Integrated workflow for 3D documentation and spatial analysis of Jewish sepulchral heritage – Project "Stone Witnesses Digital: Space, Form, Inscription."

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Abstract

The "Stone Witnesses Digital" project ensures the exemplary documentation of a selected number of German Jewish graveyards. This paper presents the results from the first years of the project's geomatics work, including the development of an integrated multi-sensor workflow for 3D imaging—ranging from geographic-scale documentation of entire graveyards (1:200 scale) to detailed feature imaging of individual gravestones (1:20 scale). The workflow supports the long-term research project on Jewish sepulchral culture and brings together expertise from Jewish Studies, Digital Technologies in Heritage Conservation, and Historic Building Research. The overarching scope is to document the location and context of gravestones, their materiality, decorative elements, inscriptions, and the meanings embedded within them—summarized under the guiding concept "Space, Form, Inscription." The aim of the project is to create a comprehensive digital dataset that documents inscriptions as well as the spatial and structural characteristics of gravestones, thereby ensuring their long-term preservation and making them accessible for further academic research. To achieve this, the workflow must integrate various sensing and 3D imaging techniques, ensure reliable and sustainable data storage, and support reproducible dataset creation for spatio-temporal analyses and long-term monitoring of graveyards throughout the 24-year project period. It also enables the combination of advanced sensing technologies with semantic web standards and facilitates the creation of informative Open Access outputs compliant with FAIR data principles.

1. Introduction

The documentation of local Jewish cemeteries and their funerary culture - through geometric survey and textual recording - plays a crucial role in creating a resource accessible to stakeholders such as historians, epigraphers, heritage professionals, and local communities. Such documentation allows users to explore the cultural traditions and historical contexts of the German Jewish community and their ancestors. The need for comprehensive and precise documentation is deeply rooted in Jewish cultural beliefs. This is particularly relevant for Jewish cemeteries, which possess an ephemeral character and are traditionally regarded as Houses of Eternity, where extensive restoration is culturally prohibited.

The project *Stone Witnesses Digital – German-Jewish Sepulchral Culture between the Middle Ages and Modernity. Space, Form, Inscription* ensures the exemplary documentation of German Jewish graveyards in a larger interdisciplinary context (Steinerne Zeugen digital, 2026). The project started in 2023 as part of the research program of the German Academies of Sciences and Humanities. Researchers from the Steinheim-Institute (Essen) and the University of Bamberg work together to document and analyse Jewish cemeteries in German-speaking regions dating back to the 16th century (Project team 'Steinerne Zeugen digital', 2025). The project brings together expertise from Jewish Studies, Digital Technologies in Heritage Conservation, and Historic Building Research as well as Digital Humanities approaches. The aim of the project is to create a comprehensive digital dataset to form a corpus that documents inscriptions as well as the spatial and structural characteristics of Jewish gravestones, thereby ensuring their long-term preservation and making them accessible for further academic research. 35 cemeteries in Germany with more than 34,000 gravestones and 20,000 inscriptions are being recorded through a fully digital workflow (Talabardon and Hess, 2025). This approach allows the gravestones of selected cemeteries - their inscriptions, design and construction, materiality, state of preservation, and spatial arrangement – to be systematically analysed both synchronically and diachronically. The resulting dataset and its database will provide a valuable foundation for exploring the significance of these monuments for German-Jewish history of the pre-modern period.

This paper presents the results from the initial years of the project's geomatic work, including the development of an integrated multi-sensor workflow for 3D imaging, which covers a wide range of scales, from geographic-scale documentation of entire graveyards (1:200) to detailed feature

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recording of individual gravestones (1:10) see Figure 1. For the purposes of this paper, one representative gravestone has been selected as a case study at Walsdorf Cemetery (Figure 4). An analysis of the 3D imaging technologies applied within the project is presented. Particular attention is given to the achievable level of detail and the resulting level of information, as well as to the relationship between data quality and scale.

