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Modern technologies and artificial intelligence in archaeology and bioarchaeology *

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Abstract

This paper discusses the importance of adopting and applying new technologies in scientific fields to increase the rate of progress. It emphasises the need for networking and multidisciplinary collaboration to apply technologies developed for other purposes to solve scientific or professional issues. The paper reviews modern technologies used in archaeology and bioarchaeology, including ground penetrating radar, LiDAR, drones, 3D printing, remote sensing, GIS, and portable X-ray fluorescence. It also presents modern technologies in bioarchaeology such as DNA analysis, stable isotope analysis, radiocarbon dating, microscopic analysis, CT and MRI, and proteomics. The paper introduces palaeoradiology, a branch of radiology that uses imaging technologies to examine bioarchaeological or even archaeological material, and discusses its importance in gaining knowledge about the health, lifestyle, and causes of death of past populations.

Keywords: artificial intelligence; archaeology; bioarchaeology

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Introduction

The speed of progress in a particular scientific field is very often proportional to the speed of adoption and application of new technologies in the daily work of experts in that field. Unfortunately, we often experience situations where new research methods based on new technologies have been developed, but sometimes there are no trained and competent experts who would try to apply them and thus perhaps come to new discoveries and insights. One of the common reasons for this is the simple fact that the scientists themselves do not even know what technologies have been developed in the meantime that might be useful to them in their research work. The fast pace of private and business life often does not leave enough time to expand one's horizons beyond the scope set by professional tasks.

Technologies that were originally designed for other purposes can very often be successfully applied in areas for which they were not primarily invented (1–3). To do this, we first need to know at least roughly what is available, then we need to know what is available to us and under what conditions, and finally we need to find a way to use it to solve the scientific or professional question to which we want an answer. In all of this, networking and multidisciplinary collaboration are of great importance. An example of this is DNA analysis, which was not originally intended as a technology for bioarchaeological research but is now almost unavoidable. In the past, it was difficult to sequence whole genomes from very fragmented ancient DNA samples (2). However, breakthroughs have been made with the development of next-generation sequencing (NGS) technologies and the improvement of DNA isolation protocols. These advances have enabled scientists to use even highly fragmented ancient DNA samples to sequence whole genomes (4).

This paper will provide a brief overview of modern technologies in archaeology and bioarchaeology, with a focus on artificial intelligence.

Modern technologies in archaeology

There are several modern technologies used in archaeology to aid in the study and interpretation of archaeological sites and artefacts. Some of these technologies are:

- Ground Penetrating Radar (GPR): This technology uses radar pulses to create images of subsurface features. It can help archaeologists identify buried structures or artefacts without excavation (5–7).
- LiDAR (Light Detection and Ranging): LiDAR uses laser pulses to produce highly detailed maps of surface features such as terrain, vegetation, and buildings. It can help archaeologists identify features that are not visible to the naked eye (8,9).
- GIS (Geographic Information Systems): Technology from GIS allows archaeologists to create detailed maps of archaeological sites, analyse data, and visualise patterns and trends (10,11).
- Portable X-ray fluorescence (PXRF): this technology allows archaeologists to analyse the chemical composition of artefacts without removing or damaging them (12,13).
- Drones: Unmanned aerial vehicles (UAVs) or drones can be used to take high-resolution aerial photographs of archaeological sites that provide an overview of the site and its surroundings (14,15).
- 3D printing: 3D printing technology can be used to create replicas of archaeological artefacts that can be used for study and educational purposes without damaging the original artefact (5,16,17).
- Remote sensing: This includes satellite imagery and aerial photography that can be used to locate and map archaeological sites and identify features that are not visible on the ground (3,18).

Modern technologies in bioarchaeology

In recent years, several modern technologies have been developed, improved, and applied in the field of bioarchaeology. They are considered important and useful for a better understanding of the biological aspects of human remains from archaeological sites. Some of these technologies include:

- DNA analysis: DNA analysis has become an important tool in bioarchaeology because it allows researchers to trace the ancestry and relationships of individuals from earlier populations. DNA can also be used to identify pathogens, such as the bacteria responsible for tuberculosis or the virus that causes smallpox (2,19,20).
- Stable isotope analysis: stable isotope analysis measures the ratio of isotopes of different elements in human tissues such as bones or teeth. This can provide information about the diet, weaning stress, migration patterns, and environmental conditions of past populations (21–23).

- Microscopic analysis: microscopic analysis uses high-resolution imaging techniques such as scanning electron microscopy (SEM) and confocal microscopy to study the structure and composition of bones and other tissues. This can provide insight into the health, lifestyle, and employment of past populations (20,24).
- CT scanning: Computed tomography (CT) is a non-invasive imaging technique that can produce detailed 3D images of bone and other tissues. CT scanning can be used to study skeletal injuries, pathologies, and dental morphology, among other applications (25,26).
- Proteomics: proteomics is the study of the proteome, the set of proteins expressed by an organism. This technology can be used to identify proteins in archaeological remains such as bones or hair, and to reconstruct the diet and health of past populations (27,28).

