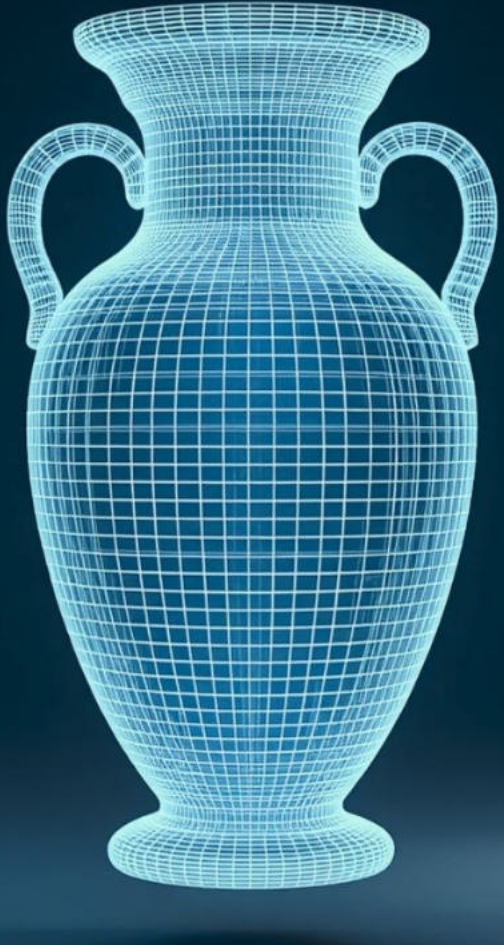
DIGI·ARCHEO·SPACE
MODERN TOOLS FOR DOCUMENTING & PRESENTING
THE CULTURAL HERITAGE IN ARCHEOLOGY

Co-funded by the European Union

A PRACTICAL GUIDE

MODERN TOOLS FOR DOCUMENTING&PRESENTING CULTURAL HERITAGE IN ARCHAEOLOGY



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MODERN TOOLS FOR DOCUMENTING AND PRESENTING THE CULTURAL HERITAGE IN ARCHAEOLOGY

A Practical Guide Developed within the Erasmus+ Project “DigiArcheoSpace”

(KA220-HED)

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Acknowledgments

This guide was developed within the Erasmus+ project DigiArcheoSpace (KA220-HED), with contributions from all project partners:

- History Museum of Primorsko, Bulgaria
- Student Computer Art Society (SCAS), Bulgaria
- Shumen University “Bishop Konstantin of Preslav” (SHU), Bulgaria
- Ss. Cyril and Methodius University in Skopje (UKIM), North Macedonia
- Bartin University (BARÜ), Turkey
- Institute of Ethnology and Folklore Research (IEF), Croatia

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1. Introduction: Purpose and Usage

The DigiArcheoSpace Guide was developed within the **Erasmus+ project DigiArcheoSpace: Modern Tools for Documenting and Presenting the Cultural Heritage in Archaeology (KA220-HED),** with the main goal of strengthening the digital capacity of higher education institutions in the field of archaeology and heritage sciences. Archaeology is undergoing a profound transformation, with digital tools redefining how researchers document, interpret, preserve, and communicate the material traces of the past. The digital turn in archaeology not only enhances the accuracy and efficiency of data collection but also democratizes access to cultural heritage through innovative methods of visualization and dissemination. Recognizing these changes, the DigiArcheoSpace project aims to equip both students and lecturers with the competences needed to operate confidently in this new environment. The guide presents a selection of digital tools and applications relevant to archaeological documentation, analysis, and presentation. It was designed to complement the learning modules developed within the project and serves as an open educational resource for universities, museums, and heritage professionals. The guide serves as a didactic and practical resource for lecturers, students, museum curators, and heritage experts interested in implementing digital tools and methodologies in archaeological documentation, analysis, and presentation.

It is designed for flexible use in **higher education**, as part of existing archaeology or cultural heritage curricula, but also for **non-formal and lifelong learning** contexts.

By bridging theory and practice, the guide encourages a hands-on understanding of how digital technologies can be implemented in archaeological work—from field data acquisition to 3D visualization, digital storytelling, and public engagement. The guide supports the six educational modules developed under DigiArcheoSpace and aligns with the project's **Competence Framework** and **micro-credential approach**, ensuring that learners can progressively acquire, apply, and evaluate digital competences relevant to archaeology.

Ultimately, this publication embodies the project's mission: to foster a sustainable, innovative, and inclusive approach to cultural heritage education across Europe. It invites its users to think beyond traditional methods, embrace digital literacy, and integrate technology as a natural part of archaeological research and interpretation.

2. How the Tools Were Selected

The digital tools presented in this guide were identified through a **collaborative process** among all project partners and 20 participants in a survey The initial list of over thirty potential tools was refined to **twenty core technologies** based on the following criteria:

1. **Pedagogical relevance:** suitability for teaching and learning in archaeology and cultural heritage studies;
2. **Cost and accessibility:** preference for open-source or low-cost tools to ensure wide applicability;
3. **Interdisciplinary potential:** capacity to connect archaeology with fields such as computer science, geography, and visual arts;
4. **Sustainability:** support for open standards, interoperability, and long-term preservation;
5. **Practical value:** real-world applicability in fieldwork, laboratory analysis, and heritage presentation.

A voting process among partners defined the final list of tools, grouped by **low, medium, and high-cost categories**.

Together, these tools cover the full archaeological workflow—from **data acquisition and management** to **analysis, visualization, and public dissemination**—and provide a foundation for developing digital literacy within archaeology curricula.

3. Modern Tendencies in Presenting Documented Data

Digital transformation has fundamentally reshaped how cultural heritage is recorded, visualized, and shared with both professional and public audiences. This section highlights **contemporary approaches** to the presentation of documented archaeological data, reflecting ongoing innovations in visualization, storytelling, and accessibility.

3.1 Interactive Digital Platforms

Web-based tools such as **story maps**, **interactive timelines**, and **GIS web viewers** enable scholars and the public to explore archaeological datasets dynamically. Online platforms like **ArcGIS StoryMaps**, **IIIF**, and **Sketchfab** facilitate open access to 3D models, maps, and images, making heritage interpretation more participatory and transparent.

3.2 Immersive and Mixed Realities

The integration of **Virtual Reality (VR)** and **Augmented Reality (AR)** technologies offers unprecedented opportunities for heritage visualization. Virtual reconstructions of ancient spaces allow users to walk through historical environments, while AR applications overlay archaeological reconstructions directly onto existing landscapes or artifacts. These methods enhance both **educational impact** and **visitor engagement**.

3.3 Museum and Outreach Applications

Modern museums increasingly rely on **digital storytelling**—through touchscreens, interactive projections, or online exhibitions—to create multisensory experiences. Public-facing applications of archaeological data ensure that research outcomes are accessible beyond academic circles, fostering community connection and cultural awareness.

3.4 Accessibility, Ethics, and Sustainability

Digital heritage must also adhere to ethical and inclusive standards. Open-access policies, multilingual resources, and the provision of alternative text, captions, and low-bandwidth options ensure that digital materials remain accessible to diverse audiences. Furthermore, the **ethical sharing of sensitive data**—especially concerning sacred or endangered sites—requires thoughtful curation and community collaboration.

4. Using This Guide in Teaching

This guide is conceived as a **teaching aid** that complements both theoretical and practical training in archaeology. It provides educators with structured examples of how digital tools can be integrated into the curriculum and how learners can progressively build competencies in digital archaeology.

Educators may select relevant tools depending on course objectives—ranging from basic field documentation to advanced data visualization.

The guide also supports **self-directed learning**: independent learners can explore tools, tutorials, and datasets at their own pace, developing practical digital skills while understanding their archaeological significance.

5. Digital Tools for Archaeology

This section presents the partner-contributed digital tools used for documenting, analyzing, and presenting cultural heritage in archaeology.

Submission Metadata

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Language	English
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Tool 1: LiDAR

Category (cost tier)	High
Developer / Provider	Hesai, Velodyne Lidar, Luminar, Leice, Ouster
Platforms	Global Mapper (with LiDAR module), CloudCompare, QGIS, GRASS GIS, LAStools, UgCS
Typical license	Typical commercial; GRASS GIS has with open source tool; LAStools and UgCS also have open-source tools.
Skill level	High level of education and practical experience
Typical use in archaeology	The LiDAR system can detect surface anomalies. Bathymetric LiDAR is also used to study underwater objects such as sunken settlements and vessels.

1) What the tool does (Short description)

LiDAR—laser altimetry (a branch of geometry that deals with measuring heights)—is an acronym for light detection and ranging. It refers to remote sensing technology that emits intense, focused beams of light and measures the time it takes for the reflections to be detected by the sensor. The three-dimensional coordinates (e.g., x, y, z, or latitude, longitude, and altitude) of target objects are calculated from the time difference between the emission and return of the laser pulse, the angle at which the pulse was "fired," and the absolute location of the sensor on or above the surface of the object being studied.

Light mapping is a method for generating accurate and directly georeferenced spatial information about the shape and characteristics of objects. These technologies enable scientists, cartographers, and archaeologists to study nature and build environments across a wide range of scales with greater accuracy, precision, and flexibility (img. 1).

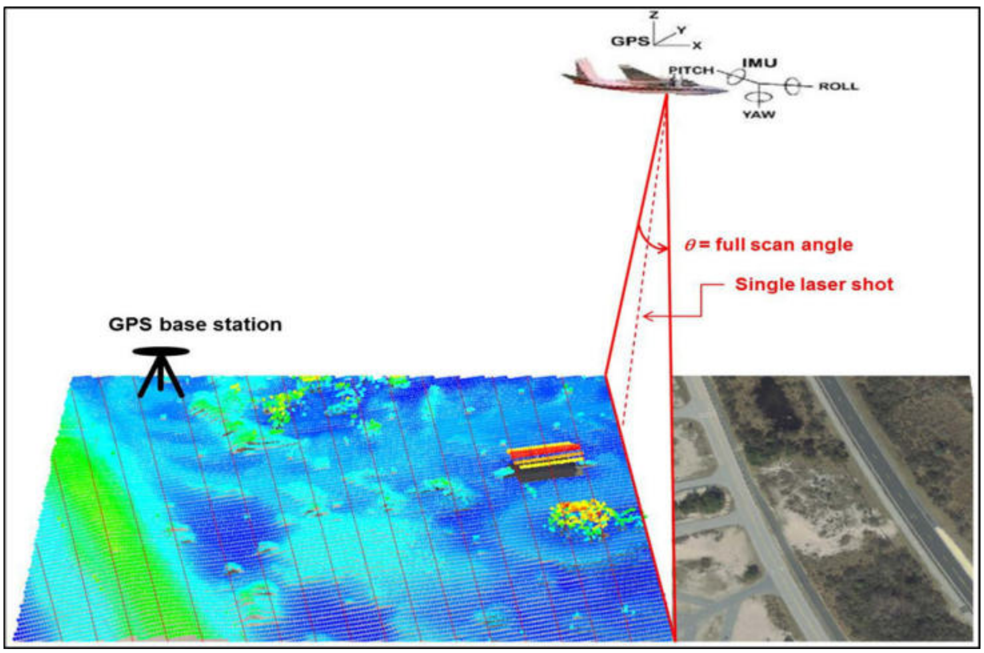


Image 1: Schematic diagram of an airborne LiDAR performing linear scanning, resulting in parallel lines of measured points. Workflow & educational use. Image source: https://www.cnblogs.com/

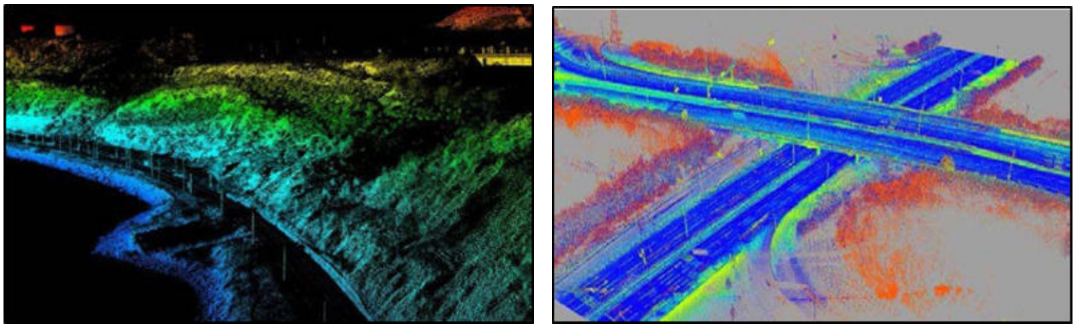
2) Workflow & educational use

Remote sensing technologies are passive and active, distinguished by the energy source used to detect a specific target. Passive systems detect radiation generated by an external energy source, such as the sun, while active systems generate and direct energy toward the target and subsequently detect the radiation. LiDAR systems are active systems; they emit light pulses (i.e., laser beams) and detect the reflected light. This feature allows data to be collected at night, when the air is typically clearer and the sky contains less air traffic than during the day. LiDAR cannot penetrate clouds, rain, or thick fog and must be operated in good weather.

LiDAR systems provide the ability to "see under trees," which facilitates the acquisition of elevation data through remote sensing collected above the Earth's surface. Most of the larger datasets are generated using technologies that cannot penetrate vegetation, but there are usually enough individual "points" to provide adequate coverage in forested areas. In practice, LiDAR can see through gaps in canopies or vegetation, which is extremely useful in archaeological surveys.

