Convolutional Neural Network Classification On 2d Craniofacial Images

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Abstract

This study presents a craniofacial superimposition consisting of filtering, feature extraction, classification for skull modeling. Initially, the Gaussian filter removes the noise and Otsu thresholding extracts the features. The extracted features is sent as a trained data to the Convolutional Neural Network (CNN). The experiment is carried out on 100 input image set that encompasses both the cranial and facial image. The experiment is conducted on new input image and it is then applied directly to the CNN classifier. The experimental results show that the CNN classifier achieves higher classification rate for 2D landmark and skull modelling than the existing methods.

Keywords*:ROI extraction, Craniofacial superimposition, Otsu threshold, CNN classification*

1. Introduction

Craniofacial superimposition is a method by which photos of a skull from the forensic settings are contrasted to facial pictures of a once living person who could represent the skull. The method has been used commonly when samples are suspected to be linked to a certain missing person, for whom photos are visible. In particular in the last two decades, the methodology and the nature of the applications have evolved considerably. Such progress was influenced by engineering, developments in forensic anthropology and forensics and, more recently, by data and morphometric analyzes specialists. [1].

Facial reconstruction is the effort made by examining the extracted skull to approximate an individual visual appearance [3] – [10]. In the forensic sense, it is used when a crane, considered to be new and therefore of forensic significance, has been recovered or attempts have been made to associate with traditional methods. Facial reconstruction is then used to create a facial picture and present information regarding missing people, typically via the press, to the general public. Farther, for the researchers, craniofacial superimposition is one of the time consuming jobs. However, there is no standardized approach but typically that specialist uses a specific process. Therefore, the design of automated processes to enable the forensic anthropologist to execute them is of major importance [2].

The study present a craniofacial superimposition using a series of processing that encompasses ROI point extraction, CNN classification for 2D landmark and skull modelling. The first step is the process of noise removal from the input 2D facial and cranial image using Gaussian filtering. The features are extracted using Multi-level Otsu thresholding process. The extracted features from the images are enhanced using morphological erosion, edge-off and area opening operator. It is then sent to the ROI point extraction that extracts effectively the points in both the images.

2. Proposed Method

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The architecture of the proposed method is given in Figure 1 and the entire processing is given in following sub-sections.

