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Evolution In Forensic Facial Imaging "A Valuable Approach of Recognition in Disaster's Victim Management"

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Abstract

A disaster or catastrophe is an impulsive devastating event that utterly disrupts the functioning of a community, a society comprising of widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources. The death of a loved one leaves an indelible mark on the survivors, and unfortunately, because of the lack of information, the families of the deceased suffer additional harm due to the inadequate ways in which the bodies of the deceased are handled. These secondary injuries are unacceptable, particularly when they are under the consequences of direct authorization or action on the part of the authorities or those responsible for humanitarian assistance. The most serious aspect is that these measures are being carried out without respecting identification procedures or preserving the individuality and dignity of the deceased. Disaster victim identification (DVI) is an intensive and arduous task which needs the contribution of specialists from various disciplines. Here in these exotic situations, forensic facial recognition may act as a boon for revealing the identity of the victims. A lot of face recognition algorithms, along with their modifications, have been developed during the past decades. This paper seeks to present a review of the existing literature in this domain and discuss several aspects, significance and requirements for forensic face recognition systems particularly focusing the various advances and trends of facial imaging which may provide a great beneficiary value in face recognition mechanism of victims in the case of different fatalities.

Keywords: Calamitous • Humanitarian • DVI • Forensic facial recognition • Fatalities

Introduction

Disaster literally means 'catastrophe'. Every disaster is unique and involves interplay of distinct factors and circumstances such as: nature of disaster, number of victims, extent of body fragmentation etc. that ultimately challenges the disaster response planning. A natural calamity or mass disaster is commonly construed as an event (air, naval, railway, or motorway accident, flooding, earthquake, and so on), resulting in a huge number of victims that need to be identified and should be subjected to medico legal investigation. Whatever the case may be, the procedure is the same, and it consists of a meticulous collection of both ante-mortem and postmortem data. Consequently, the identification modalities to be applied will vary according to the quality of the ante-mortem data available and preservation conditions of the victims. The preservation of life is the top most priority at any major incident. So the disaster response teams mainly aim at rescue and care of the survivors and most of the disaster response plans don't cater the need of Disaster Victim Identification issue sufficiently. Once the post mortem data is compiled this will need to be checked against ante mortem evidence. Whilst one team is working on the collection from the bodies another team (the ante mortem team) will be compiling the list of likely missing persons from aircraft manifest and other such sources. The ante mortem team will collate identification details from a variety of sources. Mass fatality incidents (MFI) generate large numbers of victims, often suddenly and unexpectedly. They are being categorized as 'disasters' and victim identification is generally retrieved by following disaster victim identification (DVI) protocols. A MFI can be sub-divided into: major, mass or catastrophic, depending on the total quantity of victims. MFI can be further categorized as environmental (e.g. earth-quakes, tsunamis, hurricanes), medical (e.g. famine, disease; such as the 2014 Ebola outbreak), vehicle (e.g. aircraft, car, train, ship), industrial (e.g. explosions, fires) or terrorist (e.g. chemical, biological, radiological, nuclear, or explosive attacks i.e. so-called CBRNE).Human Rights (HR) violations may also be considered to be mass disasters; although they may occur diachronically over a larger geographical area.

Disaster victim identification

Various international as well as national capabilities and standards are required for the process of disaster victim identification. Till date, the International Police Organizations (Interpol) resolution on DVI is the only internationally recognized legislation, which functions under international law, to specifically address this issue. They recommend that all 187-member countries should adopt a common procedure for identifying victims in any type of disaster, regardless of its cause or scale. In 1984, Interpol published the first DVI manual. The aim was to provide information relating to mass disaster handling in general, and the identification process in particular, to increase the efficiency and effectiveness of DVI. In order to achieve, maintain and improve standards, and to facilitate international liaison, Interpol recommends that each member country establishes one or more permanent disaster victim identification Teams [1]. They should have a responsibility not only for disaster response, but also for the vital functions of pre-planning and training of key personnel. The Interpol DVI guide assumes that post-mortem intervention will be organized and therefore describes the DVI process including 3 key steps. These are recovery and examination of bodies to establish post-mortem evidence from the deceased, search for ante-mortem information for possible victims and the comparison of ante-mortem and post-mortem data. In order to ensure that a thorough search is conducted and photographically documented, recovery and victim identification teams should first acquire an accurate map of the disaster site. Ideally, this map should then be overlaid with a grid in order to facilitate a logical search operation. The grid and search area should, where possible cover the entire disaster site and should be searched systematically for body recovery, evidence collection and victim identification reasons. Matching the gridded location of remains to identities, and using that match as a reconstructive approach to create a cartographic understanding of the event,