LiDAR sensors can be mounted on fixed-position tripods and produce point data with centimeter accuracy; a feature often used for mapping survey terrain.

Modern navigation and positioning systems enable the use of water and land mobile platforms to collect data from the ground and the air. These systems are typically mounted on high-clear vehicles when collecting data from the ground and on drones, helicopters, small aircraft, and other flying vehicles when collecting data from the air. Airplanes and helicopters are the most common and cost-effective platforms for obtaining LiDAR data over large, continuous areas. The desired information is obtained by mounting a system inside an aircraft and flying over the target area. Most airborne platforms can cover about 50 square kilometers per hour and still produce high-accuracy data that meets application requirements. Airborne platforms are also ideal for collecting bathymetric data in relatively clear, shallow waters. Combined topographic and bathymetric LiDAR systems on airborne platforms are used to map coastlines and coastal areas, which is useful for underwater surveys (img. 2).



Imig 2. Mobile liDAR collected from a vehicle (left) and a boat (right). Images provided by Sanborn and Fugro

The application of LiDAR technology in archaeology is mainly related to the search and localization of archaeological sites unknown to science, which have not yet come to the attention of specialists. One of the reasons for this may be the presence of dense vegetation and limited access to the site. The use of this innovative technology effectively eliminates vegetation, and after a detailed inspection of the earth's surface and processing of the data from the surveyed area, traces of material remain that are not apparently part of the natural surrounding terrain become visible. Thanks to LiDAR technology, the list of archaeological sites has grown significantly in recent years. This type of research is used when the terrain is very rugged, steep, or densely overgrown, making it difficult to traverse. This method of research is most often used to discover traces of settlements, fortresses, buildings, individual burial mounds, necropolises, etc. Once the existence of a site is suspected, the specific area is surveyed and visited by specialists. Measurements of the site's territorial scope are taken, and materials are collected from the surface to help archaeologists date the site's period of operation as accurately as possible.

Inertial measurement units (IMUs) and inertial navigation systems (INS) are crucial for ensuring the accurate positioning of research objects. These systems can measure movement in all directions and convert these measurements into a specific position. However, they are not perfect and lose accuracy after a short time (e.g., 1 second). A highly sophisticated GPS device that records several types of signals from GPS satellites is used to "update or reset" the INS or IMU every second. GPS positions are recorded by the aircraft as well as by a ground station with a known position. The data is usually in raster files with formats including GeoTiff (.tif), Esri Grid (.adf), floating point raster (.flt), or ERDAS Imagine (.img). In some cases, the data is available in TIN format (e.g., Esri TIN). In raster cases, they are created with point files and can be interpolated using many different techniques (img. 3).

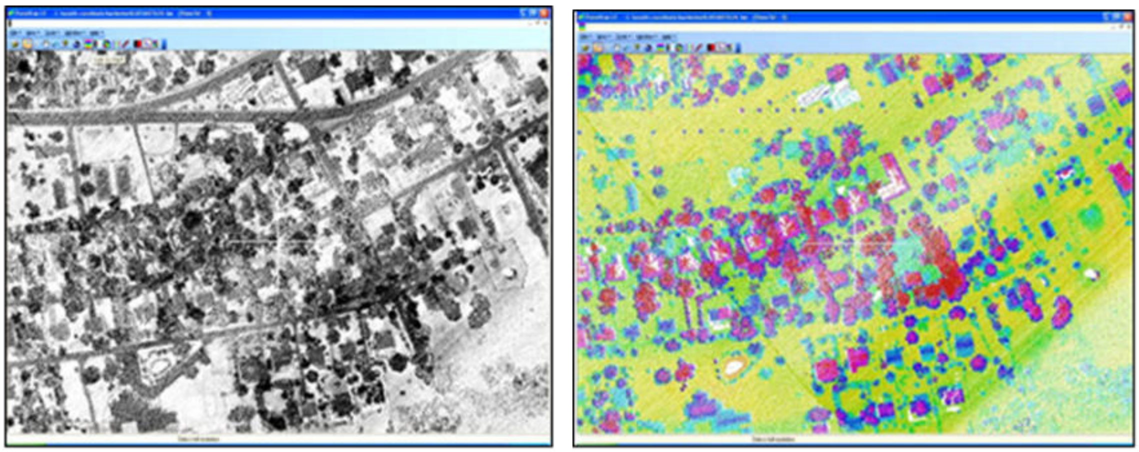


Image 3. Lidar points colored to represent different data attributes.

Image source: https://www.cnblogs.com/

3) Example(s) / Field work with LiDAR

In a working environment, students learn about the specifics of working with a LiDAR system. Specific skills required, which were acquired with the availability of LiDAR and completion of a specialized training course. If the system is attached to a drone, students must also complete a pilot. Trainees provided raw data extracted from a radar system, which they try to interpret and compare with satellite images from different time ranges (with and without leaves on the trees) and compare with the data. After a detailed examination of the collected materials, a visit to the site of the presumed structures, and a survey of the terrain, it is possible to locate an area that could be interpreted as an archaeological site that has not been registered.

4) Advantages & limitations (LiDAR)

Advantages	Limitations / Requirements
• Ability to use LiDAR systems installed on small aircraft (drones, small aircraft) and vehicles with high ground clearance, which are easily accessible, and which supports the work of specialists. • Helps to discover new archaeological sites from a distance. Provides extended visibility over large areas and the ability to track individual sites and their connection with complexes and structures. Aerial LiDAR scanning provides access to information through trees and other vegetation, which helps archaeological activities. • The data obtained is ready for automated processing and analysis.	Working with a LiDAR system requires special training. Purchasing LiDAR equipment requires considerable financial resources. Mounting them on unmanned and piloted aircraft requires special operating skills. The effectiveness of LiDAR systems decreases in poor weather conditions, as laser pulses can be scattered or blocked, leading to inaccurate data and gaps in scanning. LiDAR systems generate complex and voluminous data and require specialized software for processing and analysis.

5) Technical requirements

Software: LP360 universal software for LiDAR data processing, laser scanning and photogrammetry; Free LiDAR software tools and viewers: QGIS 3, Fugro Viewer, Plas.io, SAGA GIS (Automated Geoscientific Analysis System), GRASS: Geographic Resource Analysis Support System

Hardware: LiDAR sensor/scanner. Positioning and navigation system (GPS/GNSS and IMU). Minimum 8 GB RAM, with 32 GB or more recommended for processing large data clouds. Processor (CPU). Dual-core Intel Core i5 /i7 processors or higher, with a base clock speed of at least 4 GHz. Video card (GPU) with powerful NVIDIA graphics with at least 2-4 GB of video memory, supporting technologies such as OpenGL 4.6. SSD (Solid-state drive) for fast access and processing of substantial amounts of data

File formats: LAS, LAZ, ASCII, E57.

6) Ethical & data considerations

When starting planned archaeological research, during a site visit, if the site is on private property, it is appropriate to request permission from the owners to carry out the research. If new objects unknown to science are discovered, the owners should be notified as a first step.

7) Quick start (optional)

• Discovering new archaeological sites, areas, buildings, and other structures hidden under vegetation or soil using LiDAR, without the need for physical excavation.

• Accurate mapping of archaeological sites with LiDAR and creation of accurate and detailed cartographic models of archaeological sites to facilitate the planning of excavations, conservation, and management of the site under study.

• Analysis of the distribution of archaeological sites within the entire landscape structure, providing information on ancient transport networks, water systems, and agricultural practices.

• Monitoring and assessment of environmental dynamics and potential threats to archaeological sites, such as erosion, afforestation, or human activity.

• Restoration and visualization of archaeological sites. Three-dimensional images created using LiDAR facilitate the restoration and visualization of archaeological sites and structures.

8) References & links

Official site /docs	www.csc.noaa.gov
Webpage	www.asprs.org/a/society/committees/lidar/lidar_format.html www.asprs.org/a/society/committees/lidar/Downloads/Vertical_Accuracy_Reporting_f or_Lidar_Data.pdf
Literature	Campana, S., & Dabas, M. (2011). Archaeological research and remote sensing sensors. Cambridge University Press. White, S., C. Parrish, B. Calder, S. Pe'eri, and Y. Rzhanov. 2011. "LIDAR-Derived National Shoreline: Empirical and Stochastic Uncertainty Analyses." Journal of Coastal Research. Special Issue 62. ASPRS. 2007. "Common Lidar Data Exchange Format – .LAS Industry Initiative."

Tool 2: Geographic Information System GIS

Category (cost tier)	Medium
Developer / Provider	Software development: Design and implementation of GIS applications, web maps, and tools using programming languages such as C#, Python, JavaScript
Platforms	ArcGIS (Esri), ArcGIS Pro, ArcMap, ArcGIS Online, GeoNode
Typical license	Typical commercial, but there is an option to use them open source as well.
Skill level	Advanced
Typical use in archaeology	GIS is used as the preferred tool in archaeology when it comes to hard-to-reach areas for surveying and discovering new sites.

1) What the tool does (Short description)

The Geographic Information System (GIS) is a computer-based system that creates, publishes, registers, and stores electronic documents. It includes basic software and cadastral application systems. Its capabilities allow for the integration of separate thematic layers of spatial information reflecting various geographical data – altitude, soil, vegetation cover, water, settlements, roads, etc. The combination of this information allows the formulation of various queries and the performance of a comprehensive analysis of the geographical environment and its individual elements, considering the various influencing factors. Geographical data in GIS is a fundamental element that allows the precise location of a given object, including archaeological ones, on the earth's surface to be determined through a system of coordinates represented in a corresponding coordinate system and datum. In essence, the coordinate system, in the sense of a mathematical abstraction unrelated to the earth for locating the position of a point through coordinates (usually latitude, longitude, and altitude) and the datum, which defines the semantics of the coordinate system and its connection to the earth in horizontal and vertical planes, are the basic components of a coordinate reference system.

To represent the model of the three-dimensional Earth's surface (approximated as an ellipsoid, sphere, or geoid) in a two-dimensional flat image on a map, it is necessary to apply a cartographic projection, which determines the shape, area, distance, and direction of spatial objects.

The concept and philosophy behind the development of GIS geared towards creating a solid data foundation for the implementation of a unified information array, as an indispensable tool for upgrading conventional methods, using powerful tools such as GIS for managing and analyzing ongoing processes (img. 1).

Image 1. GIS. Image source: https://www.online.uc.edu/

2) Working with Raster and Vector formats

GIS software allows working with various vector and raster file formats - GeoTIFF, ECW, Esri GRID, IMG, AutoCAD, DXF, Keyhole Markup Language (KML), Shapefile Esri, GeoJSON, etc., with the preference for one or another depending on the objectives of the analysis being conducted. Compared to raster formats, vector formats contain information about the coordinates of the points along the contour of the object, which is why they are smaller in file size (Fig. 1).

For the purposes of archaeology, GIS used to register newly discovered archaeological sites.

Over the past decade, archaeologists have rapidly adapted to GIS, a circumstance attributed to the fact that most specialists are already well acquainted with computer technologies and readily embrace innovations in this field. The main functions used are related to terrain model reconstruction, computer mapping, and use of DEM in the studied areas, albeit only for visualization, computer simulations, or predictive modeling for spatial decision-making, as well as for controlled management of cultural heritage (fig. 2).

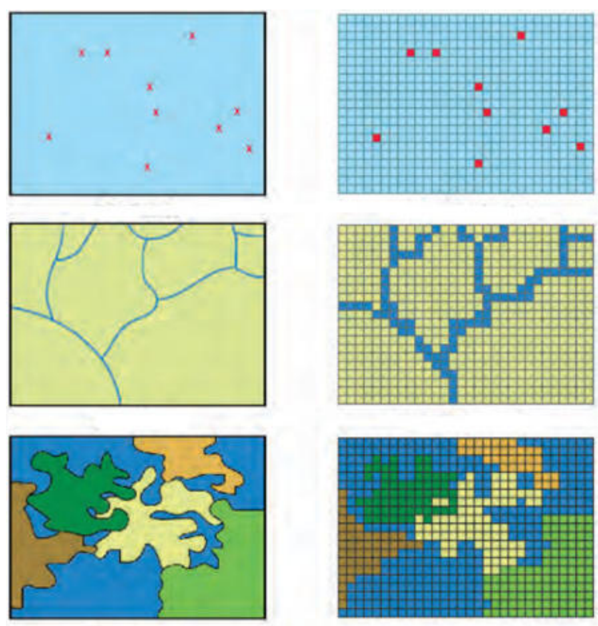


Image 2: Comparison between raster and vector models of geometric data.

Image source: Esri

2a) Geographic Information Systems for archaeological purposes

For archaeological purposes, GIS is mainly used to register newly discovered archaeological sites.

Over the last decade, archaeologists have rapidly adapted to GIS, a circumstance attributed to the fact that most specialists are already well acquainted with computer technologies and easily accept innovations in this field. The main functions used are related to terrain model reconstruction, computer mapping, and the use of DEM in the areas under study, albeit only for visualization, computer simulations or predictive modeling for spatial decision-making, as well as for the controlled management of cultural heritage.

