

Communication

Interacting with the Artificial Intelligence (AI) Language Model ChatGPT: A Synopsis of Earth Observation and Remote Sensing in Archaeology

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Abstract: In this communication we aim to provide an overview of Earth observation and remote sensing in archaeology following a non-traditional literature review approach, that is, investigating recent developments in artificial intelligence (AI) and language models. Towards this direction, the generative pre-trained transformer (ChatGPT) language model was used to extract relevant information. The ChatGPT language model—recently released by OpenAI—appears to provide an alternative way for retrieving comprehensive information for various thematic topics. ChatGPT is currently operated on a beta version by millions of users worldwide, free of access for a limited period. In this study, specific queries related to Earth observation and remote sensing in archaeology were made by the authors to the ChatGPT. Innovations and limitations are discussed, while a comparison with traditional bibliographic analysis is performed.

Keywords: review; Earth observation archaeology; cropmarks; satellite archaeology; programming model; ChatGPT



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1. Introduction

As defined by the international Group on Earth Observation (GEO), “Earth observation is the gathering of information about planet Earth’s physical, chemical and biological systems. It involves monitoring and assessing the status of, and changes in, the natural and man-made environment. In recent years, Earth observation has become more and more sophisticated with the development of remote-sensing satellites and increasingly high-tech in-situ instruments” [1]. As argued by [2], in the domain of archaeology both “Earth observation” and “remote sensing” terms, are being used to define all the techniques used for archaeological exploration purposes, using active and passive sensors. For the needs of this communication, both terms are used interchangeably, covering the entire spectrum of sensors, technologies, and applications.

Earth observation and remote sensing techniques have been widely adopted for various archaeological applications in the recent past. Several scientific articles discuss a range of related topics, such as sensors, platforms, and specific applications for archaeology [2–9]. Even though Earth observation and archaeological remote sensing is not a new field, the technological advancements of remote sensors and image processing techniques are constantly evolving [10–13]. This advancement requires scholars to be constantly informed and updated, able to follow developments in the space sector, computer vision and mathematics, as well as image processing techniques. On top of that, research in remote sensing archaeology is driven by archaeological questions and needs. Therefore, the review process can be challenging as it requires a diverse and multidisciplinary approach.

So far, review papers related to remote sensing archaeology are primarily based on scientific articles deriving from repositories such as Scopus and Web of Science [2–6].

Language models are pre-trained using a massive dataset of text generated from websites, articles, and books that are available online, based on advanced AI models. In recent years, artificial intelligence (AI) interacts with users in a conversational way [14–16].

Following, recent directions for the use of ChatGPT [17], an advanced language model recently released by OpenAI research laboratory in November 2022, in scientific fields such as chemistry [18], psychiatry, [19] and medicine [20], this communication provides an overview of remote sensing archaeology through interaction with the specific language model. The model was trained with data available up to 2021, hence it has knowledge about events and information that were available until then.

The methodology followed for the needs of this communication is presented in Section 2. Specific queries were posed by the authors to the model and each response is given in quotation marks (e.g., “text from programming model”) under Section 3, to showcase the depth and extent of the ChatGPT replies. In Section 4, the advantages, and disadvantages of the language model, as well as its overall performance in the specific scientific domain are discussed. The communication ends with the conclusions in Section 5.

2. Methodology

Following an approach similar to a literature review for remote sensing archaeology based on scientific journal citations retrieved from web search engines [6], as well as other recent review papers [4,7], here the authors performed a series of queries to ChatGPT, related to Earth observation and remote sensing archaeology (see Table 1). These queries were grouped into five thematic categories as follow:

1. Queries group 1: Related to the ChatGPT itself (functions; architecture; training datasets, etc.).
2. Queries group 2: Definitions related to Earth observation, archaeology, and Earth observation in archaeology.
3. Queries group 3: Related to remote sensing sensors used, applications, technologies, and relevant software.
4. Queries group 4: Related to detection of buried remains using remote sensing and cropmarks.
5. Queries group 5: Related to trends observed in the domain of remote sensing archaeology.

Table 1. Queries designed for the ChatGPT language model.

Query Group	Query
1	<i>About the programming model</i> What are you? (ChatGPT) How do you work? (ChatGPT) Can you provide more details about your model? Can you text/respond only in English? The data input is generated from where?
2	<i>Definitions</i> What is Earth observation? What is archaeology? How is Earth observation used for archaeology? Has Earth observation been applied in the past for archaeology? In Eastern Mediterranean?
3	<i>Technologies</i> What are the technologies used for remote sensing archaeology? Which satellite sensors are used for remote sensing archaeology? What type of UAVs are used for remote sensing archaeology? Do you know any specific UAVs used? What software do we use in remote sensing archaeology?

Table 1. Cont.

Query Group	Query
4	<p><i>Archaeological buried remains and fusion of data</i></p> <p>Is Earth observation used for detection of buried remains? Can you provide more details regarding the changes in vegetation cover and buried remains? What do you know about cropmarks related with buried archaeological remains? What about fusion of remote sensing data for detection of buried archaeological remains?</p>
5	<p><i>Trends</i></p> <p>What is the trend in remote sensing archaeology?</p>

The aforementioned queries aimed to extract details dealing with basic definitions, technology used, and examples of Earth observation/remote sensing applications in archaeology. In addition, specialized topics, such as cropmark formation used for the detection of shallow buried archaeological remains and fusion of data, were raised. Moreover, trends in the domain were queried.