These are just a few examples of the modern technologies now being used in bioarchaeology. As technology advances, new tools and techniques are likely to be developed that will further enhance our ability to study and understand the life and culture of past peoples.

Palaeoradiology

The development of new technologies has led to new forms of multidisciplinary collaboration and the creation of new specialties, such as palaeoradiology. Palaeoradiology is a science that uses imaging techniques to examine and diagnose diseases, injuries, and other conditions in ancient human or animal remains. It can be used in scientific study of material remains as well. Palaeoradiologists use imaging techniques such as X-rays, computed tomography (CT) or magnetic resonance imaging (MRI) to examine skeletal remains and other artefacts from archaeological sites (21,29).

The use of imaging can provide valuable insights into the health status, lifestyle, and cause of death of past populations. For example, radiographs and CT scans can provide clues to fractures, bone infections, dental cavities, and tumours in ancient skeletal remains. Although CT can be used to examine soft tissues such as muscles or organ remains, contrast resolution due to taphonomic changes is too low. MRI can be used as additional tool in tissues that are rich with collagen or in differential diagnosis (30–34). These new insights, can help researchers better understand the physical abilities and limitations of past populations (35). Although palaeoradiology is almost as old as radiology it is still underused, but has evolved significantly over the past few decades. As radiological imaging technology continues to advance, it is likely that new applications for palaeoradiology will emerge that further expand our understanding of the health and lifestyles of early populations. The latest use of artificial intelligence in paleoradiology could open a whole new scientific niche (36).

Artificial intelligence in archaeology

Artificial intelligence has the potential to revolutionise the field of archaeology by facilitating the analysis and interpretation of large amounts of data from historical sites and artefacts (3,37). Here are some ways artificial intelligence can be used in archaeology:

- Image recognition: artificial intelligence algorithms can be trained to recognise and classify different types of artefacts based on images. This can help archaeologists quickly identify and categorise objects found at archaeological sites (38,39).
- Data analysis: artificial intelligence algorithms can be used to analyse large amounts of data such as survey data, aerial imagery, and satellite imagery to identify patterns and trends that may not be visible to the human eye. This can help archaeologists make more informed decisions about where to excavate and which areas to focus on (40,41).
- 3D modelling: artificial intelligence can be used to create highly detailed 3D models of archaeological sites that can be used to visualise and study the site in more detail. This can help archaeologists better understand the layout of a site and how it may have changed over time (42).
- Language translation: artificial intelligence can be used to translate ancient languages so that archaeologists can better understand texts found at archaeological sites. This can provide valuable insights into the cultures and societies that produced these texts (43).
- Predictive modelling: artificial intelligence can be used to make predictions about where archaeological sites might be located based on geological and environmental data. This can help archaeologists identify new areas to explore and discover previously undiscovered historical sites (44,45).

Overall, the application of artificial intelligence in archaeology has the potential to significantly accelerate our understanding of the past and allow us to gain new insights and learn more about the lives and cultures of our ancestors.

Artificial intelligence in bioarchaeology

Artificial intelligence can be used in a variety of ways in the study of ancient skeletal remains to aid in the analysis of data and to provide valuable insights. Below are some ways artificial intelligence can be used in the study of human remains from archaeological sites:

- Skeletal analysis: artificial intelligence can assist bioarchaeologists in analysing skeletal remains to identify and reconstruct the physical characteristics of individuals, such as age, gender, and ancestry (46,47).
- Trauma analysis: artificial intelligence can be used to analyse skeletal remains to identify and reconstruct trauma patterns that can provide insight into the causes of death or injury and the nature of past societies, as well as the social and political contexts in which these injuries occurred (48,49).
- Age estimation: artificial intelligence can be used to analyse dental images and other features of remains to help bioarchaeologists estimate the age of individuals (45,50).
- Sex estimation: artificial intelligence algorithms can be used to estimate the sex of skeletal remains based on factors such as bone density, tooth wear, and skull morphology (36,47,51).
- Image analysis: artificial intelligence can be used to analyse images of remains, such as CT scans, to assist bioarchaeologists in reconstructing the physical characteristics of individuals (52).
- Predictive analytics: Artificial intelligence can help predict the likelihood of certain diseases and conditions based on remains to understand the health of past populations.
- Automation: artificial intelligence can be used to automate certain tasks, such as the analysis of imaging and skeletal data, which can reduce the need for manual labor and increase the speed and accuracy of the process (38).
- Skeletal and dental databases: artificial intelligence can be used to search and match skeletal and dental data in databases, which can help identify individuals and reconstruct their lives.
- Genomic analysis: artificial intelligence can be used to analyze large amounts of genomic data, enabling bioarchaeologists and anthropologists to trace the evolutionary history of different populations and identify genetic markers that can be associated with specific traits or conditions (4,53–55).
- Disease detection: Artificial intelligence algorithms can be used to detect signs of disease in skeletal remains, such as arthritis or tuberculosis. This can provide insight into the prevalence of diseases in different populations and how diseases have evolved over time (56).
- Facial recognition: artificial intelligence algorithms can be used to analyze facial features and identify patterns that may be typical of particular populations or cultures. This can be helpful in better understanding of human migration patterns and the evolution of physical features (57).
- Facial reconstruction: artificial intelligence algorithms can be used to create 3D models of skulls and predict facial features based on bone structure. This can help create more accurate and lifelike facial reconstructions of ancient individuals (57).
- Ancestry and migration: Artificial intelligence can be used to analyze the genetic composition of skeletal remains, allowing anthropologists to trace the ancestry and migration patterns of different populations.

