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Pre-Operative Tool for Facial-Post-Surgical Estimation and Detection

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***Abstract*—**Goal: Purpose of the project was to make a plastic surgery prediction by using pre-operative images for the plastic surgeries' patients and to show this prediction on a screen to compare between the current case and the appearance after the surgery. Methods: To this aim, we implemented a software which used data from the internet for facial skin diseases, skin burns, pre-and post-images for plastic surgeries then the post- surgical prediction is done by using K-nearest neighbor (KNN). So we designed and fabricated a smart mirror divided into two parts a screen and a reflective mirror so patient's pre- and post-appearance will be showed at the same time. Results: We worked on some skin diseases like vitiligo, skin burns and wrinkles. We classified the three degrees of burns using KNN classifier with accuracy 60%. We also succeeded in segmenting the area of vitiligo. Our future work will include working on more skin diseases, classify them and give a prediction for the look after the surgery. Also we will go deeper into facial deformities and plastic surgeries like nose reshaping and face slim down. Conclusion: Our project will give a prediction relates strongly to the real look after surgery and decrease different diagnoses among doctors. Significance: The mirror may have broad societal appeal as it will make the distance between patient's satisfaction and the medical standards smaller.

***Keywords*—**K-nearest neighbor, face detection, vitiligo, bone deformity.

I. Introduction

PLASTIC surgery deals with the reform, reconstruction, or permutation of physical defects of function or form involving the musculoskeletal system, skin, and cosmetic enhancement of these areas of the body. Those surgeries especially facial plastic surgeries have been more popular in recent years, according to American society of plastic surgeons (ASPS). Total cosmetic procedures reach 17.7 million and 5.8 million total reconstructive procedures including 204.5 thousands for Maxillofacial surgery in 2018 [1] revealing that plastic surgeries especially facial plastic surgeries have been more popular in recent years and it should guarantee a natural look even for people who want to cover their facial burn or for people with some facial skin diseases like vitiligo, melasma and melanoma, or who want to minimize the appearance of wrinkles and folds, reshape their noses or slimming down their faces.

Human face plays an important role in daily life. Since face consists of many layers as shown in Fig. 1, we worked on skin diseases which extend to subcutaneous layer and problems in bone layer which may be head trauma due to an accident or facial genetic bone deformity which is known as craniofacial bone deformity.

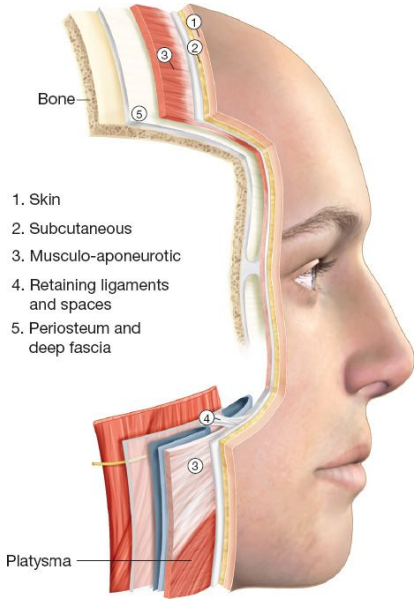

Fig. 1 Facial Anatomy Layers

For skin, generally it is made up of three layers as shown in Fig. 2: (i) the epidermis, which is the outermost layer of the skin, (ii) the dermis, lay underneath the epidermis layer and is divided into two sub-layers, papillary layer (superficial) and reticular layer (deep) and (iii) the Subcutaneous layer (hypodermis), which is the inner layer of the skin, it is made up of fat and connective tissue [2].

According to Fig. 2, severity and also the depth of each degree of burn are shown. Burn injuries do not only affect the body by their aggressive scars but also they affect people who are burnt functionally, cosmetically and psychologically. The road to recovery should include cosmetic, functional and psychological recovery so we decided to begin with burn depth assessment which is needed to decide the way of treatment as some of these degrees can be cured by skin care products and others need plastic surgeries. There are many ways to determine the burn depth automatically without any human help such as laser Doppler imaging (LDI) as in [3] and [4], while [5] uses another method which is photoacoustic imaging system (PAI) and it is proved that PAI is more accurate than LDI by [6], but we used digital photos and

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machine learning for burn depth assessment as done by [7] and [8] since we cared about the simplicity of our smart mirror's use, fast diagnosis and the price.