3. Results

In this section, the replies of the ChatGPT for every question in Table 1 are given verbatim within quotation marks. Particularly long answers were limited to meet the objectives of this communication article. Discussion on the replies follows in Section 4.

3.1. About the Language Model

3.1.1. What Are You? (ChatGPT)

“ChatGPT is a large language model, trained by OpenAI to assist with tasks such as answering questions and generating text. ChatGPT work by using machine learning techniques, specifically deep learning, to analyze patterns in the data that it was trained on. This allows ChatGPT to understand the context and intent of text inputs and generate appropriate responses. ChatGPT use a variant of the transformer architecture, which allows it to process input sequences of any length and generate output sequences of any length. The model is trained on a massive dataset of text and fine-tuned for specific tasks. The fine-tuning process allows the model to learn to perform the task of interest while still leveraging the knowledge learned during the pre-training phase”.

3.1.2. How Do You Work? (ChatGPT)

“ChatGPT model is based on the transformer architecture, which was introduced in a 2017 paper by Google. The transformer architecture is a neural network architecture that uses self-attention mechanisms to process input sequences in parallel, rather than in a sequential manner as in previous architectures such as RNNs and LSTMs. This allows for much faster training and processing of input sequences of any length [. . .]. The specific variant of the transformer architecture that the model uses is called GPT (Generative Pre-trained Transformer). GPT-2 and GPT-3 are the latest version of GPT series [. . .].”

3.1.3. Can You Provide More Details about Your Model (ChatGPT)?

“ChatGPT model has been trained on a large dataset of text and fine-tuned to perform specific tasks like answering questions and generating text. The fine-tuning process allows the model to learn to perform the task of interest while still leveraging the knowledge learned during the pre-training phase.

The GPT-3 model is a transformer-based architecture model with 175 billion parameters, which is considered one of the largest language models in the industry, it can generate text that is often indistinguishable from text written by a human”.

3.1.4. Can You Text/Respond Only in English?

“ChatGPT is trained to understand and generate text in English. ChatGPT can understand and respond to text inputs in English, and generate text in English”.

3.1.5. The Data Input Is Generated from Where?

“The data that ChatGPT was trained on came from a variety of sources on the internet, including web pages, articles, and books. This data was preprocessed and cleaned to make it suitable for training a language model. The training data includes a wide range of topics and styles, which allows the model to learn about a wide variety of subjects and to generate text in a variety of formats.

The data used to train GPT-3 specifically came from a diverse set of internet sources, including books, articles, and websites. The model was trained on a diverse set of texts to give it a broad understanding of the world and various subjects, which allows it to generate text that is often similar to text written by humans [. . .].”

3.2. Definitions

3.2.1. What Is Earth Observation?

“Earth observation is the collection of data about the Earth’s land surface, oceans, and atmosphere using remote sensing techniques. These techniques involve the use of instruments and technologies such as satellites, aircraft, and ground-based sensors to measure various parameters such as temperature, humidity, vegetation cover, and sea level. The data collected from these instruments is used for a wide range of applications such as monitoring weather and climate, managing natural resources, and studying the Earth’s ecosystems. This data can also be used to generate maps and images of the Earth, which can be used for navigation, urban planning, and scientific research”.

3.2.2. What Is Archaeology?

“Archaeology is the study of human history and prehistory through the excavation and analysis of artifacts and structures. It seeks to understand past cultures and societies, and how they interacted with their environments. This can include studying the remains of buildings, tools, and other objects, as well as analyzing the physical remains of human bodies and analyzing the soil and other features of the site. It is a multi-disciplinary field, drawing on the methods and techniques of anthropology, history, geology, and other sciences”.

3.2.3. How Is Earth Observation Used for Archaeology?

“Earth observation, or the use of remote sensing technology to study the Earth’s surface, has become an increasingly important tool in archaeology in recent years. This technology allows archaeologists to study and map large areas of land quickly and efficiently, which can be particularly useful in remote or hard-to-reach areas.”

3.2.4. Has Earth Observation Been Applied in the Past for Archaeology?

“There are various types of remote sensing techniques that can be used in archaeology, including satellite imagery, aerial photography, and lidar (light detection and ranging). These techniques can be used to identify and map archaeological sites, to study land use and land cover changes, and to study environmental factors that may have influenced human settlements in the past.

Satellite imagery, for example, can be used to detect subtle changes in land cover, such as the presence of crop marks or soil marks that indicate the presence of buried archaeological features. Aerial photography can be used to study the layout and structure of archaeological sites, while lidar can be used to create detailed 3D models of the landscape and to identify buried features such as walls and ditches.