2. State-of-the art for multi-scale recording of cemeteries

In the context of heritage conservation, minimum documentation refers to the lowest level of geometric and semantic information required to reliably record, understand, and preserve a cultural asset for future research, conservation, and interpretation. It ensures that essential characteristics - such as form, dimensions, material properties, condition, and inscriptions - are captured with sufficient accuracy and resolution to support conservation decisions, monitoring, and scholarly analysis (Schuller, 2002; Letellier, Schmid and LeBlanc, 2008).

This understanding is consistent with recent work by (Markiewicz *et al.*, 2025), who define heritage documentation as the integrated recording of and synthesis of geometric and qualitative information, adapted to the specific purpose, scale, and constraints of a project to give overarching guidelines. This concept aligns with current approaches in digital heritage documentation, where a required level of detail is defined according to the intended use, significance of the object, and needs of different disciplines. As such, minimum documentation can be understood as a threshold within the framework of the Level of Information Need, ensuring that data acquisition is efficient and fit for purpose, as also emphasized in the context of integrated European recommendations for heritage documentation (Markiewicz *et al.*, 2025). Several international projects provide valuable references for the digital documentation of cemeteries and sepulchral heritage, combining geomatic, archaeological, and digital humanities methods. This ensures that data acquisition is fit for purpose, balancing efficiency with scientific and preservation relevance.

A detailed state-of-the-art discussion has recently been provided by Puglisi and Hess (2026). In summary, numerous cemetery documentation projects have employed multiple complementary technologies to deliver a comprehensive and detailed representation of geometry, texture, and inscriptions. A notable example is the research conducted by the Bruno Kessler Foundation, which demonstrates efficient on-site recording and integration of diverse data sources. (Remondino and Rizzi, 2010). Previous research in heritage documentation highlights the importance of differentiating model detail and information requirements to serve varied analytical objectives. Schokland case studies underline the necessity for multiscale, integrated data approaches, implying the need for variable levels of model detail (Van Lanen, Van Beek and Kosian, 2022). Some projects address lost or destroyed cemeteries, such as the Julfa Cemetery Digital Repatriation Project (Armenia), where archival photographs and 3D reconstruction were combined to virtually restore gravestones (Short, Crispin and Baker, 2017). Digitized funerary art initiatives, e.g., Bellu Cemetery (Romania), focus on cultural-historical interpretation and public engagement rather than strict geometric accuracy (Angheluță and Tănașcu, 2025). From a technological perspective, projects exhibit a heterogeneous use of sensing technologies. TLS remains the standard for high-resolution documentation of static monuments, while Mobile Laser Scanning (MLS) captures extended spatial context (Zachos and Anagnostopoulos, 2024). Integrative workflows combining UAV, TLS, and MLS allow scalable, context-rich digital twins (Lee *et al.*, 2025), while TLS alone suffices for detailed 3D modeling of individual objects (Downs *et al.*, 2020)

