ISSN: 2710-0170

Construction of a Low-Cost GIS-Based Recording System for Archaeological Excavation Data: Necessity and Feasibility

Zhen Wang

Beijing Union University, Beijing, China

Abstract

Field recording in archaeological excavation has long been constrained by funding, time, and personnel; data are still organized mainly through manual drawing and textual records, and stable spatial links between the different classes of records are generally absent. This paper examines whether a low-cost recording system for excavation data can be established in grassroots archaeological projects on the basis of consumer-grade equipment and open-source software, with a Geographic Information System (GIS) serving as the core of data organization. The paper first surveys the performance and cost characteristics of the equipment and software in common use, and then reviews existing work in three directions – GIS applications, 3D reconstruction and digital drawing, and platform- and database-based information management – identifying their shortcomings in data integration and cost control. In response, requirements are formulated for recording practice, system cost, and the management of 3D models. A five-stage architecture covering acquisition, processing, ingestion, management, and output is proposed, together with a hierarchical data organization scheme running from site, excavation square, and feature to artifact, file, and model, and feasibility is assessed from technical, economic, operational, and organizational perspectives. The analysis indicates that the proposed technical route is feasible for small- and medium-sized sites and rescue excavations, provided that the proportion of commercial software is controlled, data standards and naming rules are unified, and a small-scale pilot is carried out in advance. 3D models must undergo format conversion or platform-based publication before they can enter a GIS with consistent coordinates; they cannot simply be attached as ordinary files.

Keywords

Excavation data recording; geographic information system (GIS); low cost; 3D reconstruction; field archaeology.

1. Introduction

In 2021, Gao Zhenhua, Hou Miaole, Ma Sheng, and colleagues took the excavation of the Jiwutou cemetery in Wenxi, Shanxi Province, as a case study to discuss the integrated application of multiple surveying and mapping technologies in the recording of archaeological excavation information [1]. The paper drew attention to a phenomenon: considered purely as a matter of technology, surveying is already quite mature in archaeology, yet projects and institutions that actually apply several surveying techniques simultaneously to excavation recording remain few – insufficient funding, conservative attitudes of excavation directors, and the limited technical proficiency of excavation staff are all contributing causes. Field practice at the grassroots level is largely in the same situation. Recording the spatial information of features and artifacts objectively and completely remains a persistent difficulty in archaeological documentation.

Archaeological excavation is a basic link in the protection and study of cultural heritage. Because archaeological remains are non-renewable and excavation itself is irreversible and

ISSN: 2710-0170

destructive, the completeness, accuracy, and standardization of on-site records directly affect the quality of subsequent research and conservation. In recent years, archaeological institutions across China have gradually purchased surveying and imaging equipment, but municipal institutions undertake mostly rescue excavations tied to construction projects, where schedules are tight and budgets limited, and equipment and staffing often fall short of the level of research-driven excavation projects. The traditional practice of manual drawing supplemented by textual records is of limited efficiency in data integration and analysis; materials are scattered and time-consuming to compile, a gap that is evident when measured against modern archaeology's requirements for informational completeness and analytical depth.

The question addressed in this paper is the following: under existing conditions, can the forms, texts, photographs, images, and 3D models generated during excavation be organized, with GIS as the carrier, into a unified framework of spatial and excavation units, so as to form a recording system for excavation data whose cost is controllable and which grassroots institutions can operate and maintain independently? Sections 2 and 3 describe the technical conditions and review the state of research; Section 4 sets out the system requirements and overall design, with particular attention to the workflow by which 3D models enter the GIS; Section 5 analyzes feasibility from the technical, economic, operational, and organizational perspectives; Sections 6 and 7 discuss limitations and the boundary of applicability, and draw conclusions.

2. Technical Conditions for Excavation Recording: Equipment and Software

Each stage of archaeological recording depends on different technical conditions: spatial positioning and image acquisition rely on hardware, the production of drawings and 3D results relies on specialized software, and the organization and retrieval of multi-source data rely on GIS platforms. Table 1 lists the equipment and software in common use; their performance and cost characteristics form the premise of system construction.