GIS provides archaeologists with extensive opportunities for data collection and georeferencing through layer integration, spatial analysis, visualization, and interpretation. The general attitude of archaeology towards GIS allows us to focus on its use not only as a tool for storage, processing, and visualization, but above all as a means for complex spatial analysis through the many functions that the software provides. Revealing the analytical potential of GIS is central to the research of several scholars who affirm its application in archaeology and lay the foundations of predictive modeling to identify the presumed locations of objects through statistical extrapolations and correlations. In this regard, two main perspectives on its use can be outlined – in cultural heritage management and for spatial analysis of archaeological landscapes, which most broadly correspond to its practical and scientific significance.

Although they use the same tools, they have different ultimate goals and therefore require different approaches. In terms of cultural heritage management, GIS provides good opportunities for organizing large data sets and maintaining registers of cultural monuments by providing quick access to information from various government or scientific organizations. As a method, predictive modeling allows the calculation of the potential volume of archaeological monuments for areas where there is no complete archaeological research. While in pure scientific research predictive modeling serves to formulate and test hypotheses, in cultural heritage management it must provide a reliable assessment of the probability of archaeological sites occurring in each area. Of great importance for the scientific aspect is the so-called pluralism in GIS, i.e. the possibility of admitting, constructing and arguing multiple hypotheses in an archaeological study depending on the variations. In this sense, GIS should not be perceived as confirming a single correct solution, which is essentially a central point of the scientific approach in the humanities.

Contemporary developments in science are leading to the increasingly widespread integration of different research areas within an interdisciplinary and transdisciplinary approach. An expression of this trend is the proposed concept of "digital geoarchaeology" – combining developments in landscape archaeology, geoarchaeology, archaeometry, earth sciences, and computer technologies, which is emerging as a field of application for GIS.

A significant impetus for the adoption of GIS among the tools of archaeology, and hence its main capabilities for data storage, processing, and visualization, have been provided by the field surveys conducted during major infrastructure projects, carried out according to a standardized methodology using mobile GIS.

3) Example(s) /Case study (GIS)

To pinpoint the exact location of a newly discovered archaeological site, a group of students must visit the site together with specialists (archaeologists and surveyors). After its discovery in the field, the students survey the surrounding area with the aim of collecting materials from the surface and providing them with specialist archaeologists for initial dating. This is followed by surveying the structures using surveying instruments and processing the data obtained. GIS allows us to upload specific details about the nature and dating of the archaeological site, in addition to its exact location.

4) Advantages & limitations

Advantages	Limitations / Requirements
Fast and accurate localization Possibility to establish detailed parameters from a distance. Possibility of other archaeological sites and complexes near each other, located by previous studies Details on specific information about the dating and functions of the archaeological site. GIS helps to make more informed and better decisions. This technology applied to the study of objects and phenomena and to analysis in archaeology. The use of geographic information systems (GIS) during surveys makes it possible to collect a large amount of information and consider the current conditions.	Payment or exclusive access to the service may require. A server requires a large database.

GIS makes it possible to combine all data related to the study of archaeological sites, as well as to access this information at various levels – for scientists, for the public, for educational purposes, etc. They also provide a good opportunity to promote the cultural values found during the studies.	

5) Technical requirements

Software: ArcGIS Pro (leading commercial software), QGIS (free open-source software), gvSIG, MapInfo, ArcGIS Server, MapServer, ArcGIS for Mobile, GISExplorer Desktop; QGIS.bg.

Hardware: EDM – ITRC; GRASS; SAGA.

6) Ethical & data considerations

In cases where the place where the interdisciplinary study is to be carried out is privately owned, in addition to the fact that it is necessary to issue a permit in a timely manner and in due course, the consent of the owner to carry out the excavations must also be requested.

7) Quick start (optional)

• Mapping of archaeological sites based on their status; analysis of their location according to the contemporary geographical environment.

• Addition of geodata, attribute data, and land cover to the base GIS.

• Identification of factors contributing to the emergence and functioning of settlements.

• Parameterization of spatial relationships based on already established connections, determination of indicators for predictive assessment, construction of GIS layers corresponding to the factors and their indicators (buffer – water, buffer – mounds, etc.).

• Categorization of cells according to individual indicators and integrated GIS model with layers – forecast modules and options for filtering cells with the highest potential.

• Expanding the reference territory, synthesizing the most important characteristics of settlement systems and factor impact during different periods of historical development, increasing detail by using smaller spatial modules, refining rank values, including more accurate geodata, etc.

8) References & links

Webpage	www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf www.csc.noaa.gov/digitalcoast/_/pdf/Lidar-provisioning-guidance.pdf http://campus.esri.com http://www.spatialanalysisonline.com/index.html
Literature	Longley P., Goodchild M., Maguire D., Rhind D. 2005. Geographical Information Systems and Science (2nd edn). John Wiley & So. Kemp K. (ed.). 2008. Encyclopedia of Geographic Information Science. SAGE Publ. Kraak M-J., Ormeling F. 2010. Cartography: Visualization of Geospatial Data (3rd edn). Pearson. De Smith M., Goodchild M., Longley P. 2015. Geospatial Analysis: A Comprehensive Guide to Principles, Techniques and Software Tools (5th edn).

Submission Metadata

Partner (institution)	SCAS
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Language	English
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Tool 3: Digital Epigraphy: Using RTI and 3D scanning to document and analyze inscribed surfaces.

Category (cost tier)	Low / Medium
Developer / Provider	Relight: relightable images (RTI) By Visual Computing Lab of ISTI / CNR (Pisa, Italy).It is open source
Platforms	Windows / macOS / Linux
Typical license	Open-source
Skill level	Beginner / Intermediate
Typical use in archaeology	document and analyze inscribed surfaces

1) What the tool does (Short description)

A field of practice within archaeology and epigraphic studies that uses digital tools (RTI, photogrammetry, 3D scanning, laser scanning, digital drawing) to document, analyze, and publish inscriptions. Reflectance Transformation Imaging (RTI) is a digital imaging method that captures how light interacts with a surface by photographing an object multiple times under different lighting angles. 3D scanning in archaeology uses laser scanners or structured-light devices to capture the precise geometry of artefacts, inscriptions, and architectural features, producing high-resolution digital models. Both methods can digitally enhance surface visibility much more than standard photography, making them very useful for reading marks, surface wear, or carving techniques, damaged or weathered archaeological inscriptions.

Image 1: Normals visualization from the RTI Viewer 1.1. It is a false-color rendering that shows the orientation of the normals of each pixel and make it easier to read the surface features. Image source: Cultural Heritage Science Open Source

Image 2: 3D scanning with portable scanner, small lightroom and a turntable. Image source: Student Computer Art Society.

2) Workflow & educational use

RTI fits naturally into both field and post-excavation documentation. Researchers can photograph artefacts, inscriptions, or architectural surfaces using a fixed camera position and systematically varied light angles. In post-processing, these image sets are combined in software (e.g., RTIBuilder (legacy software) or RelightLab) to generate an RTI file that allows interactive relighting.

A typical workflow begins with capturing an object or surface using a structured-light or laser scanner to obtain dense point clouds. These scans are then cleaned, aligned, and merged in software to produce a watertight, accurately scaled 3D mesh. The final model can be analyzed for surface details, compared across datasets, or published for research, conservation, and public engagement. Open source software that can help with this task are: MeshLab, CloudCompare, Blender and many others.

During analysis, the fine details are explored such as tool marks, faded inscriptions, carving depth, or weathering patterns that are difficult to detect with standard photography. Finally, for presentation and dissemination, RTI files and 3D models can be rendered and shared with students, colleagues, and the public to enable virtual, non-destructive inspection of objects.

Suggested micro-learning outcomes:

• Identify the core RTI functions relevant to archaeology.

• Perform a basic RTI workflow: capture a small photo set with varied lighting, process it in software, and view the result.

• Interpret RTI outputs by describing observed surface features and discussing limitations

2a) Knowledge & skills of the expert (3D Scanning + RTI)

• Core knowledge: Basics of digital imaging and 3D geometry; light interaction with surfaces; point clouds, meshes, and RTI file types.

• Practical skills: Operating scanners or camera setups, capturing high-quality data, aligning/cleaning meshes, processing RTI images, and exporting usable outputs.

• Recommended background: Introductory training in digital documentation; familiarity with tools like MeshLab, CloudCompare, or RTIBuilder/RelightLab.

• Time to proficiency: 10–20 hours for core workflow

3) Example(s) / Case study (RTI with minimal equipment)

In a teaching lab, students document a coin using a fixed camera and multiple hand-held light positions. The images are processed in RelightLab to create an RTI file, allowing interactive relighting of the coin's surface. The resulting model reveals fine details such as worn inscriptions, mint marks, and subtle relief features that are difficult to see under normal lighting. Students practice interpreting these features, comparing wear patterns and engraving styles, and discussing what they indicate about circulation and minting. This exercise illustrates how RTI and RelightLab enhance surface analysis and support hands-on learning in digital epigraphy.

4) Advantages & limitations (3D Scanning + RTI)

Advantages	Limitations / Requirements
High-detail surface capture Non-destructive Interactive analysis and visualization Supports documentation, teaching, and publication Integrates with other digital workflows	Equipment needed (scanner, camera, light source, tripod) Software has a learning curve Sensitive to reflective/large surfaces do not work well with RTI Processing time and data storage Some technical expertise required

5) Technical requirements

Software: RelightLab, MeshLab, CloudCompare, Blender, COLMAP/OpenMVS (photogrammetry).

6) Ethical & data considerations

For 3D scanning and RTI, ethical and data considerations include careful handling of artefacts, respecting permissions for culturally sensitive objects, and avoiding disclosure of exact site locations.

7) Quick start (optional)

Set up – Place the object on a stable surface; fix camera/scanner and control lighting.

Capture – Take multiple images for RTI or scan the object for 3D.

Process – Use RelightLab (RTI) or MeshLab/CloudCompare (3D).

Explore – Inspect the RTI or 3D model interactively.

Export – Save outputs for analysis or presentation.

Document – Record basic metadata for reproducibility.

8) References & links

Official site of RelightLab	https://vcg.isti.cnr.it/vcgtools/relight/
An online Web3d presentation of	An online Web3d presentation

the paper A Compact Representation of Relightable Images for the Web	
Paper: A Compact Representation of Relightable Images for the Web	https://vcg.isti.cnr.it/vcgtools/relight/compact-representation-relightable.pdf
3D Laser Scanning for Heritage: Advice and Guidance on the Use of Laser Scanning in Archaeology and Architecture	https://historicengland.org.uk/images-books/publications/3d-laser-scanning-heritage/heag155-3d-laser-scanning
Dense Point Cloud	https://pressbooks.bccampus.ca/ericsaczuk/chapter/chapter-2-1-dense-point-cloud/

Tool 4: Mass Spectrometry (AMS, ICP-MS): High-precision analysis for radiocarbon dating, sourcing, and residue analysis.

Category (cost tier)	High
Developer / Provider	Common providers include companies like Thermo Fisher Scientific, Bruker, Agilent Technologies, and specialized research facilities or university labs that operate AMS or ICP-MS instruments for archaeological analysis.
Platforms	Depends of the hardware
Typical license	Typically commercial, depends on the provider company
Skill level	Advanced

Typical use in archaeology	Used for precise radiocarbon dating, tracing elemental composition, analyzing residues to reconstruct chronology and past human activities.

1) What the tool does (Short description)

Mass Spectrometry (AMS / ICP-MS) is a high-precision analytical technique used to measure the elemental or isotopic composition of archaeological materials. Accelerator Mass Spectrometry (AMS) allows extremely accurate radiocarbon dating from very small samples, while Inductively Coupled Plasma Mass Spectrometry (ICP-MS) identifies trace elements and isotopes for sourcing raw materials or analyzing residues. These methods reveal chronological information, provenance, and usage patterns of artefacts such as ceramics, metals, or organic residues.

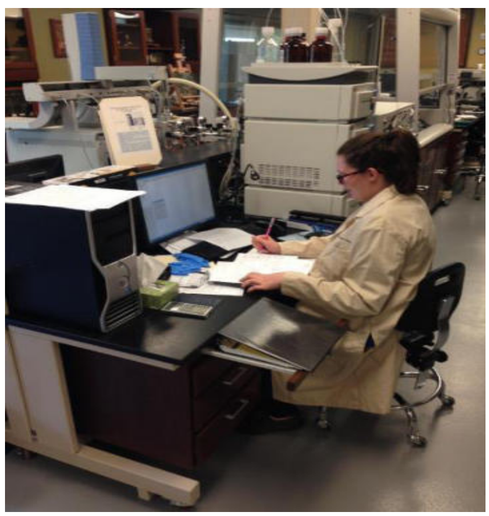

Image 3: Indianapolis Museum of Art conservation scientist performing liquid chromatography–mass spectrometry, Image source: Wikimedia Commons, CC BY-SA 3.0

2) Workflow & educational use

Mass spectrometry is primarily used during post-excavation analysis. Samples collected in the field (e.g., charcoal, bone, ceramic, metal, or residue) are carefully prepared in the lab, often requiring chemical treatment or digestion. The AMS or ICP-MS instrument measures isotopic or elemental composition, generating precise data for radiocarbon dating, provenance studies, or residue analysis. Analysts then interpret the results to reconstruct chronology, raw material sources, or past human behaviors, which can be presented in reports, publications, or integrated into 3D visualizations of artefacts and sites.

Lecturers can integrate mass spectrometry into teaching through a mini-project using provided datasets. Students can explore real AMS/ICP-MS results, practice interpreting isotopic or elemental patterns, and relate findings to archaeological questions. Homework assignments could involve comparing datasets or assessing how sample quality affects results. Furthermore an educational visit to a laboratory working with Mass Spectrometry and discussion with an expert there could be very useful for the students.

