Facial Image Reconstruction From A Single Frontal Image Using Intensity Histograms and 3-D Mapping

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Summary
Face Recognition [Pentland et al 1991] confronts innumerable hurdles in the form of variations in lighting conditions during image capture, Occlusions, damage in facial portions due to accidents etc. Hence recovery of the complete picture of a human face from partially occluded images is quite a challenge in Image Processing. Facial imaging proposed in this paper is the method of generating 3-D face mask of a subject. This process involves receiving one frontal image of the subject from a digital imaging device (Cameras in Smartphone, tablet or PC) and applying algorithms for edge recovery of the face. Once the face edges are detected, the light intensity incident on the face is mapped as a 3-D histogram. The intensity gradients formed due to the contour [Kass et al 1998] of the face are then mapped on to the face as depth points in a grid-based space. Finally, the representation determined from the database is used to generate 3D facial data of the subject based on the best mapping

Key words:
Face recognition, histograms, personal identification numbers(PIN), 3- D Mapping, Edge Detection.

1. Introduction

Mapping a 2-D image to 3-D image has always been a challenge to researchers. It is one of the latest developments in computer vision [8] along with image processing. It has many applications like face detection and recognition, body imaging etc. One of the main application areas in image processing methods is to extract the feature and intensity gradient information for expression interpretation.
Image reconstruction techniques are widely used to convert 3-D images from sets of 2-D projections [1]. These reconstruction techniques form the basis for common imaging modalities such as Military bases, Security purposes and they are useful in medicine, biology, earth science, archaeology, materials science, and nondestructive testing.
The mathematical foundation for these reconstruction methods are the Radon transform [2], the inverse Radon transform, and the projection slice theorem [2]. Computational techniques include filtered back projection and a variety of iterative methods. Several projection geometries are commonly used, including parallel beam, fan beam, and cone beam.
In this paper we have used the intensity gradient to develop the 3-d face image using only the frontal image of human face. The resultant image would be a 3-D mask of the original face. The work is divided into 7 sections. Section 2 describes the history and related work. Section 3 describes the methodology. Section 4 shows the experimentation and section 5 discusses the results and their analysis. Section 6 makes an attempt to list some applications of the work where as section 8 provides future scope of research and conclusion to the paper.

2. Literature Survey

2.1 Background

Image processing is any form of signal processing for which the input is an image, such as a photograph or video frame, the output of image processing may be either an image or a set of characteristics or parameters related to the image. Image processing usually refers to digital image processing, but optical and analog image processing are also possible [20].
In the beginning of the 1970's, facial image recognition was considered to be a 2D pattern recognition problem. The distances between important points were used to recognize known faces, such as measuring the distance between the eyes or other important points or measuring different angles of facial components. The following methods were and are used in face recognition [2].
Eigen value Methods [19].
Feature-based (structural) Methods [20].
Hybrid Methods [21].

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Of the above cited methods, Hybrid methods are considerably modern and require a discernible description. Hybrid face recognition systems use a combination of both holistic and feature extraction methods. Generally, 3-D Images are used in hybrid methods. The image of a person's face is captured in 3-D, allowing the system to note the curves of the eye sockets, for example, or the shapes of the chin or forehead. Even a face in profile would serve because the system uses depth, and an axis of measurement, which gives it enough information to construct a full face. The 3-D system usually proceeds with Detection, Position, Measurement, Representation and Matching.

(i) Detection - Capturing a face either from a scanning, a photograph or photographing a person's face in real time.
(ii) Position - Determining the location, size and angle of the head using any of the available edge detection methods.

2.2 Measurement

Assigning quantified measurements to each curve of the face to make a template with specific focus on the following

(i) outside of the eye
(ii) the inside of the eye
(iii) the contour of the forehead
(iv) The surface between the eye and the brow
(v) the width and height of the mouth
(vi) the curves of the cheek
(vii) the angle of the nose vertically
(viii) the width of the nose at the bottom

2.3 Representation

Converting the template into a code – a numerical representation of the face using digitization process

2.4 Matching

Comparing the received data with faces in the existing database. The data base consists of images that have gone through the above listed process as a part of the training of the system.

