PERSPECTIVE OF FORENSIC ARCHAEOLOGY - REVIEW ARTICLE

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ABSTRACT

Forensic archaeology is a specialized branch of archaeology focused on applying archaeological techniques to legal investigations, particularly in discovering and examining human remains and associated evidence at crime scenes. This field prioritizes methodical excavation, precise contextual analysis, and detailed documentation to preserve the integrity of evidence. Forensic archaeologists collaborate with other forensic professionals to offer critical insights into the circumstances surrounding a death, assist in identifying victims, and contribute to the judicial process. Ethical considerations and the necessity for legally admissible evidence are central to forensic archaeology, making it an essential aspect of criminal investigations and courtroom proceedings.

Keywords: Burnt, Magnetometry, LiDAR, Forensic, Archaeology.

I. INTRODUCTION

Forensic archaeology has seen significant advances at the intersection of archaeology and forensic science. It applies archaeological techniques to legal investigations, focusing on the recovery and analysis of human remains and evidence from crime scenes.

Recent research emphasizes the growing importance of forensic archaeology in addressing complex criminal cases, particularly in locating evidence in challenging scenarios such as clandestine graves and mass burial sites. Advanced techniques such as remote sensing, 3D spatial analysis, and forensic geophysics have greatly improved the accuracy and effectiveness of forensic archaeological investigations.

Technologies like ground-penetrating radar (GPR) and LiDAR have enhanced the ability to detect and map subsurface anomalies, crucial for identifying and documenting crime scenes with minimal disruption.

The field is also advancing in methods for evidence recovery and preservation, including new excavation techniques and innovative documentation practices. Ethical considerations, such as the respectful handling of human remains and cultural sensitivities, are increasingly considered.

Forensic archaeologists now collaborate closely with forensic anthropologists, pathologists, and law enforcement to provide detailed analyses that support criminal justice. As the field continues to evolve, it is expected to refine methodologies further and enhance its role within the legal system.

II. HISTORY

The field of forensic archaeology builds upon the foundational archaeological methods that were formalized in the 19th century by pioneers such as Heinrich Schliemann and Sir Arthur Evans. These early archaeologists contributed to the development of techniques for excavation and stratigraphy, which have since had a significant impact on forensic applications.

The necessity for forensic expertise became more apparent during and after World War II. The examination of war crimes and mass graves emphasized the need for organized approaches to retrieve and examine human remains. This era marked the commencement of integrating archaeological methods into forensic inquiries.

In 1984, after the anti-Sikh riots in India, which erupted in response to the assassination of Prime Minister Indira Gandhi, the police handed a case involving a skull to a forensic pathologist. Out of the 8,000 people who died, many bodies were either incinerated or buried, with some left to decompose.

The police investigation revealed that the skull had been discovered under some bushes. Examination of the skull showed a distinctive fracture on the occipital bone, suggesting the cause of death was a blunt object, likely an iron rod. Furthermore, unique dental features helped identify the victim as one of the missing Sikh

individuals. The forensic pathologist went to the scene of the discovery and used archaeological methods to search for more human remains. This led to the identification of several additional bodies. Some were positively identified through unique characteristics like dental fillings, prosthetics, and personal belongings such as diaries, watches, and leather bags.

In January 2011, the village of Hondh-Chillar, which had been burned and abandoned, was discovered in northern Haryana, where 32 Sikhs were murdered on November 2, 1984. Later, in March 1985, another site in nearby Pataudi, where 17 people had been killed, was found. However, the bodies from this second site have not yet been recovered by the authorities.

A key aspect of these works is their practical recommendations, which assist in determining if the conclusions were reached following established guidelines. According to best practices, it is essential to reference reliable monographic studies and original literature before arriving at conclusions.