2a) Knowledge & skills of the expert (Mass Spectrometry technician / analyst)

• Core knowledge: Analytical chemistry, mass spectrometry (AMS / ICP-MS), isotopes, trace elements, sample preparation, lab standards, data formats, quality control

• Practical skills: operate instruments and software, prepare and process samples safely, perform quality control, troubleshoot, export data, interpret spectra and results

• Recommended background: degree or training in chemistry/geochemistry, lab experience with chemicals and instruments, teamwork with archaeologists and conservators

• Time to proficiency: For independent operation: months of supervised experience, for advanced expertise: years of practice

3) Example(s) / Case study (concise)

A realistic quick-start experience for students could be an educational visit to an AMS or ICP-MS laboratory which could include introduction to the laboratory and a tour guided by a mass spectrometry expert, including an overview of the instruments and work protocols. The technician could demonstrate how samples are loaded and measured, highlighting key steps in operating the AMS or ICP-MS. Students can then explore the resulting data using the instrument’s software. The session could conclude with a discussion with the group and the expert/technician followed by a brief reflection from the students.

4) Advantages & limitations

Advantages	Limitations / Requirements
High precision and sensitivity Minimal sample size required Enables dating, provenance, residue analysis Supports robust archaeological interpretation Generates quantitative, reproducible data	High instrument and maintenance cost Requires specialized lab and trained personnel Sample preparation can be complex Destructive to small samples Steep learning curve for operation and data interpretation

5) Technical requirements

Minimum Hardware: Laboratory-grade AMS or ICP-MS instrument; sample preparation equipment (balances, digestion vessels, pipettes, fume hood); computer for instrument control and data analysis

Dependencies / Notes: Requires clean lab conditions and safety protocols; Chemicals and consumables for sample digestion; Calibration standards and reference materials for accuracy; Supervised operation by trained personnel.

6) Ethical & data considerations

AMS and ICP-MS often require small but destructive sampling, so permissions and minimization of material removal are essential.

7) References & links

Video: How ICP-MS Works: A Detailed Guide to Its Working Principles	https://youtu.be/Zer537veqW0?si=NFpljZQazDUfFAt_&t=1
Accelerator Mass Spectrometry (AMS) Dating	https://www.radiocarbon.com/accelerator-mass-spectrometry.htm

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Tool 5: Geophysical Survey (GPR, Magnetometry): Subsurface imaging to detect buried features non-invasively.

Category (cost tier)	High
Developer / Provider	Company (equipment and software vendors)
Platforms	Windows / macOS (processing); field systems vendor-specific
Typical license	Commercial (typical); some academic/education licenses
Skill level	Intermediate
Typical use in archaeology	Non-invasive subsurface imaging techniques are used to detect and map buried archaeological features, structures, or anomalies by measuring variations in soil properties and magnetic fields.

1) What the tool does (Short description)

Geophysical survey methods are essential tools in digital archaeology for the non-invasive investigation of buried archaeological sites. Ground penetrating radar (GPR) and magnetometry are techniques that use electromagnetic waves and magnetic field measurements to detect subsurface anomalies that may indicate walls, graves, or artifacts without excavating the ground.

A ground-penetrating radar (GPR) is a device that detects the presence of objects in the ground by emitting radio waves and analyzing the return signals generated by the reflection of the waves at places where there are differences in the dielectric properties of the material. Magnetic measurements record spatial variations in the Earth's magnetic field, and magnetometry is also used in terrestrial and underwater archaeology.The spatial data obtained from the application of GPR or magnetometry are processed into detailed maps or three-dimensional surfaces, offering insight into the structure and stratigraphy of the site. By applying these techniques, archaeologists can more effectively document and interpret sites. Geophysical surveys preserve cultural heritage while improving the accuracy of research and public presentation.

2) Workflow & educational use

Within a typical archaeological workflow, these techniques are applied primarily before excavation begins. The measured data in the field are then processed using specialized software to filter out noise, enhance contrast, and transfer spatial information to a specific platform for further analysis and interpretation. Archaeologists analyze and interpret anomalies in relation to known contexts at the site, guiding targeted excavation and reducing unnecessary disturbance. The data obtained from GPR and magnetometry, supported by other modern digital techniques (digital platforms, GIS, 3D reconstructions, etc.), help in the presentation and promotion of cultural heritage to academic and public audiences. To achieve better continuity in teaching, lecturers could present these tools through a 90-minute laboratory session that combines short demonstrations of equipment and exercises in software data interpretation. As a homework assignment, students could analyze a given data set to identify possible archaeological features. Developing a mini-project that could include comparing the strengths and limitations of GPR and magnetometry at different types of sites encourages critical thinking about how to investigate and interpret data.

Suggested micro-learning outcomes:

• Identify appropriate geophysical methods (GPR vs magnetometry) for a given archaeological research question and site conditions.

• Perform basic survey planning and data acquisition steps (grid setup, calibration, data collection) and export results for further analysis.

• Interpret key anomalies and assess uncertainty/limitations, relating results to archaeological features and decisions for targeted excavation.

2a) Knowledge & skills of the expert (role profile)

Geophysical survey techniques such as Ground Penetrating Radar (GPR) and Magnetometry require a combination of technical, analytical, and interpretative skills. While these tools may be operated by geophysicists or trained technicians, archaeologists must also understand the principles behind their use and interpretation.

• Core knowledge: Understanding geophysical principles, soil conductivity, and magnetic susceptibility; knowledge of archaeological stratigraphy and context-based interpretation.
• Practical skills: Equipment calibration and operation, data acquisition in varying field conditions, processing and visualization of geophysical data using specialized software (e.g., TerraSurveyor, Geoplot).
• Recommended background: Prior field experience in archaeological prospection, training in geophysical mapping, and familiarity with GIS for integrating spatial datasets.
• Time to proficiency: Basic operation may be achieved after 1–2 weeks of supervised fieldwork; full competence in survey design, data analysis, and interpretation typically requires several months of practice and training.

3) Example(s) / Case study (concise)

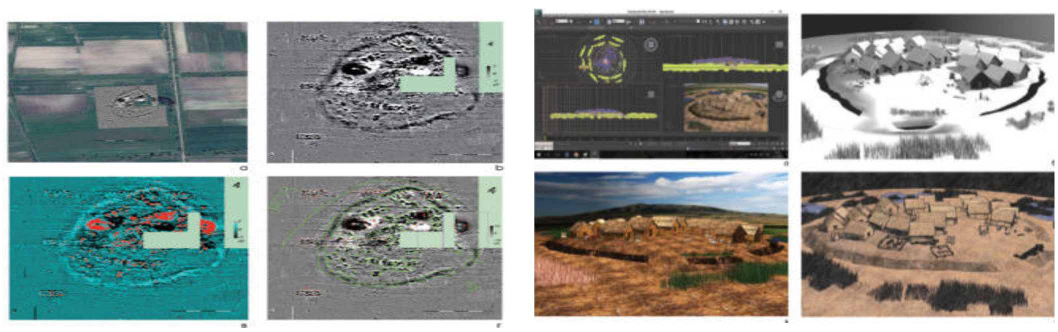
- Archaeological site Gradishte, village Crnobuki, city of Bitola, Macedonia. The site is a fortified settlement from the Hellenistic and Late Antique period. Parts of a Hellenistic house were discovered, and in it a large number of samples and fragments of quality ceramics, bronze and silver coins from the same period. Measurements with GPR were carried out at the site in order to precisely carry out archaeological excavations (Fig. 1).

a) *b)*

Fig.1 a) Measurement with GPR. b) Results of measurement with GPR.

Credit: Authors' archive (UKIM), 2025.

- The archaeological site Vrbjanska Čuka, village of Vrbjani, city of Prilep, Macedonia, is a mound and a Neolithic settlement characteristic of the Pelagonian region. Multidisciplinary research has been carried out at the archaeological site, where geomagnetic scanning has also been performed. Thanks to the results of the excavations and magnetic scanning, a virtual reconstruction has been made (Fig. 2).



a) *b)*

Fig.2 a) Results of geomagnetic scanning. b) Conceptual virtual reconstruction.

Credit: Authors' archive (UKIM), 2025.

4) Advantages & limitations

Technique	Advantages	Limitations / Requirements
Ground Penetrating Radar (GPR)	• Provides vertical and 3D subsurface profiles. • Detects a wide range of materials (stone, brick, voids).	• Performance depends on soil conditions (dry, sandy soils ideal; clay/wet soils reduce penetration). • Requires careful calibration and skilled data processing.

Magnetometry	• Rapid data collection over large areas. • Sensitive to anthropogenic features (burnt areas, ditches, walls).	• Cannot easily determine feature depth. • Limited in detecting non-magnetic materials (e.g., stone).

5) Technical requirements

Aspect	Ground Penetrating Radar (GPR)	Magnetometry
Minimum Hardware	• GPR unit with control console and antenna (200–900 MHz, depending on site depth).• GPS or total station for georeferencing.	• Fluxgate or cesium vapor gradiometer system.• GPS or total station for grid setup and georeferencing.
Software	• Proprietary processing tools (e.g., **GSSI RADAN**, **Mala Object Mapper**, **EKKO_Project**).	• Processing and visualization tools (**Geoplot**, **ArchaeoSurveyor**, **MagPick**).
Supported Data Formats	• Native GPR formats: *.rd3*, *.dzt*, *.gpr*, *.DT1*.• Export options: *.csv*, *.txt*, *.tiff*, *.las*, *.shp*.	• Native magnetometry formats: *.xyz*, *.dat*, *.grd*.• Export options: *.csv*, *.txt*, *.tiff*, *.shp*.

6) Ethical & data considerations

Data privacy is crucial, as location coordinates are sensitive; publicly sharing exact locations can lead to looting. Using standard data formats when documenting ensures that data sets can be reused. Cultural and legal considerations require researchers to adhere to local cultural heritage laws and engage respectfully with local communities. Ethical practice ensures both the protection of archaeological resources and the enhanced process of scientific research.

7) References & links

Witten, A. J. (2005). Handbook of geophysics and archaeology. Routledge.

Conolly, J., & Lake, M. (2006). Geographical information systems in archaeology. Cambridge University Press.

Oswin, J. (2009). A field guide to geophysics in archaeology. Springer.

Daly, P., & Evans, T. L. (Eds.). (2005). Digital archaeology: Bridging method and theory. Routledge.

Vukadinović, M. (2011). Primena geofizike u arheologiji. Kraljevo.

Tool 6: AI and Machine Learning: Automating tasks like data analysis, pattern recognition, and artifact classification.

Category (cost tier)	Medium
Developer / Provider	Open-source community & companies (tool ecosystem)
Platforms	Windows / macOS / Linux / Web (e.g., cloud notebooks)
Typical license	Open-source (typical) + commercial cloud services (optional)
Skill level	Intermediate
Typical use in archaeology	Advanced computational methods that automate data analysis, pattern recognition, and artifact classification enhance the efficiency and accuracy of archaeological research.

1) What the tool does (Short description)

AI and machine learning tools are transforming digital archaeology by automating complex tasks such as data analysis, pattern recognition, and artifact classification. These systems can quickly process large datasets from excavations, satellite imagery, and 3D scans, identifying trends and relationships that might be overlooked by human researchers. By training algorithms on existing archaeological records, the tools can classify artifacts, detect site features, and even predict potential excavation areas. This automation accelerates research, enhances accuracy, and reduces human error. Ultimately, AI-driven analysis supports the documentation and preservation of cultural heritage by making archaeological data more accessible, consistent, and interpretable.

2) Workflow & educational use

AI and ML streamline workflows, reveal hidden patterns, and support decision-making in archaeological research. Students can practice basic workflows such as data preparation, model training/testing, and interpreting outputs, while developing critical awareness of data quality and bias in archaeological applications.

Suggested micro-learning outcomes:

• Identify suitable AI/ML approaches (e.g., classification, clustering, prediction) for specific archaeological datasets and questions.

• Perform a basic ML workflow using a prepared dataset (preprocessing, training, evaluation, and exporting results).

• Interpret model outputs critically, including uncertainty, bias, and validation limits, and relate results to archaeological interpretation.

In education, AI can be introduced through labs, homework, and mini-projects. For example, a 90-minute lab might train students to classify artifact images and evaluate model accuracy. Homework can involve applying clustering or regression to small datasets, while mini-projects allow for predictive mapping or advanced artifact classification. These activities build technical skills and a critical understanding of AI's role in archaeology.

2a) Knowledge & Skills of the Expert (Role Profile)

Artificial Intelligence (AI) and Machine Learning (ML) applications in archaeology demand both computational expertise and domain understanding. While archaeologists may not always build algorithms themselves, they must understand data preparation, interpretation, and the ethical dimensions of automated analysis.

• **Core knowledge:** Understanding of AI and ML principles, data structures, and training models; familiarity with archaeological datasets and typologies used for pattern recognition and classification.
• **Practical skills:** Using open-source or commercial ML platforms (e.g., TensorFlow, PyTorch, Weka); preparing and cleaning data; labeling and evaluating model outputs; interpreting automated results in archaeological context.
• **Recommended background:** Training in data science or digital archaeology, experience with coding (Python or R), statistical reasoning, and interdisciplinary collaboration with computer scientists.
• **Time to proficiency:** Introductory understanding achievable through short-term courses (20–40 hours); developing custom models or conducting research-level applications may require several months of dedicated practice.