Advantages and disadvantages of the use of artificial intelligence in bioarchaeology

The use of artificial intelligence in bioarchaeology has several advantages (58,59):

- Improved accuracy: artificial intelligence can be used to analyze large amounts of data faster and more accurately than humans. For example, artificial intelligence algorithms can analyze complex 3D scans of bones and detect patterns or anomalies that are not immediately apparent to human observers. This can help researchers make more accurate and reliable interpretations of the data.
- Increased efficiency: artificial intelligence can help researchers process and analyze large amounts of data more quickly and efficiently than with traditional manual methods. This can save time and resources and allow researchers to focus on other aspects of their research.
- Improved visualization: artificial intelligence can be used to create visual representations of bioarchaeological data, such as 3D models of skeletal remains. This can help researchers better understand the spatial relationships between different bones and features, and can help identify pathologies or other abnormalities.

- Improved classification: artificial intelligence can be used to classify skeletal remains based on various criteria such as age, sex, and ancestry. This can help researchers create more accurate demographic profiles of past populations, which in turn can contribute to a better understanding of social and cultural dynamics in the past.
- New research opportunities: Finally, the use of artificial intelligence in bioarchaeology opens up new avenues for research and collaboration between different disciplines. For example, artificial intelligence algorithms developed for other applications, such as face or speech recognition, could be adapted for use in bioarchaeological research. This may lead to new insights and discoveries that would not be possible using traditional methods alone.

While the use of artificial intelligence in bioarchaeology offers many potential benefits, there are also some drawbacks that researchers should be aware of (59,60).
Lack of interpretive context: artificial intelligence algorithms are only as good as the data on which they are trained. If the data used to train the artificial intelligence model is incomplete or biased, the resulting analysis may not accurately reflect past reality. In addition, the use of artificial intelligence may lead to over-reliance on quantitative data and disregard qualitative data and interpretive context.
Ethical concerns: the use of artificial intelligence in bioarchaeology raises ethical questions about the appropriate handling of human remains. For example, some researchers have expressed concerns about using artificial intelligence to create 3D models of skeletal remains because it could be seen as disrespectful to the deceased.
Technical limitations: The use of artificial intelligence in bioarchaeology requires access to specialized hardware and software, as well as expertise in machine learning and data analysis. This can be a barrier to entry for smaller research teams or those without specialized technical knowledge.
Lack of transparency: artificial intelligence algorithms can be difficult to interpret and understand, which can make it difficult for researchers to fully assess the accuracy and reliability of the results they produce.
Cost: The cost of developing and implementing artificial intelligence technologies can be prohibitive, especially for smaller research projects or those with limited funds.

Overall, it is important for researchers to carefully consider both the potential benefits and drawbacks of using artificial intelligence in bioarchaeology and to use these tools in ways that are responsible, ethical, and based on a deep understanding of the interpretive context of the data.

Conclusion

In summary, the advancement and use of modern technologies including artificial intelligence in the fields of archaeology and bioarchaeology have led to significant advances in our understanding of past human cultures and societies. Ground penetrating radar, LiDAR, drones, 3D printing, remote sensing, GIS, and portable X-ray fluorescence are some of the modern technologies used in archaeology, while DNA analysis, stable isotope analysis, microscopic analysis, CT, and proteomics are some of the modern technologies used in bioarchaeology. There are more and more of these mentioned technologies that also use the power of artificial intelligence in their work. As technology advances, new tools and techniques will emerge that will further expand our ability to study and understand the lives and cultures of past peoples. The further development of specialties, such as palaeoradiology, underscores the importance of multidisciplinary collaboration and the value of applying modern technologies to interdisciplinary research. Of course, development cannot be expected to go as fast as in clinical medicine and radiology, because the number of cases where artificial intelligence and deep learning could be applied is significantly smaller.

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Declaration of Interest

None

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