Earth observation technology can provide a wealth of data that can be used to study archaeological sites and landscapes, and it has become an important tool for conducting

research in archaeology. However, it should be noted that remote sensing technology is not a substitute for ground-based survey and excavation, but rather a complementary tool that can greatly aid archaeological research. A few examples of how earth observation technology has been used in archaeology are:

- i. Mapping and identifying archaeological sites: Satellite imagery and aerial photography have been used to identify and map archaeological sites that are difficult to detect on the ground. For example, in Egypt, satellite imagery was used to identify previously unknown pyramids, while in Peru, aerial photography was used to map the extensive network of ancient roads and settlements of the Inca Empire.
- ii. Land use and land cover change: Remote sensing technology can be used to study changes in land use and land cover over time, which can provide insight into how human settlements have interacted with their environment in the past. For example, in Syria, satellite imagery was used to study how ancient irrigation systems were modified and expanded over time, providing insight into the evolution of agricultural practices.
- iii. Environmental archaeology: Remote sensing technology can be used to study the relationship between past human settlements and the environment. For example, in Jordan, lidar was used to study the ancient city of Petra and the surrounding landscape, providing insight into how the city was built and how it interacted with its environment.
- iv. Underwater archaeology: Remote sensing technology can be used to study underwater archaeological sites. For example, in the Mediterranean Sea, sonar and multibeam echosounder have been used to map shipwrecks and other underwater archaeological sites.
- v. Monitoring and preservation: Remote sensing technology can be used to monitor and preserve archaeological sites. For example, in Italy, satellite imagery and aerial photography have been used to monitor and document the erosion of the ancient city of Pompeii, which was buried by the eruption of Mount Vesuvius in AD 79."

3.2.5. Has Earth Observation Been Applied in the Past for Archaeology in the Mediterranean?

"The Eastern Mediterranean region, including countries such as Israel, Lebanon, Jordan, Syria, and Turkey, has a rich archaeological heritage and earth observation technology has been widely used in this region to study and preserve its cultural heritage. Here are a few examples of how earth observation technology has been used in the Eastern Mediterranean region: Satellite imagery and aerial photography have been used to map and identify previously unknown archaeological sites in the Eastern Mediterranean region. For example, in Israel, satellite imagery was used to identify the ancient city of Bethsaida, which is believed to be the home of the apostles Peter, Andrew, and Philip. Remote sensing technology has been used to study land use and land cover changes in the Eastern Mediterranean region. For example, in Lebanon, satellite imagery was used to study the ancient Phoenician city of Tyre and to track changes in land use and land cover over time [. . .]. Remote sensing technology has been used to monitor and preserve archaeological sites in the Eastern Mediterranean region. For example, in Turkey, satellite imagery and aerial photography have been used to monitor and document the erosion of the ancient city of Ephesus, one of the most important archaeological sites in the Eastern Mediterranean region".

3.3. Remote Sensing Technologies

3.3.1. What Are the Technologies Used for Remote Sensing Archaeology?

"There are a variety of technologies used for remote sensing archaeology, including:

- i. Aerial Photography: This involves taking photographs of the ground from an aircraft or drone. These photographs can be used to identify potential archaeological sites and features, such as earthworks or crop marks.

- ii. Lidar: This stands for Light Detection and Ranging, and it uses laser pulses to create detailed 3D models of the ground surface. Lidar can reveal features that are not visible on the surface, such as buried walls or ditches.
- iii. Ground-penetrating radar (GPR): This uses radar waves to penetrate the ground and create images of subsurface features. GPR can be used to locate buried structures, such as foundations or tombs.
- iv. Magnetic gradiometry: It uses a sensor to measure the magnetic field of the Earth. It can help locate features such as buried walls, foundations, or hearths.
- v. Infrared thermography: It uses infrared radiation to create images of temperature variations on the surface. It can be used to identify subsurface features, such as buried walls or ditches, by detecting differences in temperature between the subsurface feature and the surrounding soil.
- vi. Multispectral/Hyperspectral imagery: This uses sensors to capture images in multiple wavelength bands, which can be used to identify different types of materials, such as clay, stone, or vegetation.”

3.3.2. Which Satellite Sensors Are Used for Remote Sensing Archaeology?

“There are a number of satellite sensors that are used for remote sensing archaeology, including:

- i. Landsat: This is a long-running series of satellites operated by NASA and USGS that provides high-resolution imagery of the Earth’s surface. Landsat data can be used to identify and map archaeological sites, as well as monitor changes to the land over time.
- ii. SPOT: This is a series of satellites operated by CNES (French National Centre for Space Studies) that provides high-resolution imagery of the Earth’s surface. SPOT data can be used to identify and map archaeological sites, as well as monitor changes to the land over time.
- iii. WorldView: This is a series of high-resolution commercial satellites operated by DigitalGlobe that provides imagery of the Earth’s surface. WorldView data can be used to identify and map archaeological sites and monitor changes to the land over time.
- iv. Sentinel: This is a series of satellites operated by the European Space Agency (ESA) in the context of the Copernicus program. Sentinel-2 and Sentinel-3 provide high-resolution multispectral imagery, it can be used to detect changes, map and monitor agricultural, forestry, and land-use, as well as for archaeological mapping.
- v. RADARSAT: This is a series of radar imaging satellites operated by the Canadian Space Agency (CSA). RADARSAT data can be used to create digital elevation models (DEMs) and to detect subsurface features, such as buried structures or ditches, and
- vi. ALOS: This is a series of satellites operated by JAXA (Japanese Aerospace Exploration Agency) that provides high-resolution imagery of the Earth’s surface. ALOS data can be used to identify and map archaeological sites, as well as monitor changes to the land over time”.