Table 1: Commonly used equipment and software for recording archaeological excavation information

Category	Equipment / software	Main uses	Cost and learning curve	Remarks
Equipment	Cameras, camcorders	Recording of features, artifacts, and work progress	Low cost; mature and easy to operate	Widely used
Equipment	Total station, automatic level	Measurement and layout of excavation grids	Moderate cost; training required	Technically mature
Equipment	UAV (drone)	Aerial photography, orthophotos, 3D reconstruction	Consumer models below RMB 10,000	e.g., DJI Mini and Air series
Equipment	RTK	High-precision positioning, control-point measurement	Several thousand to tens of thousands of RMB	e.g., Hi-Target, CHCNAV, South Surveying
Drawing software	Photoshop, CorelDRAW,	Artifact drawings, feature drawings,	Variable cost; vector and CAD	Good format compatibility

ISSN: 2710-0170

	Illustrator, AutoCAD	site plans, square drawings	software require training	
3D software	Metashape, Pix4Dmapper, ContextCapture, 3ds Max, Blender, WebODM	3D reconstruction, model editing	Commercial licenses relatively expensive; Blender and WebODM are open source	Licensing must be distinguished
GIS software	ArcGIS, QGIS, PostGIS	Spatial data management, query, mapping	ArcGIS is commercial; QGIS and PostGIS are open source	Open-source options suit low-cost configurations

2.1. Hardware

Cameras, camcorders, levels, and total stations entered archaeological fieldwork early and are technically mature; they are used mainly for image recording, measurement, and grid layout, and are not discussed further here. Only UAVs and RTK are briefly described below.

A UAV takes off on rotor lift and can hover and operate at low altitude. In archaeology it is used mainly for rapid reconnaissance, overhead observation, and high-definition imaging; it can acquire high-resolution imagery over large areas for generating site orthophotos and 3D models, and repeated acquisition over the same area also permits monitoring of surface change. The DJI series is by far the most widely used in Chinese archaeology; its consumer-grade models (such as the Mini, Air, and Avata series) mostly cost below RMB 10,000 and already meet the accuracy requirements of routine excavation recording.

RTK (Real-Time Kinematic) is a high-precision differential GNSS positioning technique based on carrier-phase observations. During operation, a base station at a known position and one or more rovers exchange satellite observation data in real time; after common errors are reduced by differencing, positioning can reach centimeter-level accuracy. The technique requires no intervisibility between stations, delivers stable accuracy, and is little affected by weather, which makes it suitable for site control-point measurement and square positioning. The principal domestic RTK manufacturers are Hi-Target, CHCNAV, and South Surveying; prices vary widely by brand and model, from several thousand to tens of thousands of RMB.

2.2. Graphics and 3D Software

Drawing software entered the organization of archaeological materials early on, initially to digitize paper drawings of artifacts, features, strata, and subsurface plans. Each of the commonly used packages has its own division of labor: Photoshop excels at bitmap processing and can produce artifact decoration drawings that support cropping and modification, with strong pictorial expressiveness; CorelDRAW combines vector and bitmap functions, makes modest demands on hardware, and is relatively inexpensive; Illustrator produces vector graphics – small files that scale without loss of quality, with even, clear lines that are easy to revise and to export in multiple formats – and drawings intended for long-term use or publication are usually produced with it.

AutoCAD is more often used for site general plans and auger-hole layout. Combining point data measured by RTK with excavation layout plans allows feature distribution maps across a site to be drawn, and auger-hole placement and profile drawings within survey areas can also be produced with it. In addition, taking auger holes or the four walls of a square as the datum and

ISSN: 2710-0170

applying polygon topology generation, simple polygon triangulation, and Boolean operations on 3D solids, the strata within an excavation area can be modeled individually and then joined to obtain 3D models of squares and even of individual features. The viability of this approach was verified by Hu Yu, who built a prototype system for the 3D modeling of excavation squares based on sections in his master's thesis [2].