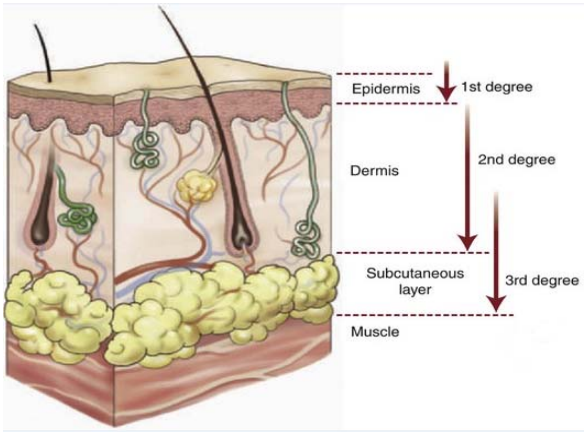


Fig. 2 Degrees of burn and their severities

Since skin grafting is a functional and cosmetic treatment for skin burns also it should be a psychological treatment not issue as is the case for all plastic surgeries which put a high value on the post-operative appearances as patients care more about for their great significance. Unfortunately, it is inconvenient and inefficient to make physician-patient communication about issues of the surgery and to perform a surgical planning just based on a simple sketch or on some pre- and post- surgical images for similar cases, also the patient should see accurate measurements to visualize his/her current condition and the simulated changes the that doctor can do in order not to overestimate his/her look after the plastic surgery. Therefore, there is a need for a method to provide both surgeons and patients by the results after the operation to meet a satisfaction point between patient's expectations and medical standards. To this aim some surgery simulation researches have been carried out. A study by Keeve et al. [9] presents a system using finite element model and linear formulation to simulate the operation result. Koch et al. [10] designs a prototype system to predict facial appearances after craniofacial and maxillofacial surgeries using finite element model constructed from facial data set. However, it is troublesome for doctors to try time after time to simulate the wanted operation on a skull model. In this case, using software is more powerful. Jie Liu et al. [11] takes the features of pre- and post-operative faces and treated them as training examples for both support vector regression (SVR) predictor and KNN predictor then a postoperative face is predicted. Jamrozik et al. [12] present a technology for planning the plastic surgery by digitalization of the patient body. It is realized by 3D structured light scanner. The scanning data are transferred into 3dsMax software and used for planning plastic surgery. Also FaceTouchUp and Crisalix both are web and mobile applications that give a pre-operative prediction but they are not included in any medical device.

The surgeons also use mimics, mishmixer, 3-matic and 3Dslicer by taking a scan for the deformed skull in the form of computed tomography (CT) DICOM files, and then they apply the reshaping to the deformed area and cure it.

Our work is a software for plastic surgery prediction connected to a smart mirror, which gives live post-plastic surgery prediction in one half of the mirror and on the other half the current appearance is showed, also it helped doctors to diagnose some diseases and extract quantitative information helping doctors in following up with patients to see the effect of medication prescribed. For skin burns, classification of skin burn degree is done and if the case needs only skin care products images for current case would be taken and quantitative information is taken from images and saved to compare it with the information from images of following up. For other skin diseases, diagnosing is the first phase and if the case needs plastic surgery a pre-operative post- surgery prediction is done by using machine learning algorithm where features of pre- and post-operative faces is taken and treated as training datasets for KNN predictor then a post-operative face is predicted with a new patient's preoperative face entered as in [11], this will enhance the mutual understanding between the surgeon's and the patient's point of views.

II. Materials and Methods

A. Mirror Prototype Design

We designed and fabricated, as shown in Fig. 3, a prototype of smart mirror in which a two way glass mirror is used and a black opaque oil cloth is used and put behind a part of the reflective mirror making it a permanent glass mirror leaving a space for DELL Monitor with model no. E2016H, all these components are framed with wooden frame.

(a) (b)

Fig. 3 (a) Front view for (80 cm × 64 cm) the mirror. (b) Back view for the mirror

B. Data Acquisition

Burned patients' data and vitiligo skin diseases are collected from internet and also we are trying to take images from Al-Kasr Al Ainy hospital. For plastic surgeries data, we relied on collecting pictures for pre- and post- operative faces from the internet. For the patient's data, we relied on datasets from International skin imaging collaboration (ISIC).

In the Smart mirror, data acquisition would be by Canon EOS 600D (EOS Rebel T3i/EOS Kiss X5) digital cameras with resolution (5184 × 3456) to view live video and taking photos for storing patients' data.

C. Software

We used Python 3.6 for algorithms' implementation. Since we are working on face so the first step is face detection and

we used Viola-Jones object detection framework as we need fast detection. The second step is skin tone determination as it is important for the phase of skin grafting and filling the area of interest with normal skin. Segmentation is sufficient for diagnosing some diseases like vitiligo and this happens by taking the b-channel from RGB-space image as it gives the highest contrast between the normal skin and the areas that have lost pigment then we used k-means clustering, so vitiligo was diagnosed Fig. 6.