3.3.3. What Type of UAVs Are Used for Remote Sensing Archaeology?

“There are a variety of unmanned aerial vehicles (UAVs), also known as drones, that are used for remote sensing archaeology. These can be broadly categorized into two main types: fixed-wing and rotary-wing.

- i. Fixed-wing UAVs: These are designed to fly like an airplane and are typically used for large-scale mapping and survey work. They are equipped with cameras and sensors that can capture high-resolution imagery and lidar data. Examples include the eBee, Albatross, and HawkEye III.
- ii. Rotary-wing UAVs: These are designed to fly like a helicopter and are typically used for more localized survey work. They are equipped with cameras and sensors that can

capture high-resolution imagery and lidar data. Examples include the DJI Phantom, Inspire, and Matrice.

Both types of UAVs have their own advantages and disadvantages and the choice of which type of UAV to use depends on the specific requirements of the project, such as the size of the area to be surveyed, the resolution of the data required, and the accessibility of the site.

Some UAVs are specifically designed for archaeological remote sensing, they may have a payload capacity to carry multiple sensors, they may have a long flight duration and they may have a specific flight planning software that can be used to plan and execute flights over archaeological sites.

In addition to the UAVs, there are also a number of other types of aerial platforms that are used for remote sensing archaeology, such as balloons, kites, and even manned aircraft. These platforms can also be equipped with cameras and other sensors to capture imagery and data of archaeological sites.

It's worth noting that the use of UAVs in remote sensing archaeology is subject to regulations and laws, it's important to comply with the local laws and regulations regarding the use of UAVs, also, flying UAVs over archaeological sites may require special permissions and agreements with the relevant authorities".

3.3.4. Do You Know Any Specific UAVs Used?

"Several specific UAVs that are commonly used for remote sensing archaeology, some examples include:

- i. DJI Phantom: This is a popular rotary-wing UAV that is widely used for remote sensing archaeology due to its ease of use, stability, and high-resolution camera. The DJI Phantom series can be equipped with a variety of cameras and sensors, including high-resolution RGB cameras, thermal cameras and multispectral cameras.
- ii. DJI Matrice: This is a versatile and rugged rotary-wing UAV that is widely used for remote sensing archaeology. The DJI Matrice series can be equipped with a variety of cameras and sensors, including high-resolution RGB cameras, thermal cameras, Lidar sensors and multispectral cameras.
- iii. eBee: This is a fixed-wing UAV that is widely used for remote sensing archaeology. The eBee series can be equipped with a variety of cameras and sensors, including high-resolution RGB cameras, thermal cameras, Lidar sensors and multispectral cameras.
- iv. Albatross: This is a fixed-wing UAV that is widely used for remote sensing archaeology. The Albatross series can be equipped with a variety of cameras and sensors, including high-resolution RGB cameras, thermal cameras, Lidar sensors and multispectral cameras.
- v. HawkEye III: This is a fixed-wing UAV that is widely used for remote sensing archaeology. The HawkEye III series can be equipped with a variety of cameras and sensors, including high-resolution RGB cameras, thermal cameras, Lidar sensors and multispectral cameras.
- vi. senseFly eBee Plus: This is a fixed-wing UAV specifically designed for mapping and surveying. It can be equipped with a variety of cameras and sensors, including high-resolution RGB cameras, thermal cameras, Lidar sensors and multispectral cameras.
- vii. senseFly Albris: This is a fixed-wing UAV specifically designed for mapping and surveying. It can be equipped with a variety of cameras and sensors, including high-resolution RGB cameras, thermal cameras, Lidar sensors and multispectral cameras.

These are just a few examples of UAVs that are commonly used for remote sensing archaeology. There are many other UAVs available on the market and new models are constantly being developed, so the choice of UAV depends on the specific requirements of the project".

3.3.5. What Software Do We Use in Remote Sensing Archaeology?

“There are a variety of software programs that are commonly used in remote sensing archaeology, depending on the specific application and type of data being analyzed. Some examples include:

- i. Photogrammetry software: This type of software is used to process aerial photographs and create digital elevation models (DEMs) and orthophotos (geometrically corrected images). Examples include Agisoft Photoscan, Pix4D, and ContextCapture.
- ii. Lidar processing software: This software is used to process lidar data and create digital elevation models (DEMs) and point cloud data. Examples include FUSION, TerraScan, and LAS Tools.
- iii. GPR processing software: This software is used to process and interpret ground-penetrating radar data. Examples include RadExplorer, GPR-SLICE, and Radan.
- iv. Magnetic gradiometry processing software: This software is used to process and interpret magnetic gradiometry data. Examples include MagMap, Mag2CAD and Oasis Montaj
- v. Infrared thermography processing software: This software is used to process and interpret infrared thermography data. Examples include Flir Tools, ThermaCAM Researcher and ThermaCAM Researcher Pro
- vi. Multispectral/Hyperspectral processing software: This software is used to process and interpret multispectral and hyperspectral data. Examples include ENVI, PCI Geomatica, and eCognition.
- vii. 3D modeling and visualization software: This software is used to create 3D models and visualizations of archaeological sites and features. Examples include SketchUp, AutoCAD, and Blender.
- viii. Machine learning, computer vision and deep learning software: This type of software is used to analyze and extract information from the data collected by remote sensing technologies. Some examples include Python, TensorFlow, Keras, OpenCV, among others.