3) Case study - Automated Pottery Classification

At a Neolithic site, students work with a dataset of pottery sherd images from excavations. Using a machine learning model, they classify sherds by type, decoration, and manufacturing technique. Expected outputs include labeled images, accuracy reports, and visualizations of artifact distribution. Learning value comes from hands-on experience with AI-assisted artifact analysis, understanding how automated classification speeds up post-excavation processing, and critically assessing model performance and limitations.

4) Advantages & limitations

Workflow Stage	***Advantages***	***Limitations***
Survey	Speeds up survey, detects subtle features	Requires high-quality imagery, may miss small/hidden features
Excavation	Reduces manual recording, improves accuracy	Limited by model training, may mislabel unusual artifacts
Post-Processing	Saves time, consistent labeling	Needs large datasets; rare/damaged artifacts may be misclassified
Analysis	Reveals hidden trends	AI cannot fully interpret cultural/historical context
Presentation	Enhances communication, integrates with GIS	Resource-intensive; requires technical skills

5) Technical requirements

Category	***Optional***
Hardware	GPU recommended for deep learning (NVIDIA GTX 1050+), 16 GB preferred for large datasets, SSD improves processing speed; large or dual monitors are helpful for visualization
Programming Environment	Jupyter Notebook or Google Colab recommended
Libraries / Dependencies	Deep learning for image classification; classical ML algorithms , Image processing; data handling & visualization
Visualization Tools	For spatial mapping or 3D reconstructions

6) Ethical & data considerations

AI in archaeology requires attention to data licensing, ensuring proper use and attribution of datasets and outputs. Privacy is crucial for sensitive site locations to prevent looting. Accessibility ensures tools and data can be used by all students and researchers. Users should also watch for bias in AI models, which can affect artifact classification or pattern interpretation.

7) Quick start (optional)

* Prepare Data – Collect and organize artifact images into labeled folders (e.g., pottery types).

* Set Up Environment – Install Python, Jupyter Notebook (or use Google Colab), and libraries: TensorFlow/PyTorch, OpenCV, NumPy, pandas.

* Load and Preprocess Images – Resize, normalize, and split images into training and testing sets.

* Train Model – Use a simple or pre-trained model to classify images.

* Evaluate Performance – Check accuracy, confusion matrix, and adjust parameters if needed.

* Visualize & Interpret – Display classified images, trends, or patterns for analysis.

8) References & links

Barceló, J. A., & Bogdanovic, I. (2020). Mathematics and archaeology. CRC Press.

Müller, K. (2021). Digital archives and collections: Creating online access to cultural heritage. Berghahn Books.

Warwick, C., & Aske, K. (2025). Navigating artificial intelligence for cultural heritage organisations. UCL Press.

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Tool 7: Photogrammetry and 3D Modeling: Creating detailed 3D models of small find artifacts from photographs

Category (cost tier)	Low / Medium
Developer / Provider	In terms of computer software, various free, open-source, and paid digital options are available for personal, educational, or commercial use in the close-range photogrammetry and 2D-3D documentation. Some of the diverse developer and/or provider companies, institutions, or associations, and the software they offer, can be listed as: Drone Emotions Ltd. - Agisoft Metashape, AliceVision – Meshroom The Inkscape Project - Inkscape biçiminde sıralanabilir.
Platforms	Windows / macOS / Linux / Web / Mobile
Typical license	Free / Open-source / Academic / Commercial / Personel / Educational
Skill level	Intermediate / Advanced
Typical use in archaeology	2D and 3D imaging and dokümantasyon of archaeological cultural heritage. Creation of 3D models. 2D drawing of archaeological small finds.

1) What the tool does (Short description)

Documentation in archaeology is one of the fundamental requirements and applications of science. The accurate documentation and archiving of reality, its availability for use by professionals and academics, its publication, and transmission to future generations as an ancient cultural heritage, hold a very important place in this discipline. In this context, along with developing technology, one of the fundamental tools and methods used in archaeological documentation is photogrammetry (Cerasoni et al. 2022). In archaeology, photogrammetry and the 2D-3D documentation of artifacts should be considered a digital tool, method, or workflow because it requires the use of specific software in a computer environment.

Photogrammetry can be briefly defined as the discipline of measuring and interpreting photographic images of objects using digital methods (Aber et al. 2010, 23 ff). It has a wide range of applications, from the detection and identification of very large-scale archaeological sites by combining visual information obtained from sources such as Drones, LIDAR, satellite images, and digital cameras with Remote Sensing Methods, to the 3D visualization and documentation of small-scale ancient cultural heritage elements (Renfrew and Bahn 2016, 82-86; Dall'Asta et al. 2016, 243-245).

Photogrammetry is important in terms of providing modern methods for documenting and presenting archaeological cultural heritage, providing faster and more accurate results compared to older methods, being effective in obtaining 3D images, and offering more diverse opportunities for disseminating information (Aber et al. 2010; Marín-Buzón et al. 2021). Furthermore, the variety of photogrammetry software available today offers very low-cost, or even cost-free solutions for 3D imaging and modeling. For example, users with a desktop computer, a laptop, and a smartphone can create diverse models after learning and some training 3D imaging techniques.

2) Workflow & educational use

Some of the basic functions of close-range photogrammetric applications (such as Meshroom etc.) in archaeological science can be summarized as follows;

a) Horizontal and vertical documentation and visualization of trench stratigraphy during an archaeological excavation,
b) Documentation and 3D visualization of finds discovered during excavations and surface surveys,

c) Presentation of archaeological material and dissemination of information to the public,

Lecturers can integrate close-range photogrammetric applications into their teaching processes within the scope of items a, b, c listed above.

Suggested micro-learning outcomes:

- Identifying and implementing rapid, low-cost, and new methods for 3D modeling of small finds obtained through archaeological excavations and/or surface surveys.

- Obtaining the basic requirements (hardware, software, computer, laboratory/classroom). Building experience (teacher-learner/student interaction; software learning, digital photography, digital imaging and modeling knowledge) and applying basic modeling steps. Preparing 3D information for usage, publicaton and dissemination.

- Interpreting 3D modeling techniques to gain a proper perspective on archaeological cultural heritage elements as small finds. Understanding the minimum requirements for model creation and observing the proportional relationship between the model and the real object. The perception of the speed and ease that digital tools provide in acquiring information and transforming it into virtual objects. Understanding the current state of the technological environment in terms of adequacy, applicability, cost, and accessibility.

Success on the learner/student platform can be achieved after several lesson phases averaging 240 minutes and completion of necessary homework assignments. Analytical and stylistic analyses of small finds identified during archaeological excavations or field research can be strengthened with the aforementioned imaging methods, leading to more effective learning.

Sample basic task/mini-workflow:

Digital stereoscopic photography and visualization in a basic software environment of a small find discovered during excavation and/or surface survey can be carried out practically in a laboratory or classroom environment.

Outputs and Limitations:

Outputs will be in high-quality digital formats. For proper and long-term data storage, multiple backups and safekeeping on hard drives with sufficient capacity are recommended.

The gradual obsolescence of saved and backed-up file formats requires measures against the removal of software bundles.

Data must be updated to be compatible with new methods and file formats of changing and transforming technologies.

The outputs are primarily intended for users familiar with computer environments. Basic computer skills may not be sufficient. Both the teacher and the learning community require intermediate to advanced hardware, software, and application knowledge and experience.

3) Example(s) / Case study (concise)

Short example: Small Find 3D Imaging and Documentation;

30-40 digital stereoscopic photographs of the find,

Uploading images saved in the folder into basic photogrammetry software,

Basic automatic software processes: Image alignment, matching, point cloud, meshing, texturing, ***Result:*** Structure from Motion (SfM), 3D Object (obj.).

4) Advantages & limitations

Advantages	Limitations / Requirements
- Relatively low cost, - Easy to learn, - Detailed imaging, - Enables rapid public outreach - Long-term protection - Remote access, - Reaching a much wider user and/or learner environment, - Availability of free and/or open access software	- Desktop and Laptop computer experiences, - GPU needed, - License costs, - Advanced computer hardware and software requirements, - Requires intermediate computing experiences, - Digital capturing devices (digital camera, turntable, tripot, illumination device etc.)

5) Technical requirements

It requires advanced computer hardware.

It requires a sufficient graphics card and up-to-date drivers.

It requires sufficient GPU, RAM, SSD, VRAM capacity.

Licensed, free, open access or limited edition software:

Photo processing software: Photoshop, Gimp, Krita, Affinity Photo

Photogrammetry software: Agisoft MetaShape, RealityCapture – RealityScan, Meshroom
3D Illustration and Rendering: 3Ds Max, Blender, Cinema 4D
Supported data formats consist of the basic extensions used by the programs listed above (.jpeg, .bitmap, .mp4, .psd, .blend, .obj etc.).

Minimum Requirements	
Operating systems	Windows x64, Linux, macOS
CPU	Recent Intel or AMD
RAM	8 Gb
Hard drive	~400 MB for Meshroom +
GPU	NVIDIA CUDA-enabled GPU (compute capability >= 2.0)

6) Ethical & data considerations

Ethical considerations: The main considerations include but are not limited to cultural appropriation, desecration of sacred sites, and unauthorized commercial exploitation and destruction of archaeological sites, artifacts, structures and natural resources. Developers must obtain explicit, informed consent from researchers, local indigenous communities and land managers.

- Researcher and publication rights.
- Copyright, Privacy and security concerns.
- Concerns of cultural appropriation voiced by native communities.
- Issues with long-term preservation and archiving of data.
- Concerns over unequal access when used for educational and outreach purposes.

7) Quick start (optional)

Prepare 30-40 digital stereoscopic photographs of the small find,

Save the images to a specific folder,

Uploade images or folder folder into basic photogrammetry software,

Start the digital 3D imaging process: Image alignment, matching, point cloud, meshing, texturing, ***Result:*** Structure from Motion (SfM), 3D Object (obj.).

Check the final object. If necessary, clean the mesh and unwanted points and point clouds to achieve a model with correct and clean surface.

Official site / docs	Software example: Meshroom (https://alicevision.org/), (https://alicevision.org/#meshroom), Agisoft Metashape, (https://www.agisoft.com/), The Inkscape Project Website (https://inkscape.org/).
Learning resources	(https://www.youtube.com/watch?v=yKbyVDK2Ep8), (https://www.youtube.com/watch?v=tiOeMgLHSrA)

8) References & links

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Cerasoni, J. N., do Nascimento Rodrigues, F., Tang, Y., & Hallett, E. Y. (2022). Do-it-yourself digital archaeology: Introduction and practical applications of photography and photogrammetry for the 2D and 3D representation of small objects and artefacts. PLOS ONE, 17(4), e0267168.

Dall'Asta, E., Bruno, N., Bigliardi, G., Zerbi, A., & Roncella, R. (2016). Photogrammetric techniques for promotion of archaeological heritage: The Archaeological Museum of Parma (Italy). The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLI-B5, 243–250.

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Marín-Buzón, C., Pérez-Romero, A., López-Castro, J. L., Ben Jerbania, I., & Manzano-Agugliaro, F. (2021). Photogrammetry as a new scientific tool in archaeology: Worldwide research trends. Sustainability, 13, 5319.

Renfrew, C., & Bahn, P. (2016). Archaeology: Theories, methods and practice. Thames & Hudson.

Tool 8: Virtual and Augmented Reality (VR/AR): Reconstructing sites and objects for visualization, education, and public outreach.

Category (cost tier)	Medium- High
Developer / Provider	This guide refers to an ecosystem of digital tools thus using various examples of specific digital tools throughout. There is a variety of **open-source, open-community, and closed-source commercial** tools in the VR/AR ecosystem. Companies include Unity and Nexus Studios among many.
Platforms	To an extent all of the following platforms are used: Windows / macOS / Linux / Web / Mobile
Typical license	Free: Blender and Google ARcore / Open-source: Godot and A-Frame / Academic / Commercial: Unity. Some AR/VR technologies are free to use initially however licenses can be costly for commercial tools.
Skill level	Beginners can create simple reconstructions or AR models (using Blender and Sketchfab for example) Intermediate level requires technical knowledge to create Interactive VR walkthroughs of excavated sites or AR overlays on excavation sites. Blender and Maya are examples of tools that can be used at this level. Advanced technical skills means that archaeologists, cultural heritage experts and developers can create high-fidelity, scientifically accurate, and interactive experiences that go far beyond simple visualization.
Typical use in archaeology	Augmented Reality (AR) allows for the creation of interactive 3D models of archaeological sites and artifacts. Whereas, Virtual Reality (VR) provides a computer generated fully immersive experience using equipment.

1) What the tool does (Short description)

Augmented reality (AR) and virtual reality (VR) are separate technologies that employ computer-generated environments to improve or substitute real-world experiences (Kukreja, V. et.al., 2024: 1). Through the use of stimulated environments both AR and VR offer a unique insight into the cultural heritage of archaeology as users can explore reconstructed sites as if they were physically present, engaging with historical artifacts and cultural heritage legacy in ways that traditional methods cannot replicate. AR and VR also is instrumental in the preservation of archaeological sites and artifacts. From an outreach perspective, AR and VR transcend boundaries of geography, time and space, allowing access to all. This is particularly important for those from disadvantaged groups and for victims of war and displacement who can benefit greatly from these technologies that help to keep collective memory and cultural heritage alive. AR and VR are both valuable tools for providing educational enrichment by introducing innovative technologies to students of all ages.

