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Automated Framework for Skull Damage Detection and Repair Using KNN and Template Matching Methods

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ABSTRACT: In 3D computer vision domain of medical applications, geometric data completion of person body parts is key research problem since from last decade. Human skull damage detection and repairing is one such application. The current machines used for scanning first collects the fragments of skull and then automatically assemble them to form the original skull image from such fragments.But the machines generating the automated assemble skull images having possibility of losing data or having damage in certain areas of skull images.Automated skull damage detection and repair is vital requirement for medical researchers and groups to save their time and focus on accurate analysis. In this paper we proposed the automated framework for skull damage detection and repair using two different approaches. First goal of our framework is to detect whether input skull is damage or not before proceeding to medical analysis. The damage detection is done by using machine learning approach in which first features are extracted and then fed to k-nearest neighbours (KNN) algorithm for detection of skull damage. If the skull is normal then it should not go for skull repair process, else damage skull is given input to skull repair process. The skull repairs are done by using reliable symmetry detection algorithm and template based method on damaged models, and use it to repair the skull.For performance evaluation we used neural network classifier to estimate the accuracy of detection and repair.

KEYWORDS: Damage, Assembly, Skull Fragments, Skull Repair, Geometric Features, Gradient Features, KNN, Accuracy.

I. INTRODUCTION

In vision processing and medical imaging skull damage repairing is one the key challenges to mitigate for proper treatment. The damages in human skull images are nothing but the linear fractures in skull base which are the part of facial fractures multitude which extending the skull base. The major commonly used site for such skull fractures are foramen magnum, sphenoid wings, temporal bone and sphenoid sinus. From one survey, in United States, it is noted that approximately around 2 million injuries of head. Such injuries are resulted into the disability as well as death of children. In many industry oriented countries the main cause of trauma is motor vehicle accidents. In accidents of motor vehicle, injuries related to neck and head occurring around 1/3 of the accidents. In addition to this, overall 28 % fractures are resulted from the accidents of motor vehicle.
The fractures those are skull base occur in range of 3.5 % to 24 % with all the head injuries. This resulted into only 2 % of all the traumas. In 2013, author Behbahani et al reported the study over retrospective of 1606 points of the head trauma. Author observed that around 965 of such patients was head fractures in which around 220 were related to the

skull base. These 220 were further categories into different kinds of fractures such as orbital roof fractures were 47, ethmoid were 21, clivus were 2, sphenoid were 44, temporal bone were 78 etc.The skull base fracture incident was increased along with fractures of orbital wall rim as well as ZMC. The mandible and nasal bone fractures was not required to correlate with the skull base fractures. In addition, skull base fractures incidence was increased along with the total number of the skull fractures with the increase of incidence of 10 to 12 % with 2 or more fractures. The fractures like temporal bone was around 18 % to 40 % of time, whereas frontal fractures were 15 % to 20 %.

The search for human welfare and longevity has always been one of the objectives of the various areas of knowledge. The medical field is one that has this goal as the main focus of its research as the development of prostheses to improve the welfare of people with disabilities. Develop such a product is not a trivial process and still being carried out by hand by the surgeon due to unique physical characteristics of each patient. With existing technologies such as CAD/ CAM, computerized tomography and artificial intelligence techniques, it is possible to integrate them and create a process for obtaining optimal solutions [2]. Using computed tomography (CT) is possible to indirectly map the region of interest of the human body to obtain the first information [1] and from CAD (Computed-Aid Design) to reconstruct a three-dimensional geometric representation [5]. To perform this procedure are used images provided by CT in which are the skull's "slices".

Skull repairing is done by image processing terminologies recently. There are few methods introduced for automatic skull repairing. MRI and CT imaging are recent technologies and advances of medical imaging which allowing the 3D reconstruction process of structures like anatomic in many medical applications with inclusion of custom made implants designs.There are number of researches presented for crania implants with the benefits of adopting the various computer aided design (CAD) as well as advance manufacturing platforms. However there is no single study presented for detection of skull damage automatically and applying skull repair process only if there is damage detected.