These are just a few examples of the various software programs that are used in remote sensing archaeology, there are many other programs and tools that can be used depending on the specific requirements and data.”

3.4. Archaeological Buried Remains and Fusion of Data

3.4.1. Detection of Archaeological Buried Remains

“Earth observation technology can be used to detect buried remains through space-based applications. Remote sensing techniques such as satellite imagery, lidar, and radar can be used to detect buried remains by looking for subtle changes in the surface of the ground that may indicate the presence of buried structures or artifacts.

For example, lidar can be used to create detailed 3D maps of the ground surface, which can reveal changes in elevation that may indicate the presence of buried structures. Satellite imagery can be used to detect changes in vegetation cover that may indicate the presence of buried structures. Radar can be used to detect changes in the subsurface of the ground that may indicate the presence of buried structures.

These techniques have been used in several projects around the world to detect buried remains, such as the detection of ancient Mayan pyramids in Mexico, buried Roman cities in Italy, and ancient tombs in Egypt. It’s worth noting that these techniques are not always conclusive and can’t substitute the excavation and archaeological survey that must be done by experts on the field. However, they can help to identify potential locations for further investigation and can also help to provide valuable information about the location, size, and condition of buried remains before the excavation process begins.”

3.4.2. Can You Provide More Details Regarding the Changes in Vegetation Cover and Buried Remains?

“Changes in vegetation cover can be an indication of buried remains because buried structures or artifacts can affect the growth of plants above them. For example, buried structures or artifacts can affect the distribution of water and nutrients in the soil, which can in turn affect the growth of vegetation above.

Satellite imagery can be used to detect these changes in vegetation cover by comparing images taken at different times. For example, an image of an area taken during a dry season might show a particular pattern of vegetation, while an image of the same area taken during a wet season might show a different pattern. This change in vegetation pattern may indicate the presence of buried remains, such as an ancient underground structure, an archaeological site, or a buried tomb.

Satellite imagery can also be used to detect changes in vegetation cover by comparing images taken at different wavelengths. Different types of vegetation have different spectral signatures, which can be detected using different types of sensors. For example, vegetation that is growing over a buried structure may have a different spectral signature than vegetation that is growing in an undisturbed area [. . .].”

3.4.3. What Do You Know about Cropmarks Related to Buried Archaeological Remains?

“Cropmarks are patterns that can appear in fields of crops, such as variations in color, growth, or height, which can indicate the presence of buried archaeological remains. These marks are caused by differences in the moisture content and soil conditions above buried structures or features.

For example, buried structures can affect the growth of crops above them by altering the moisture content and nutrient levels of the soil. Buried ditches, for example, can cause the crops above them to be taller and healthier, while buried walls can cause the crops above them to be shorter and less healthy. These differences in crop growth can create patterns, such as lines or circles, that are visible from the air.

Cropmarks are often used as a method of identifying and locating buried archaeological remains. Aerial photography, including drones, and satellite imagery can be used to capture images of cropmarks, which can then be analyzed to identify potential archaeological features. Cropmarks are useful because they can reveal the presence of buried remains that are not visible on the surface, such as buried walls, ditches, and other structures.

It is important to note that cropmarks can be caused by natural as well as human-made features and not always indicate the presence of archaeological remains. For example, natural features such as buried rock formations or variations in soil type can also create cropmarks. Therefore, it is important to use other methods, such as ground-based survey and excavation, to confirm the presence of buried remains [. . .], these techniques should be used in conjunction with other methods, such as ground-based survey and excavation, to confirm the presence of buried remains”.

3.4.4. Fusion of Data

“Fusion of remote sensing data can be a powerful technique for detecting buried archaeological remains. By combining data from different sensors, it is possible to create a more comprehensive and detailed understanding of the site and its features. For example, the combination of different types of remote sensing data, such as satellite imagery, aerial photography, LIDAR, and ground-penetrating radar, can be used to create a more detailed and accurate map of the site. This can reveal the presence of buried structures or artifacts that might not be visible with a single sensor.

Another example of data fusion is the combination of hyperspectral data with other remote sensing data, such as lidar or SAR. Hyperspectral data can provide information about the chemical composition of the soil, which can reveal the presence of buried archaeological remains. When combined with other remote sensing data, such as lidar or SAR, it

can provide a detailed 3D image of the subsurface, giving information on the shape, size, and depth of buried remains.