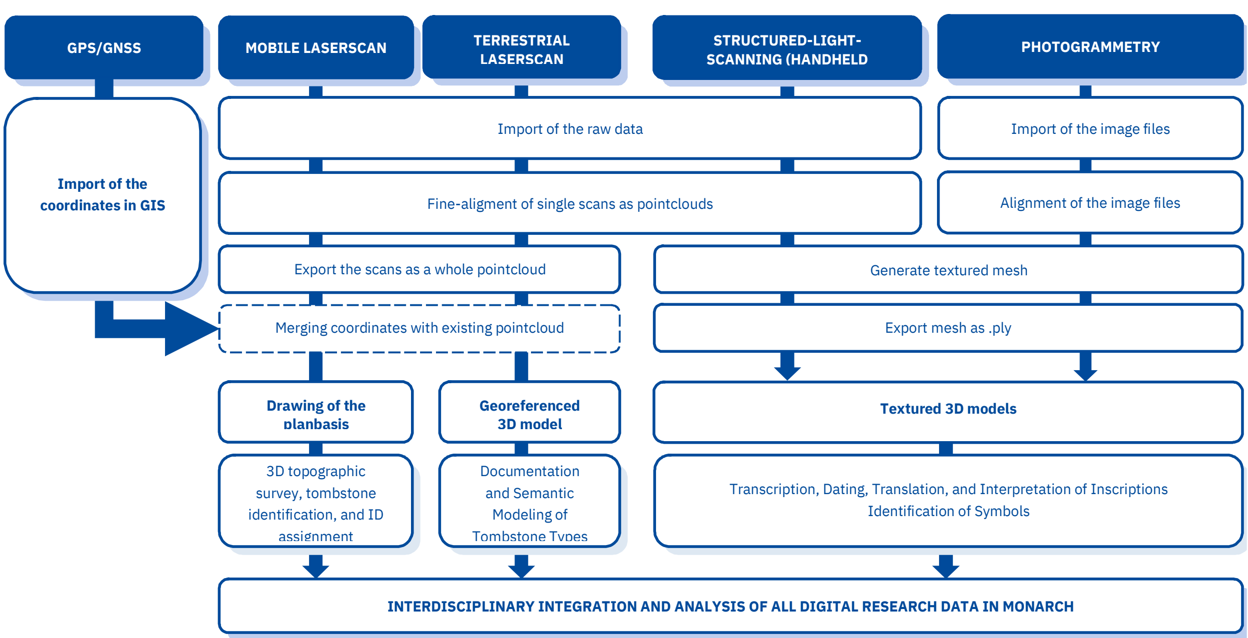


Figure 1. Generalised processing workflow for Stone Witnesses digital.

A particularly relevant reference for object-centered documentation is the STECCI project (Stone Epitaphs: Textual, Cultural and Contextual Information) (‘STECCI’, 2026). This is an interdisciplinary digital heritage initiative dedicated to the high-resolution 3D documentation and semantic enrichment of stone inscriptions. It combines TLS with image-based photogrammetry (SfM) to produce detailed 3D models, enhancing texture quality, micromorphology, and inscription legibility. These models are further enriched through semantic annotation and GIS/database integration, linking geometry, text, materiality, and contextual information within a coherent digital framework. Although focused on individual objects, workflows are highly transferable to cemetery-scale projects, particularly for epigraphic analysis, material documentation, and semantic 3D modeling (Drešković and Radulović, 2024).

The reviewed projects highlight the importance of multi-scale, multi-sensor, and semantically enriched approaches. They demonstrate that combining UAV, TLS, MLS, GIS, and semantic modeling in a unified digital framework allows detailed spatial and temporal analyses of cemeteries as complex cultural landscapes, aligning with the principles outlined in the study of Puglisi and Hess, 2026.

3. Methodology: data acquisition - recording of space, form, inscription

The overarching aim is to document the location and context of gravestones, their materiality, decorative elements, inscriptions, and the meanings embedded within them - summarized under the guiding concept of the project ‘Space, Form, Inscription’. To achieve this, the workflow must integrate various sensing and 3D imaging techniques, ensure reliable and sustainable data storage, and support reproducible dataset creation for spatio-temporal analyses and long-term monitoring of graveyards throughout the 24-year project period. The workflow is designed to provide a feasible and transferable methodology for heritage recording that can be applied to other cemeteries and sepulchral contexts in an interdisciplinary context (Figure 1). The measurement and recording workflow is discussed as focus in this paper.

For an integrated workflow the following sensor technologies are employed: MLS for rapid large-area acquisition, TLS for high-precision spatial documentation, close-range photogrammetry for detailed surface imaging and close-range structured-light or laser scanning for high-resolution recording of inscriptions and material characteristics. As and when needed, geo-referencing is included in a variety of ways (ie, as part of a Riegl scanner system or external GPS/GNSS). The sensors used at the time of writing (Spring 2026) are specified in Table 1. All these modalities must be interoperable not only within the project but also with external stakeholders, such as the Bavarian Heritage authorities and their GIS databases. Furthermore, a workflow for the unique identification of each gravestone - supported by clear, standardized images of all sides - is required to facilitate collaboration with researchers from Epigraphy, Jewish Studies, and Historic Building Research. The reason for employing such a diverse set of methods and sensors is fundamentally tied to the workflow of cemetery documentation. After locating each stone on a general plan, each gravestone must be uniquely identified, i.e., its precise location determined. Then, the gravestone itself must be recorded, which can require different methods and