In literature we study that completion of geometric data is vital research challenge in domain of 3D computer vision. Therefore in this paper we are presenting the novel automated, efficient approach for skull repairing framework and detection in order to save medical experts time required for surgery. The goal of this paper is propose the design and algorithm of efficient framework for skull damage repair and completion. In medical fields such as forensic analysis, archaeological analysis and anthropological analysis, skulls provides important information. In case of forensic analysis, face reconstruction is done by using the skulls in order to get the details of their appearances. The various subject skulls are valuable those are from museums and hence should be pollute. Thus with the use of 3D scanning, such skulls are introduced in computer and then processed under the digital environment. There are three basic steps of pipeline in order to construct the original face from the skulls such as (a) collection of skulls, cleaning of skulls and preparation of skulls, (b) damaged skull repairing and (c) procedure of facial skin clay modelling. For skull completion, there are two main problems or challenges such as (a) most of times skulls are fragmented and hence the areas those having important information can be damage. (b) Second challenge is that skull which repaired should have high conformity.

In medical field for 3D computer vision, completion of geometric data of human body is a one of research challenge. The medical devices scan the human skulls in fragmented skulls or damaged skulls. The recent medical equipment’s internally assemble the fragmented skulls and generate full single skull using those fragments. However, the generated 3D data for skull is damaged and missing some important data for furt her medical analysis. Therefore it is required automated system to detect such damages on skull and repair automatically for accurate medical analysis. Still to the date is only few research studies presented on skull damage repair automatically but not fully developed and having less accuracy. The recent method presented framework for complete damaged and fragmented skulls using image processing terminologies. The limitation of this method is that, it is working in two modes such as skull completion using skull fragments and skull repairing from incomplete skulls. As discussed above, skull completion is not required as medical equipment’s providing both fragment skulls and entire skull data.

Therefore to overcome the current research problem and limitations stated above, in this project we are presenting the novel framework for skull damage detection and repair using two different approaches. First goal of our framework is to detect whether input skull is damage or not before proceeding to medical analysis. The damage detection is done by using machine learning approach in which first features are extracted and then fed to k-nearest neighbors (KNN) algorithm for detection of skull damage. If the skull is normal then it should not go for skull repair

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process, else damage skull is given input to skull repair process. In section II, we are presenting the different techniques proposed for skull repairing using image processing terminologies. In section III, we are presenting and discussing the methodology proposed with algorithms used. In section IV, the current results and expected results are discussed. Section V presenting the conclusion and future work.

II. LITERATURE SURVEY

In this section we listed the existing skull assembly and skull repair techniques using image processing concepts.The efficient and effective skull assembly method is highly important for the further tasks such as completion, modeling and analysis.

2.1. Techniques of Skull Assemble

In [2], Author Cooper et al. introduced the method for 3D pot fragments assembly depending on 3D measurement as well as matching of sherd normal and break curves.

In [3], author Willis et al. proposed approach which is
improved and based on method presented in [2]. In this technique author adopted the Bayesian analysis for the assembly of pots depending on semi-automatic matching process. The practical results showing that method of curve matching having good results on pottery assembly. Curves matching additionally performed by adopting the optimization methods, and hence it resulted into reduction in least square estimation of the point patterns. The limitation of this approach is that it needs more searching space and curve matching time.

In [4], author Johnson et al. proposed the framework for spin image design for identifying the related regions with the similar geometry.

2.2. Techniques of Skull Repair

There are number of techniques proposed for data completion those are scanned like holes filling caused by the scanning occlusions.

In [5], author Mitra et al. pointed the models symmetry via
the scheme of voting. Author use the clustering technique in order to get the symmetry pointed by paired surface and randomly sampled points.

In [6], author proposed new method which is improved version of method presented in [5] for discovering the structural regularity.

In [7], author Raviv et al. adopted the heat diffusion technique for inducing the dene non rigid symmetries and shape metric as the self-isometries along with the diffusion metrics.

In [8], author Simari et al. proposed the GM estimator
technique for detecting the symmetry regions. Also presented the folding tree data structure technique, this is nothing but the hierarchical union of the planar asymmetric and symmetric factors.