Machine learning algorithms can also be used to analyze the data fusion, which can be used to automatically identify and classify features in remote sensing data . . . it is worth noting that remote sensing data fusion is still an emerging field and research is ongoing to develop new methods and techniques to improve the detection of buried archaeological remains. Data fusion can be a complex process that requires a good understanding of the different types of remote sensing data and the capabilities and limitations of the sensors used. It's also important to consider that data fusion is not always conclusive, and should be used in conjunction with other methods, such as ground-based survey and excavation, to confirm the presence of buried remains".

3.5. Trends

What Is the Trend in Remote Sensing Archaeology?

"The trend in remote sensing archaeology is towards the use of more advanced and sophisticated technologies that can provide high-resolution and highly detailed images of archaeological sites and features. The integration of multiple sensors, such as lidar and hyperspectral imaging, is becoming increasingly popular as it allows for the collection of a wide range of data in a single survey, providing a more comprehensive understanding of the site. Another trend is the use of unmanned aerial vehicles (UAVs), or drones, for aerial photography and lidar surveys. Drones can cover large areas quickly and at a low cost, and they can also access areas that may be difficult or impossible for manned aircraft to reach. Additionally, there has been a growing trend in using machine learning, computer vision and deep learning to analyze and extract information from the data collected by remote sensing technologies, this allows for more efficient and effective analysis of the data, another trend is the increasing use of 3D modeling and visualization techniques to represent archaeological sites and features. These techniques can help to better understand the spatial relationships of different features within a site and can also be used for virtual heritage management and cultural heritage tourism."

4. Discussion

Following the interaction with the ChatGPT, the primary strengths and weaknesses of the model are summarized in this section.

To the authors' view, and best of their knowledge, the ChatGPT language model overall displayed accurate and valid information regarding the state of the art of Earth observation and remote sensing technologies in archaeology, as can be confirmed from existing publications. In addition, specific examples were given by the language model, to further document each reply. Indeed, an advantage of the ChatGPT was its ability to provide a reply conversationally, giving specific examples for a range of case studies, instruments used, sensors, typologies, etc. The replies, therefore, were comprehensive and supported by real examples and previous relevant demonstrations. An additional strength of the model is its ability to acknowledge that its replies should be considered tentative, and that far more occurs in the specific domain (e.g., new technologies, sensors, methodologies). In this sense, the model drives the user to search for additional information on the specific topic (i.e., remote sensing archaeology). An example is the model's reply on the fusion of remote sensing data (Section 3.3.4). As correctly reported by the ChatGPT, remote sensing data fusion is complex and it still has limitations regarding archaeological applications, an opinion also suggested by [21]. The replies of the ChatGPT could only be delivered by experts in the domain, and not by non-specialists, which can be considered a significant advantage of the pre-trained model.

Another advantage of the trained model is that it overcomes existing research complexities of the domain, which requires the combination of a range of remote sensing techniques, methodologies, and sensors targeted to address specific needs of a project, taking into consideration characteristics of the case study area (e.g., underwater). Indeed,

in practice, remote sensing sensors, tools, and methods are adjusted in the archaeological context of each case study to retrieve the optimum results. This is of extreme importance for archaeological remote sensing research and application, as each case study has a unique archaeological context and dynamic environmental conditions. Therefore, the fusion of data from remote sensors is usually sought out and employed by researchers towards the enhancement of the overall results.

A weakness of the model is that several follow-up questions by the user seem to be necessary to achieve a full, in-depth, and comprehensive reply on a topic. Therefore, targeted input is needed in terms of raising the correct question to the model. For instance, in the query related to remote sensing used in archaeology (Section 3.3.2), the system provided a list of five satellite sensors. Not all of them, however, are widely used for archaeological purposes. That being the case, ChatGPT's reply cannot be considered incorrect, as these sensors were used in the past for archaeological prospection and monitoring of heritage sites, but should be considered inaccurate, since these sensors would not be the first to start with for an expert in the field.

A major drawback of the ChatGPT is the absence of any bibliographic reference since the model does not provide information about its sources. Therefore, there is no possibility of cross-checking the replies, other than the expert's view. This is a substantial limitation of the ChatGPT compared to traditional literature review, as references form an essential part of any scientific research.

As pointed out by [22] another limitation of the model concerns the training sample, which uses data published up to 2021. Therefore, recent trends, new concepts, and changes in this domain are excluded. Finally, ethical issues are fundamental when using such AI language models but will not be discussed here since they are beyond the scope of the present communication and the authors' expertise. Pertinent concerns can be found in [22–24].

In the light of the above, it is evident that the overall performance of the ChatGPT's replies cannot be easily quantified (see for instance [25]). Towards this direction, Table 2 summarizes the strengths and weaknesses emerged from the interaction with the ChatGPT, to qualitatively quantify/evaluate its performance compared to traditional literature review methods. This assessment is based upon the authors' scientific profile and expertise. The table is divided into five topics related to design aspects of each approach (i.e., ChatGPT vs traditional literature review), information regarding the bibliographical sources, quality control of the results, issues regarding the general performance of each approach, etc. The comparison between the "ChatGPT language model" and the "Traditional literature review methods" is achieved using performance indicators of three levels of effectiveness:

- Level 0: Not effective (indicated with red color in Table 2).
- Level 1: Medium effectiveness, between level 0 and level 1 (indicated with yellow color, In Table 2).
- Level 2: Effective (indicated with green color, in Table 2).