In case of 2-D images the image in question needs to be similar to the images in database by more than 66% to be considered a match where as in Case the 3-D image is to be compared with an existing 3-D image, the existing image in the database must match with a similarity of 80% or more.

LDA [19]: Linear Discriminant Analysis is the most prevalent algorithm for feature selection in appearance-based methods. LDA is used to maximize the different power of feature selection. LDA separates the data by transforming the original data space into small dimensional feature space. The main aim of LDA technique is to maximize the between-class scatter matrix measure. But the accuracy of the result in LDA depends upon how efficiently database is created. hence a different technique, 3-D face recognition is used for achieving more accurate result.

ICA: Independent component analysis (ICA) [12] is a method for finding underlying factors or components from multivariate (multidimensional) statistical data. There is need to implement face recognition system using ICA for facial images having face orientations and different illumination conditions, which will give better results as compared with existing systems. What distinguishes ICA from other methods is that, it looks for component that are both statistically independent and non-Gaussian. The ICA is similar to blind source separation problem that boils down to finding a linear representation in which the components are statistically independent.

2.5 Dimensional Recognition

A newly emerging trend, claimed to achieve improved accuracies, is 3-D face recognition [16]. This technique uses 3-D sensors to match information about the shape of a face. This information is used to identify distinctive features of a face, such as the shape of the eye sockets, chin and nose. One advantage of 3-D facial recognition is that it is not affected by changes in lighting like other techniques. It can also identify a face from a range [15] of viewing angles, including a profile view. 3-D data points from a face vastly improve the precision of facial recognition. 3-D research is inflated by the development of sophisticated sensors that do a better job of capturing 3-D face imagery. Each sensor represents a different part of the spectrum. But even a perfect 3-D matching technique can be sensitive to expressions. However, all the techniques listed above require a frontal image and a profile image (left or right) in the least. Some methods even require the rear image of the head. This has been a major issue with almost all the 2-D to 3-D facial image mapping systems.

More recently there have been developments such as generating a 3-D mask of a human face just using a frontal image [21]. The new technique uses a reference face model as base to generate the 3-D mask of a given human face with a single input image of the front view. It can generate 3 views based on the single input namely frontal, turned left and turned right. The idea used is incremental minimization of distances between the reference image boundaries and the input image boundaries. As the authors have stated, here the requirement is that the images are taken under controlled conditions [21] and 3-D model is built on top of the reference images.

In [22], a research project-based paper, the authors show an algorithm to generate a 3-D morphable model (3-

DMM) using a single frontal image of a human face. Here a regression-based model is used, where a neural network [22] runs the volumetric regression to generate the 3-D model. Also, this is the only method that claims to work for different tilts, turns as well as occluded images. From the results it is evident that the algorithm can handle some occlusion. This algorithm uses voxelisation [22] to enhance the smoothening of the generated face model.
The base for the algorithm designed, developed and analyzed in this paper is FIREACH- Facial Image Reconstruction using Elliptical Approximation & Convex Hull [1]. The system in FIREACH uses the elliptical nature of human faces and the approximate vertical symmetry to reconstruct missing areas of occluded human faces. The algorithm then uses the convex nature of the curves that build the human face from a frontal view to generate the output of a complete face.

3. Methodology

We have used the “Edge detection Based face Recognition" method. The idea here is to develop a system that can first separate the foreground image from the background. Edge detection is a necessary preprocessing step in many computer vision algorithms [2].