The role of contemporary forensic anthropology is broadening, building on its traditional foundations while addressing a range of additional concerns. These include human rights, gender discrimination, family rights, and international law, as well as advancements in surveying and remote sensing techniques, taphonomy, and more.
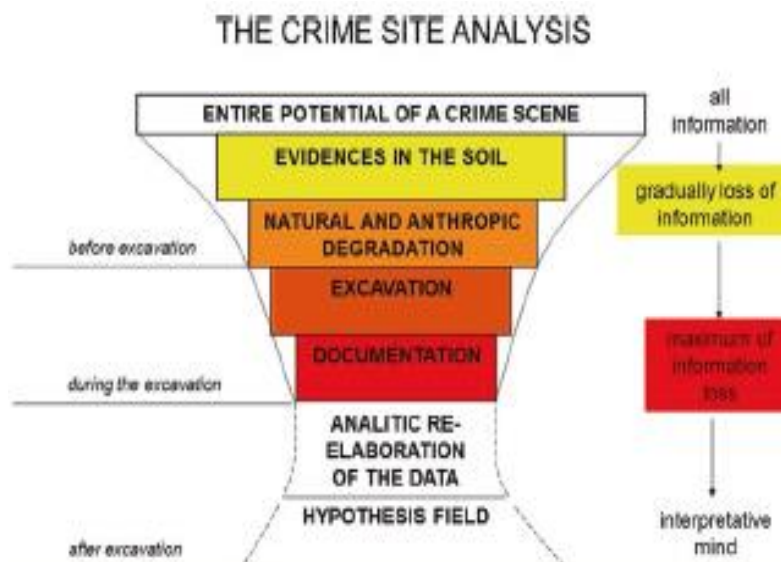

Figure 1-The crime scene analysis

BASIC ARCHAEOLOGICAL TECHNIQUES

Historical excavation methods have already been detailed in Hester et al. 2009) as follows -

1. Stratigraphic Excavation: This method involves digging in horizontal layers to reveal the sequence of deposition and understand the chronological development of a site.

2. Test Excavations: Small-scale exploratory digs, such as test pits, are used to evaluate the potential of a site and inform further excavation strategies.

3. Open-Area Excavation: Large, contiguous areas of soil are removed to examine spatial relationships between features and artifacts across a broader section of the site.

4. Vertical Excavation: Focuses on digging down through specific areas to expose and record the stratigraphy, providing insights into the site's historical layering.

5. Controlled Excavation: This approach ensures precise and careful excavation, with detailed recording to capture all pertinent information and reduce disturbance.

6. Screening and Washing: Soil is sifted through mesh screens or washed to recover smaller artifacts and ecofacts that might otherwise be missed.

7. Recording Techniques: Detailed documentation is maintained through field notes, drawings, photographs, and digital tools such as 3D modeling and GIS to ensure accurate analysis and preservation of data.
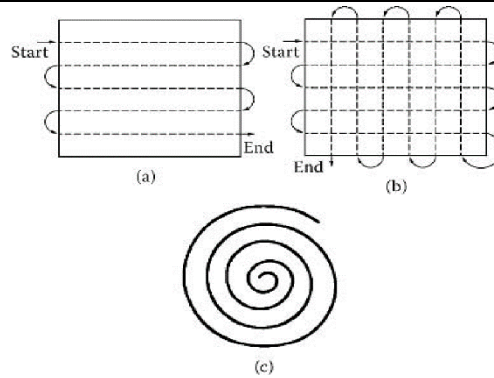
Figure 2 - Search patterns- (a) line or strip search; (b) grid search; and (c) spiral search

Figure 3-Skeletal elements from a primary burial found in an anatomical position

Recent developments in archaeological techniques have introduced several innovative methods and technologies that enhance the precision and efficiency of investigations. Non-invasive and minimal disturbance techniques aim to gather evidence and information while preserving the integrity of the site. These techniques include-

1. Remote Sensing Technologies
2. 3D Imaging and Visualization Technology
3. Magnetometry
4. Analytical Technology
5. Environmental Technology
6. Digital Technology

REMOTE SENSING TECHNOLOGIES: encompass various methods and devices used to gather information about objects or areas without needing physical contact. Typically, these technologies employ sensors installed on satellites, aircraft, drones, or ground-based platforms to collect data from afar. Some of them are listed below:-

LiDAR (Light Detection and Ranging): technology utilizes laser pulses to create intricate 3D maps of landscapes. It can penetrate vegetation, uncovering features hidden beneath forest cover, which makes it especially effective for mapping large areas and identifying ancient structures.