The situation with 3D software is more complex and falls broadly into two groups. The photogrammetric group recovers geometry and texture through automatic matching of multi-view imagery; Agisoft Metashape (formerly Photoscan), Pix4Dmapper, and ContextCapture all belong to it. Metashape automatically generates 3D models and high-resolution textures through image feature analysis, supports a variety of cameras, and handles imagery ranging from aerial photographs to close-range shots; Pix4Dmapper targets UAV data processing and automatically converts images into 3D models, point clouds, digital surface models, and orthophotos; ContextCapture, built on computer vision and photogrammetric methods, computes feature points, camera poses, and spatial coordinates from multi-angle photographs or laser point clouds, and is widely used in the reality-based 3D reconstruction of large sites. The other group centers on manual modeling and result editing: 3ds Max offers comprehensive modeling, texturing, lighting, rendering, and animation workflows suited to the post-processing and presentation of models, while Blender, free and open source, has comparable modeling, editing, and rendering capabilities. WebODM lies between the two groups: based on the open-source photogrammetric framework OpenDroneMap, it can be deployed locally to produce orthophotos and 3D models. The two groups differ in accuracy control, automation, and modes of presentation, and the differences in licensing and price directly determine how software is allocated in a low-cost scheme.

2.3. GIS Platforms

ArcGIS is a computer software system for managing and processing geographic information. Drawing on a computer's capacities for storage, mathematical analysis, retrieval, simulation, and display, it handles large volumes of geographic data, with functions spanning spatial data modeling, data capture and input, processing and analysis, and output and visualization. Foreign archaeological research institutions and universities adopted it early for site survey, excavation, and research; in recent years, some major Chinese excavation projects have also begun to use it for the digital recording of sites.

QGIS is an open-source GIS written in C++ that runs cross-platform and reads and writes a wide range of geodata formats through the GDAL/OGR libraries, offering data browsing and management, cartography, spatial analysis, and plugin extension. It is free and supports a broader range of data formats than ArcGIS, with a simpler interface; ArcGIS offers more complete functionality and toolboxes, better performance and stability with large datasets, and professional technical support. PostGIS is a spatial extension of PostgreSQL that stores vector and raster data at the database level and provides spatial query capability. The data volume of archaeological excavation records is limited to a single site, and analytical needs center on retrieval, statistics, and mapping, which QGIS and PostGIS are fully able to shoulder as the backbone of data organization – one of the main reasons why this paper chooses an open-source foundation for the system.

3. Research Status and Its Shortcomings

Work relevant to this paper falls roughly into three directions: GIS applications in archaeological research, 3D reconstruction and digital drawing, and the construction of archaeological information platforms and databases. They are reviewed in that order, and the shortcomings of existing research are then identified.

ISSN: 2710-0170

3.1. GIS Applications in Archaeological Research

Liu Jianguo was among the first to introduce systematically the application of GIS in archaeological research, covering the processing of spatial data and its support for settlement-pattern and regional studies [3]. Later, reviewing a century of archaeological surveying and mapping, he further observed that the renewal of surveying techniques and the development of archaeology have continuously reinforced each other [4]. These two works prepared the methodological ground for GIS to enter archaeological recording.

The representative effort to apply GIS to the organization of concrete records is Fu Zhongyang's discussion of drawing feature maps with ArcGIS in combination with Illustrator. Beyond demonstrating the efficiency of ArcGIS in producing feature plans, the paper attends to its value in spatial analysis: with GIS spatial data models and algorithms, various spatial data models can be generated to reveal the links among records and their patterns of change, serving archaeological research, heritage conservation, and records management [5]. In this work, drawing ceased to be merely a means of presentation and began to serve the analysis of spatial relations.

Yu Chong's attention turned instead to attribute data. Taking zooarchaeology as an example, he noted that thematic research based on identifications or reports of excavated animal bones consumes much time in the collection, classification, and retrieval of basic materials, and that discriminating, decomposing, computing, and comparing the data are equally inconvenient; since such basic work varies with the individual, derived data carry considerable error, and comprehensive research is difficult to advance. His solution was to introduce database technology into the standardized entry and analysis of zooarchaeological records, and he further discussed the feasibility of organizing relational data into geographic spatial information models with software such as ArcGIS, in support of integrated research across multiple data items [6]. By this point, the two basic roles of GIS in record organization – fixing spatial positions and linking spatial positions with attribute data – had both been put into practice.