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is one of the key elements of forensic DVI. Interpol has devised specific forms for recording the ante-mortem (AM) and post-mortem (PM) information to assist this process and have also provided an official 'Victim Identification Report'; Completion of which generally acts as a prerequisite for issuing a death certificate and the final conclusion of the identification process [2]. The AM team collects data of suspected victims, prepares corresponding missing persons files and notifies the relevant authorities regarding successful identifications. The PM team collects all the relevant dental, medical, and forensic data from the deceased bodies for the purpose of identification of victims. The AM and PM data is then processed by the reconciliation team, who attempts to match the information collected by both teams and identify the victims (Figure 1).

Methodology

Medico legal procedure of specific identification in mass disasters

- At the scene of the accident, according to the situations, medico legal staff should make efforts in recording victims' position, condition, under limited time constraint with the intervention of emergency personnel (fire department, first aid, and rescue units). Once all has been registered, every victim should be assigned a number, photographed, and delicate areas should be protected under the surveillance of police and other intervening bodies
- After the removal of remains, the bodies should be brought to a morgue for medico legal activity. During the preliminary procedure a place where to interview relatives of the victims must be established in the presence of mass media. A AM team (or several AM teams, depending on the number of victims), preferably constituted by a forensic pathologist, an odontologist, a geneticist, and a psychologist, for possible assistance to mourning relatives must be set up so as to collect clinical and nonclinical data related to the victims, and to register the information on appropriate forms which includes information on personal effects; clothing; jewelry worn; descriptors such as age, sex, height, race, hair and eye color, tattoos, scars, moles, malformations, prosthetic devices, osseous and dental pathologies; and any clinical, in particular radiological, and dental data (along with a contact name or number of physicians and dentists of the victim), pictures of the victim alive, possibly when smiling and displaying the front teeth (in order to be able to carry out an identification *via* the dental profile). These are clinical medical and odontological records, radiographs, personal effects, such as combs, razors and toothbrushes used by the victims (useful for DNA analysis), and photographs [3].
- Collaterally, the programming of body examinations and autopsy is carried out in which PM teams are organized for the collection of all data useful for identification of the human remains including pathologist, odontologist, anthropologist, a geneticist, a toxicologist, a morgue technician, and a secretary. From the point of view of identification, the pathologist, on external examination, should clean the skin looking for scars, tattoos, and the like, and, once the autopsy has begun, should look for signs of surgery and important pathologies useful for identification. Appropriate sampling for toxicological and other laboratory analyses should also be performed. Minimal anthropological sampling should also be performed including samples for aging (dental and osteological)—pubic symphyses and fourth rib and one mono-radicular tooth should always be taken. Aging may greatly aid in an initial matching of ante-mortem and PM data.
- X-ray analysis, if soft tissue is still present, will be useful in distinguishing the adult and sub adult individuals. Of course, if cadavers are skeletonized, the role of the anthropologists becomes more relevant as sexing, determination of ancestry, and stature may be crucial, as well as full skeletal analyses. Finally, the geneticist will assist in collecting adequate samples of tissue for DNA extraction. All data can then be put into a database. Interpol does have appropriate software for cross matching data and selecting best matches; however, it is very expensive for non-police organizations, such as universities. For this reason, a simpler database for initial comparison can be used, such as Microsoft Excel or Access, on which one can then search for common descriptors.
- The AM and PM data are then cross matched in order to obtain best matches among the victims with the passenger list. The modality of identification depends on the state of conservation and condition of the corpses and on the available AM documentation. It should always be kept in mind that visual identification on well preserved cadavers in such cases should always be double-checked with another biological method. Finally, according to respected country's requirements, documents necessary for the burial and transportation of the body must be prepared. In cases of foreign victims a direct channel with consulates and embassies should always be kept. Most countries in Europe require a declaration of identity, cause of death, and magistrates 'and civil statuses' permission to bury the body.