2) Workflow & educational use

AR and VR improves several phases of the archaeological workflow by improving visualization, spatial perception, and interpretive capacity. During survey and excavation**,** AR overlays spatial or stratigraphic data directly onto the field environment, while VR allows for virtual walk-throughs and rehearsal of survey strategies. In post-processing and analysis**,** immersive environments allow students/users to examine 3D models, stratigraphy, and reconstructions from different angles, allowing for improved interpretation and collaborative review. For presentation**,** both of the technologies advocate engaging public outreach through on-site AR reconstructions and remote VR site tours.

For teaching purposes, AR/VR can be combined into a 90-minute lab with a short introduction followed by hands-on exploration of VR trench models or AR reconstructions, followed by an activity that involves short analysis. This structure trains students to identify features, understand spatial relationships, and assess archaeological interpretations within immersive environments. The aim is to allows students to experience how AR/VR changes their perception of data compared to traditional 2D plans or photos.

Assignments for students can include annotating a VR model, critiquing an AR reconstruction, or comparing 2D and 3D documentation outputs. More comprehensive student projects can involve building a basic AR reconstruction, designing a short interpretive VR tour, or analysing how AR/VR supports a particular part of the archaeological workflow. These activities help students connect immersive technologies to real archaeological practice and develop critical digital skill.

3) Example(s) / Case study (concise)

Site type: Constructing a new Virtual Reality experience focusing on the Tios Archaeological site in Zonguldak. VR can be used to virtually "walk" reconstructed Acropolis Temples, Basilica, Necropolis, coast wall and other structures too. Using AR to project digital models of pottery and other artifacts.

Activity: Unique 3D reconstruction using both Augmented Reality and Virtual Reality.

Expected output: providing a realistic feel of what life may have been like in Roman times.

Learning outcome: learning how to use both Augmented Reality and Virtual Reality technologies for both educational and outreach purposes.

4) Advantages & limitations

Advantages	Limitations / Requirements
• High Immersion and Presence. • Virtual and augmented reality technologies immerse learners in historical environments, allowing them to explore ancient sites and artefacts from unique perspectives. • Some technologies are open-source and open-community which can provide a low-cost option. • Enables archaeologists to digitally recreate ancient landscapes, structures, and urban settings. • Enhances public engagement and social outreach. • Useful outreach tool for both educational purposes and for disadvantaged groups. • Skills and stimulation that would be difficult to practice at actual sites can be gained via these technologies.	• High-quality VR and AR models require significant computational power and advanced hardware capabilities. • The software needed for creating, maintaining, and updating immersive experiences can be a steep learning curve. • Budget constraints can mean that the necessary investments in equipment and training cannot be made. • Some archaeological sites do not have the required infrastructure to support high-end digital tools, which can impact more on disadvantaged regions. • Privacy and data security concerns. • Long-term preservation challenges. • Ethical concerns such as cultural appropriation etc.

5) Technical requirements

Requirement	AR	VR
Minimum Hardware	- Mobile device (A12 Bionic / Snapdragon 845+) - 3–4 GB RAM - Camera + motion sensors - Optional: AR headsets	- Standalone headset (Quest 2/3, Pico 4) **or** PC-VR (i5/Ryzen 5+, GTX 1060+, 8–16 GB RAM) - USB/DP/HDMI ports - Integrated/external tracking
Minimum Software	- iOS 13+ (ARKit) or Android 8+ (ARCore) - Unity/Unreal (AR Foundation) - Xcode/Android Studio	- Meta Quest OS, SteamVR, Windows MR - Unity (XR Toolkit), Unreal VR - OpenXR, Oculus SDK, SteamVR SDK
Supported Data Formats	- 3D: USDZ, GLTF/GLB, FBX, OBJ - Images: PNG, JPEG - Marker/scene files	- 3D: FBX, OBJ, GLTF/GLB - Textures: PNG, JPEG, HDR - 360° video (MP4 H.264/H.265)
Dependencies	- ARKit/ARCore support - Camera + sensors - Optional depth/location APIs	- VR runtime (OpenXR/Oculus/SteamVR) - Updated GPU drivers - Optional: hand-tracking, haptics

In terms of long-term preservation, AR and VR models tend to be rendered in 3D models therefore it is crucial that long-term preservation/archiving is given sufficient thought.

6) Ethical & data considerations

- Privacy and security concerns.

- Concerns of cultural appropriation voiced by native communities.

- Issues with long-term preservation and archiving of data.

- Concerns over unequal access when used for educational and outreach purposes.

- In AR and VR applications, clearly distinguishing between evidence-based reconstructions from hypothetical reconstructions is a must to ensure a transparent, authentic, and truly ethical user experience.

7) Quick start (optional)

VR Quick-Start Demo (generic):

-User puts on headset and achieves the following:

- 6DoF head tracking

- Hand/controller interaction

- Basic immersion

8) References & links

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Dutertre, A. (2023). The ethical challenges of AR and VR. https://medium.com/@alex24dutertre/the-ethical-challenges-of-ar-vr-a5333594f909

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Turkish Museums. (n.d.). https://turkishmuseums.com/Uploads/M%C3%BCze/Dosya/77106171-c599-49f0-abe6-3ebcfc8d8b9b.pdf

Wessex Archaeology. (n.d.). Virtual reality (VR), augmented reality (AR) and gaming. https://www.wessexarch.co.uk/archaeological-services/virtual-reality-vr-augmented-reality-ar-and-gaming

iDig Sheffield. (2025). Virtual reality and augmented reality in archaeological interpretation. https://www.idigsheffield.org.uk/virtual-reality-and-augmented-reality-in-archaeological-interpretation.html

Werner, L., Brey, P., & Henschke, A. (2025). Augmented reality and ethics: Key issues. Virtual Reality, 29, 122. https://doi.org/10.1007/s10055-025-01172-7

Submission Metadata

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Tool 9: Field Data Collection (Mobile Apps): Using tablets and smartphones for standardized data recording in the field.

Category (cost tier)	Low
Developer / Provider	Primarily small open-source and commercial providers: OPENGIS.ch (QField), Softwel (SW Maps), Lutra Consulting (Mergin Maps)
Platforms	Windows / macOS / Linux / Web / Mobile
Typical license	QField – free, open-source; SW Maps – free; Mergin Maps – freemium (commercial with free tier)
Skill level	Beginner–Intermediate (basic GIS knowledge recommended)
Typical use in archaeology	Used for standardized, georeferenced recording during survey and excavation (sites, features, trenches, finds, photos, notes) on smartphones or tablets, with data synced to QGIS for mapping, analysis, and long-term archiving.

1) What the tool does (Short description)

Field data collection mobile apps such as QField, SW Maps, and Mergin Maps enable archaeologists to use smartphones and tablets for standardized, georeferenced recording directly in the field. Building on the kind of low-cost, modular workflow described by Isaac Ullah (2017), where hardware (tablet plus GNSS receiver) and software (mobile app plus desktop GIS) are clearly separated, these tools allow users to digitize points, lines, and polygons, attach photos and notes, and store attributes in structured forms.

Projects prepared in QGIS can be deployed on mobile devices, used offline in the field, and then synchronized back to the desktop environment for further mapping and analysis, with selected datasets prepared for long-term archiving (Montagnetti &

Guarino, 2021; QGIS Development Team, n.d.). In the context of cultural heritage in archaeology, these apps are particularly suited for documenting sites, features, excavations, and heritage landscapes consistently, and can significantly reduce transcription errors compared to paper forms.

2) Workflow & educational use

In a typical workflow inspired by Ullah's mobile data-collection model (Ullah, 2017), the team first defines the data model and recording strategy (i.e., what to map, which attributes, and required fields), then prepares the project in QGIS and deploys it to mobile devices. During survey or excavation, archaeologists use QField, SW Maps, or Mergin Maps to collect geometries (site locations, features, trenches, find spots), fill in standardized attribute forms, and attach photos, all while working offline. At the end of the day, data are exported or synchronized back into QGIS, where they are checked, cleaned, and integrated with other spatial datasets, such as DEMs, historical maps or remote-sensing layers.

For teaching, these tools support small, well-defined learning activities:

- Short lab + field exercise (90–120 minutes): students load a prepared QGIS project onto a mobile app, collect a limited number of test features around the training area, and then visualize the results in QGIS.
- Mini-project in a field school: students help design attribute forms, collect data during several survey days, and later evaluate data quality, completeness and spatial patterns.

Suggested micro-learning outcomes:

- Identify the main functions and typical use cases of mobile field data collection apps in archaeological survey and excavation.
- Perform a basic field data collection workflow using a pre-configured QGIS project and a mobile app (QField / SW Maps / Mergin Maps).
- Interpret the collected data in QGIS by inspecting attribute tables and maps, identifying basic data quality issues and possible improvements to the recording scheme.

2a) Knowledge & skills of the expert (role profile)

The tools are usually set up and maintained by a GIS-literate archaeologist or heritage professional.

- Core knowledge: basic GIS concepts and use of QGIS; archaeological recording standards (contexts, features, site codes, controlled vocabularies); awareness of data management and long-term preservation.
- Practical skills: preparing QGIS projects for field use (layers, forms, symbology, offline basemaps); configuring and operating QField / SW Maps / Mergin Maps,

including offline work and external GNSS if needed; exporting, synchronizing and documenting datasets.
- Time to proficiency: for using a pre-configured project (basic recording and export), roughly 4–8 hours of guided training plus one or two field exercises; for designing robust projects, integrating high-precision GNSS and managing multi-user workflows, several days of practice across multiple field campaigns.

3) Example(s) / Case study (concise)

A concrete and well-documented example is the archaeological field course at Uppsala University, where students used Mergin Maps and QGIS to collect standardized field data. In this course, Mergin Maps was used to deploy QGIS projects to mobile devices, enabling students to record features with coordinates, attributes, and photos even in offline conditions (Aherin et al., 2024) merginmaps.com. The collected data were then synchronized back to a shared project, improving both the quality and structure of the dataset and the students' understanding of geospatial workflows and their engagement with the fieldwork.

Another example is the citizen-science project in the Netherlands in which volunteers used Mergin Maps to map and document burial mounds and other archaeological features, demonstrating how mobile GIS can support participatory heritage documentation while still producing usable research data (Petrík et al., 2021) merginmaps.com.

These examples can be adapted for DigiArcheoSpace: students document elements of archaeological or movement heritage (paths, features, viewpoints) with a mobile app, and later use QGIS to analyse distributions, conditions and risks.

4) Advantages & limitations

Advantages	Limitations / Requirements
• Low-cost, modular setup: standard smartphone or tablet (optional GNSS) plus free/open-source GIS tools. • Full offline use, suitable for remote archaeological and heritage sites. • Direct integration with QGIS, reducing re-typing and transcription errors. • Customisable forms with photos and notes, supporting local recording practices. • Equally suitable for professional teams, student field schools, and citizen-science projects.	• Requiring a well-designed data model, poorly structured forms quickly lead to messy data. • Limited GPS accuracy on mobile devices; high-precision survey needs external GNSS/RTK and a more complex setup. • Depend on battery life, device robustness, and weather conditions in the field. • Large or multi-user projects with many photos may require paid cloud services and careful data management.

5) Technical requirements

Hardware: Smartphone or tablet (Android or iOS) with built-in GPS; rugged cases and power banks recommended for field work; Optional external Bluetooth GNSS/RTK receiver to achieve sub-meter or centimetre accuracy.

Software: QGIS desktop for project preparation and analysis; One or more mobile apps: QField, SW Maps, Mergin Maps, depending on project needs; Optional synchronization services such as QFieldCloud or the Mergin Maps platform.

Data formats: Vector data - common formats include GeoPackage, Shapefile and GeoJSON, all natively supported by QGIS and compatible with the mobile tools; Raster data - offline basemaps and orthophotos prepared in QGIS or cached via the app, depending on licensing.

6) Ethical & data considerations

Sensitive site locations: Precise coordinates of vulnerable archaeological sites or burial grounds should not be shared publicly without careful risk assessment; generalization or masking may be required in public outputs.

Personal data: If the forms include the names of landowners, finders, or community members, GDPR and other privacy regulations apply. Identifiers should be minimized, pseudonymized, or excluded from open datasets.

Licensing: Projects should clarify ownership, access rights, and licenses for both spatial data and imagery (for example, CC BY/CC BY-NC for attribute data and careful respect of basemap licences).

Data management: Mobile data collection should be embedded in an explicit data management plan that covers backup, documentation, long-term storage and potential deposition of selected datasets in institutional or national repositories.

7) Quick start (optional)

- Install QGIS on a laptop and create a simple project with one vector layer (for example, "Features") and a small set of attributes (type, condition, notes).
- Configure the project for field use (symbology, forms, offline basemap) and export it to a mobile app such as QField or Mergin Maps.
- In the field, use the app on a smartphone or tablet to record 10–20 test features, adding photos and short descriptions.
- Back in the classroom, synchronize or export the data to QGIS, inspect the attribute table and geometries, and discuss data quality and possible improvements to the recording scheme.