3.2. 3D Reconstruction and Digital Drawing

Zhou Zhenyu and colleagues were early to bring 3D reconstruction into field archaeology. Zhou first described the use of multi-view 3D reconstruction in the field archaeology of Paleolithic sites [7] and subsequently worked with Guan Ying to apply the technique to lithic studies, examining what 3D models can contribute to the measurement and recording of stone artifacts [8]. He Kai approached the matter from the perspective of drawing and summarized practical experience in applying multi-view 3D reconstruction to field archaeological drawing [9]. These studies point to the same conclusion: 3D models serve not only presentation but also measurement and cartography.

It was again Fu Zhongyang who pushed this line further toward integration. In 2016, building on his 2014 research, he used Photoscan to complete the 3D reconstruction of features and combined it with Illustrator for field archaeological drawing, linking the production of 3D models with that of 2D line drawings [10]; in 2018 he chained Photoscan, Photoshop, and Illustrator together for artifact drawing, improving both drafting accuracy and working efficiency [11]. 3D reconstruction thereby acquired a place in the routine workflow of archaeological drawing.

More recent work comes from Qi Bing and Cui Junjun, who comparatively evaluated ContextCapture and Blender for reconstruction: at comparable processing time, ContextCapture produced models of more accurate dimensions and richer detail, outperforming other mainstream reconstruction software in model accuracy, computation time, texture quality, and memory management, while Blender's strengths lie in being free, open source, easy to learn, and fully featured [12]. The scheme was demonstrated on a bronze

ISSN: 2710-0170

ding excavated from the Zhou-period cemetery at Taosibei, Shanxi, covering the operational workflow and precautions from image capture to model computation, together with Blender-based export of front orthographic views, half-sections, segmented decoration unfoldings, virtual photography, and digital rubbings; the authors consider the scheme readily extendable to the 3D reconstruction of pottery, stone artifacts, and features. By this stage, the outputs of 3D reconstruction had grown beyond visualization models to survey-grade drawings – but models and images alike were still stored separately.

3.3. Archaeological Information Platforms and Remaining Gaps

In platform construction, the work at the Qin Mausoleum is the most systematic. For the Qin Mausoleum archaeological information system, Zhang Yi, Zhang Liying and Zhang Weixing, and Xu Yanchao successively proposed GIS- or WebGIS-based schemes [13][14][15], and Zhang Chunsen et al. presented a design and implementation under the B/S model [16]. Similar local initiatives include Yao Ya's exploration of an archaeological GIS for the Liangzhu site cluster [17], the GIS-based archaeological information sharing platform for Northeast Anti-Japanese United Army sites designed by Cong Xiaodan et al. [18], and the database of ancient glass beads unearthed in China built by Feng Bailing [19]. At the level of specialized applications, the 3D GIS for cultural relic management designed by Cui Lipeng et al. [20] and Xu Lei and Tian Lin's discussion of the hierarchical construction of an informatized cultural-resource management system oriented to the "one map" of territorial spatial planning [21] also belong to this category.

These practices demonstrate that GIS is capable of carrying the integrated management of excavation records and relic information; the difficulty lies in the model of construction. Such systems are mostly custom-built by professional teams for a particular site or institution; their functions and data structures are hard to port, and development, maintenance, and upgrading all depend on dedicated IT staff, so the investment per system is high and beyond the reach of municipal institutions and rescue projects in both cost and personnel. As for GIS in regional archaeological survey, although its spatial analysis capability has been demonstrated, such work is oriented to human–land relations at the regional scale and does not touch the organization of on-site excavation records.

Viewed together, the three bodies of work expose their gaps. Equipment, software, and platforms each handle one segment and pass material on by hand; an integrated workflow for the excavation site has yet to be assembled. 3D models remain loosely coupled to squares, feature units, and artifact numbers; how models enter a GIS and how coordinates and attributes stay consistent have received little discussion, and no mature scheme appears in the literature known to the author. And on how a system should be configured, operated, and staffed under low-cost conditions, existing platforms – generally built with complete functionality as the goal – offer little systematic argument. The lightweight scheme proposed in this paper, based on open-source software with GIS at the core of data organization, is directed precisely at these three points; the design is set out below, and its feasibility is then argued.

