CISH: Craniofacial Identification using Superimposition and HIPI

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Abstract:- **One of the most prominent disciplines in forensic medicine is human identification. With increase in number of natural calamities, there is a significant increase in casualties and identification of the person becomes difficult. Thus for human identification many approaches have been developed over the years. Among them, craniofacial superimposition is one of them. It is a forensic process, where a 3D model of the skull is overlayed on the 2D photograph of the missing person to make the decision regarding the identification of missing person. 3D models are very large and occupy more than 1 GB of space. Further the need may be to compare the skull image with more than 1 lakh photo images .Inorder to improve the performance of the comparison, we propose an parallel distributed computational big data model "CISH- Craniofacial Identification using superimposition and HIPI" using HIPI. The goal of the proposed model is to compare the landmarks obtained from the 3D constructed model of the skull with the facial landmarks of the missing person photographs which are stored in the Hadoop Distributed File System. The HIPI framework helps in the decision regarding the identification of the missing person based on the comparisons.**

Keywords: Forensic identification, Craniofacial superimposition, Skull 3D model reconstruction, Skull-face overlay, Fuzzy landmarks,HIPI

I. INTRODUCTION

CranioFacial SuperImposition is a skeleton based identification which involved obtaining the negative of the original photograph and marking the cephalometric landmarks on it[1].The same task was done with a photograph of the skull. Both the negatives were overlapped and the positive was developed. This procedure was specifically named photographic superimposition. The computer based CranioFacial SuperImposition is a three stage process.

This is a 3stage process can be illustrated as follows

The first stage involves achieving a 3D digital model of the skull. The second stage is the skull-face overlay (SFO). It consists of searching for the best overlay of both 2D images of the skull and face or of the 3D model of the skull and the 2D image of the face achieved during the first stage. This stage is a 3D-2D Image Registration problem. It is a fundamental task in computer vision and computer graphics used to find either a spatial transformation (e.g. rotation, translation, etc.) or a correspondence (matching of similar image features) among two or more images acquired under different conditions: at different times, using different sensors, from different viewpoints, or a combination of them. IR aims to achieve the best possible overlap transforming those independent images into a common one.

Finally, the third stage of the CS process corresponds to the decision making. Based on the SFO achieved, the identification decision is made by either judging the matching between the corresponding landmarks in the skull and in the face, or by analyzing the respective profiles.3D images occupy a lot of space and we need to operate on large data sets such as 1 lakh photo comparisions. Our proposed model CISH aims to automate the performance of the decision making stage by using HIPI(HIPI: A Hadoop Image Processing Interface for Image-based MapReduce Tasks) .

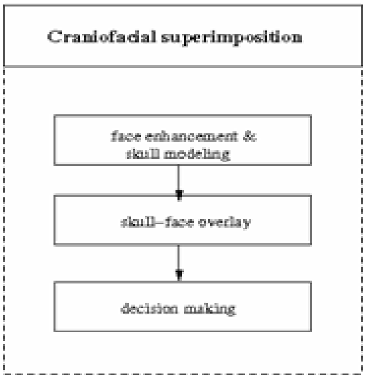

Fig 1: Craniofacial Superimposition

II. THE HIPI FRAMEWORK

HIPI was created to empower researchers and present them with a capable tool that would enable research involving image processing and vision to be performed extremely easily[3][4]. It's goals are

1.Provide an extended image processing framework for image processing and computer vision applications in a Map Reduce framework.

2.Allow simple filtering for a set of images.

3. Present users with an intutiative interface for image based operations and hide the details of the MapReduce framework.

A. Data storage

Hadoop uses a distributed file system to store files on various machines throughout the cluster. Hadoop allows files be accessed ,however, without knowledge of where it is stored in the cluster, so that users can reference files the same way they would on a local machine and Hadoop will present the file accordingly.

When performing MapReduce jobs, Hadoop attempts to run Map and Reduce tasks at the machines were the data being processed is located so that data does not have to be copied between machines. As such, MapReduce tasks run more efficiently when the input is one large file as opposed to many small files.

The MapReduce framework operates more efficiently when the data being processed is local to the machines performing the processing.

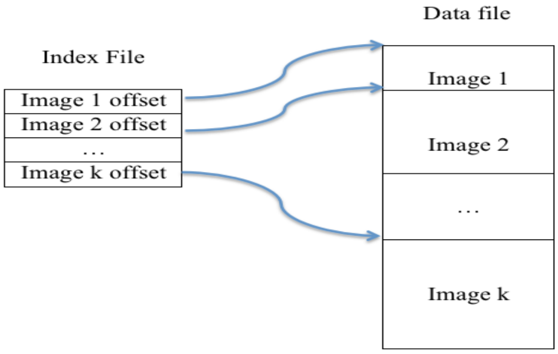

Fig 2: A depiction of the relationship between the index and data files in a HIPI Image Bundle

Small files are files that are considerably smaller than the file block size for the machine where the file resides. A HIPI Image Bundle data type stores many images in one large file so that MapReduce jobs can be performed more efficiently. A HIPI Image Bundle consists of two files: a data file containing concatenated images and an index file containing information about the offsets of images in the data file as shown in Figure-2. This setup allows us to easily access images across the entire bundle without having to read in every image.