Different methods assisting in victim's identification in mass disasters

Fingerprint analysis: Fingerprints are the specific traits which are found to be unique because of absolute congruency between the papillary edges in the fingers of two different individuals or fingers of the same person do not exist. Further, they do not change as the papillary are formed in the fourth month of gestation and remain unchanged even beyond death and

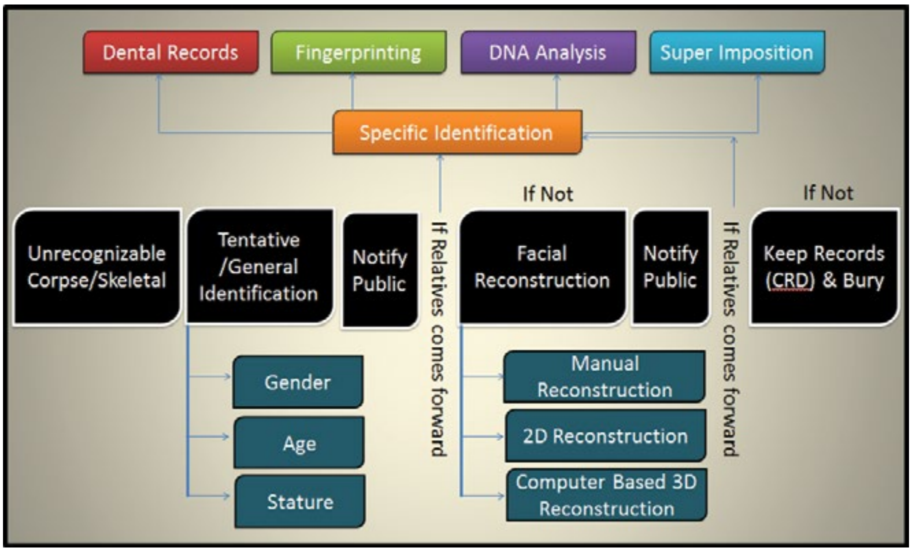

Figure 1. Flow chart representing specific identification.

grow back in the same pattern following minor injuries which may result in permanent scarring due to several injuries. Fingerprints can be classified, they can be identified and registered systematically and thus subsequently retrieved easily for purposes of comparison.

Forensic Odontology: The unique structures and traits of human teeth and jaws readily lend themselves to use in the identification of living and deceased victims. Dental data can be recovered and recorded at the time of post mortem examination and compared to ante mortem data that are supplied by generalist and/or specialist dentists who treated the victim during their lifetime. The teeth are well protected in the oral cavity and are able to withstand many external influences at, near or after the time of death. Teeth comprise the hardest and most resilient substances in the body, so as the body's soft tissues deteriorate; the dental characteristics that are so valuable for identification purposes remain accessible [4]. This is especially true of treatments in the teeth, such as restorative and aesthetic fillings and crowns, root canal procedures and dentures since these are custom made as unique treatments for each individual. But other anatomical and morphological traits can also be compared even when no dental treatments are present, and these also provide useful data for identification purposes.

DNA analysis: DNA is a proven source of material to use for identification, as a significant portion of the genetic information contained in a cell is unique to a specific individual and thus differs – except in identical twins from one person to the next. DNA testing can be performed even on cases involving partial, severely decomposed remains. DNA matching is the best way to identify body parts. DNA analysis can be automated with a high throughput. DNA matching can be based on profiles from relatives, self samples or belongings. DNA analysis can be automated enabling a high quality and high throughput setting. DNA matching can be based on profiles from relatives, self samples or belongings being the only method for primary identification independent from direct comparison.

Dental radiology: Many factors may affect PM-radiographic image collection: the presence of suitable dental X-ray equipment but also the body condition such as rigor mortis, positioning the victim's bodies and aiming the x-ray beam, electricity supply, working area and equipment. Therefore, during mass disasters the recovery team needs to transport the remains to compartments equipped with fixed dental x-ray unit(s) -suitable for performing dental autopsies. These light weight and autonomic working devices can easily be brought next to the bodies, allowing an immediate forensic odontologic investigation in combination. In addition, new technologies provide new accessories for X-ray viewing in the field of disaster. Some companies have launched a portable X-ray machine with a viewing display attached to the machine itself. Others provide a small portable X-ray viewing gadget. When operated in a wireless environment, data and images could thus be easily transmitted in both directions. This may help to facilitate the radiographic interpretation more rapidly than in the past.