In [9] [10], authors of this two papers introduced the different template based methods for skull completion for repairing incomplete models with lost data by using the template model.

III. PROPOSED METHODOLOGY

3.1. Introduction

To overcome the limitations of existing methods of skull damage repair and skull damage detection efficiently and automatically, here we are presenting the new automated framework for not only efficient repairing of damage skull images but also before proceeding input skull image to damage repair functionality it should be tested for detection of skull damaged. Figure 1 is showing the detailed flowchart for proposed methodology.

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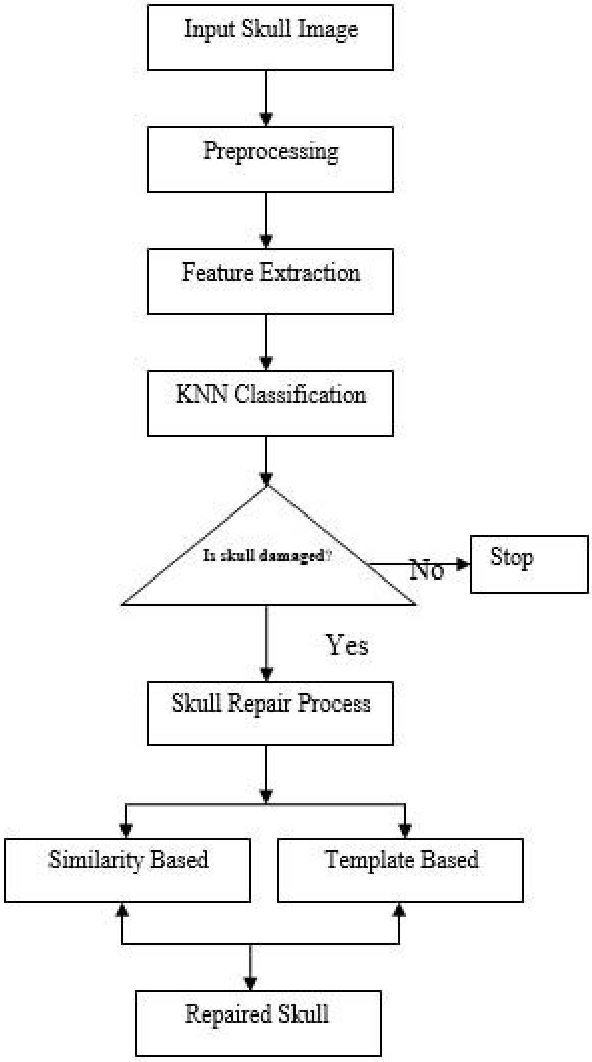

Figure 1: Detailed Flowchart for proposed work

3.2. Designed Algorithms

Algorithm 1: Image Preprocessing
Step 1: Image acquisition: browse input skull image
Step 2: Image resizing: resize input image to fix 512 * 512 size using imresize function.
Step 3: Grayscale conversion: RGB image is required to be converted grayscale which is done by using rgb2gray function.
Step 4: Image denoising and smoothing
Once image is resized and converted into grayscale format, further we have to preprocess it for removal of noise and enhance its contrast by using Gaussian filter. We are using Gaussian filter using sigma 2 and size for filter is [2 2].
Step 5: Final preprocessed image is generated as output of preprocessing.

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Algorithm 2: Extraction of Features
Input: Pre-processed skull image
Step 1: Apply geometric feature extraction technique on pre-processed skull image.
Step 2: Store results of feature extraction in FR1.
Step 3: Gradient features extraction
Step 4: Results are Gradient and Direction
Step 4.1: Compute the standard deviation and mean of Gradient.
Step 4.2: Compute the standard deviation and mean of Direction.
Step 4.3: Store computed values as gradient features in FR2
Step 5: Store FR1 and FR2 in final feature vector FR. Output: FR.

Algorithm 3: Detection of Skull Damage
This can be done by using KNN classifier. KNN (K-Nearest Neighbors) classifier is frequently used in pattern recognition domain. KNN is non-parametric technique used for regression and classification. In feature space of KNN, input is composed of K nearest samples.The use of KNN is based on its use whether is used for regression or classification.