B. Image-based MapReduce

HIPI library focuses on bringing familiar image-based datatypes directly to the user for easy use in MapReduce applications.

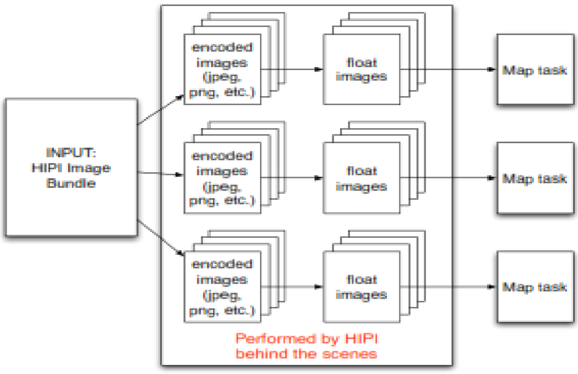

Fig 3:HIPI behind the scene

As shown in Figure 3,the user only needs to specify a HIPI Image Bundle as an input, and HIPI will take care of parallelizing the task and sending float images to the mappers. The specification works on HIPI Image Bundles for various image types, sizes, and varying amounts of header and exit information.. The float images are brought directly to the Maptasks in a highly parallelized fashion.

During the distribution of inputs but before the map tasks start a culling stage is introduced to the MapReduce pipeline. The culling stage allows for images to be filtered based on image properties. The user specifies a culling class that describes how the images will be filtered. Only images that pass the culling stage will be distributed to the map tasks, preventing unnecessary copying of data additionally, images are distributed as float images so that users can immediately have access to pixel values for image processing and vision operations. Images are always stored as standard image types (e.g. JPEG, PNG, etc.) for efficient storage, but HIPI takes care of encoding and decoding images to present the user with float images within the MapReduce pipeline. As a result, programs such as calculating the mean value of all pixels in a set of images can be written in merely lines.

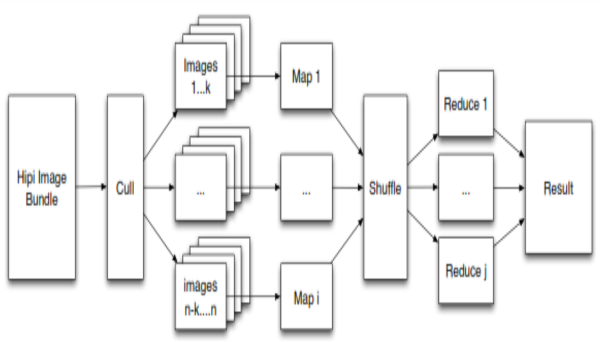

Fig 4: Typical Image processing using HIPI

III. OVERVIEW OF FUZZY LOGIC

Fuzzy Logic was initiated in 1965 ,byLotfi A. Zadeh , professor for computer science at the University of California in Berkeley. Basically, Fuzzy Logic (FL) is a multivalued logic,that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low, etc. Notions like rather tall or very fast can be formulated mathematically and processed by computers, in order to apply a more human-like way of thinking in the programming of computers]. One of these, the "Law of the Excluded Middle," states that every proposition must either be True or False.. Fuzzy Logic has emerged as a a profitable tool for the controlling and steering of systems and complex industrial processes, as well as for other expert systems and applications like the classification of SAR data. The very basic notion of fuzzy systems is a fuzzy subset. In classical mathematics we are familiar with what we call crisp sets. For example, the possible interferometric coherence g values are the set X of all real numbers between 0 and 1. From this set X a subset A can be defined, (e.g. all values $0 \leq g \leq 0.2$.The elements which have been assigned the number 1 can be interpreted as the elements that are in the set A and the elements which have assigned the number 0. as the elements that are not in the set. A fuzzy set allows us to define such a notion. The aim is to use fuzzy sets in order to make computers more 'intelligent', therefore, the idea above has to

be coded more formally. A straight way to generalize this concept is to allow more values between 0 and 1. In fact, infinitely many alternatives can be allowed between the boundaries 0 and 1, namely the unit interval I = [0, 1]. Humans tend to use a combination of predicate logic and fuzzy logic. If you are an outfielder catching a baseball hit into the air; then your precise logic will calculate trajectory and start you running to the point of intercept (catching). However, once close to the ball the eyes and brain of the outfielder lacks the ability to accurately estimate distance and speed because the ball is coming straight at the outfielder. The human brain switches to fuzzy logic that says "get me closer", "get me closer", and so on. That is why you see outfielders in baseball run to a spot and then move around as the ball gets closer.
Predicate logic says calculate the point to be at to catch the ball. Fuzzy logic says because of wind or other things you might not be in the correct place so just keep getting closer until you catch the ball.
In predicate logic it is the mathematics of calculating the path of the ball that determines your action. In fuzzy logic it is the error of your calculations that determines your action.
In effect, it's like your brain trying to control your finger to pick your nose while traveling down a bumpy road.