In forensic archaeology, LiDAR is used to uncover and document concealed evidence at crime scenes or historical sites. The technology penetrates soil and vegetation to reveal hidden features such as clandestine graves, traces of past activities, or structural remnants. This allows forensic archaeologists to precisely locate and analyze potential evidence, aiding in investigations and helping reconstruct events related to criminal activities or historical occurrences as such one implemented for Balana Fort.
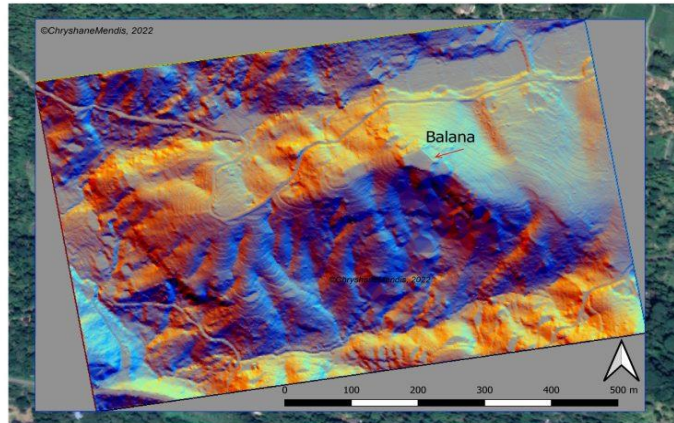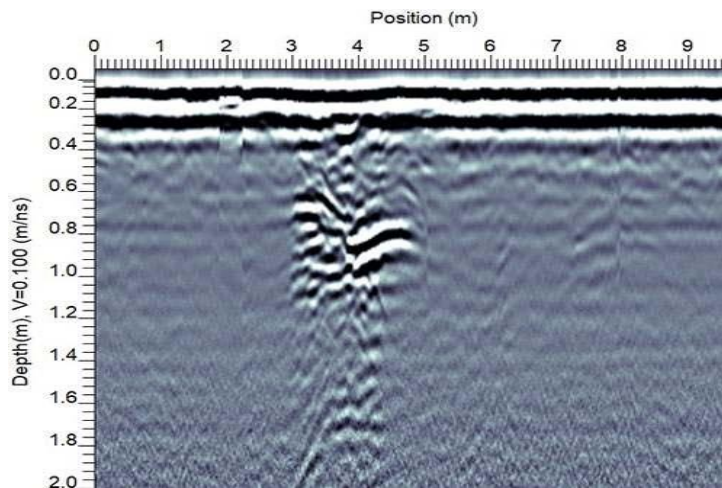
Figure 4- Balana fort with Sky-view factor

Figure 5- LMX150™ FINDAR

Project	Demo
Screen Capture Number	3
Screen Name	Grid Scan
Date Collected	April 17 2019 8:56 AM
Mode	SliceView
Grid	Grid01
Grid Size	5 x 5 m
Grid Spacing	0.5 m (0.5 m)
Soil Cal	Moist Soil (100)
Slice Depth	0.8-0.9 m
Slice Color Palette (Gain)	2 (Low)
Grid Line Visibility	OFF
Selected Line	LineY1
Depth	2.0 m
Line Color Palette	1
Filter	ON (3)
Gain Level	4

Figure 6- LMX150™ MINI REPORT

Ground-Penetrating Radar: uses radar waves to detect and map underground structures. Recent improvements have increased the clarity and depth of GPR imaging, enabling more accurate identification of buried archaeological features.

3D IMAGING AND VISUALIZATION- In forensic archaeology, 3D imaging, and visualization techniques are used to create precise three-dimensional models of crime scenes or archaeological sites. Technologies like laser scanning, photogrammetry, and structured light scanning capture and reconstruct the spatial layout and details of these areas with high accuracy.