Method of acquisition	**Mobile laser scanning**	**Terrestrial laser scanning**	**Handheld/ Fringe Projection scanning**	**Photogrammetry**
System	Geoslam Horizon (2020)	BLK Gen.1 Leica Geosystems (2018)	Shining 3D Einscan Libre 1.0,1.(2024)	SfM
Wavelength	903nm	830nm (invisible)	IR, VIS, blue laser	VIS (RGB)
Range precision/ accuracy	Scan range noise ±30mm	6 mm at 10 m, 8 mm at 20m	Point distance (resolution) 0.05 ~ 3 mm (Laser HD Mode)	0,1mm
Max. range	100m	60m @78% albedo	1.0 m (at Laser HD Mode)	0,01m-unlimited
Scan rate per scanner	300,000 points/s; 160 lines/s (16 lines @ 10Hz)	360,000 points/second	4,500,000 points/s	not applicable
Distance measurement method	TOF coupled with IMU	TOF (time of flight) with Waveform Digitising (WFD)	Infrared VCSEL, IR Laser Lines, Blue Laser Line	Triangulation from overlapping images (SfM)
Colour recording	Yes, separate Camera	yes, 3x HDR, 2592x1944 pix, full panorama 150Mpx, 360 x 300 deg	48MP color camera	colour calibrated from images (X-rite)
Weight	ca. 3,5kg + 0,6 kg (battery)	1 kg (scanhead), 2kg (est. Tripod Manfrotto)	approximately 1,8 kg including battery	0,5-1,0 kg (camera only)
Assigned architectural scale	**Macro (1:200)**	**Meso (1:100/ 1:50)**	**Micro (1:50/ 1:10)**	**Micro (1:50/ 1:10)**

Table 1. Sensor specification table for the project in Spring 2026.

varying levels of effort depending on its condition. For instance, weathered surfaces, uneven stones, or fragile materials demand specialized techniques: oblique or raking light, or high-resolution structured-light scanners can solve problems that other methods cannot. This multi-sensor approach ensures that every gravestone is documented accurately and comprehensively, regardless of its physical state. Above named technologies form the basis for iterative improvement, scalability, and methodological refinement as new sensor systems, automation tools, and data standards emerge over the coming decades. The following section should give further details on the recording and the employed technologies.

3.1 Existing plans and maps from partner project

All data handling and dissemination activities are governed by copyright regulations and stakeholder agreements, including contractual arrangements between the project partners. These agreements define ownership, usage rights, and responsibilities and are essential to balancing openness with legal and ethical obligations, for example with State Heritage Offices, local history researchers, and municipalities. The project has actively partnered with the heritage authorities, and where plans for tachymetric recording or drone-based Structure-from-Motion (SfM) surveys were available, these were integrated into the research workflow. The integration of existing plans often revealed discrepancies: sometimes more (previously overlooked) stones were detected, while in other cases fewer stones were document-