4. System Requirements and Overall Design

It is worth stating first what the system is and is not. It is not a custom-developed information platform; its core is a single task: with GIS as the hub of data organization, to place the various records generated during excavation into spatial and excavation units so that they can be retrieved and consulted while excavation is under way. Business functions such as excavation management and personnel scheduling are out of scope – the boundary of the system ends at the organization and output of records.

4.1. Requirements Analysis

Problems in the current recording of field archaeological data concentrate in three areas.

ISSN: 2710-0170

The recording method is the most visible problem. Manual drawing and textual records remain the norm; data gathered on site are usually left to be sorted out during the post-excavation stage, which is inefficient, and drawing quality and precision vary with the draughtsperson's experience; the stockpiling approach to processing also delays the publication of data and of excavation reports.

Cost is equally prominent. The Qin Mausoleum systems and university thematic databases described above were built with dedicated funds and professional teams and are beyond the reach of ordinary municipal institutions; according to public reports, the Sanxingdui excavation team and the Beijing Archaeological Research Institute, among others, maintain internal resource management systems of a similar kind, and licensing fees for commercial GIS and 3D software add a further burden to rescue projects with tight budgets.

The third problem lies with 3D models. In most projects that do carry out reconstruction, models are stored as isolated files with no stable links to squares, feature units, artifact numbers, photographs, or forms, and cannot be retrieved by unit during post-excavation processing. Archaeological remains are non-renewable; omissions in on-site records cannot be remedied later.

In response, the system must satisfy at least three requirements: unified numbering rules and data standards, so that records produced by different people at different stages correspond to the same spatial unit; construction and operating costs held within what a grassroots institution can bear, without reliance on dedicated IT staff; and associative retrieval linking multi-source records (including 3D models) to spatial positions. The design goals may be summarized as usable, maintainable, and transferable.

4.2. Overall Architecture and Data Organization

The system consists of five stages – acquisition, processing, ingestion, management, and output – joined by unified numbering and directory structures.

Acquisition uses conventional equipment: cameras, UAVs, RTK, total stations, plus field forms. The key at this stage lies in precise rules: images are named uniformly as "site code – year – square number – unit number – file type – serial number"; RTK and total-station data must record the coordinate system and central meridian employed; form fields cover unit number, stratigraphic position, dimensions, condition of preservation, capture time, equipment, and photographer, with fields reserved for linking to model files.

Processing covers two tasks, 2D drawing and 3D reconstruction. Artifact and feature drawings are produced with Illustrator, Photoshop, or CorelDRAW as the object requires; 3D models of features and squares are processed with software chosen by object scale, as detailed in Section 4.3.

Ingestion rests on QGIS and PostGIS, with QGIS plus a file-based database as an option where data volumes are small. The hierarchy runs from site, square, feature, artifact, and file to 3D model and spatial coordinates: each feature carries a unique number; every file is bound to a number; and model files additionally carry metadata recording the coordinate system, scale, capture time, processing software, achieved accuracy, and person responsible. JPG, PNG, PDF, and DXF outputs from drawing software are all read directly by the GIS without conversion. Once organized in this way, maps, aerial photographs, and images supply positions, texts and data tables supply attributes, and numbering and coordinates match the two classes of records to each other – the capacity of GIS to handle spatial and non-spatial data together is realized in this system precisely as such associations.

Management covers form entry, image management, model indexing, a feature tree, spatial query, layer management, and export of results. Four classes of users hold different permissions: excavators may enter and view only the records of their own unit; draftsmen maintain drawings and model files; numbering, ingestion, and backup belong to the records

ISSN: 2710-0170

administrator; and full-database query and export rest with the excavation director. Deployment need not be accomplished in one step – a stand-alone or LAN version comes first, and WebGIS can be considered as data volumes and collaboration needs grow.

Output includes feature plans, square drawings, artifact drawings, 3D model viewers, statistics tables, and illustrations for excavation reports. The functional scope ends there: records can be stored, retrieved, matched, and output – and no further.

Three considerations underlie this design: no custom development, with cost compressed through combinations of existing software; coexistence of files and a database, to accommodate large model data; and metadata that guarantees the traceability of results.

4.3. Generation and Ingestion of 3D Models

Whether 3D models can enter the GIS stably is the most critical link in the system design. By object scale, the reconstruction workflow falls into two classes.