The goal of the proposed model is to compare the landmarks obtained from the 3D constructed model of the skull with the facial landmarks of the missing person photographs which are stored in the Hadoop Distributed File System (HDFS) .The confidence level percentage obtained in the comparison helps in determining the accuracy of photograph comparison.This confidence interval parameter is calculated based on fuzzy logic.

IV. SYSTEM MODEL

In our proposed model we are considering two inputs to be provided to the map reduce framework of Hadoop .

1. The image bundle comprising nearly one lakh 2D photographs of the missing persons to the HIPI framework
2. The single 3D skull image which is directly given as the input to the Map Reduce framework without passing through HIPI.

The input processing through the different stages can be described as follows[6].

i) .Map Stage:
Each 2D image is ovelayed on the 3D skull image and is given as the input to the various map instances distributed across the parallel network.The output of the mapping stage is basically a key value pair<K,V> where key comprises the confidence level percentage(depending on the matching) and the value is mainly the photo ids of the 2D photographs which corresponds to the confidence level.

The confidence level is obtained from decision making stage.
In our proposed model we determine the identification of the photograph, by calculating the confidence interval. This interval can be calculated based on Fuzzy Logic which involves the pairing of the landmarks found in the superimposition of the previous subsystem. The overview of the landmarks is described in the figures given below.

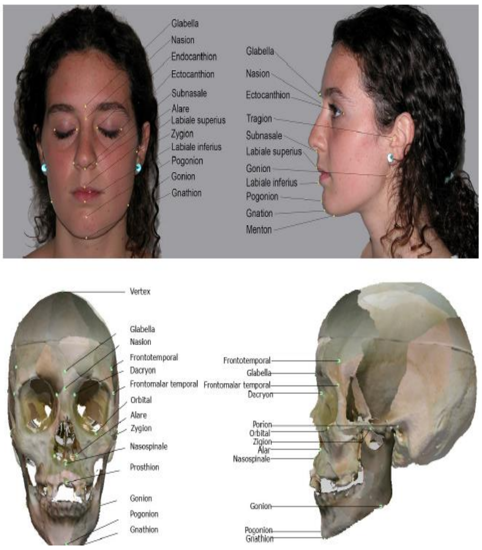

Fig 5: Landmarks considered for superimposition

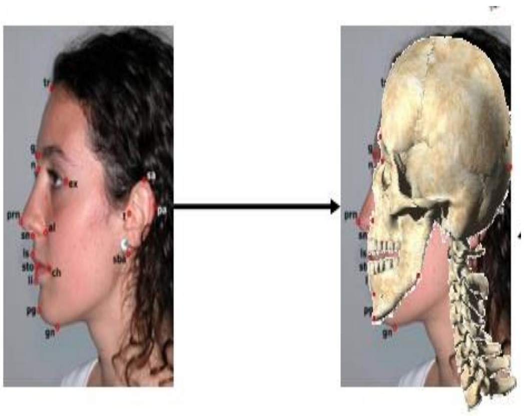

Fig 6: Skull Face Overlay

To accomplish this, a fuzzy inference system is designed in this subsystem with assistance from the forensic experts[2]. The inputs to this system are the degrees of certainty in the location of the landmarks and the pairing of each pair of points. Fuzzy addition operators are used to combine and make the final decision. Via the fuzzy inference mechanism that models the knowledge of forensic anthropologists, the system provides a recommendation to the forensic anthropologist regarding the degree of correspondence between the model of the found skull and the photograph of the missing person's face. This recommendation may be one of the following five: Positive, negative, probably positive, probably negative or uncertain. The certainty value associated with the recommendation is also provided.
The advantages provided by the inclusion of this subsystem are very important since on one hand, it aids the forensic expert in issuing a final judgment regarding the correspondence between the skull and the face and on the other hand, it can also be used independently, without the need for a forensic expert. Also, based on this last

operational description, the present invention allows comparing a single skull against a repository of photographs of missing persons, selecting the photograph with the highest degree of correspondence with the skull. In this case, it also provides a recommendation to the expert (positive, negative, probably positive, probably negative or uncertain) and the degree of certainty associated with the recommendation.
The Scatter Search algorithm is used as the optimization method, which searches for the values of the twelve unknowns of the aforementioned system of equations so the resulting transformation minimizes the lens function (or error function).
The lens function (or error function) is the mean of the sum of the distances between each pair of landmarks to be paired (each skull marker [craniometric point], must be paired with a marker on the face [cephalometric point]). The considered distance is a “fuzzy” distance that takes into account the uncertainty relative to each marker (the larger the size of the ellipse representing the marker, the greater the uncertainty
To perform the skull-face projection the correspondence between the 3D model of the skull and the photograph of the face is carried out using similarity transformation sets and perspective projections.