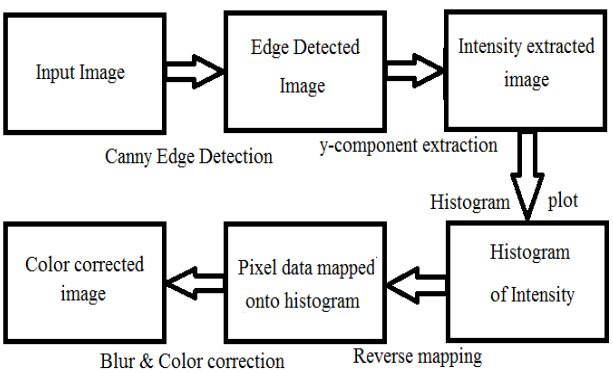

Fig. 1 The Flow diagram of proposed method

Phase 1: Canny [19] edge detection method is a popular method for detecting edges. The algorithm presented in this paper uses this method as a preprocessing phase. The result of the edge detection is the face image minus the background where the edges are represented by white pixels [19]. This makes it easier for the algorithm to proceed with the color and intensity information extraction.

Fig. 2 The edge detected image sample

Phase 2: After the edge detected image is formed, in the next phase the intensity values of each pixel are stored in a 2-D array. The extraction phase parses through the image file reading pixel after pixel, copying the CMYK data into a buffer.
The next phase involves drawing of the histogram of the intensity of the image using the 2-D array as the matrix.

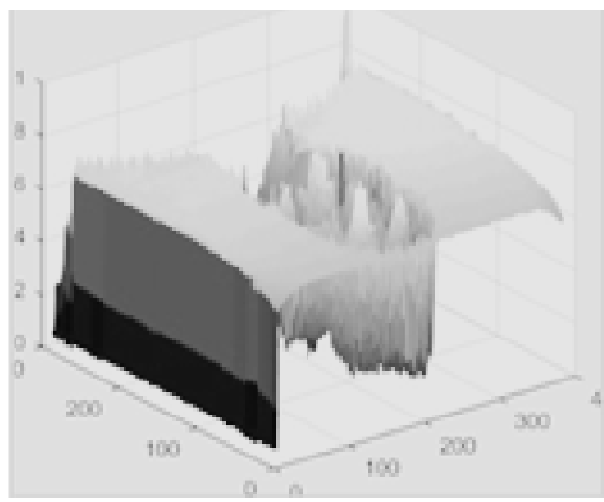

Fig. 3 The histogram of intensity

Then the image is mapped on to the intensity histogram using the flat background as the base line and all other points are elevated in z- dimension.

Fig. 4 The histogram mapped back onto the image before color correction

The resulting image is then color corrected. The colors are taken from the original image and averages are computed for nearest neighboring points and filled.
The final image is then given "rotation" along all the three axes and compared with the input image for obtaining the loss/gain in color information.

4. Experimental Consideration

We have used MatLab™, for testing. The experiments were done on images submitted by authors and volunteers (Figure 5 through Figure 10) and Free image data bases (Figure 11 and 12). The resulting image is given 3-d rotation to verify the intensity gradient and the 3-d nature of the output. The images generated are presented as they appear in the MatLab™ window.

Fig. 5 A sample image input (Author 2)

Fig. 6 The 3-d mask frontal from image in Figure 5

Fig. 7 Image input (Author 1)

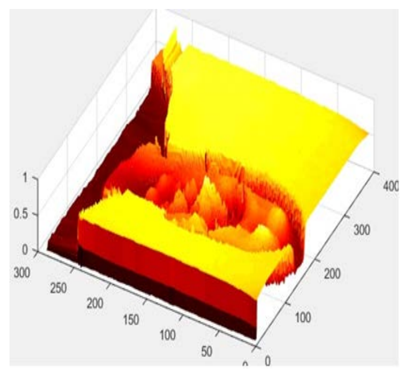

Fig. 8 The 3-d mask turned about x and y axes from image in Figure 7

Fig. 9 Image input (Volunteer)

Fig. 10 The 3-d mask frontal from image in Figure 9

Fig. 11 A second sample from BERN database [6]