For large features the workflow proceeds in several steps: multi-angle image capture first; import into Metashape for aerial triangulation, dense matching, and tie-pointing, exporting a Block Exchange XML file (file names must be restricted to letters and digits to avoid character-encoding problems); then wholesale import of the triangulated block into ContextCapture for reality-based 3D reconstruction, and export of the final OSGB model together with its accompanying Data folder and metadata files. Small features and artifacts are far simpler – ContextCapture reconstructs and exports OSGB directly. The author has practiced this workflow: image capture takes less time than drawing in the field, reconstruction runs offline automatically once parameters are set, and the accuracy of the results is reasonably stable.

A model fresh from export does not yet meet the conditions for ingestion. OSGB is oriented to reality-based 3D viewing, and desktop GIS such as QGIS lack native layer management for it, so two steps are required before ingestion: first, convert OSGB into 3D Tiles, glTF, or similar formats that support 3D tile scheduling and network transfer; second, align the model's coordinate system and scale with the site control points. Where online viewing and sharing are needed, the model can also be published as a 3D service through Cesium or GeoServer and attached to the system by its service address. Storing model files in a fixed folder and noting their spatial positions amounts to archival only, not to a system function; format conversion and coordinate matching must be settled at the workflow-design stage, or the models will remain isolated files.

After these steps, models are bound to feature numbers, with reconstruction accuracy and processing parameters recorded in the metadata. During post-excavation processing, models of different excavation stages can then be retrieved by square or unit and cross-checked against images and forms – a far more intuitive procedure than verification from plans and photographs alone.

5. Feasibility Analysis

5.1. Technical Feasibility

For acquisition, consumer-grade UAVs and ordinary cameras suffice for on-site imagery, with control points supplied by RTK; the reconstruction needs of small and medium features and artifacts can be met. For processing, the reconstruction capabilities of Metashape and ContextCapture have been validated in multiple studies [7][10][12]; editing and retouching can be left to Blender, and WebODM offers a reconstruction path free of commercial licensing. Management and output are comparatively simple: QGIS supports a wide range of vector and raster formats, PostGIS carries spatial data storage and query, and together they suffice for the records management of a single site; JPG, PNG, PDF, and DXF outputs from common drawing software can also be exchanged with the GIS in both directions.

ISSN: 2710-0170

The real difficulty lies not in reconstruction itself – once models enter the GIS, whether coordinates, numbers, and attributes still match up is what matters. It is essentially a workflow-design problem: unify the naming rules, the coordinate system, and the metadata tables, and the technical obstacles disappear.

5.2. Economic Feasibility

"Low cost" in this paper does not mean spending nothing; it means that construction and operating outlays stay within what a grassroots archaeological institution can bear and that daily operation requires no dedicated IT staff. Within this definition, the amount of commercial software determines two routes: the fully open-source route uses only QGIS, PostGIS, WebODM, and Blender, an option for rescue projects under budget pressure; the hybrid route retains a small number of commercial licenses on the open-source base, drawn on for high-precision reconstruction or complex graphics. The cost items and configuration logic of the two routes are compared in Table 2.

Table 2: Cost items and configuration of the two low-cost options

Cost item	Fully open-source option	Hybrid option	Notes
UAV	Consumer model (below RMB 10,000)	Consumer model	Meets routine recording accuracy
Camera	Existing equipment or consumer camera	Existing equipment or mid-range camera	High-resolution models unnecessary
RTK	Rental or shared across projects	Entry-level purchase (from several thousand RMB)	For control-point measurement
Computer	Standard graphics workstation	Higher-specification workstation	3D processing limited by memory and GPU
3D software	WebODM, Blender (free)	Per-project licenses of Metashape or ContextCapture	Commercial licenses configured per project, not kept on hand
GIS software	QGIS, PostGIS (free)	QGIS, PostGIS (free)	Sufficient for data organization and mapping
Storage and backup	Portable hard drive	NAS plus off-site backup	Large image and model data volumes
Training	Internal training	Internal plus short external training	A fixed workflow must be established

Note: Prices in Table 2 are indicative of magnitude only; actual outlays for equipment and software fluctuate with brand, model, and procurement channel, and each institution should determine them by local quotation.