For burns, the first step was segmentation. It is based on converting RGB- space image to YCbCr color space taking the Cr channel [7] as it represents red component related to green channel and the most of skin information is encoded by the red-green channels, for second degree the wounded area is with the Highest Cr-channel intensity, for third degree the wounded area with the lowest Cr-channel intensity. As shown in Fig. 3, by using K-means clustering, the wound area is segmented and classified from both normal skin and background, after that the segmented image becomes input to the KNN classifier, and the features like mean and Discrete Cosine Transform (DCT) are chosen to train the classifiers [8]. For other plastic surgeries, till now we detected forehead wrinkles by using edge detection which is Canny edge detector as it takes into consideration the connectedness through the hysteresis threshold and non-maximum suppression to suppress wrinkles' neighbors.

Also we used 3D scanners for bone deformity scanning and we used mimics version 21.0 and 3matic version 13.0 for applying some reshaping on a deformed skull then we used 3matic for finishing. The files from the 3D scanner can't be connected with the mimics so we used DICOM files. We are still working on enhancing the diagnoses of skin diseases and we will go deeper in plastic surgeries like nose
Reshaping, face slim down also refilling the wounded skin or any area needs to be covered will be included in our work.

III. Results And Discussion

A. Face Detection

We used Viola-Jones object detection framework for fast and live detection due to adaboost, integral image and cascading of features which decreases calculations and their complexity, the results after applying after applying Viola-Jones are shown in Fig. 4 with accuracy 79.5%, this accuracy was due to some tilted faces as Viola-Jones requires full view frontal upright faces to match the Haar features.

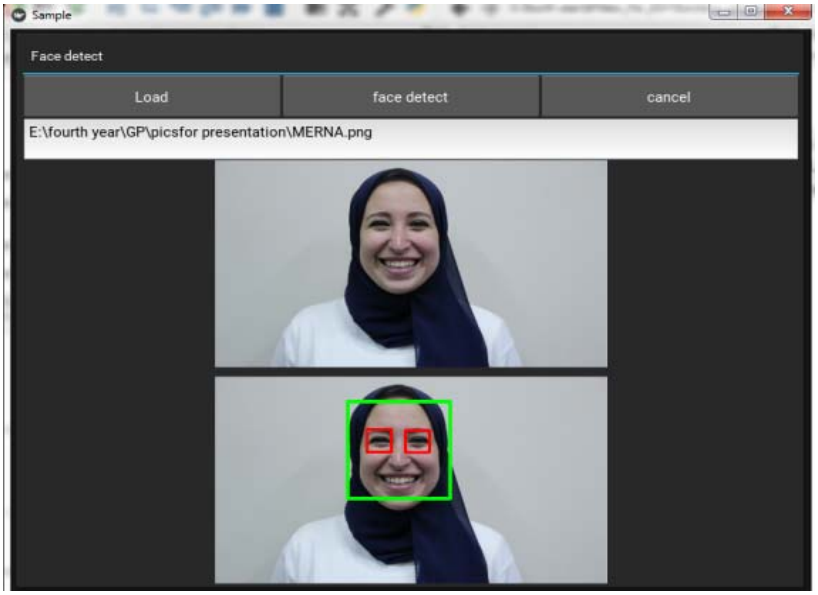


Fig. 4 Results of face detection in our GUI

B. Skin Tone

We applied skin tone by applying a global operator on the image which is taking mean of the grey scale-face detected-image and comparing it with the mean of the grey scale of colors of skin tone palette, the results are shown in Fig. 5 with accuracy of the algorithm reaches 70% due to the change in illumination from picture to the other and this is treated by constant illumination on face and the palette used.

C. Vitiligo Skin Diseases

B-channel is clustered by K-means taking the maximum intensity range and ignoring the other clusters, the area that has lost pigment is detected as shown in Fig. 6.

Including more skin diseases like melanoma and melasma to our work will lead us to use more effective criteria for diagnosing and differentiate between several skin diseases, so till now segmentation by k-means clustering is efficient for diagnosing Vitiligo.

D. Burns

Using segmented burn images as shown in Fig. 7 and using KNN classifier with mean and Discrete Cosine Transform as features and the results of classification is shown in Fig. 8, accuracy reached is 70%. But we will improve the accuracy by

training more pictures after taking data from Al-Kasr Al Ainy hospital and applying more features like contrast and homogeneity as done by Wntanajittikul et al. [7].