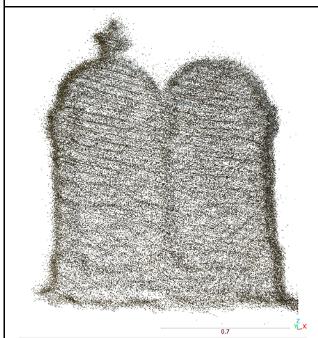
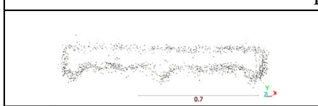
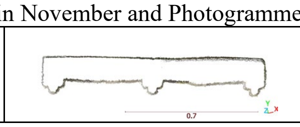
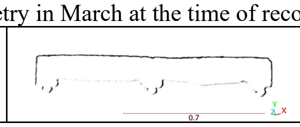
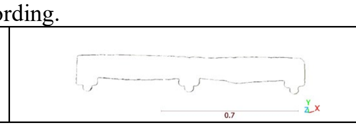
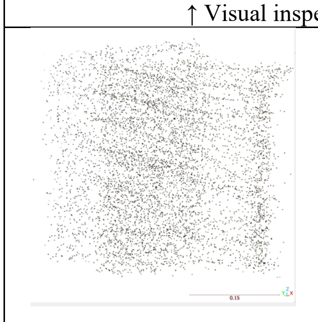
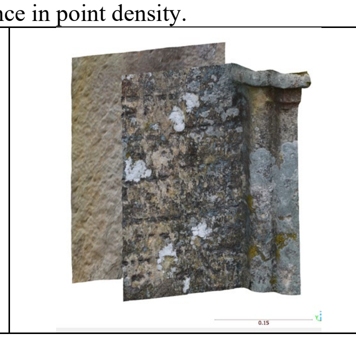
MLS (mobile laser scan)	TLS (terrestrial laser scan)	Handheld	Photogrammetry
			
↑ Visual inspection of Stone of the front facing inscribed aspect. Notable is the difference in vegetation encountered during TLS in November and Photogrammetry in March at the time of recording.			
			
↑ Visual inspection of cross-section at ca. 1 m height. Notable is the difference in point density.			
			
↑ Detail of visual inspection of Stone on its front face on an area 25 x 35cm.			
5–10 cm/ 10 cm	5mm / 3-5mm	1-2mm / 3mm	0.2mm/pixel / 0.02mm resolution
↑ Expected resolution (point to point distance/ point spacing) per technology/ vs. realised resolution			
13,914 pts	426,686 pts	59,183 triangles	97,834 triangles
↑ Number of points per sample area			
↓ Useability per discipline represented in the project:			
Survey / Digital Terrain model (DTM/DEM) - > Maps and plans	Building research / architectural history	Epigraphy/ architectural history - > reading of text/ semantic description of elements	Epigraphy/ architectural history - reading of stones, artificial lighting
Scale 1:500/ 1:200	Scale 1:100/ 1:50	Scale 1:20/1:10	Scale 1:10 Details

Table 2. Results of quantitative analysis of sensors used on the example of one selected gravestone of the Bruell couple. A sample area was selected to include architectural (column capital and columns) as well as Hebrew Script.

ed due to decay or displacement since the earlier surveys.

Often numbered plans are already present, but as our recording considers not only the footprint of gravestones but also their inclination, development, and displacement over time on sloping terrain, a comprehensive 3D survey is essential. Given the long-term nature of the project, the team aims to monitor changes over time, which can provide early warnings - for example, identifying stones at risk of falling that may require stabilization - through systematic, automated analyses of stone angles relative to terrain. Our outputs should be complementing existing plans of partners and other stakeholders.

3.2 Geo-referencing/ GPS/ GNSS

Initial tests were conducted using fixed control points placed along pathways and at access gates, with particular care taken to avoid areas that might overlay unmarked graves to respect burial sites. In practice, however, the introduction of additional control points within the cemeteries was largely avoided due to cultural sensitivities. This is primarily due to cultural sensitivities related to burial practices, as well as the complex historical evolution of cemetery boundaries, including processes of expansion, reduction, and reconfiguration over time. As an alternative, high-precision terrestrial laser scanners (e.g. Riegl) equipped with integrated GNSS are employed, allowing for indirect georeferencing without the need for intrusive ground control points. While GNSS provides absolute positioning, its application in cemetery environments is often limited by vegetation cover and restricted sky visibility, which can reduce positional accuracy. For this reason, UAV-based photogrammetry was considered but ultimately not applied in most cases due to dense vegetation and limited line-of-sight conditions.