These models facilitate in-depth analysis, detailed documentation of evidence, and the reconstruction of past events. Additionally, the ability to view and analyze these 3D models remotely allows experts to collaborate and assess the site from various locations. Overall, these advanced imaging methods significantly improve the documentation, analysis, and presentation of forensic evidence, enhancing the overall investigative process.

Photogrammetry: This technique captures multiple photographs from various angles to construct detailed 3D models of artifacts, structures, and excavation sites. Advances in software and equipment have streamlined the process, making it easier and more precise to create high-resolution 3D models.
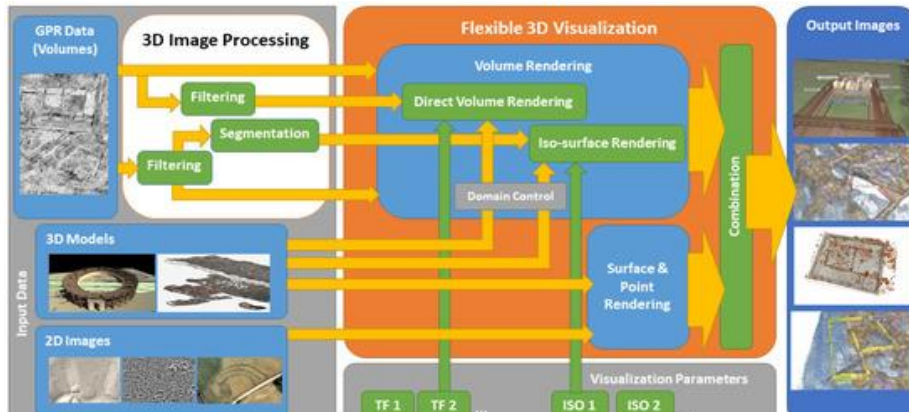

Figure 6- 3D visualization system

3D Laser Scanning: Uses laser beams to obtain precise measurements of physical objects and landscapes, creating highly accurate digital models. This technology is essential for the analysis, preservation, and development of virtual reconstructions.
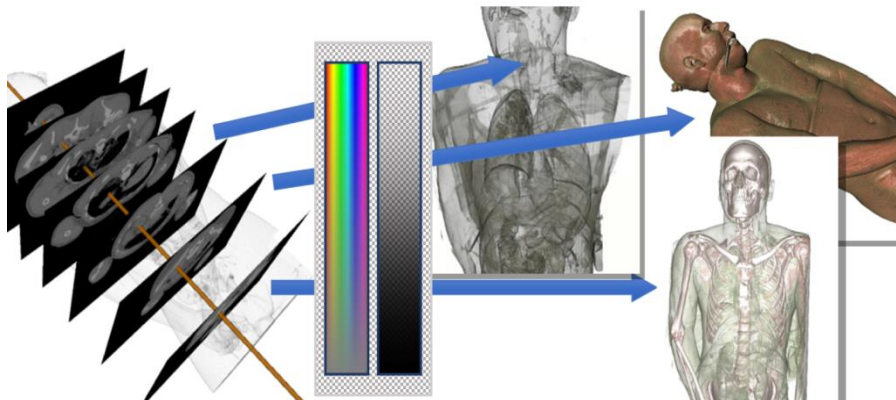

Figure 7- 3D configuration of the GPR data

ELECTROMAGNETIC INDUCTION: Techniques like electromagnetic induction (EMI) are used to identify buried features by detecting changes in soil properties. Recent advancements have increased the sensitivity and precision of EMI, allowing for the detection of subtle subsurface anomalies. This technique uses sensors to create an alternating magnetic field and measures the resulting disturbances to identify anomalies that may indicate the presence of metal artifacts or structural remnants.

It provides detailed maps of these features while preserving the site's integrity through non-invasive exploration. Often used alongside other non-invasive methods like ground-penetrating radar (GPR) or magnetometry, electromagnetic induction enhances the overall analysis of a site by offering a more comprehensive understanding of hidden evidence.

MAGNETOMETRY: is a non-invasive approach in forensic archaeology that identifies and maps underground objects or structures by detecting variations in the Earth's magnetic field. It identifies variations in the Earth's magnetic field caused by buried features. These variations, triggered by materials like metals or fired clay, help uncover the locations of artifacts, graves, or other concealed features.

