration studies [11]. In this study, the researchers compare human skin with skins of rats and pigs (domestic pigs and mini pigs). The researchers concludes that the skin of pig has the closest model to the human skin model, and in result in the case of the absence of human tissue, the skin of pig is the best replacement. The researchers in this study use a professional laboratory as well as different chemicals and drugs. Moreover the researchers need professional and accurate microscopes for observation.

Some research was performed on two major physical essences that influence light propagation in skin tissue; absorption and scattering. The researchers used Monte Carlo inversion method to measure optical coefficients of ex-vivo tissues regarding the two physical mechanisms (absorption and scattering) in different wavelength from 620 nanometres to 1000 nanometres [12]. The mediums used in this study contain; a broadband tungsten lamp, quartz optical fibre, a pair of achromatic lenses, a variable aperture, tissue sample, an integrating sphere, optical fibre bundle, CCD spectrometer and a personal computer.

There are also several studies regarding human skin color in which researchers consider the color skin as an important parameter for face detection [13] [14] [15].

3. Statement of the problem

There are several researches and works regarding human skin color (or darkness), and we considered some of them. Although all of these researches are powerful and functional in their field of studies, none of them is capable to compare the skin of two persons regarding darkness. Moreover some of these systems such as [11] and [12] need technical and professional tools and environment that are costly.

4. Objective of the study

Based on the problems mentioned above, the objective of this research is to design and implement a simple and not costly system to compare the skin of two persons and distinguishes which of these two has darker (or lighter) skin. The system uses digital image analysis and works on two forearms of two case persons.

5. Methodology

The proposed system is applied on skin of two persons who desire to be compared regarding skin darkness. The forearms of the persons are the case sites for comparison since forearms are accessible for taking picture. Moreover forearms mostly are free of hair and skin wrinkles. The system follows several steps. These steps are considered as following.

5.1. Taking Picture

Two forearms of persons (one forearm of each person) are placed beside each other. Then some picture is taken such that two forearms cover somehow entire height of the image (see Figure 1).

Figure 1. Original colored image captured by camera
5.2. **Greyscaling**

The original colored image is converted to a grayscale image using average method in which greyness of each pixel is computed using equation (1) where Grey is the greyness of the pixel and R, G, and B are the redness, greenness and blueness of the pixel respectively (see Figure 2).

\[
\text{Grey} = \frac{R + G + B}{3}
\]  

**Figure 2.** Greyscale version of the original image

5.3. **Partitioning**

The greyscale image is vertically partitioned into two equal parts; UP (upper part) and LP (lower part) while each part contains a forearm as Figure 3 shows.

**Figure 3.** Vertically partitioning of the greyscale image

5.4. **Sampling**

At each part (UP and LP) of the greyscale image, the pixels of centroid rectangle (see Figure 4) are considered as representative of each forearm while width and height of the rectangles are computed based on equations (2) and (3) in which “w”, “h”, “IW” and “IH” mean width of the rectangle, height of the rectangle, image width and image height respectively.

\[
w = IW \times 10\%
\]  
\[
h = IH \times 10\%
\]

As equations 2 and 3 show, the sizes of width and height of UR (upper rectangle) and LR (lower rectangle) are identical and equal to one-tenth of the width and the height of the image respectively.

5.5. **Darkness computation**

We compute the average darkness (greyness) of UR and LR using equations (4) and (5) in which “UG” is the average greyness of upper rectangle, “LG” is the average greyness of lower rectangle, “Grey” is the greyness of the pixel (computed in 5.2) in the relevant rectangle and “n” is the number of pixels at each rectangle that is equal to one-hundredth of the size of the image.

\[
UG = \frac{\sum \text{Grey}}{n}
\]  
\[
LG = \frac{\sum \text{Grey}}{n}
\]
5.6. *Darkness comparison*

As we mentioned in 5.4, each rectangle is the representative of the forearm and in result the representative of the relevant person. We compare the two darkness values computed in the last step (UG and LG). The larger number of darkness means the lighter skin, or the less number of darkness means the darker skin.

6. *Test, result and discussion*

Two parameters are considered in the test of the system that conducted by the researchers; difference on greyness and image quality (megapixel). The images used in the test were printed greyscale images that were divided into upper and lower parts and had different greyness form 1 to 20 such that the initial greyness was 120. The image qualities were 1.0 MP, 3.0 MP, 5.0 MP, 8.0 MP and 13.0 MP, which were all available in the settings of the smartphone that was used in image capturing. Table 1, Table 2 and Table 3 show the result of five times testing while the system failed at least once, at least three times and all five times respectively based on different cases of image quality and greyness difference.

Table 1. Result of the system in different qualities and greyness differences (at least once from five-times failed) – CMPTNT: Competent (Passed)

| Greyness Difference | Image Quality | Accuracy (%) |
|---------------------|---------------|--------------|
|                     | 1 MQ  | 3 MP  | 5 MP  | 8 MP  | 13 MP |
| 1                   | Failed | Failed | Failed | Failed | Failed | 0   |
| 2                   | Failed | Failed | Failed | Failed | Failed | 40  |
| 3                   | Failed | Failed | Failed | Failed | Failed | 20  |
| 4                   | Failed | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 80  |
| 5                   | Failed | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 6                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 7                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 8                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 9                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 10                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 11                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 12                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 13                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 14                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 15                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 16                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 17                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 18                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 19                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
| 20                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100 |
Table 2. Result of the system in different qualities and greyness differences (at least three-times from five-times failed) – CMPTNT: Competent (Passed)

| Greyness Difference | Image Quality | Accuracy (%) |
|---------------------|---------------|--------------|
|                     | 1 MP | 3 MP | 5 MP | 8 MP | 13 MP |   |
| 1                   | Failed | Failed | Failed | Failed | Failed | 0  |
| 2                   | Failed | CMPTNT | Failed | CMPTNT | CMPTNT | 40 |
| 3                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 20 |
| 4                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 80 |
| 5                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 6                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 7                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 8                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 9                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 10                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 11                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 12                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 13                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 14                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 15                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 16                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 17                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 18                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 19                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 20                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|

Table 3. Result of the system in different qualities and greyness differences (all five-times from five-times failed) – CMPTNT: Competent (Passed)

| Greyness Difference | Image Quality | Accuracy (%) |
|---------------------|---------------|--------------|
|                     | 1 MP | 3 MP | 5 MP | 8 MP | 13 MP |   |
| 1                   | Failed | Failed | Failed | Failed | Failed | 0  |
| 2                   | Failed | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 40 |
| 3                   | Failed | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 20 |
| 4                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 80 |
| 5                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 6                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 7                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 8                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 9                   | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 10                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 11                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 12                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 13                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 14                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 15                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 16                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 17                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 18                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 19                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
| 20                  | CMPTNT | CMPTNT | CMPTNT | CMPTNT | CMPTNT | 100|
Based on the three tables above, we conclude that even in the worst case (failing at least once – see Table 1) the system works well when the greyness difference is more than 5. In other words, system works in 251 cases of all possible 256 greyness difference cases. In result, the system has accuracy of 251/255 that is 98%.

7. Future work
This study does not focuses on noises. In the future study the researchers will consider possible noises on the skin of forearms such as hair or mole that can affect the average greyness of centroid rectangle.

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