- k-NN classification: Here the result is group membership. The classification of object is done by its neighbors majority voting with particular object being correlated to the class which is most common from its k nearest neighbors. Note that K must be the positive integer and should be small. If the value of K is 1, then input object for classification is grouped to the single nearest neighbour.
- k-NN regression: In this case, result is objects property value. The output value is nothing but its K nearest neighbors average values.

Algorithm 4: Skull Repair and Completion
The skulls which are assembled are incomplete most of time which can having the missing areas, gaps and self- intersections among assembled skull fragments.In this paper, we introduced the efficient symmetry based detection and repair method for damaged regions. If the damages presents on both sides with respect to the symmetric plan, then template based method is used for repair in order to ensure the skull completion. Figure 2 is showing this process.

Skull Repair Using Symmetry-Based Method: The inherent symmetry of skulls usually can provide a relatively accurate repair on damaged regions. In contrast, popular whole filling approaches based on fairing tend to smooth out subtle geometric details, and template-based methods tend to fill holes using the geometric variance of template instead of the substrate of the subject skull itself. Preserving subtlety of skulls is critical to the accuracy of the subsequent tasks such as facial reconstruction/superimposition.

Skull Repair Using Template Based Method: Despite its accuracy, symmetry-based completion cannot repair skulls whose both sides (with respect to the symmetric plane) are missing. As the name indicates, this method is using the templates of skull to fill the holes in original damaged skull image. We combine the symmetric based and template based methods to repair skull image completely without missing anything.

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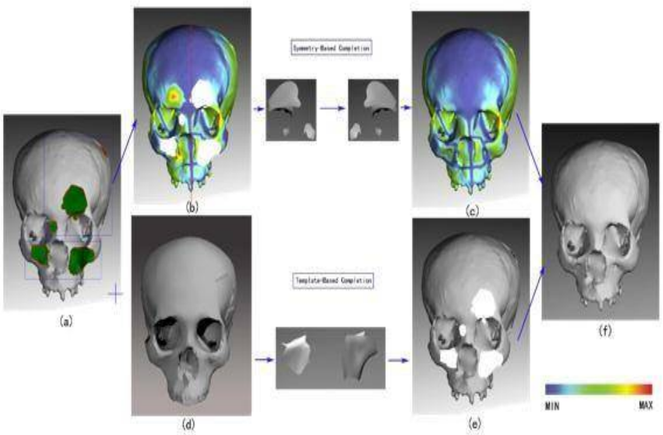

Figure 2: Skull Repair Framework

IV. SIMULATION AND ANALYSIS

The practical analysis and simulation of proposed approach is done by using MATLAB simulator with dataset of skull images scanned by NextEngine 3D Laser Scanner for European and African males and females. Figure 3 is showing the sample for such skull images dataset .By using dataset, we have below set of results achieved during the practical work analysis for each step like preprocessing, segmentation, feature extraction, damage detection and detection or recognition accuracy. Along with the recognition accuracy we have also measured the performances such as true positive, false negative and total execution time required for detection of skull image whether it is damaged.
Figure 4 is showing the overall framework with input skull image is taken on which first preprocessing steps are applied and its outputs are showing in frame 2 and frame 3 for resized with grayscale image and preprocessed image respectively.