Facial reconstruction: Humans often use faces to recognize individuals and advancements in computing capability over the past few decades now enable similar recognitions automatically. Early face recognition algorithms used simple geometric models, but the recognition process has now matured into a science of sophisticated mathematical representations and matching processes. Major advancements and initiatives in the past ten to fifteen years have propelled face recognition technology into the spotlight. Face recognition can be used for both verification and identification (open-set and closed-set).When confronted with a corpse that is unrecognizable due to its state of decomposition, skeletisation, mutilation or calcination, a cranio-facial reconstruction (CFR) should be considered. The goal of CFR is to recreate a likeness with the face of missing individuals immediately prior to their death. Presenting this reconstructed face to the public can get the identification process out of the impasse by triggering recognition. Several 3D manual methods for CFR are being initialized for the better concealment of this process. This method is the main focused area of this study.

History of facial recognition

- Automated face recognition is a proportionately new conceptual phase of identification. Major advancements and initiatives in the past ten to fifteen years have propelled face recognition technology into the spotlight. Face recognition can be used for both verification and identification.
- In 1884, the anatomist Welcker compared Raphael's skull with a self-portrait, and compared the supposed skull of Kant with his death mask, and found that the respective correlations were too good for chance. Welker used two-dimensional techniques; he provided accurate orthogonal perspective drawings as an outline of the skull and the death mask, and then attempted to superimpose the outlines, while making allowance for the outer tissues [5].
- In the 1960s, the first semi-automated system for face recognition required the administrator to locate features (such as eyes, ears, nose, and mouth) on the photographs before it calculated distances and ratios to a common reference point, which were then compared to reference data.
- In the 1970s, Goldstein, Harmon, and Lesk1 used 21 specific subjective markers such as hair color and lip thickness to automate the recognition. The problem with both of these early solutions was that the measurements and locations were manually computed.
- In 1988, Kirby and Sirovich applied principle component analysis, a standard linear algebra technique, to the face recognition problem. This was considered somewhat of a milestone as it showed that less than one hundred values were required to accurately code a suitably aligned and normalized face images [6].
- In1991, Turk and Pentland discovered that while using the Eigen faces techniques, the residual error could be used to detect faces in images3 – a discovery that enabled reliable real-time automated face recognition systems. Although the approach was somehow constrained by environmental factors, it created significant interest in proceeding development of automated face recognition technologies. Since 1993, the error rate of automatic face-recognition systems has decreased by a factor of 272. The reduction applies to systems that match people with face images captured in studio or mugshot environments.
- In 1994, Farkas et al described how the variability of facial proportions ensures the individuality of the human face.
- In 1998, Nelson and Michael described a system of computer facial reconstruction named Volume Deformation. This system started with MRI, and its greatest limitation was that it used a face that the end result would ultimately resemble and therefore was only as close to the real face as the sample face.
- In January 2001, the technology first captured the public's attention from the media reaction to a trial implementation at the Super Bowl, which incorporated surveillance images and compared them to a database of digital mugshots and this demonstration initiated much-needed analysis on how to use the technology to support national needs.
- In 2005, De Greef and Willems also worked on computer-aided reconstructions, especially for the eyes and mouth. Many other computerized facial reconstruction systems have been developed and proposed, with varying degrees of success.
- In early 2007, the National Institute of Standards and Technology (NIST) published the results of its Face Recognition Vendor Test (FRVT) 2006. Research had reached a point where the operational use of facial recognition on high-resolution frontal images taken in a controlled environment was now feasible. Naturally, these results did not put an end to work on the recognition of facial images captured in controlled conditions. And while more improvements were expected, facial recognition has become a biometric technique in its own right [7].
- In January 2013 Japanese researchers created 'privacy visor' glasses from the national institute of informatics that uses nearly infrared light to make the face underneath it unrecognizable to face recognition software. The latest version uses a titanium frame, light-reflective material and

a mask which uses angles and patterns to disrupt facial recognition technology through both absorbing and bouncing back light source.