The method produces detailed maps that visually represent these magnetic anomalies, allowing archaeologists to understand subsurface features without disrupting the site. Particularly effective for surveying large areas, magnetometry quickly pinpoints regions that may need closer examination while preserving the site's archaeological context.

Recent advancements in magnetometer technology have increased sensitivity and resolution, allowing for the detection of smaller and deeper anomalies.
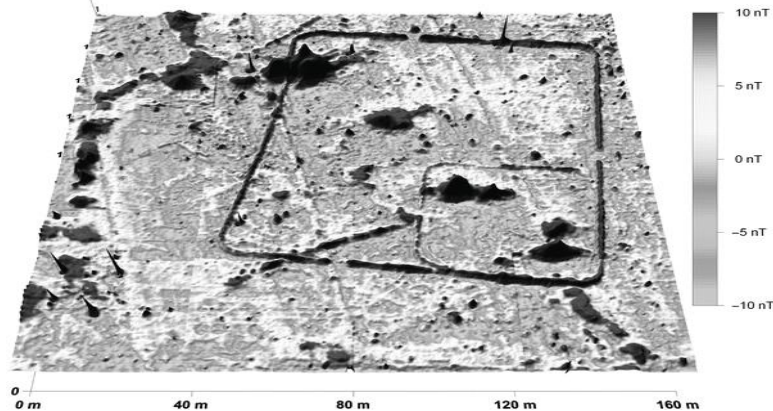

Figure 8- Magnetic Prospection

ADVANCED ANALYTICAL METHODS: examines the incorporation of advanced analytical techniques into forensic archaeology, a field that applies archaeological methods to legal investigations. Geophysical surveys, chemical testing, and DNA analysis, are all employed to detect, uncover, and examine human remains within a forensic setting.

Isotope Analysis: In forensic archaeology examines the chemical makeup of bones, teeth, and artifacts to gain insights into human behavior, environmental conditions, and migration patterns. By analyzing the ratios of isotopes like carbon and nitrogen, researchers can reconstruct diets, while oxygen and strontium isotopes help pinpoint geographic origins and track migration. This technique also reveals past environmental conditions and significant life events by studying isotopes formed during different life stages. In forensic investigations, isotope analysis is valuable for identifying unknown individuals by comparing their I sotopic signatures to known geographic profiles, providing clues about their origins, diets, and movements. Advancements in stable isotope analysis techniques enable more detailed reconstructions of past environments, diets, and migration patterns. These methods offer valuable insights into ancient populations.

DNA Analysis: Recent improvements: in extracting and sequencing ancient DNA (aDNA) have enhanced the analysis of genetic material from archaeological remains, providing deeper insights into past populations, diseases, and evolutionary changes.
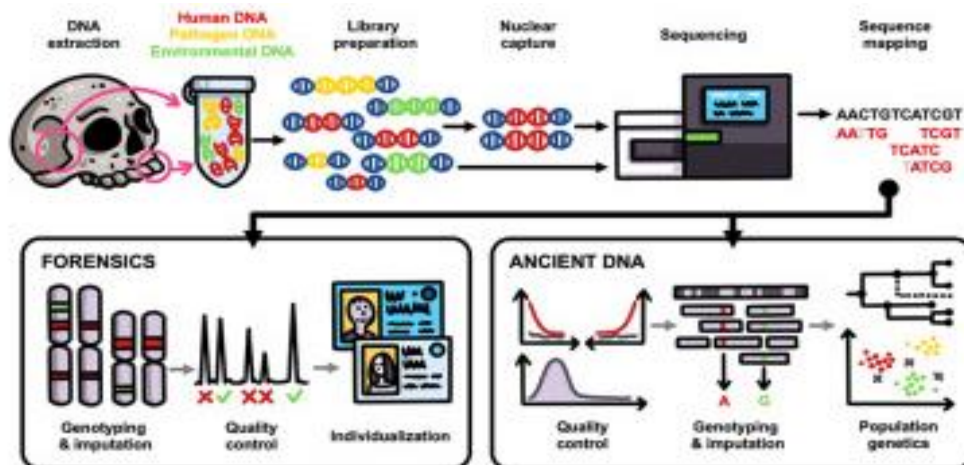

Figure 9- Forensic and Ancient Genetic Analyses

ENVIRONMENTAL AND CONTEXTUAL ANALYSIS: investigates environmental conditions and contextual factors to enhance understanding of events, artifacts, or phenomena.