8) References & links

Aherin, R., Paulovic, J., & Lindgren, S. (2024, August 9). Digging into the benefits of Mergin Maps for archaeological research. Mergin Maps.	https://merginmaps.com/case-studies/digging-into-the-benefits-of-mergin-maps-for-archaeological-research merginmaps.com
Montagnetti, R., & Guarino, G. (2021). From QGIS to QField and vice versa: How the new Android application is facilitating the work of the archaeologist in the field. Environmental Sciences Proceedings, 10(1), 6.	https://doi.org/10.3390/environsciproc2021010006
Petrík, P., Harris, P., & Pruiksma, K. (2021, December 7). Archaeological discoveries in the hands of citizens. Mergin Maps.	https://merginmaps.com/case-studies/archaeological-discoveries merginmaps.com
QGIS Development Team. (n.d.). QGIS documentation. QGIS Project.	https://docs.qgis.org
Ullah, I. I. (2017, April 28). A mobile data-collection workflow for archaeologists. CompArch: Computational Archaeology Lab.	https://isaacullah.github.io/A-mobile-field-data-collection-workflow/ isaacullah.github.io

Tool 10: Digital Conservation and Preservation: Monitoring and documenting the condition of heritage sites and artifacts

Category (cost tier)	Medium
Developer / Provider	Mixed ecosystem (open-source communities + commercial service providers)
Platforms	Windows / macOS / Linux / Web
Typical license	Mixed licensing model: open-source software + optional commercial licences and cloud services
Skill level	Intermediate
Typical use in archaeology	Used to monitor condition changes of sites and artifacts over time and to support conservation planning within a mixed digital documentation ecosystem.

1) What the tool does (Short description)

Digital conservation and preservation refers to digital methods used to monitor and document the condition of heritage sites and artifacts. It includes visual macroscopic and microscopic analysis, digital photography, photogrammetry, and remote-sensing approaches such as structured-light scanning and LiDAR. These tools support the systematic recording of erosion, deterioration, discoloration, and other physical changes observable on cultural heritage objects. By generating repeatable, high-resolution visual and metric data, they enable time-series comparison and provide evidence for conservation planning and risk assessment. In archaeology, these methods are essential because they support non-destructive documentation and long-term monitoring, ensuring that heritage can be effectively studied, protected, and presented.

2) Workflow & educational use

Digital monitoring typically begins with a condition assessment, carried out before, during, and after excavation or conservation interventions. The process starts with visual inspection supported by digital photography to map deterioration patterns (e.g., cracks, flaking, biological growth, discoloration). Photogrammetry is then used to create 3D models and textured surfaces that allow comparison of relief and color across different time periods. For larger structures or outdoor rock formations, structured-light scanning and terrestrial or aerial LiDAR are used to capture metric data for long-term monitoring. The resulting datasets are processed, interpreted, archived, and used to support conservation decisions or public presentations.
Suggested micro-learning outcomes:

- Identify the main digital monitoring methods relevant to archaeology.
- Perform a basic workflow (photographing, mapping deterioration, generating a simple 3D model).
- Interpret outputs and discuss technical and methodological limitations.

2a) Knowledge & skills of the expert (role profile)

Briefly describe the competencies typically required to use this tool in practice (can be a technician other than the archaeologist):
• Core knowledge: basics of conservation and deterioration processes; principles of visual documentation; fundamentals of photogrammetry, structured-light scanning, and LiDAR; image formats (JPEG, TIFF, RAW) and 3D formats (OBJ, PLY, LAS/LAZ); standards for metadata and conservation documentation (e.g., CIDOC-CRM).
• Practical skills: Operating digital cameras and scanners; capturing high-quality images; preparing and executing photogrammetric surveys; performing quality control of datasets; processing and aligning 3D models; generating deterioration maps; exporting, archiving, and maintaining long-term datasets.
• Recommended background: Training in digital documentation and conservation workflows, prior field experience, adherence to safety protocols (especially for outdoor scanning), and collaborative skills to work with archaeologists, conservators, and heritage managers.
• Time to proficiency: Introductory competence typically requires 10–20 hours of guided practice; advanced proficiency in photogrammetry, LiDAR, and change-detection workflows may require several months of training and project experience.

3) Example(s) / Case study (concise)

The Mravinca project documents a prehistoric necropolis composed of stone burial mounds in Dubrovačko primorje, Croatia. The team used a low-cost UAV to collect high- and low-altitude photographs and applied photogrammetry to generate detailed 3D models of individual mounds and a digital terrain model of the entire site. The expected outputs included accurate spatial and volumetric data, high-resolution surface models, and improved documentation of the current site condition. The work also led to the identification of a previously unnoticed archaeological feature visible on the DTM.

The learning value lies in showing how UAV-based photogrammetry can support analysis, discovery, and comparative research, especially in landscapes with large numbers of similar features (Perkić and Vuković, 2018).

4) Advantages & limitations

Advantages	Limitations / Requirements
• Provides high-resolution visual and metric data. • Enables repeatable, long-term comparison. • Supports evidence-based conservation and risk assessment. • Applicable to small artifacts, as well as large structures and landscapes. • Non-destructive documentation methods. • Facilitates interdisciplinary collaboration between archaeologists, conservators, and heritage managers.	• Requires technical training and methodological consistency. • Access to specialized and potentially expensive equipment (e.g. LiDAR, structured-light scanners). • Large datasets require reliable long-term storage solutions. • Data capture quality depends on environmental conditions (e.g. lighting, weather). • Some tools and workflows rely on commercial software licences. • Long-term comparability requires adherence to documentation standards.

5) Technical requirements

- Hardware: Digital camera (DSLR/mirrorless), tripod, controlled lighting (optional); structured-light scanner; terrestrial or aerial LiDAR.
- Software: Photogrammetry suites (Agisoft Metashape, RealityCapture); 3D data processing tools (CloudCompare, MeshLab); GIS for mapping; image-processing software (Photoshop, GIMP).
- Data formats: JPEG, TIFF, RAW (photography); OBJ, PLY, STL (3D models); LAS/LAZ (LiDAR); CSV, XML for metadata.
- Dependencies: Reliable data storage (external HDD, NAS, servers); calibration targets and controlled conditions when possible.

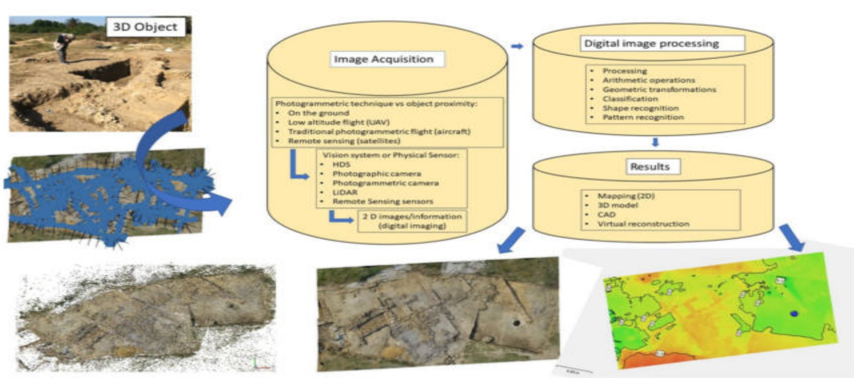

Figure 1. Summary of photogrammetric processes involved in archaeology.

Resource: Marín-Buzón C, Pérez-Romero A, López-Castro JL, Ben Jerbania I, Manzano-Agugliaro F. Photogrammetry as a New Scientific Tool in Archaeology: Worldwide Research Trends. Sustainability. 2021; 13(9):5319. https://doi.org/10.3390/su13095319

6) Ethical & data considerations

Data must follow appropriate copyright and licensing practices (e.g., Creative Commons for open datasets). Sensitive information—such as precise coordinates of vulnerable sites—must be restricted to authorized users to avoid risks like looting. Long-term preservation requires using stable, non-proprietary file formats and robust metadata. Ethical publication should avoid revealing information that could endanger the site or facilitate damage, and should follow local and institutional conservation policies.

8) References and Links

Agisoft Metashape	https://www.agisoft.com/
Official Adobe Photoshop	https://www.adobe.com/products/photoshop.html
GIMP - GNU Image Manipulation Program	https://www.gimp.org/
MeshLab	https://www.meshlab.net/
Bentowska-Kafel A. & L. MacDonald. 2017. Digital technologies for documenting and preserving cultural heritage. ARCHumanities Press.	https://library.oapen.org/bitstream/id/741cdc96-14f1-475a-8339-b71328800c6b/9781942401353.pdf
Perkić, D. & Vuković, M. (2018). Documenting an archaeological landscape and its features using a low cost UAV – Case study: Mravinca in Dubrovačko primorje. Opvscvla archaeologica, 39/40 (1), 75-83.	https://hrcak.srce.hr/en/214173
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Marinos Ioannides, Eleanor Fink, Lorenzo Cantoni & Erik Champion, ed. 2021. Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection. Springer.	https://www.springerprofessional.de/en/digital-heritage-progress-in-cultural-heritage-documentation-pre/19062194?tocPage=1

Panayot, N., Bou-Rizk, A., Yassine, M.K., Kawtharani, R., Asmar, D. (2025). Digital Heritage Documentation for Protecting and Rebuilding Tangible Heritage in Natural Disaster and Conflict Zones. In: Ioannides, M., Issini, G., Oliveira, D. (eds) 3D Research Challenges in Cultural Heritage IV. Lecture Notes in Computer Science, vol 13577. Springer, Cham.	https://link.springer.com/chapter/10.1007/978-3-031-93753-8_12#citeas
Archaeology Guidelines Supplement Photogrammetry, 2022, Ohio History Connection.	https://www.ohiohistory.org/wp-content/uploads/2022/12/Archaeology_Guidelines_Supplement_Photogrammetry.pdf

Submission Metadata

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Tool 11: Data Management and Curation: Creating structured databases and digital repositories to preserve and share research data.

Category (cost tier)	Varies - [**Low** / **Medium** / **High**]
Developer / Provider	[**Company** / **Open-source community**]
Platforms	[**Windows** / **macOS** / Linux / **Web** / Mobile]
Typical license	[Free / **Open-source** / **Academic** / **Commercial**]
Skill level	[Beginner / Intermediate / **Advanced**]
Typical use in archaeology	Creating structured databases and digital repositories with the aim to preserve and share research data is essential for the work of archaeologists, museum specialists, other heritage professionals, as well as students and researchers. These people who handle archaeological data can be both a developer and user of the according databases.

1) What the tool does (Short description)

Creating structured databases and digital repositories to preserve and share research data is not a technology or a tool in itself. This is rather the result of applying a combination of choices, which involves specialists, tools and technologies, based on specified criteria, which depends on the purpose and aim one wishes to accomplish. If the purpose is to preserve and share research data, the choices on how to do it depend on who the developer is, a person, a team or an institution, and the resources they have access to.

On the one hand people who create such databases do it so the potentially large amounts of archaeological data can be manageable - so it can be organized, access, edited, secured and easily retrieved. This includes the generation of new content, which sometimes is done by the users of the same data.

The profile of the creators of such databases often overlaps with its users. This structured information is being used in the work of archaeologists, museum specialists, other heritage professionals, as well as students and other researchers.

2) Workflow & educational use

The workflow of the digital database creation is specific and differs from the regular archaeological work, which for its part generates sources, used for the creation of digital data. However, archaeologists could be involved in the database creation process. This is valid for the museum specialists and other heritage professionals, who catalogue artefacts and create inventories.

Depending on the needed outcome, the process of creating structured databases and repositories may include data entry into a web platform or on a computer system, as well as storing the primary data on an electronic medium. This will be handled in a different way if the dataset is stored in a physical form – a paper-based database.

If the database is created in an online environment, there is a need of an IT who specializes in the field or a team of web developers. In short, a Database Management System (DBMS) should be created. This is a challenging task and requires large financial and specialized human endeavor. This may include the services and/or products of a company specializing in the field of online database creation.

If the database will be developed on a computer system there will be a need for appropriate software, suited for the purpose. It could be that the software contains the core data and metadata, and the primary data in the form of digital files is stored separately on a HDD (less likely on a SSD) or on a server system. The choice of software and how it is used depends on the individual or an institution/company which is developing the structured database as well as the aims of the developer.

If the developer is a private person, e. g. an archaeologist, they will gather information about archaeological sites while conducting surveys and archaeological excavations (photographs, maps, geospatial data, drawings, diaries, etc.) and might create a digital database of their own work on their own computer. Usually this is done on Windows software, such as Microsoft Excel, where datasheets will contain different categories of data and metadata. The primary data could be stored on external hard drives and/or servers.

If the database creator is a heritage institution, e. g. a museum, the information will be organized and used for the creation of databases of a larger scale. Data generated by archaeologists will also be used here but these databases will also include primary data generated by other specialists – historians, ethnographers, sociologists, heritage professionals, etc. Institutions can sometimes afford to hire a company or a team of IT experts who will create their digital database. Another option, which is more suitable for museums, is to use purchase a database management software and pay for training on how to use it and adapt it to the needs of the museum.

If we shall conduct a teaching on how to create one's own digital database (e.g. using Microsoft Excel) for a small-scale project, here are the mains steps to follow:

- Explain what databases are and what are the specifics of digital databases. This should include a clarification on what DBMS is, as well as what its main components are (core data, metadata, database schema, etc.).

- If the main subject is archaeology, the specifics in relation to archaeological databases should be presented in short. This includes the database structure (it is necessary to include information about database schema in archaeology and in the heritage sector), and specifically the Dublin Core metadata standard, Europeana Semantic Elements and the Europeana Data Model.