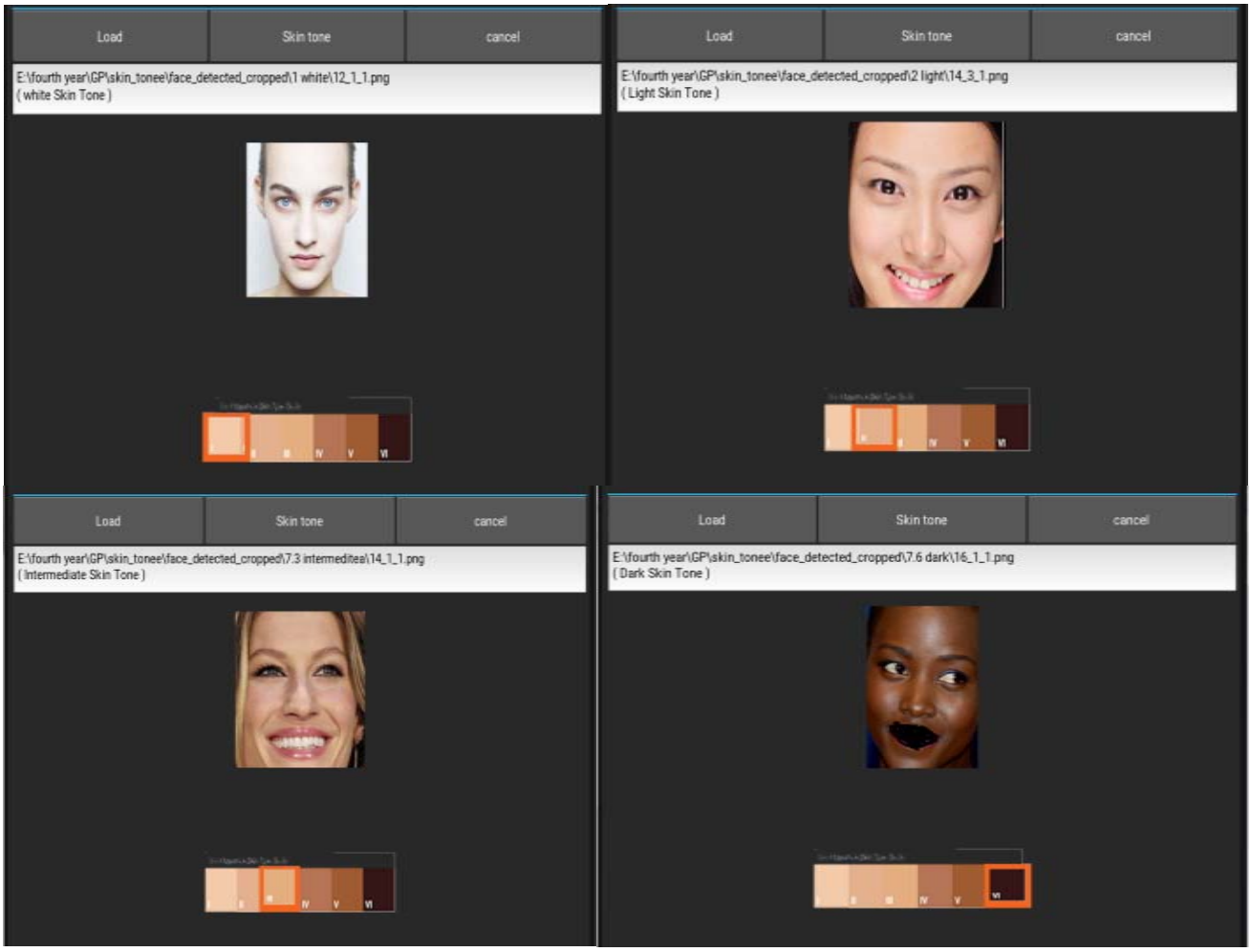
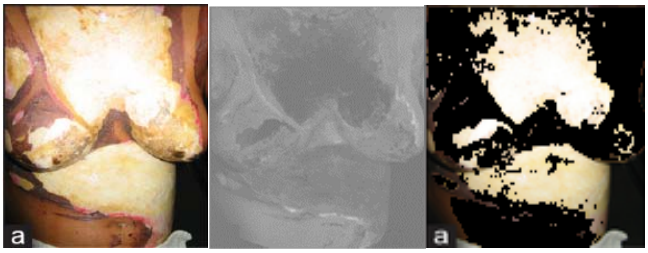