Geospatial Analysis: Contemporary Geographic Information Systems (GIS) and spatial analysis tools aid in examining spatial patterns and relationships within archaeological data.
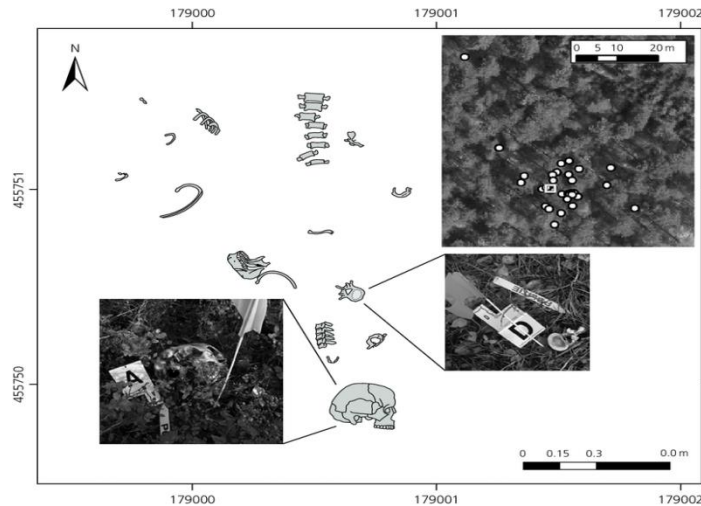

Figure 10 - GIS analysis of skeletonized human remains in a forest

Sedimentology: examines sediments—materials resulting from rock weathering, erosion, and biological activity—and their processes of deposition and transformation. Forensic archaeology provides insights into site conditions by analyzing sediment characteristics, including grain size and mineral content. The study of sediment layers helps establish chronological sequences and understand how sediments were transported and deposited. Additionally, sedimentology explores site formation processes, such as erosion and bioturbation, to interpret how a site has changed over time. This knowledge aids in understanding the context of archaeological and forensic sites, helping to reconstruct past environments and events.

Advancements in sediment analysis techniques, including micromorphology and soil chemistry, offer valuable insights into past environmental conditions, site formation processes, and human activities.

DIGITAL AND COMPUTATIONAL INNOVATIONS

Artificial Intelligence and Machine Learning: Artificial intelligence (AI) and machine learning are increasingly applied to analyze extensive archaeological datasets, detect pattern, and predict site locations. These technologies facilitate more efficient data processing than traditional methods.

Virtual Reality and Augmented Reality: Virtual reality and augmented reality technologies are employed to craft immersive experiences and interactive reconstructions of archaeological sites. These tools enhance visualization, support educational efforts, and generate interactive 3D environments that users can explore using VR headsets and controllers, creating a sense of real immersion.

In forensic archaeology, Virtual Reality is used to analyze and interact with detailed 3D models of sites, artifacts, and crime scenes, enhancing the understanding of spatial relationships and site details. It improves data visualization by presenting complex information, like site layouts and artifact distributions, intuitively. VR also allows for the recreation of historical settings and events, aiding in the interpretation of both archaeological and forensic data.