- In December 2016 a form of anti-CCTV and facial recognition sunglasses called 'reflectacles' were invented by a custom-spectacle-craftsmen based in Chicago named Scott Urban. They reflect infrared and, optionally, visible light which makes the users face a white blur to cameras. The project easily surpassed its crowd funding goal of $28,000 and reflectacles will be commercially available by June 2017. It is conceivable that such technology might be fused with future head mounting displays such as potential successors of Holo lens [8].

Different methods of facial recognition technique

There are several methods which are found to be relevant in different situations of fatalities, which can be entangled by prominent techniques of reconstruction (Figure 2).

2D- reconstruction: Two-dimensional facial reconstructions are based on ante mortem photographs, and the skull. Deliberately, skull radiographs are used but this is not ideal since many cranial structures are not visible or at the correct scale. This technique usually requires the collaboration of an artist and a forensic anthropologist. A commonly used method of 2D facial reconstruction was pioneered by Karen Taylor of Austin, Texas during the 1980s.Taylor's method involves adhering tissue depth markers on an unidentified skull at various anthropological landmarks, then photographing the skull. Life-size or one-to-one frontal and lateral photographic prints are then used as a foundation for facial drawings done on transparent vellum. Recently developed, the F.A.C.E. and C.A.R.E.S. computer software programs quickly produce two-dimensional facial approximations that can be edited and manipulated with relative ease. These programs may help in speeding up the reconstruction process and allow subtle variations to be applied to the drawing, though they may produce more generic images than hand-drawn art work [9].

3D- reconstruction: Three-dimensional facial reconstructions are either sculptures (made from casts of cranial remains) created with modeling clay and other materials or high-resolution, three dimensional computer images. Like two-dimensional reconstructions, three-dimensional reconstructions usually require both an artist and a forensic anthropologist. Computer programs create three-dimensional reconstructions by manipulating scanned photographs of the unidentified cranial remains, stock photographs of facial features, and other available reconstructions. These computer approximations are usually most effective in victim identification because they do not appear too artificial. This method has been adapted by the National centre for missing and exploited children which uses this method often to show approximations of an unidentified descendents to release to the public in hopes to identify the subject (Figure 3).

Superimposition: is a technique that is sometimes included among the methods of forensic facial reconstruction. It is not always included as a technique because investigators must already have some kind of knowledge about the identity of the skeletal remains with which they are dealing (as opposed to 2D and 3D reconstructions, when the identity of the skeletal remains are generally completely unknown). Forensic superimposition are created by superimposing a photograph of an individual suspected of belonging to the unidentified skeletal remains over an X-ray of the unidentified skull. If the skull and the photograph are of the same individual, then the anatomical features of the face should align accurately (Figure 4).

Predominant approaches for facial recognition methodology

There are two predominant approaches to the face recognition problem: geometric and photometric. As researcher interest in face recognition continued, many different algorithms were developed, three of which have been well studied in face recognition literature: Principal Components Analysis (PCA), Linear Discriminant Analysis (LDA), and Elastic Bunch Graph Matching (EBGM).

Principal Components Analysis (PCA): PCA, commonly referred to as the use of eigenfaces, is the technique pioneered by Kirby and Sirivich in 1988. With PCA, the probe and gallery images must be the same size and must first be normalized to line up the eyes and mouth of the subjects within the images. The PCA approach is then used to reduce the dimension of the data by means of data compression basics2 and reveals the most effective low dimensional structure of facial patterns. This reduction in dimensions removes information that is not useful4 and precisely decomposes the face structure into orthogonal (uncorrelated) components known as Eigen faces. Each face image may be represented as a weighted sum (feature vector) of the Eigenfaces, which are stored in a 1D array. A probe image is compared