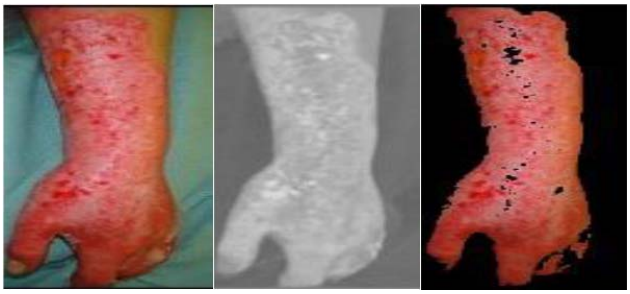
Fig. 5 Results of skin tone in our GUI

(a) (b) (c)

Fig. 6 (a) RGB-space image with vitiligo. (b) b-channel image. (c) Areas lost pigment, with black color, are segmented

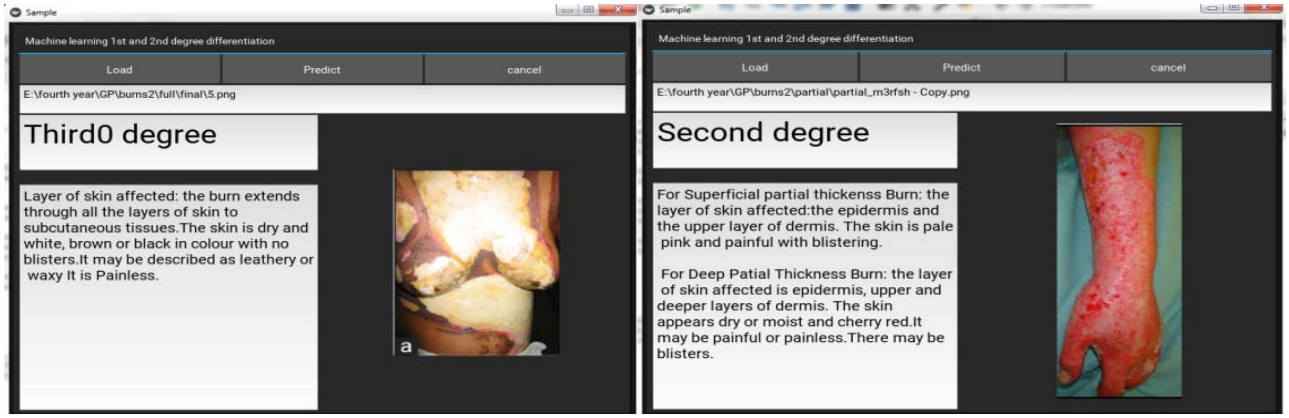


(a) (b) (c)



(d) (e) (f)

Fig. 7 (a) Third degree burn in RGB color space. (b) Third degree burn Cr-channel. (c) Third degree burn after segmentation. (d) Second degree burn in RGB color space. (e) Second degree burn Cr-channel. (f) Second degree burn after segmentation



(a) (b)

Fig. 8 Results of burn degree classification using KNN algorithm in our GUI showing the picture, the degree of burn and general information about the degree of burn. (a)Third degree burn image. (b) Second degree burn image

E. Other Cosmetic Surgeries

For wrinkles detection, we worked here on forehead wrinkles then we applied Canny edge detection, the results are shown in Fig. 9.

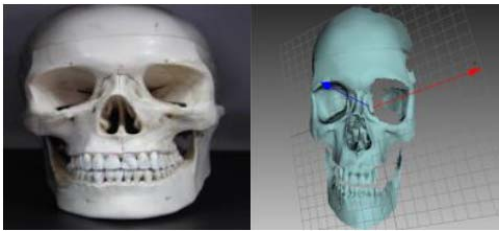
(a) (b) (c)

Fig. 9 (a) Image for fore-head wrinkle detection. (b) Image with fore-headcropped. (c) Image after applying edge detection

Nose reshaping (rhinoplasty) plastic surgery is still under investigation.

F. Bone Deformity

Here are the results after scanning a skull shown in Fig. 10.



(a) (b)

Fig. 10 (a) Real skull, (b) Scan for the skull

We worked on CT DICOM files and applied mirroring on the 3D skull so the next step would be taking from the undamaged side and cover the damaged one and from these files accurate measurements for patients facial landmarks would help doctor in plastic surgery planning also will help patients visualize their current condition and simulated changes.

IV. Conclusion

Software gives post-operative prediction for many facial plastic surgeries with a smart mirror to show difference between the patient's current appearance and the post-surgical prediction. This will make balance between patient's satisfaction and medical standards' satisfaction, decrease different diagnoses, and will help doctor to follow up the improvement in patient's case.

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