As a result, not all point clouds generated within the project are fully georeferenced in a consistent global coordinate system. Instead, locally referenced datasets are frequently used for detailed analysis and documentation and transformed to the coordinate system of CAD plans with the Bavarian Survey Authorities. The integration and visualization of georeferenced point clouds remain an ongoing task within the project, particularly with regard to their incorporation into the research data management system (MonArch), where full geospatial functionality is not yet implemented. For the processing, registration, and potential georeferencing of point clouds (GIS), established software solutions such as CloudCompare (open source), RiSCAN PRO (Riegl), and Agisoft Metashape are suitable, enabling alignment, transformation, and export into standardized coordinate systems. The gradual establishment of consistently georeferenced datasets is therefore considered a key objective for future workflow development.

3.3 MLS of topography, terrain and stone location

For the 3D acquisition of the overall terrain a mobile laser scanner (MLS) Geoslam Horizon equipped with a Velodyne LiDAR sensor, a Firefly action camera, and a panoramic camera (Geoslam, 2019) was employed (Figure 3, Figure 4). Both camera systems can support cemetery documentation by providing visual overviews of the site, including general information on topography, the spatial distribution of gravestones, and the overall condition of the terrain (i.e., recording the 'space'). However, the colour and panoramic imagery do not significantly contribute to the geometric or analytical information content required for detailed documentation. For this acquisition approach, an expected spatial resolution of 5–10 cm and an accuracy of ±5 cm was assumed, based on previous work (Hess and Ferreyra, 2021). The extent to which these expectations are met will be evaluated in the following sections, and in Table 2.

3.4 TLS for gravestone location and form recording

For Terrestrial Laser Scanning (TLS) at medium scale, the Leica Geosystems BLK Gen.1 was used (Leica Geosystems, 2018) placed on a Manfrotto tripod, together with checkerboard targets and spheres. These control points were placed strategically on a surveying pole between the gravestones or on pathways. The lightweight laser scanner proved advantageous for moving through the terrain. The duration of the high-resolution scan with HDR-photography - 6 minutes - proved lengthy but necessary to achieve the required detail (see Table 2). The 3D scanning results could be registered on-site on a tablet, which sped up later post-processing in the office.

The use of TLS was intended to generate sufficient detail to be able to do a first art historical description (recording of the 'form') of the gravestones, and to see them in context of neighbouring stones. The on-board photography also enables the identification of the stones in the context of their identification photography. The expectations for TLS acquisition in geometry and colour was a resolution of 3-5mm with an accuracy of +/-5mm. These 3D TLS- Scans enabled a closer and more detailed view of the geometry than MLS, in which small stones on the ground or stones obscured by vegetation could often not be identified. To improve recording speed, a RIEGL terrestrial laser scanner will be used, acknowledging the trade-off of increased equipment weight during fieldwork. The final mapping as a ground plan, together with unique identification numbers for each stone has to be verified by an on-site inspection whilst comparing the plan drawing derived from MLS and TLS with details on-site. Often stones exist only as fragments or have fallen to the ground where they might be covered by a layer of moss or leaves. The causes of the damage may be intentional destruction, but are more often the result of weathering and decay, as well as tree growth.

3.5 Close range recording: handheld laser scanning or photogrammetry for single gravestones

For detailed close-range recording, approximately 10% of the gravestones of a cemetery are documented using either photogrammetry or handheld 3D scanning. For the purposes of this study, both methods are treated equivalently, although photogrammetric recording requires significantly more time on-site (approx. 20 minutes per stone for around 300-400 images) and for post-processing (approx. 3–4 hours). It is therefore primarily reserved for gravestones where sub-millimetre resolution is required for detailed visualization and magnified analysis.

The handheld 3D scanning was carried out using the EinScan Libre (version 1.0.1; EinScan Multifunctional 3D Scanner Specs, 2024 (Shining3D, 2025), applying the Laser HD mode with combined texture and geometry alignment. The standalone device, although moderately heavy, provided immediate feedback via the integrated display, allowing real-time inspection of data completeness. This proved to be a flexible and efficient tool for on-site acquisition, with an average scanning time of approximately 10–15 minutes per object. For handheld scanning (laser and structured light projection), an expected resolution of 1–2 mm and an accuracy of approximately ±3 mm was assumed (Table 2).