Moreover, it enables remote collaboration by letting multiple users interact within the same virtual environment from different locations and acts as an effective educational tool, providing practical experience with virtual simulations.
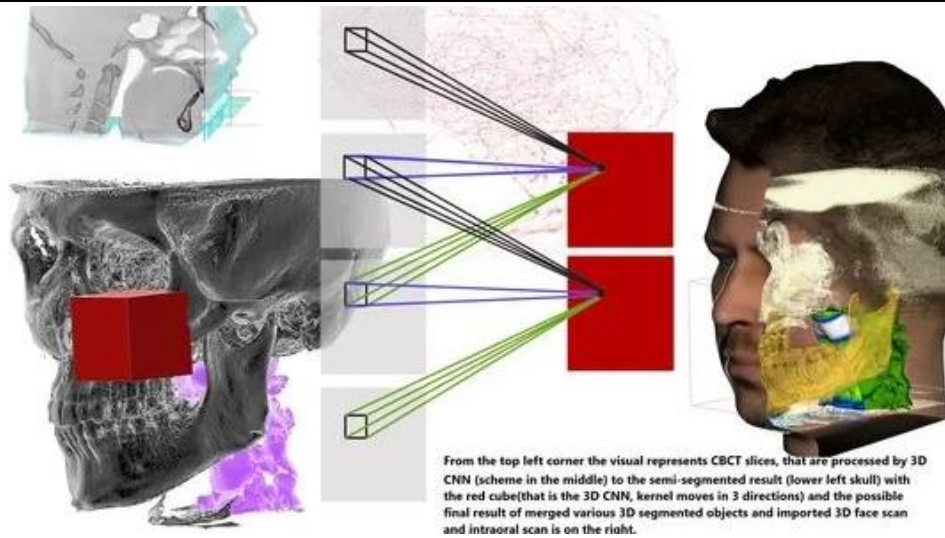
From the top left corner the visual represents CBCT slices, that are processed by 3D CNN (scheme in the middle) to the semi-segmented result (lower left skull) with the red cube(that is the 3D CNN, kernel moves in 3 directions) and the possible final result of merged various 3D segmented objects and imported 3D face scan and intraoral scan is on the right.

Figure 11-advanced artificial intelligence

BURNT SKELETAL REMAINS

Burnt Skeletal remains vary widely from normal skeletal remains since burning up at high temperatures changes the color of bone leading to explosion sometimes as well.

When bones are exposed to fire, they undergo several distinct physical changes that are key to forensic analysis. Initially, bones may turn black due to the combustion of organic material and the accumulation of carbon residues.

As the temperature increases, the bones often transition from gray to white, indicating that the organic material has been completely burned off and that the calcium phosphate in the bones has transformed. These color changes are critical markers that help forensic experts assess the level of heat and the duration of exposure.

The structural integrity of the bones also changes under the influence of fire. Rapid heating and subsequent cooling can cause bones to develop cracks and fissures, which can be either transverse or longitudinal. This fracturing is a result of thermal stress and can provide clues about how quickly the fire spread and how the remains were affected during the burning process.

As bones lose water and organic material, they undergo shrinkage, leading to warping and deformation, which complicates identification. High temperatures exacerbate this, causing bones to bend or significantly distort. In extreme cases, bones may develop a shiny, glazed surface from mineral melting. These physical changes offer insights into the fire's conditions, such as intensity and duration, but also present challenges for molecular analysis, as extreme heat can degrade DNA and other biological markers, making it harder to extract usable forensic evidence.
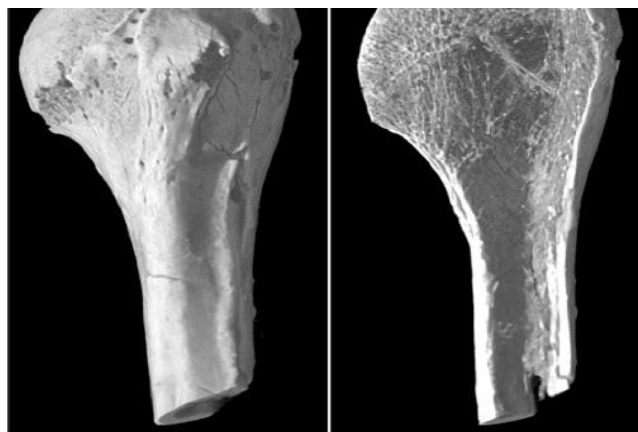

Figure 12- 3D images of a cremated proximal end of humerus, obtained by micro-CT imaging.