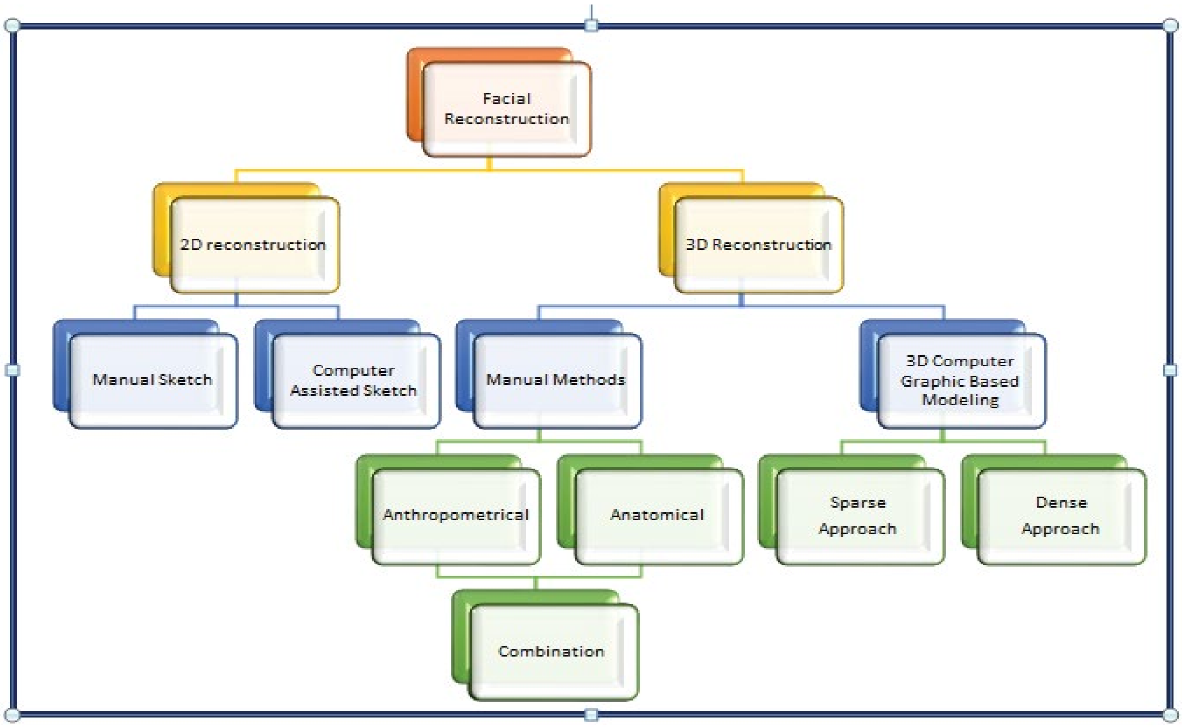

Figure 2. Flowchart demonstrating different methods of facial reconstruction.

against a gallery image by measuring the distance between their respective feature vectors. The PCA approach typically requires the full frontal face to be presented each time; otherwise the image results in poor performance. The primary advantage of this technique is that it can reduce the data

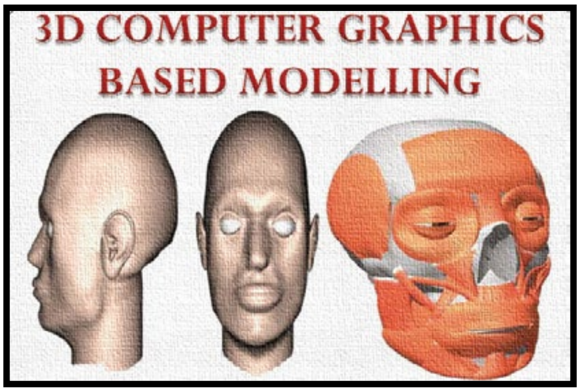

Figure 3. Image showing 3D reconstructions.

needed to identify the individual to 1/1000th of the data presented (Figure 5).

Linear Discriminate Analysis (LDA): LDA is a statistical approach for classifying samples of unknown classes based on training samples with known classes. This technique aims to maximize between-class variance and minimize within-class variance. When dealing with high dimensional face data, this technique faces the small sample size problem that arises where there are a small number of available training samples compared to the dimensionality of the sample space (Figure 6).

Elastic Bunch Graph Matching(EBGM): EBGM relies on the concept that real face images have many nonlinear characteristics that are not addressed by the linear analysis methods discussed earlier, such as variations in illumination (outdoor lighting vs. indoor fluorescents), pose (standing straight vs. leaning over) and expression (smile vs. frown). A Gabor wavelet transform creates a dynamic link architecture that projects the face onto an elastic grid. The Gabor jet is a node on the elastic grid, notated by circles on the image below, which describes the image behavior around a given pixel. It is the result of a convolution of the image with a Gabor filter, which is used to detect shapes and to extract features using image processing. [A convolution expresses the amount of overlap from functions,

Figure 4. Image showing superimposition technique helping in facial reconstruction.