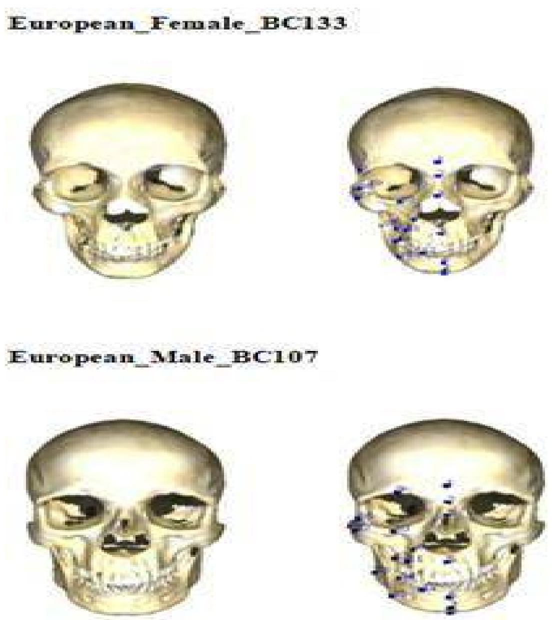

Figure 3: Example of Skull Images

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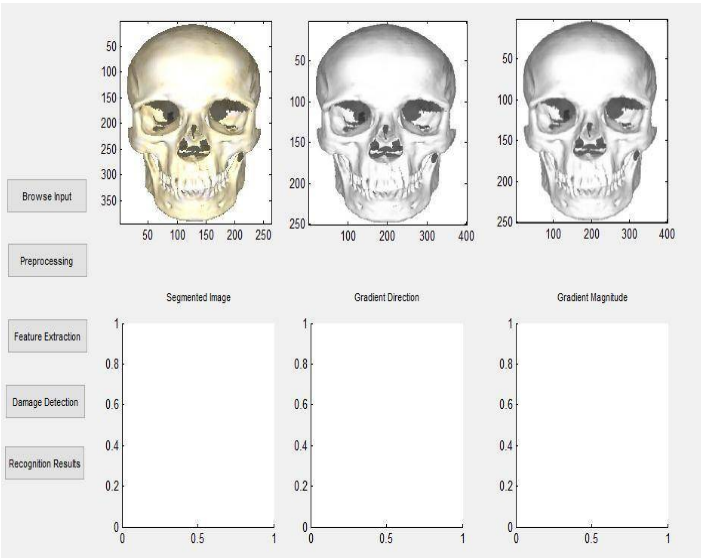

Figure 4: Image Preprocessing Results

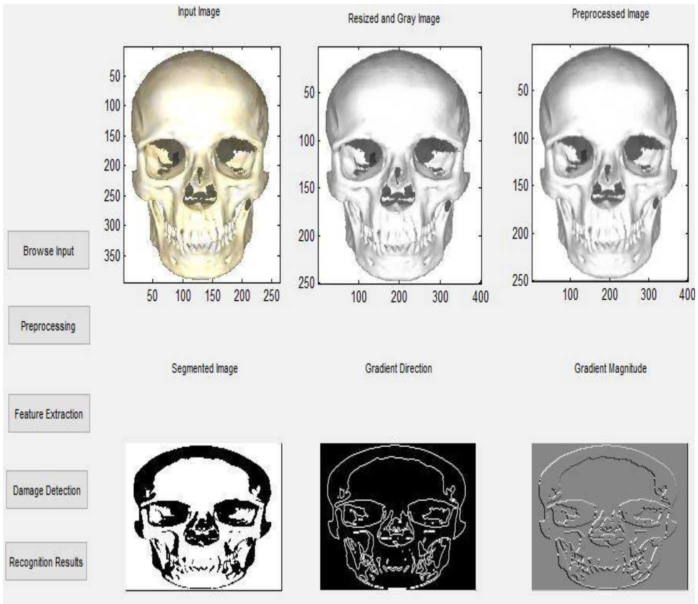

Figure 5: Results for feature extraction

Figure 5 above showing the results for feature extraction in which first step is image segmentation. The preprocessed image is segmented using binarization segmentation technique.
For feature extraction we used two different types of features such as gradient features and geometric features. We are not replying on any single type of feature extraction, hence classification process resulting into more accuracy with less false negative performance.
Figure 6 below showing the results for damage detection for input skull image. This figure showing the outputs of figure and 5 with message for damage detection that whether input skull image is damaged or not. Here it's showing

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that current image is damaged and hence needs to call repair functionality. The repair functionality is yet to implement hence its results are out of scope of this paper.