Lighting conditions occasionally posed challenges, particularly under strong sunlight. In such cases, controlled shading was introduced to ensure uniform surface illumination and to support reliable pattern projection for accurate 3D capture and real-time inspection on the device. The primary objective was to provide epigraphists with high-resolution 3D models that enable controlled, artificial re-lighting for improved readability of Hebrew inscriptions and for subsequent art-historical analysis.

The resulting models capture not only the inscriptions but also fine details of stoneworking techniques. Typically, the front side (often east-facing) exhibits carefully executed carving with architectural features, decorative motifs, and symbolic elements, while the reverse and less visible surfaces show a rougher finish, consistent with traditional stone dressing techniques (e.g., point chisel work).

Photogrammetric imaging is used to record very detailed geometry and calibrated colour imaging for the same purpose as 3D handheld scanning. The sensors used were a Nikon D3400 (APS-C crop sensor) and a Nikon D850 (full-frame sensor). The workflow followed the standard procedure in the photogrammetric software Agisoft Metashape, producing trianglar meshes with high-resolution texture. Re-lighting the model proved efficient for reading. The expectation for this acquisition was a sub-millimetric resolution (ca 0,2mm/pixel at recording, and an output of ca. 0,25mm point distance) and correct colour rendition of lychen, moss and other biogenic growth on the surface (Figure 6).

4. Data analysis and results

The multi-sensor workflow applied in this project enables a structured analysis of cemetery data across multiple spatial scales, integrating geometric, visual, and later semantic information into a coherent analytical framework. The resulting datasets support both qualitative and quantitative investigations, ranging from individual gravestone analysis to large-scale spatial patterns within entire cemeteries.

At the site scale, MLS and TLS data are processed to generate georeferenced (or locally referenced) point clouds and derived terrain models (Figure 4). From these, 2D plans and digital elevation models are extracted, forming the basis for geo-spatial and temporal analysis of grave distribution, orientation, and clustering. These datasets allow the identification of burial patterns, such as row structures, family groupings, and historically distinct burial zones. In several case studies, discrepancies between newly acquired data and pre-existing plans were identified, including previously undocumented stones as well as losses due to decay or displacement.

At the object scale, high-resolution 3D models derived from close-range photogrammetry and handheld scanning are analysed with regard to geometry, surface condition, and inscription legibility. The possibility of digitally relighting these models proved particularly effective for enhancing the readability of weathered Hebrew inscriptions. Sub-millimetre resolution data enabled detailed observation of carving techniques, tool marks, and material degradation, supporting both epigraphic interpretation and art-historical analysis (Figure 5, Figure 6). The integration of geometric and added semantic data enables complex cross-disciplinary analyses. For example, spatial proximity derived from 3D models can be combined with epigraphic

Figure 2. Fieldwork using GPS/GNSS RTK.

Figure 3. 3D *MLS* in operation at the Jewish Cemetery in Walsdorf, Franconia, Germany.

Figure 4. Photograph with unique identification number of selected gravestone in Walsdorf cemetery, Franconia.

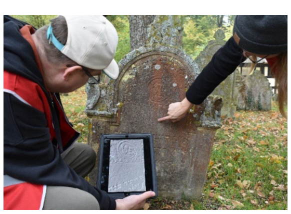


Figure 5. Collaborative work for the interpretation of text and symbols alongside the digital model.

Figure 6. Plan extracted from 3D MLS of the topographic terrain model, including gravestones, Jewish Cemetery in Walsdorf.

Figure 7. 3D model of a gravestone derived from photogrammetry, enabling enhanced readability of Hebrew inscriptions and inspection of architectural features (1 × 1m).

data to reconstruct family relationships or social structures within the cemetery. Similarly, the correlation between material condition and environmental factors (e.g., terrain inclination, vegetation cover) can be assessed to support conservation monitoring.