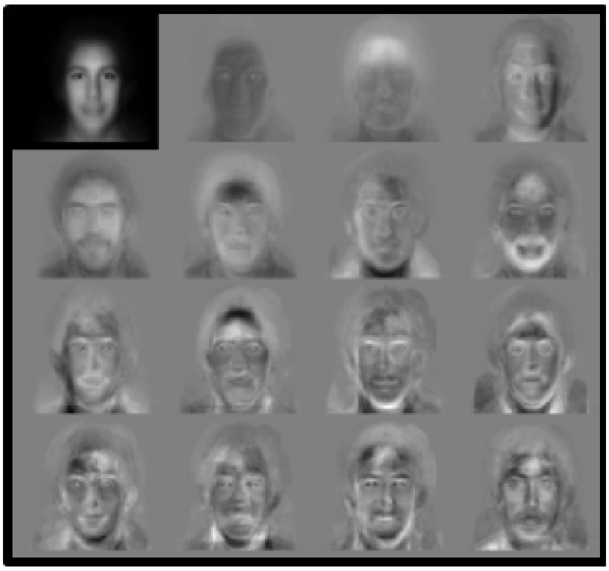

Figure 5. Standard Eigenfaces: Feature vectors are derived using Eigenfaces.

Figure 6. Example of Six Classes Using Linear Discriminate Analysis (LDA):

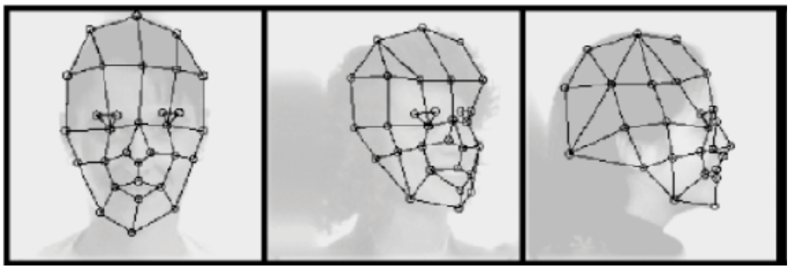

Figure 7. Elastic Bunch Map Graphing.

blending the functions together.] Recognition is based on the similarity of the Gabor filter response at each Gabor node. This biologically-based method using Gabor filters is a process executed in the visual cortex of higher mammals. The difficulty with this method is the requirement of accurate landmark localization, which can sometimes be achieved by combining PCA and LDA methods (Figure7).

Results

This current approach targeted on the study of distinct contemporary revolutions in forensic facial imaging and reconstruction in association with the field of disaster victim identification. Forensic facial imaging is one of the efficacious technique which can be accounted as a predominant as well as corroborative evidence in indigenous hazards. As forensics is a multidisciplinary science, so such sort of impactful and uprising techniques can provide a great assistance in dealing with such natural fatalities, connecting and linking people with their family members, revealing their identity, sex, and other relevant clues with respect to the individual can be achieved. The historical view of the forensic facial imaging, its positive and negative aspects, variabilities, modifications etc., are being mentioned in this domain. This paper is being discussed further with Pittyapat et al who added different views, methodologies, and tools, in relation with forensic odontology which is also included in one of the significant emerging technique of forensic science. Pittayapat (2012) discussed an intensive and demanding task of disaster victim identification (DVI) involving specialists from various disciplines. This article aimed to collate all information regarding diagnostic tools and methodologies pertaining to forensic odontological DVI, both current and future. It can be concluded that lessons learned from previous disaster incidents have helped to optimize working protocols and to develop new tools that can be applied in future DVI operation. The working procedures have been greatly improved by newly developed technologies. Soni (2018) demonstrated the heinous measures of disasters or natural calamaties and discussed the significant assistance of efficient technique termed as Forensic facial imaging which can provide superlative clues in revealing the identity of the individuals. The indelible remark left behind with the family members is really a matter of thought. This paper seeks to present a review of the existing literature in this domain and discuss several aspects, significance and requirements, particularly focusing the various advances and trends of facial imaging which may provide a great beneficiary value in face recognition mechanism of victims in the case of different fatalities.

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