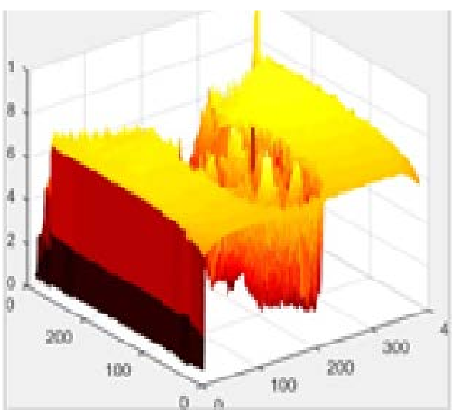

Fig. 12 The resulting 3-D mask rotated about x and y axes to show differential intensity gradient [17]

5. Results & Analysis

The results obtained in the experimentation are tested for the mapping efficiency and additional data generated to build the 3-d mask. The analysis is as follows.
The mapping efficiency E is given by, ratio of the percentage of color data preserved in the output image to the data in the input image. In the proposed solution the average ratio is 1.18. The plot of 2-d color data versus 3-d color data is shown in Figure 13. This clearly shows that the generated 3-d mask contains all color data of the input image.
However, the change in color palette can be attributed to the intensity gradient [17] merged with the color information of images [20]. Following this, the algorithm attempts to correct the color information for the increased number pixels using nearest neighbor method [1].

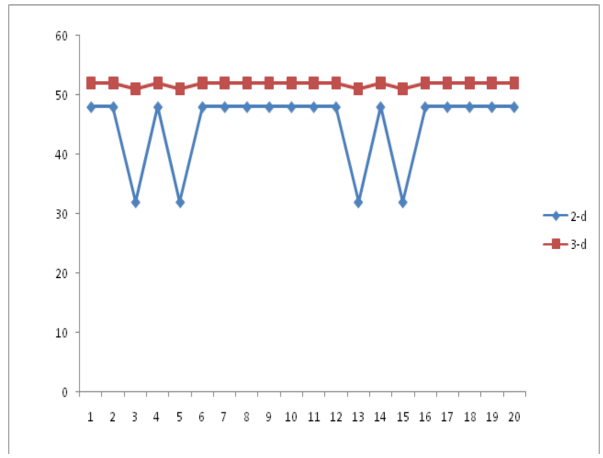

Fig. 13 The correlation between 2-d image from Figure 5 and its result from Figure 6

6. Applications

Face recognition systems identify people by their face images. Face recognition systems establish the presence of an authorized person rather than just checking whether a valid identification (ID) or key is being used or whether the user knows the secret personal identification numbers (PINs) or passwords.

A few examples are listed below:

(i) To eliminate duplicates in a nationwide voter registration.
(ii) To enable access control applications in multi user environments.
(iii) To prevent unauthorized modification of data in offline computers.
(iv) To enhance public transit security.
(v) To search image databases of licensed drivers, benefit recipients, missing children, immigrants and pending legal issues.
(vi) To authenticate users for banking, electronic commerce, identifying newborns, national IDs, passports, employee IDs.
(vii) To enable espionage and surveillance.

7. Future Scope & Conclusion

The proposed method of using light intensity to develop a 3-d contour model of a human face using only a frontal face image has been shown to function as per expectation and also shows considerable efficiency. The system developed using the proposed algorithm is implemented using MatLab™ in a simplistic manner and the experimental results clearly indicate that it functions seamlessly on the chosen platform. It is concluded that the system can be utilized effectively in security and authentication mechanisms at large areas with multi user environments. Our work can enhance security to a greater level and provide future systems with an improved staring point. Further, this work opens multiple problems such as,

(i) Detection of skin diseases using the 3-D mask as a reference
(ii) 3-D printing face masks for espionage and surgical purposes
(iii) Increasing the accuracy by enhancing the intensity quanta
(iv) Improving user experience in gaming

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