Spending concentrates on equipment and computing resources; software licensing can be compressed by raising the open-source share. Compared with commissioning a custom archaeological GIS, the initial investment and subsequent maintenance of this scheme are far cheaper, and there is no dependence on long-term support from a developer. One point, however, deserves emphasis: low cost is not the same as low investment. Storage and backup cost money, and training and record processing consume staff time; all of these must be counted in the costing – and the last two are the most easily overlooked.

ISSN: 2710-0170

5.3. Operational and Organizational Feasibility

Daily operation requires little specialized skill. Grassroots archaeologists need no command of GIS analysis; four competencies suffice: naming images and forms by the unified rules, collecting and recording control points with RTK, organizing attribute data on templates, and viewing layers and attaching external files in QGIS. 3D reconstruction is different – its demands on computing power and experience are high, and it is best concentrated in the hands of a few staff members or outsourced per project, rather than required of every excavator. Training should likewise be organized around the workflow: software principles kept to a minimum, with naming rules, coordinate systems, metadata entry, and backup procedures covered thoroughly.

Organizational work centers on two matters, piloting and institutionalization. A pilot should begin with a single square or a small site, recording labor hours for image capture and processing, model accuracy, software costs, and staffing, on the basis of which the case for wider adoption can be assessed; at the pilot stage the aim is not functional completeness but opening up the correspondence between images, forms, models, and spatial positions. At the same time, a records administrator should be designated, responsible for numbering, ingestion, and backup, with storage locations and backup cycles fixed by institutional rule so that records do not end up scattered across personal computers.

6. Discussion

Several shortcomings remain in the argument of this paper. First, no systematic accuracy validation was carried out: consumer-grade equipment performs inconsistently under different lighting, terrain, and preservation conditions, and in application, checkpoints should be installed and results assessed by sampling. Second, data volume: 3D models are large, and ordinary computers processing several squares at once easily encounter performance bottlenecks, to be mitigated through model simplification, levels of detail, and on-demand loading. Third, QGIS's native support for 3D data is limited, and the choice among OSGB, 3D Tiles, and glTF – suited respectively to viewing, analysis, and long-term preservation – still lacks accumulated practice. The last problem is institutional: long-term operation depends on institutional guarantees that individual enthusiasm cannot sustain, and handover of records when staff change must also be designed for in advance.

These limitations also mark the boundary of the conclusions. "Feasible" here means small- and medium-sized sites and rescue excavations: a lightweight GIS recording system built mainly on consumer-grade equipment and open-source software, technically attainable and economically bearable. Large sites, long-term research-driven excavations, and projects with demanding precision requirements fall outside this scope – professional equipment and commercial software remain necessary there. Compared with existing integrated platforms, the advantages of this scheme are cost and replicability, at the price of limited functional depth: cross-site synthesis and multi-institution collaboration are beyond it. Future work has two directions: comparative trials across multiple sites to accumulate accuracy data and gradually map equipment configurations to accuracy requirements; and, as 3D data standards evolve, refinement of the format specifications and metadata scheme for model ingestion.

7. Conclusion

To return to the opening question: building a low-cost GIS-based recording system for excavation data is feasible under the conditions of grassroots archaeology. The key lies not in the platform but in organization – using unified numbering rules and coordinate systems to gather the forms, texts, photographs, images, and 3D models of the excavation site into a single

ISSN: 2710-0170

spatial framework, with management and output handled by open-source tools such as QGIS. The barrier to entry falls accordingly: model editing with Blender, image-based reconstruction with WebODM, data management with QGIS and PostGIS; commercial packages such as Metashape and ContextCapture are best kept as supplements for particular stages, rather than listed as necessary conditions of a low-cost scheme.

For the system to take root, the proportion of commercial software must be controlled, data standards and naming rules unified, and a small-scale pilot run first with costs accounted on actual figures. Moreover, 3D models must complete format conversion and coordinate matching before entering the GIS – a step to be settled at the design stage, or the models will remain outside the record system.