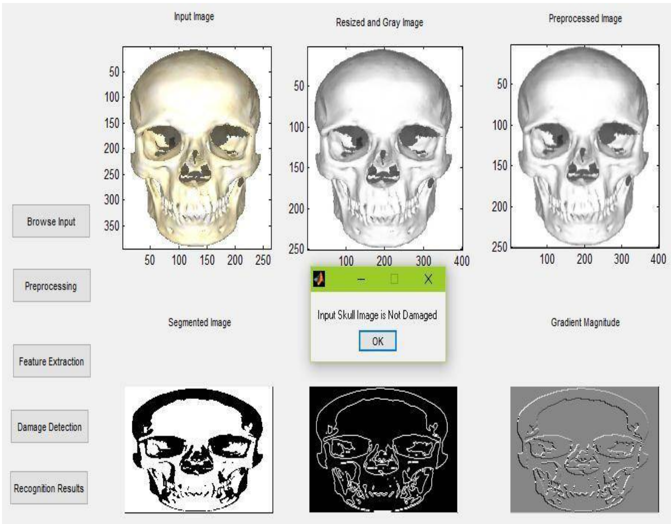

Figure 6: Result of damage detection

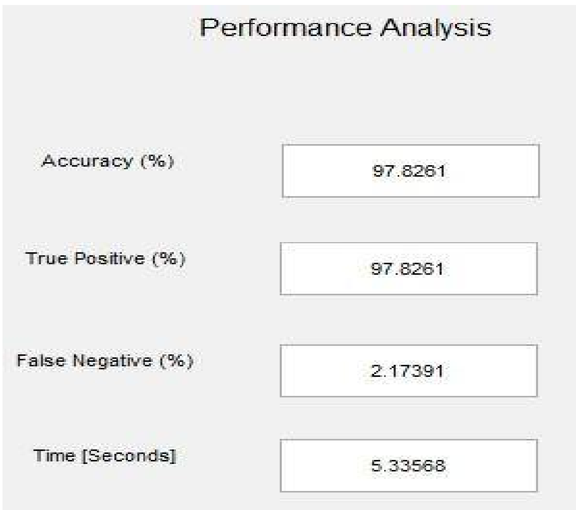

Figure 7: Performance Analysis for Skull Damage Recognition

Figure 7 is showing the results achieved for skull damage recognition for four performance metrics such as accuracy, true positive and false negative in percentage. Time is showing in seconds. Finally figure 8 is showing the complete framework for proposed approach with current results achieved.

V. CONCLUSION AND FUTURE WORK

The goal of this paper was to propose the automated framework for skull completion model in which we working on two important goals such as 1) detection of skull damages using the machine learning approach, basically this approach is used to save the computation efforts and time if the input skull image is not damaged. 2) Repairing the damaged skull using two approaches such as symmetric based method and template based method; result will be the complete

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skull image. We proposed the design and algorithms used for this work with its. The current simulation results presented are based on 75 % of project work in which we have shown, system GUI design, preprocessing results and feature extraction functionality with skull damage detection and performance results. For future work, remaining technique for automatic skull repair will be implemented and combined with current results.

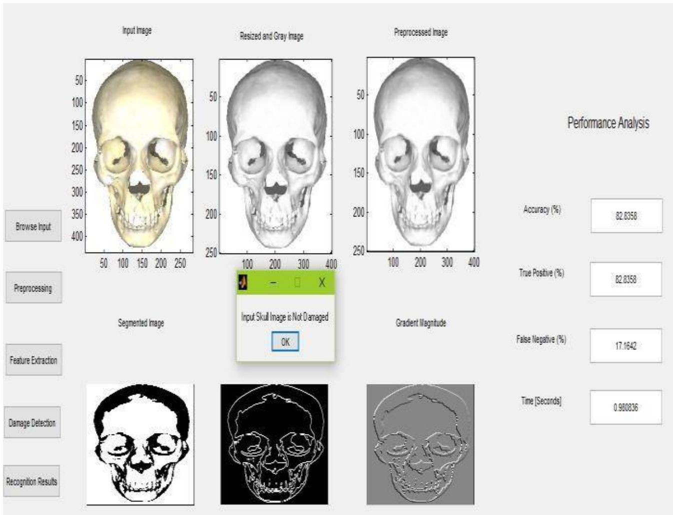

Figure 8: Complete Framework For Skull Damage Detection

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