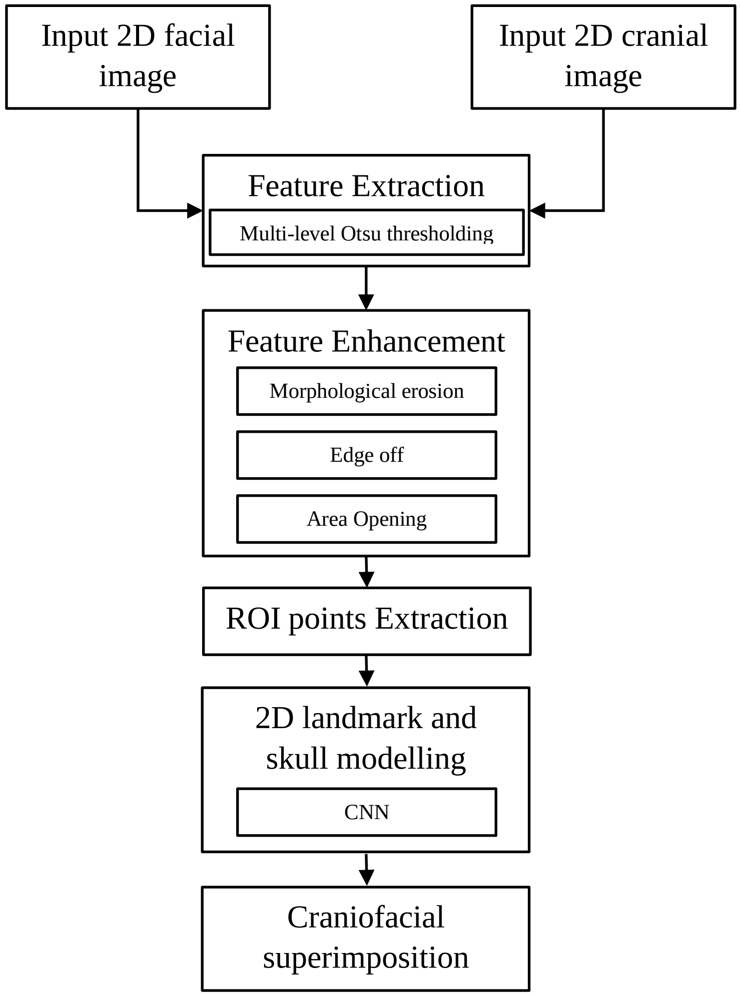

Figure 1: Architecture of the Proposed Method

a. Pre-processing

The input 2D facial and 2D cranial images are filtered using Gaussian filtering [12] for removing the noise present in the CT images.

i. Feature Extraction and Enhancement

The feature extraction initially uses the Multi-level Otsu thresholding [11] (Figure 2) to obtain the facial boundary in both 2D facial and 2D cranial images. The output image obtained from the feature extraction is mentioned as *I*. After the process of extracting the boundary layer from the images, the feature extracted image *I* is smoothened for enhancing it. This is carried out using the process of morphological erosion.

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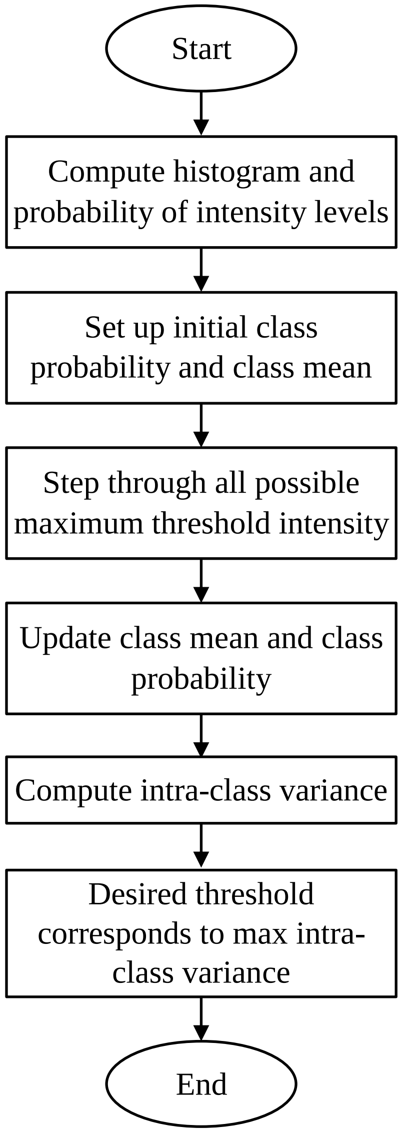

Figure 2: Multi-level Otsu thresholding

The process of morphological erosion on the feature extracted image *I* is carried out using a structural element S, which is expressed in the following equation:

$$I \oplus S = x : S_x \subset I \tag{1}$$

where $\subset$ - subset. $I \oplus S$ is formed using x points, where the S is translation using x fits in the feature extracted image I and output enhanced image is J.

Edge-off and area opening parameter is used to eliminate the unnecessary objects present in the enhanced image. The former parameter is used for eliminating the objects associated with the facial borders. The latter parameter is used for discarding a pixel if its size is lesser than the empirical threshold value R.

$$J \circ (R)_n = \bigcup P, area(P) \geq R \tag{2}$$

where J - input image and P - n-connected component area.

ii. ROI Extraction

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In the present study, we use Region of Interest (ROI) point extraction or seed point extraction from both 2D facial and 2D cranial images. For the purpose of segmenting both 2D facial and 2D cranial images, the feature points are distinguished in a specific manner. Once the target area is extracted, the position of ROI points are estimated on a condition that the ROI points must lie within the target area of both 2D facial and 2D cranial images. In both the images, initially the target region is identified and finally the characteristic ROI points are extracted. We initially apply both the procedures in cranial image, since it reflects the facial topology of the captured image, which can be sent as the reference image. Then the procedure is carried out in the facial image. Hence, the study extracts well the ROI points from both the 2D images rather than carrying out the entire pixel processing. In the following process, we consider the processing of 2D binary cranial image and the similar process is followed for 2D binary facial image.