Table 2. Comparison between the ChatGPT language model and traditional literature review methods.

Topic	ChatGPT Language Model	Traditional Literature Review Methods
Design aspects		
Research designed for literature review	No	Yes
Able to follow trends	No, the model needs to be re-trained	Yes
Able to adjust the topic for literature review	Yes	Not easily
Easily accessible	Yes	Not always
Time consuming	No	Yes

Table 2. Cont.

Topic	ChatGPT Language Model	Traditional Literature Review Methods
Bibliographical source information		
Input from scientific journals *	Yes	Yes
Input from scientific books *	Yes	Yes
Input from websites—network	Yes	No
Review based on several languages	No	Yes
Quality control checks		
Reliable information	Unknown sources	Yes
Plagiarism control	No	Yes
Transparency of sources	Limited	Mandatory
Performance		
Speed to retrieve information	Fast	Slow
Depth of information	Overview	In depth
Repeatability	Yes	Yes (but time consuming)
Able to provide comprehensive information	Yes	Yes
Other		
Illustrations	No	Yes
Graphs	No	Yes
Can be programmed	Yes	No

* In the case of archaeology, a great part of worldwide literature cannot be found online. Therefore, a scholar could proceed with ChatGPT for the technological aspects for the review of a topic related to remote sensing, but perhaps could not find detailed and specific information on the excavation records and other details related to a specific archaeological case study (e.g., printed series, archival information).

5. Conclusions

In this short communication, the authors investigated the possibility of conducting a literature review about remote sensing archaeology using the ChatGPT, an advanced language model, aiming at the same time to better understand the potential use of this new AI language model. A series of targeted questions tailored by the authors based on their scientific expertise and research interests were posed to the language model. ChatGPT provided apparently satisfactory replies, lacking however any exhaustive analysis compared to traditional literature review methods. As the model was only recently released in a beta version, improvements should be expected.

The overall evaluation results summarized in Table 2 show that the ChatGPT has both advantages and disadvantages compared to the traditional literature review method. Major limitations of the pre-trained language model concern the lack of transparency for its sources and the exclusion of developments in the field that occurred after 2021. Indeed, as argued by [22] “a significant limitation of GPT-3 was that it was trained as a fully unsupervised model, generating content that it learned out of vast amounts of information on the internet without any validation on it, making it provide often uncanny and funny responses”.

In contrast, ChatGPT is a time-saving tool which provides immediate answers, and it can be easily adjusted to any query, providing comprehensive information. Ethical aspects and limitations of the language model do not allow it to become an alternative to traditional literature review methods, especially for archaeology where much of the literature is not accessible online or is not necessarily in English. Since ChatGPT was only recently released, ethical issues are soon expected to attract the interest of more researchers. A pertinent debate concerns the inclusion or not of ChatGPT as a co-author in scientific publications for which the tool has been used [24].

A concluding remark as a result from the interaction with ChatGPT is that it could be used along with traditional literature review and as a starting point to widely familiarize a

researcher with the topic of Earth observation and remote sensing archaeology. As the ChatGPT model states, and we agree, “overall, remote sensing archaeology is becoming more sophisticated and efficient, allowing for a more detailed understanding of archaeological sites and the past human activities that took place there”.