These transformations consist of the following.

R Rotation: Transformation that seeks placing the skull in the same pose as that in the photograph. The following is needed to define the rotation: The direction of the rotation axis (dx, dy, dz), the location of the rotation axis with respect to the coordinates centre (rx, ry, rz) and the θ angle.

S Scaling: Transformation that seeks to uniformly adapt the size of the model of the skull based on the size of the missing person in the photograph.

T Translation: Transformation (tx,ty,tz) that seeks positioning the origin of coordinates in front of the camera (reproducing the initial conditions of the moment in which the photograph was taken).

P Perspective Projection: Transformation that attempts to determine how far the camera is from the skull and it has a strong relationship with the camera's angle of vision (φ).
All these transformations result in a system of equations with twelve unknowns (rx,ry,rz,dx,dy,dz,θ,S,tx,ty,tz,φ) that represent the geometric transformation that pairs each marker of the 3D model of the skull with its corresponding facial marker in the photograph.
The resulting system of equations is the following:
$F = C \times S \times T \times P$
Where:
$R = A \times D 1 \times D 2 \times \Theta \times D 2 - 1 \times D 1 - 1 \times A - 1$, $F = [\, x f 1 \;\; y f 1 \;\; 11 \; x f 2 \;\; y f 2 \;\; 11 \vdots x f N \;\; y f N \;\; 11 \,]$ y, $C = [\, x c 1 \; y c 1 \;\; z c 1 \;\; 1 \; x c 2 \;\; y c 2 \;\; z c 2 \;\; 1 \vdots x c N \;\; y c N \;\; z c N 1 \,]$

Based on the distance that exists (fuzzy) between each pair of landmarks (craniometric-cephalometric) and its theoretical distance (fuzzy), an overall degree of uncertainty associated with the superimposition is calculated. Taking into account this uncertainty and making use of a fuzzy addition operator, the system provides a recommendation regarding the cranial-photograph correspondence within the following five possibilities. Positive, negative, probably positive, probably negative or uncertain.

ii)Shuffle stage:The output of the map stage which is the <confidencelevel,photoids> are given as the input to the shuffle stage. The shuffle stage is responsible for sorting all the key value pairs based on key. In our proposed model the shuffle stage primarily needs to sort the photoids based on the confidence level percentage.

iii).Reduce Stage: The output of the shuffle stage is given as the input to the various reducer instances. The map operation that share the same key are presented to same reducer at the same time. In our proposed model, the set of photoids which share the same confidence level are given as the input to the same reducer instance. The main task of the reducer is to aggregate values together. A reducer function receives an iterator of input values from an input list. It then combines these values together, returning a single output value. In the Reduce stage the values ie the photoids corresponding to the same confidence level can be combined and finally the result which is the confidence level will enable us in predicting the correct identification of the person.

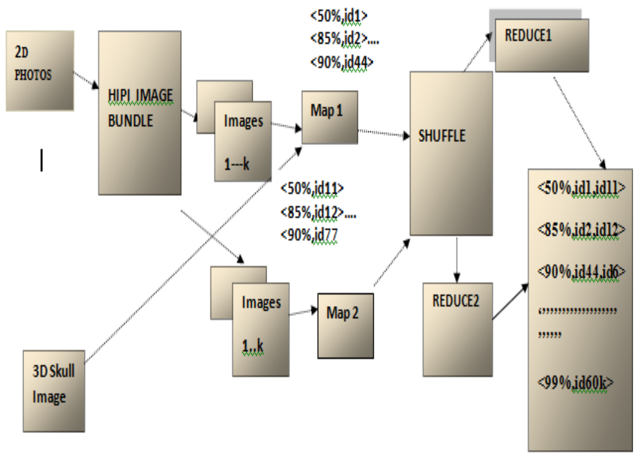

Fig 7: System Model

V. CONCLUSION

One of the primary advantages of our proposed model is intended to increase the performance by using the parallel distributed map reduce framework of Hadoop. The time taken to process one 2D photographic image can be used to process 10 2D photographs at the same time due to the Map reduce framework which we are executing on multiple nodes. Hence the processing speed of the application is 10 times faster than before. Further by utilizing HIPI we are hiding the complex details of the Map reduce framework, by filtering the image sets and optimizing the image processing activities. This will make development of large scale image processing and computer vision projects extremely accessible.

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