Despite these difficulties, forensic experts are adept at analyzing burnt remains. They can often distinguish human from non-human remains, pinpoint the location of the burning, determine the number of victims, and reconstruct the events surrounding the fire.

Dental morphology is vital for identifying individuals, tracing ancestry, and reconstructing migration patterns. Teeth provide insights into ancient diseases and injuries, helping forensic archaeologists understand past populations' health, lifestyle, and cultural practices. This expertise is essential in forensic investigations and archaeological research, especially when fire-damaged bones are involved.

The techniques for examining burnt remains involve the following:

1. Visual and Macroscopic Assessment: Evaluating the color, texture, and physical condition of bones, which may range in color from brown to white and may show signs of cracking or distortion.

2. Microscopic Analysis: Employing light and electron microscopes to scrutinize minute surface changes and structural details, which helps in determining the extent and nature of the burning.

3. Radiographic Examination: Using X-rays or CT scans to inspect internal damage and structural modifications without damaging the remains, facilitating the identification of hidden fractures and other changes.

4. Chemical Profiling: Analyzing the presence of chemical residues or alterations in bone composition with techniques such as mass spectrometry or infrared spectroscopy to detect changes in mineral content or specific chemical markers.

5. Assessment of Thermal Damage: Comparing the observed physical and chemical modifications in burnt bones to established standards or experimental data to infer the temperature and duration of the burning process.
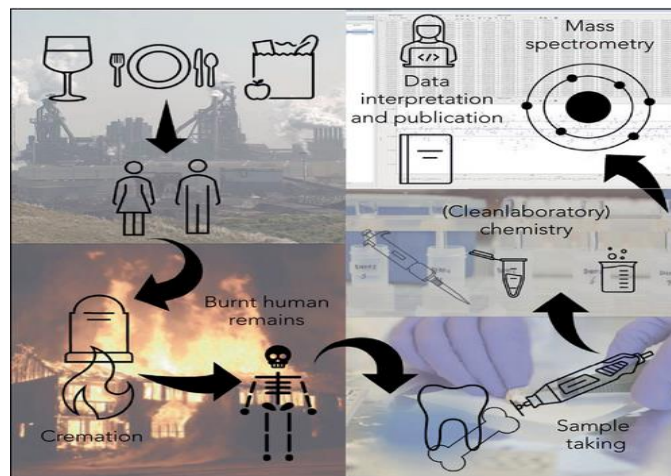

Figure 13- Isotope analysis on burnt human skeletal remain

6. Controlled Burn Experiments: Conducting laboratory burns to simulate various temperatures and durations, providing data that helps in interpreting real-life forensic cases.

7. Review of Literature and Databases: Consulting forensic and anthropological research and databases to compare findings with previously documented cases of burnt remains, aiding in recognizing patterns and understanding the implications of observed alterations.

These methods collectively offer a comprehensive approach to studying burnt skeletal remains, helping forensic experts reconstruct events and assess the context of the burning.

APPLICATIONS OF FORENSIC ARCHAEOLOGY TO CRIME SCENE

- Assist investigators by thoroughly documenting and recovering all potential evidence, reconstructing and recording the entire crime scene, and addressing questions about the victim's identity, circumstances of death, and, if applicable, identifying the perpetrator.

- Apply established archaeological methods to locate and retrieve human remains and related evidence within the scope of a forensic investigation.

- Utilize a systematic and adaptable approach that accommodates various constraints and improves accuracy in collecting and preserving skeletal and associated evidence.
- Assess and account for disturbances that may have affected the scene after its creation.
- Prevent damage to skeletal evidence postmortem and effectively reconstruct the events surrounding and following the burial.
- Document environmental conditions for future analysis by entomologists, botanists, and other experts.

III. CONCLUSION

Forensic archaeology has been identified as a key discipline in investigating crime scenes, focusing on discovering and examining human remains. Integrating archaeological methods with forensic science has improved the precision in reconstructing events surrounding deaths, offering valuable evidence in legal contexts. While the field encounters challenges, such as the complexity of dealing with decomposed remains, the study emphasized the importance of continuous advancements and collaboration across disciplines to enhance investigative techniques.

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