At the initial step, the feature enhanced image is considered as the input for ROI extraction, which is of a pure binary form. The pixels present inside the cranial region or target are is treated as "1" and vice versa. The pixel processing is iterated until entire pixel is processed.

Step 1: Divide the image into two sections using a reference line using mean value of columns.

Step 2: Find the nonzero value from left border

Step 3: Find the nonzero value from right border

Step 4: For processing a pixel in binary cranial image, say $m = 1$, the neighbouring pixels around it (i.e. eight neighbourhood pixels) should fulfil the conditions (Step 5 – Step 8) given below and then the pixel can be removed, say $m = 0$.

Step 5: The total number of pixel value of 8 neighbourhood pixel is changing from 0 to 1 in counter-clockwise direction is considered as 1;

Step 6: The total number of neighbourhood pixel should lie between [2,6];

Step 7: The product values of pixels lying in upper, right and bottom neighbourhood is considered as 0;

Step 8: The product values of pixels lying in left, right and bottom neighbourhood is considered as 0;

Step 9: For processing a pixel in binary cranial image, say $m' = 1$, the neighbouring pixels around it (i.e. eight neighbourhood pixels) should fulfil the conditions (Step 10 – Step 13) given below and then the pixel can be removed, say $m' = 0$.

Step 10: The total number of pixel value of 8 neighbourhood pixel is changing from 0 to 1 in counter-clockwise direction is considered as 1;

Step 11: The total number of neighbourhood pixel should lie between [2,6];

Step 12: The product values of pixels lying in upper, left and bottom neighbourhood is considered as 0;

Step 13: The product values of pixels lying in left, right and bottom neighbourhood is considered as 0;

At the final step of ROI extraction, Harris operator is used for generating the ROI points. The Harris corners of the 2D cranial image is stable, even if the obtained target area shape is varied. The obtained ROI is located with the obtained target area of 2D facial image. The process between the 2D cranial and 2D facial image is given below:

Step 1: Differential image between the 2D cranial and 2D facial image is estimated using following expression:

$$E(m,n) = \sum_{x,y} w(x,y)\left[J(x',y') - J(x,y)\right]^2 \quad (3)$$

where

$J(x,y)$ - 2D cranial image;

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$J(x',y')$ - 2D facial image;

$w(x,y)$ - Gauss window function.

Step 2: The image obtained after deduction is given as follows:

$$E(m,n) \approx [p,q] M \begin{bmatrix} p \\ q \end{bmatrix} \tag{4}$$

where,

$$M = \sum_{x,y} w(x,y) \begin{bmatrix} J_m^2 & J_m J_n \\ J_m J_n & J_n^2 \end{bmatrix} \tag{5}$$

Step 3: The corner response function is thus defined as:

$$R = \det M - k(traceM)^2 \tag{6}$$

where

trace$M = \lambda_1 + \lambda_2$;

det$M = \lambda_1 \lambda_2$;

λ_1 and λ_2 - Eigen value of M;

k - empirical constant.

Step 4: Differentiate the corner points using an empirical threshold value R.

b. 2D Landmark and Skull Modelling

After the extraction of the ROI points from the 2D facial and 2D cranial, the points are placed over both the images. After displaying the points on it, the difference between the ROIs of the 2D facial and 2D cranial is compared and then the skull is modeled using the extracted points from the 2D facial and 2D cranial images. The ROI of several extracted images of both 2D facial and 2D cranial image set is given as an input to the CNN algorithm, where an input of about 100 images are used for training the CNN. Finally, Craniofacial superimposition is the process of comparing the ROIs of images obtained out from the CNN algorithm and the original image. If the difference between the ROI of 2D facial and 2D cranial is large, then the facial ROI points are extracted again by iterating the ROI extraction process over that particular region and if the difference between them is lesser, it is used for modelling the skull in a two dimensional manner.

3. Results and Discussions

The study is carried out on 10 test set images that consists of both cranial and facial image with input obtained from 100 training sets. The results are evaluated against run time and the classification accuracy between the proposed and existing methods that includes: Fuzzy based Craniofacial superimposition, evolutionary algorithm and cooperative evolutionary approach. The Figure 3 shows the results of computational time and Figure 4 shows the results of classification accuracy. The result shows that the proposed method achieves improved classification accuracy with reduced run time than the existing methods.