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References

1. Group of Earth Observation. Available online: https://www.earthobservations.org/g_faq.html (accessed on 25 January 2023).
2. Luo, L.; Wang, X.; Guo, H.; Huadong Guo, H.; Lasaponara, R.; Shi, P.; Bachagha, N.; Li, L.; Yao, Y.; Masini, N.; et al. Google Earth as a Powerful Tool for Archaeological and Cultural Heritage Applications: A Review. *Remote Sens.* **2018**, *10*, 1558. [[CrossRef](#)]
3. Challis, K.; Howard, A.J. A review of trends within archaeological remote sensing in alluvial environments. *Archaeol. Prospect.* **2006**, *13*, 231–240. [[CrossRef](#)]
4. Luo, L.; Wang, X.; Guo, H.; Lasaponara, R.; Zong, X.; Masini, N.; Wang, G.; Shia, P.; Khatteli, H.; Chen, F.; et al. Airborne and spaceborne remote sensing for archaeological and cultural heritage applications: A review of the century (1907–2017). *Remote Sens. Environ.* **2019**, *232*, 111280. [[CrossRef](#)]
5. Verhoeven, G.J. Are We There Yet? A Review and Assessment of Archaeological Passive Airborne Optical Imaging Approaches in the Light of Landscape Archaeology. *Geosciences* **2017**, *7*, 86. [[CrossRef](#)]
6. Agapiou, A.; Lysandrou, V. Remote sensing archaeology: Tracking and mapping evolution in European scientific literature from 1999 to 2015. *J. Archaeol. Sci.* **2015**, *4*, 192–200. [[CrossRef](#)]
7. Cowley, D.; Verhoeven, G.; Traviglia, A. Editorial for Special Issue: “Archaeological Remote Sensing in the 21st Century: (Re)Defining Practice and Theory”. *Remote Sens.* **2021**, *13*, 1431. [[CrossRef](#)]
8. Liu, Y.; Hu, Q.; Wang, S.; Zou, F.; Ai, M.; Zhao, P. Discovering the Ancient Tomb under the Forest Using Machine Learning with Timing-Series Features of Sentinel Images: Taking Baling Mountain in Jingzhou as an Example. *Remote Sens.* **2023**, *15*, 554. [[CrossRef](#)]
9. Stewart, C.; Oren, E.D.; Cohen-Sasson, E. Satellite Remote Sensing Analysis of the Qasrawet Archaeological Site in North Sinai. *Remote Sens.* **2018**, *10*, 1090. [[CrossRef](#)]
10. Zaina, F.; Tapete, D. Satellite-Based Methodology for Purposes of Rescue Archaeology of Cultural Heritage Threatened by Dam Construction. *Remote Sens.* **2022**, *14*, 1009. [[CrossRef](#)]
11. Tapete, D.; Traviglia, A.; Delpozzi, E.; Cigna, F. Regional-Scale Systematic Mapping of Archaeological Mounds and Detection of Looting Using COSMO-SkyMed High Resolution DEM and Satellite Imagery. *Remote Sens.* **2021**, *13*, 3106. [[CrossRef](#)]
12. Agapiou, A.; Hegyi, A.; Stavičá, A. Observations of Archaeological Proxies through Phenological Analysis over the Megafort of Csanádpalota-Juhász, T. tanya in Hungary Using Sentinel-2 Images. *Remote Sens.* **2023**, *15*, 464. [[CrossRef](#)]
13. Elfadaly, A.; Abate, N.; Masini, N.; Lasaponara, R. SAR Sentinel 1 Imaging and Detection of Palaeo-Landscape Features in the Mediterranean Area. *Remote Sens.* **2020**, *12*, 2611. [[CrossRef](#)]
14. Ouyang, L.; Wu, J.; Jiang, X.; Almeida, D.; Wainwright, C.L.; Mishkin, P.; Zhang, C.; Agarwal, S.; Slama, K.; Ray, A.; et al. Training language models to follow instructions with human feedback. *arXiv* **2022**. [[CrossRef](#)]

15. Reichstein, M.; Camps-Valls, G.; Stevens, B.; Jung, M.; Denzler, J.; Carvalhais, N. Deep learning and process understanding for data-driven Earth system science. *Nature* **2019**, *566*, 195–204. [[CrossRef](#)] [[PubMed](#)]
16. Singh, M.; Acharya, N.; Rao, S.A.; Kumar, B.; Yang, Z.L.; Niyogi, D. Short-range forecasts of global precipitation using deep learning-augmented numerical weather prediction. *arXiv* **2022**. [[CrossRef](#)]
17. ChatGPT, an AI Model Developed by OpenAI. Available online: <https://openai.com/blog/chatgpt/> (accessed on 18 January 2023).
18. Castro Nascimento, C.M.; Pimentel, A.S. Do Large Language Models Understand Chemistry? A Conversation with ChatGPT. *J. Chem. Inf. Model.* **2023**, *63*, 1649–1655. [[CrossRef](#)]
19. Prada, P.; Perroud, N.; Thorens, G. Artificial intelligence and psychiatry: Questions from psychiatrists to ChatGPT. *Rev. Med. Suisse* **2023**, *19*, 532–536. (In French) [[CrossRef](#)]
20. Sng, G.G.R.; Tung, J.Y.M.; Lim, D.Y.Z.; Bee, Y.M. Potential and Pitfalls of ChatGPT and Natural-Language Artificial Intelligence Models for Diabetes Education. *Diabetes Care* **2023**, *46*, e103–e105. [[CrossRef](#)]
21. Opitz, R.; Herrmann, J. Recent Trends and Long-standing Problems in Archaeological Remote Sensing. *J. Comput. Appl. Archaeol.* **2018**, *1*, 19–41. [[CrossRef](#)]
22. Chatterjee, J.; Dethlefs, N. This new conversational AI model can be your friend, philosopher, and guide . . . and even your worst enemy. *Patterns* **2023**, *4*, 100676. [[CrossRef](#)]
23. Widder, G.D.; Wong, R. Thinking Upstream: Ethics and Policy Opportunities in AI Supply Chains. *arXiv* **2023**. [[CrossRef](#)]
24. Stokel-Walker, C. ChatGPT listed as author on research papers: Many scientists disapprove. *Nature* **2023**, *613*, 620–621. [[CrossRef](#)] [[PubMed](#)]
25. Kung, T.H.; Cheatham, M.; Medenilla, A.; Sillos, C.; De Leon, L.; Elepaño, C.; Madriaga, M.; Aggabao, R.; Diaz-Candido, G.; Maningo, J.; et al. Performance of ChatGPT on USMLE: Potential for AI-assisted medical education using large language models. *PLoS Digit. Health* **2023**, *2*, e0000198. [[CrossRef](#)] [[PubMed](#)]

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