References

[1] Gao, Z. H., Hou, M. L., Ma, S., et al. (2021). Comprehensive application of multiple surveying and mapping technologies in archaeological excavation information recording: a case study of the Jiwutou cemetery in Wenxi County. China Cultural Heritage, (1), 66–73. [In Chinese]

[2] Hu, Y. (2011). Research on the 3D modeling method of archaeological excavation squares based on sections [Master's thesis]. Nanjing Normal University. [In Chinese]

[3] Liu, J. G. (2006). Application of geographic information systems in archaeological research. Social Sciences Management and Review, (1), 79–86. [In Chinese]

[4] Liu, J. G. (2021). A century of archaeological surveying and mapping. Jianghan Archaeology, (6), 229–232. [In Chinese]

[5] Fu, Z. Y. (2014). The method and application of drawing feature maps using ArcGIS and Adobe Illustrator. Southern Cultural Relics, (3), 145–151, 144. [In Chinese]

[6] Yu, C. (2015). Application of the relational model database in zooarchaeology. Kaogu (Archaeology), (4), 102–107. [In Chinese]

[7] Zhou, Z. Y. (2016). Application of multi-view 3D reconstruction technology in the field archaeology of Paleolithic sites. Kaogu (Archaeology), (7), 102–110. [In Chinese]

[8] Zhou, Z. Y., & Guan, Y. (2017). Application of multi-view 3D reconstruction technology in the study of lithic artifacts. Acta Anthropologica Sinica, 36(1), 38–48. [In Chinese]

[9] He, K. (2022). Application of multi-view 3D reconstruction in field archaeological drawing. Popular Archaeology, (2), 86–91. [In Chinese]

[10] Fu, Z. Y. (2016). Comprehensive application of Agisoft Photoscan and Adobe Illustrator in field archaeological drawing. Sichuan Cultural Relics, (4), 88–96. [In Chinese]

[11] Fu, Z. Y. (2018). Comprehensive application of Agisoft Photoscan, Adobe Illustrator and Adobe Photoshop in archaeological artifact drawing. Southern Cultural Relics, (1), 200–209. [In Chinese]

[12] Qi, B., & Cui, J. J. (2024). A scheme for 3D reconstruction and model application of cultural relics based on Bentley ContextCapture and Blender. Kaoguxue Jikan (Chinese Journal of Archaeology), (1), 182–195. [In Chinese]

[13] Zhang, Y. (2012). Research on the implementation of the Qin Mausoleum archaeological information system based on GIS [Master's thesis]. Xi'an University of Science and Technology. [In Chinese]

[14] Zhang, L. Y., & Zhang, W. X. (2013). The archaeological information system of the Emperor Qinshihuang's Mausoleum. Museum of the Emperor Qinshihuang's Mausoleum Site, 215–219. [In Chinese]

[15] Xu, Y. C. (2014). Research on the implementation of the Qin Mausoleum archaeological information system based on WebGIS [Master's thesis]. Xi'an University of Science and Technology. [In Chinese]

[16] Zhang, C. S., Xu, Y. C., & Zhang, W. X. (2015). Design and implementation of the Qin Mausoleum archaeological GIS system based on the B/S model. Sciences of Conservation and Archaeology, 27(4), 83–87. [In Chinese]

ISSN: 2710-0170

[17] Yao, Y. (2013). Exploration of the construction of an archaeological geographic information system for the Liangzhu site cluster. Southern Cultural Relics, (3), 125–128. [In Chinese]

[18] Cong, X. D., Deng, Q., & Song, C. J. (2024). Design and implementation of a GIS-based archaeological information sharing platform for the sites of the Northeast Anti-Japanese United Army. Automation Technology and Application, 43(9), 141–145. [In Chinese]

[19] Feng, B. L. (2021). Construction and application of a database of ancient glass beads unearthed in China [Master's thesis]. Northwest University. [In Chinese]

[20] Cui, L. P., Gao, F., Ye, Z. R., et al. (2020). Design and implementation of a 3D GIS system for cultural relic management. Geotechnical Investigation and Surveying, 48(5), 75–78. [In Chinese]

[21] Xu, L., & Tian, L. (2021). Research on the construction hierarchy of an informatized management system for cultural resources oriented to the "one map" of territorial spatial planning. Science of Chinese Cultural Relics, (3), 33–41. [In Chinese]