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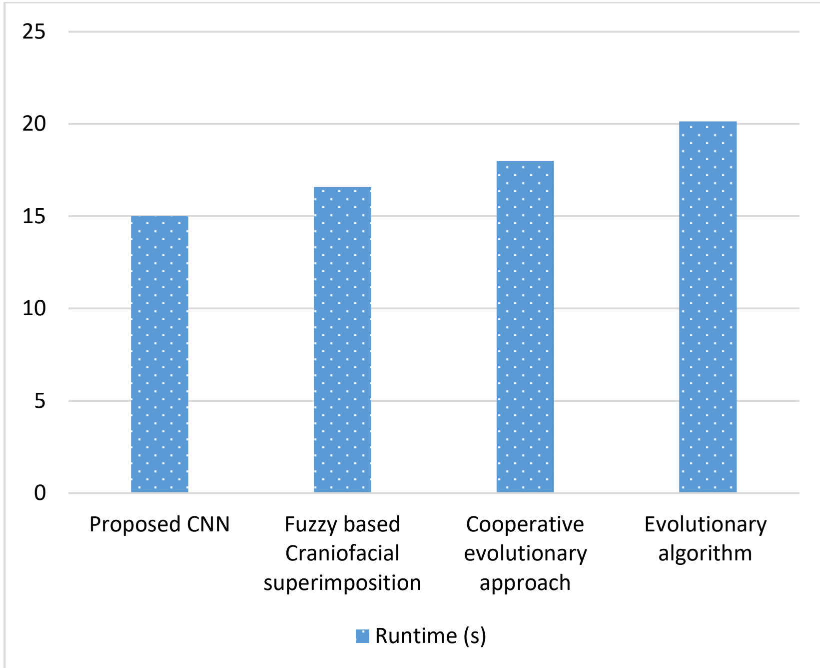

Figure 3: Computational Time

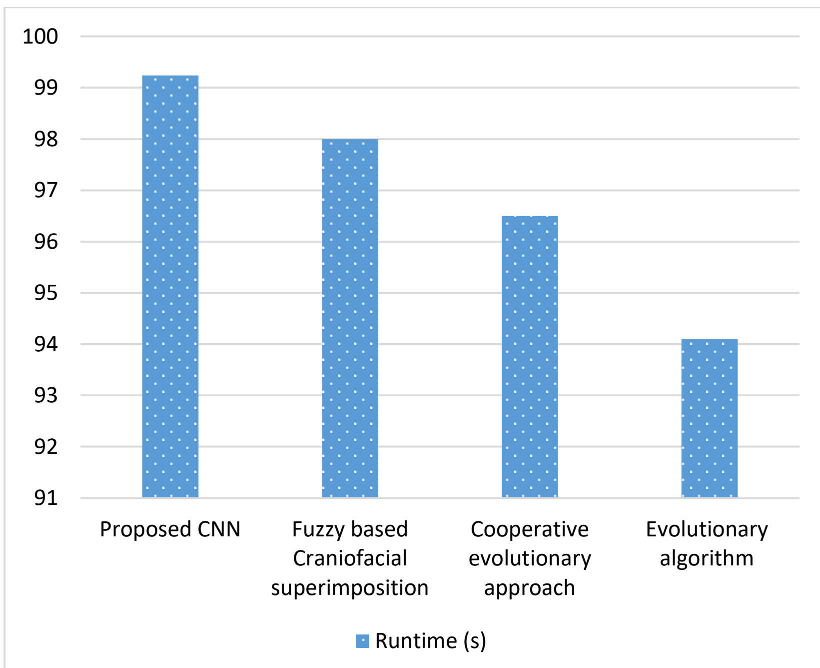

Figure 4: Classification Accuracy

4. Conclusions

In this paper, a series of processing is used for a craniofacial superimposition on 2D input image. Initially, the noise is removed using Gaussian filtering and then Multi-level Otsu thresholding extracts the features. Enhancement of the extracted features is carried out by morphological erosion, edge-off and area opening operator. The ROI points are then extracted for classification and building the 2D landmark and skull modelling. The CNN classifier is used for classifying the test images and the simulation result reveals that

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the proposed method has higher classification rate than the existing methods and it effectively used for modelling the skull.

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