In terms of accuracy and resolution, the results confirm the expected performance ranges of the applied sensors. MLS provided efficient large-area coverage with sufficient accuracy for spatial analysis, while TLS improved geometric detail for medium-scale documentation. Close-range methods achieved the highest level of detail, enabling fine-grained analysis of inscriptions and surface features. The combination of these methods proved essential, as no single technology was sufficient to cover all required levels of detail and information (Table 2).

Overall, the results demonstrate that the integrated multi-scale approach successfully captures the complexity of cemetery environments as both spatial and cultural systems. The generated datasets form a robust basis for long-term monitoring, comparative studies, and interdisciplinary research, while also supporting the development of a digital corpus of Jewish sepulchral heritage that is both analytically rich and sustainably usable.

5. Discussion and challenges

Through iterative trials over the first five years, including changes in sensors and acquisition methods before project start (Pavlovskis *et al.*, 2020) it has become clear that long-term sustainability is a major challenge in this 24-year project. A central challenge for the project arises from the constant changes occurring within the graveyards. Natural decay, biological growth, soil movement, progressive weathering of stone surfaces, and occasional vandalism lead to continuous transformations of the monuments. These processes are further intensified by climate change, including increased temperature fluctuations, more frequent extreme weather events, and altered patterns of moisture and vegetation. As a result, long-term monitoring becomes essential not only for documentation but also for understanding the dynamics of deterioration and preservation.In addition to physical changes on site, methodological and technical sustainability represent a key challenge. Over the long duration of the project, sensor technologies, software environments, and data standards are expected to evolve significantly. This requires the workflow to remain adaptable while ensuring consistency and comparability of datasets across time. The use of open formats, interoperable data structures, and standardized semantic models provides a stable foundation that supports future migration, reuse, and integration of data, even as technologies change.

Another important aspect concerns the balance between data richness and efficiency. High-resolution acquisition generates large volumes of data, which can pose challenges for storage, processing, and long-term curation as well as a data management plan according to FAIR data principles. The project therefore continuously evaluates appropriate levels of detail and information, aligning data acquisition with clearly defined research questions and disciplinary needs.

Furthermore, the integration of heterogeneous data sources—including legacy plans, archival material, and newly acquired 3D data—requires careful harmonization. Differences in accuracy, completeness, and documentation standards must be addressed through transparent processing workflows and consistent metadata practices. This integration is essential for building a coherent digital corpus that supports diachronic analysis. Ethical and cultural considerations also play a significant role. Jewish cemeteries are sensitive heritage sites, and all documentation activities must respect religious norms, the integrity of burial sites, and the perspectives of local communities and stakeholders. These considerations influence methodological decisions, such as the avoidance of intrusive survey techniques and the careful handling of data accessibility.

6. Conclusion and future work

This contribution has reported on current sensors and technologies used in the project *Stone Witnesses Digital* presented a work-in-progress development of a complex, integrated workflow that will continue to be refined and parts of it automated in the coming years. The first results are promising: they demonstrate the feasibility of the multi-sensor approach, enable access to a growing number of cemeteries in the Bavarian region and show successful integration with the regional heritage authorities and their digital infrastructures.

Looking ahead, a strong emphasis will be placed on the use of automation to enhance the efficiency and scalability of the workflow. Future developments will focus on automated segmentation of point clouds for feature extraction, automated localization of inscription fields, and the implementation of machine-learning–based approaches for script recognition and the extraction of Hebrew text. These advances aim to reduce manual processing time, improve reproducibility, and enable more comprehensive analyses of large datasets across multiple cemeteries.

The interdisciplinary project *Stone Witnesses Digital* aims to demonstrate how ‘digital twins’ of Jewish cemeteries and their gravestones can function as analytical and interpretative tools - transforming static documentation into dynamic, accessible, and intelligent cultural datasets. Through this approach, the project contributes to the long-term preservation and reinterpretation of Jewish heritage and positions its results at the intersection of digital humanities, heritage science, and Jewish Studies.

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