- In relation to formulating a training assessment or a task (mini-project), clarify what the data set will include, how the size of each file of primary data will vary, what file extensions does the data set include, and what are the system requirements in order to run each file for test. Give information about the total size of the dataset and specs of the hardware needed to store the primary data.

There should be a specific task, formulated in a way that all students can execute in a relatively familiar and accessible software environment (e. g. Microsoft Excel). It could include a practical on how to create the database framework and apply it in real life, how to name the data entries, choose a suitable variety of entries based on a standardized schema (e. g. Dublin Core), how to specify the path to the primary data, and perhaps make an attempt to create links between entries.

An example of micro-learning outcomes could be the following:

• Identify the main data entry criteria relevant to archaeology.

• Perform a basic task of creating a database.

• Interpret outputs and discuss limitations.

2a) Knowledge & skills of the expert (role profile)

Generally speaking, the person who creates a digital database, generates entries and organizes the information, cannot execute the according work without the appropriate software and/or a team, which they will collaborate with. In the heritage sector, databases are usually custom-made based on the needs of the according institution, apart from personal databases. Given that the specialist has access to a DBMS which they can adjust and manage (ready-made platform or customized for their work via an IT team), the expert needs to have the following competences:

- Knowledge of the components of the database depending on the DBMS.

- Skills to edit the DBMS, create entries, links between the entries and manage the structure of the database.

- Knowledge of the database structure appropriate for the heritage sector/archaeology (e.g. awareness and skills in how to use DC and EDM).

- Understanding the scientific or scholarly subject of the primary data.

- Time to proficiency: approximate hours for introductory competence – 2-4 weeks. Acquiring advanced level of capabilities for creating databases creation, given that the specialist has access to a DBMS which they can adjust and manage (ready-made platform or customized for their work via an IT team), can go for months and even years.

3) Example(s) / Case study (concise)

If we have a theoretical example where a museum specialist needs to create a digital database of the data and materials acquired during an archaeological excavation which has gone for 1 month, they will need to acquire processed data from the archaeologist(s), geodesist(s) and other specialist conducting research and surveys. Before organizing and entering the primary data into the database, the people responsible for the museum inventory need to take inventory of it.

Such data can consist of photographs, maps, geospatial data, drawings and sketches, metric and descriptive data of artefacts, archaeological diaries, photogrammetry surveys, geophysical surveys, condition assessment reports drawn up by specialists in conservation, etc.

When adding entries to the database, the expert undertaking the task should follow the museum protocol for organizing and structuring the data, and when necessary, add new categories of information. All this may be processed in batches and not in bulk, depending on various of factors.

4) Advantages & limitations

Advantages	Limitations / Requirements
• sustainability; • transferability; • scalability; • flexibility.	• usually the cost is high when it is related to institutions; • complex software development, subject to licensing; • in terms of hardware it is best to build a server which is complex and expensive; • steep learning curve.

5) Technical requirements

Depends on whether this is done by an individual or an institution.

- individuals should use licensed software for the purpose (options depend on the needs);

- individuals need stable computing system and storage;

- for an institutional use a complex software development is needed which is subject to licensing;

- in terms of hardware for institutions it is best to build a server;

6) Ethical & data considerations

- Software should always be licensed.

- Archaeological data is sensitive and is not always open-source. Archaeological and museum databases might have restricted access. If accessing such data as a researcher, it is one’s responsibility to keep it safe.

7) Quick start (optional)

The mains steps for a small-scale project are in section “2) Workflow & educational use”.

8) References & links

The official DublinCore website	https://www.dublincore.org (retrieved on 27.04.26)
The official Europeana website	https://pro.europeana.eu/ (retrieved on 27.04.26)
Geeks for Geeks educational portal	https://www.geeksforgeeks.org (retrieved on 27.04.26)
TechTarget information portal	https://www.techtarget.com (retrieved on 27.04.26)
Müller, K. (2021). Digital Archives and Collections: Creating Online Access to Cultural Heritage (Vol. 11). Berghahn Books. https://doi.org/10.2307/j.ctv29sfzfx	Ресурс достъпен на: https://www.jstor.org/content/oa_book_monograph/j.ctv29sfzfx (retrieved on 27.04.26)

Tool 12: Digital Publication and Open Access: Publishing research and data online for findability, accessibility, and reuse.

Category (cost tier)	[**Low** / Medium / High]
Developer / Provider	[Company / **Open-source community**]
Platforms	[Windows / macOS / Linux / **Web** / Mobile]
Typical license	[Free / **Open-source** / **Academic** / Commercial]
Skill level	[Beginner / **Intermediate** / **Advanced]**
Typical use in archaeology	The digital publication of academic work in electronic editions is used for the optimal popularization of the results from archaeological research. Online catalogues and repositories with full-text data facilitate the findability, accessibility, and citability of scientific publications.

1) What the tool does (Short description)

Publishing the results of scientific research in the field of archaeology in digital editions increases the possibility of them being easily found and accessible to a wider and more specialized audience. This increases the citability of the published work. It also facilitates the study and popularization of cultural and historical heritage in relation to archaeology.

Since electronic publications are published online, access to them is filtered through payment or registration processes within digital repositories and platforms. In the other instance, electronic publications will have open access, making them available to anyone with a browser and internet connection. Open access publications keep the publisher's and author's copyright over the text. Restricted and open access to digital scientific publications in the field of archaeology also applies to digitized publications, the originals of which are on paper. Electronic publications could be preserved for a long time and eliminate the risk of running out of copies, as the case is with paper publications.

2) Workflow & educational use

In terms of the workflow in the archaeological practice, digital publications allow for the timely dissemination of the results from archaeological research. In this case, the publication of more photographs and appendices is not limited by the cost of color pages in print publications. Also, digital photos let you publish higher-quality images that show more detail when you zoom in. Digital publication optimizes the dissemination process and increases the accessibility of the work in question. Publication in electronic editions is often much faster than publication in print.

When conducting training related to publishing scientific works in electronic and open access publications, the lecturer may include the following elements:

- Familiarizing students with the main aspects from the process of publishing at scientific journals in the field of archaeology and cultural and historical heritage.

- Differentiating between the main characteristics of printed and electronic editions.

- Commenting on questions related to accessing electronic issues as well as clarifying on the specifics of the open access to digital materials.

- Proposing examples of electronic editions and digitized issues accessible online while pinpointing such examples with restricted and open access.

- Commenting on the positive aspects of accelerated publication, findability, the potential of increased citability, and the dissemination of scientific results, as well as the risks of free online access.

- Commenting on key points from the relevant legislation regarding copyright of scientific work and materials (specifically for archaeology).

- Recommend online platforms where scientists and scholars can register and track any citations and reactions towards their own work.

Suggested micro-learning outcomes:

• Acquiring knowledge and skills related to the electronic publication of scientific works in the field of archaeology and cultural heritage.

• Acquiring the skills to make informed decisions and take the right actions regarding the uploading of digital versions of one's own works.

• Competences for tracking the resonance from one’s own academic publication, including citations.

2a) Knowledge & skills of the expert (role profile)

Prerequisites for writing academic work for publication in the field of archaeology and cultural and historical heritage:

- A degree in archaeology or in cultural and historical heritage is recommended.

- Knowledge and skills in the field of archaeology and cultural and historical heritage.

- Capacity for conducting scientific or scholarly research and formulating the results into the form of academic work (research paper).

- High linguistic culture.

Knowledge and skills of the expert for publishing research and related data in electronic publications:

- Awareness (knowledge) of specialized electronic issues and publishers in the field of archaeology and cultural and historical heritage.

- Knowledge and skills related to the process and specifics related to electronic publishing of scientific works in the field of archaeology and cultural heritage.

- Knowledge of the positive aspects of accelerated publishing, optimized findability, increased citation potential, and the dissemination of scientific results, as well as the risks of free online access.

- Knowledge of the key points from the relevant copyright legislation in relation to scientific works and materials (particularly in archaeology).

- Knowledge and skills in using credible online platforms where scientists and scholars can register and track any citations and reactions towards their own work (e.g. databases for research publications and citations).

Time to proficiency: In condition that the expert covers the prerequisites for writing academic work for publication, acquiring the knowledge and skills for publishing research papers and data in electronic publications can take from a few days to several months, depending on the speed of research and training on the subject.

3) Example(s) / Case study (concise)

An example of the digital publication process:

These are some of the main steps a researcher needs to go through to publish via https://litermedia.com/:

1. The author of the article sends the text of the article with a summary and keywords to the sub-editor.

2. The sub-editor sends it to a reviewer who assesses its quality.

3. The reviewer returns it to the sub-editor, who sends it to the editor-in-chief for verification of the English summary to an email address.

4. The editor-in-chief sends it to the technical editor for publication in Litermedia.

5. The article is published in the Library section of the website: www.litermedia.com.

There are editing and citation requirements of the work, as well as minimal length of the text and file format and size.

4) Advantages & limitations

Advantages	Limitations / Requirements
• Free to mid-range cost • Lots of Open Access resources • User-friendly • Easily accessible	• It is difficult to publish in some of the journals • In paid versions incur a cost at a low to medium price range.

5) Technical requirements

Access to a decent text editor (e. g. Microsoft Word). Occasionally access to software for image processing might be needed, as the quality of the images must be need to be good.

To access materials what is needed is a stable internet connection, web browser and some hard disc space to store downloads.

6) Ethical & data considerations

If publishing in an online open access issue, the content will be easily discoverable and open to the public. A person should be mindful of potential plagiarism risks due to the high accessibility to everyone with an internet connection and a browser.

When publishing online with restricted access to the published materials, there is a filter for the data user.

When using open access materials, one should be mindful of the limitation of the text usage and copyright.

7) Quick start (optional)

N/A

8) References & links

About the journal *Contributions to Bulgarian Archaeology*	https://publications.naim.bg/index.php/CBA/about (retrieved on 27.04.26)
Bulgarian e-Journal of Archaeology	https://be-ja.org/index.php/journal (retrieved on 27.04.26)
Archaeologia Bulgarica Supplements academic series	https://www.archaeologia-bulgarica.com/archaeologia-bulgarica-supplement/ (retrieved on 27.04.26)
Litermedia digital publishing platform	https://litermedia.com/ (retrieved on 27.04.26)
Academia.edu platform	https://www.academia.edu/ (retrieved on 27.04.26)
ReseachGate platform	https://www.researchgate.net/ (retrieved on 27.04.26)
Internet Archive digital library	https://archive.org/ (retrieved on 27.04.26)
Google Scholar	https://scholar.google.com/ (retrieved on 27.04.26)
Scopus database	https://www.elsevier.com/products/scopus (retrieved on 27.04.26)

Web of Science platform	https://clarivate.com/academia-government/scientific-and-academic-research/research-discovery-and-referencing/web-of-science/ (retrieved on 27.04.26)
Instructions for using the ScholarOne Manuscripts software platform	https://videos.clarivate.com/watch/Zi1sNSbHDWM9y7UZiCq3En (retrieved on 27.04.26)
Technical requirements for publishing an article in Litermedia	https://litermedia.com/index.php?pid=9 (retrieved on 27.04.26)

6. Example Teaching Bundles

To support modular implementation, the guide includes examples of **teaching bundles** that combine complementary tools. These bundles demonstrate how different technologies can be used together in structured learning environments.

Bundle 1: Rapid Field Documentation

Tools: Photogrammetry, Field Data Collection (Mobile Apps), GIS

Purpose: Introduce students to the workflow of capturing, processing, and visualizing field data in a short time frame.

Bundle 2: 3D Reconstruction and Visualization

Tools: 3D Scanning, Photogrammetry, Blender / Meshroom

Purpose: Teach the principles of digital reconstruction, rendering, and visualization for both academic research and museum display.

Bundle 3: Public Engagement in Archaeology

Tools: Digital Storytelling, Open Access Publishing, Virtual Reality

Purpose: Encourage learners to design accessible and engaging digital heritage outputs aimed at public audiences.

7. Conclusion

The DigiArcheoSpace Guide: Modern Tools for Documenting and Presenting the Cultural Heritage in Archaeology aims to bridge the gap between traditional archaeological practice and the evolving landscape of digital technologies. By offering a clear and structured overview of tools, methods, and workflows, the guide supports both educators and students in building the necessary knowledge, skills, and competences to operate effectively within the field of digital archaeology. The presented tools demonstrate the versatility and accessibility of digital solutions, ranging from low-cost and open-source applications to specialized high-end technologies. Each tool, when properly applied, enhances the precision, sustainability, and visibility of archaeological research and heritage documentation. More importantly, the guide promotes an integrated understanding of digital workflows, emphasizing interdisciplinary collaboration between archaeologists, IT experts, designers, and heritage professionals. Through this initiative, DigiArcheoSpace contributes to modernizing higher education curricula and enriching lifelong learning opportunities in archaeology and heritage studies. The guide is envisioned not only as a teaching resource but also as a dynamic reference framework that can evolve with technological advances and future educational needs. Ultimately, it encourages digital literacy, creativity, and innovation, helping to ensure that the documentation and presentation of our shared cultural heritage remain both scientifically rigorous and publicly engaging.

8. References and Further Reading

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3. Dallas, C. (2015). *Curating archaeological knowledge in the digital continuum: from practice to infrastructure.*
4. Kansa, E., et al. (2014). *Open Context and data reuse in archaeology.*
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DIGI·ARCHEO·SPACE
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digiarcheospace.eu

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