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Volume 2

Field and Lab Reports

Harrassowitz Verlag

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on the Archaeology of the Ancient Near East

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Ingolf Thuesen, Scott Haddow,
and Camilla Mazzucato

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Chapter 20

From Site to Tablet: Multiscalar Approaches to SFM at Nineveh

Jacopo Monastero[1], Cristiano Putzolu[2] and Marco Valeri[3]

Abstract

Structure from Motion (SfM) photogrammetry currently offers the best compromise between accuracy, speed[4], cost, and equipment requirements. Its flexibility has allowed us, since the first Iraqi-Italian archaeological campaign at Nineveh in 2019, to test the potential of this technique for the systematic documentation of the archaeological record: from landscapes (macro scale) to archaeological contexts (meso-scale) to artefacts (micro-scale). Data collection through the combined use of cameras and drones (post-processed into 3D models, DEMs and orthophotos with centimetre accuracy) has resulted in 3D and 2D maps for heritage preservation monitoring. Important results have also come from the 3D capture of inscribed clay tablets in a controlled environment. The high-resolution 3D models produced allow experts to examine even those that appear illegible due to poor preservation.

Introduction

The Iraqi-Italian Nineveh East project (NINEV_E Project) is a joint programme between the University of Bologna and the Iraqi State Board of Antiquities and Heritage (SBAH), which started in 2019 and is still ongoing.

Spatial data acquisition techniques in the project are based on Structure from Motion (SfM) photogrammetry, which is used at different scales (Olson *et al.* 2013) according to the different levels of detail (LOD) required by the multidisciplinary nature of the project[5].

SfM photogrammetry can be seen as the digital equivalent of the human ability to perceive the three-dimensionality of a scene by moving the point of observation: the different points of observation are hundreds of adjacent photographs with a good percentage of overlap. Dominic Powlesland, recalling his visit to Wroxeter with Philip Barker, wrote "by moving our viewpoint only a small distance we were able to radically increase our perception compared with the view, when stationary because we were more aware of subtle texture differences in the soils. We were effectively using what is known in photogrammetric circles as Structure from Motion (SfM) to enhance our view of the site" (Powlesland 2016: 18).

1 University of Bologna, Italy (jacopo.monastero2@unibo.it)
2 University of Bologna, Italy (cristiano.putzolu@unibo.it)
3 University of Bologna, Italy (marco.valeri4@unibo.it)

4 When mentioning speed, we deliberately refer to the effective working time of the operator and not the processing time, which in this case can be very time consuming.

5 For a discussion of the importance of the concepts of scale and level of detail in archaeology, see Harris 2006.

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The result of the photogrammetric survey is a cloud of three-dimensional points that replicate the surfaces of the surveyed object: from this cloud, a scaled and georeferenced digital surface (mesh) with photorealistic texture can be easily obtained[6].

SfM photogrammetry currently offers the best compromise between accuracy, speed, cost and equipment requirements. Its flexibility has allowed us to test the potential of this technique for the systematic documentation of the archaeological record: from landscapes (macro-scale) to archaeological contexts (meso-scale) to artefacts (micro-scale)[7].

One of the main objectives at the **macro-scale** view was to map the entire area of the ancient city of Nineveh, about 750ha, surrounded by a 12km long circuit of stone and mud-brick walls, built by King Sennacherib around 700 BCE (Reade 2016; Petit and Morandi Bonacossi 2017). For the **meso-scale**, every year (from 2019 to 2023) we acquired thousands of photos from the different archaeological contexts and monuments studied in more than 20 areas, using a drone and/or a camera mounted on a pole, and processed them in Agisoft Metashape using hundreds of ground control points (gcp) surveyed by a DGNSS system, to obtain, just as for the macro-scale, 3D models, DEMs and orthophotomodels with centimetre accuracy, resulting in 3D and 2D maps of the different stages of our excavation as well as a record of the state of preservation of individual monuments. Important results have also been achieved at the **micro-scale**, with the acquisition of inscribed clay tablets and small finds in general, such as seals and clay sealings, in a controlled environment, generating high-resolution 3D models that could allow experts to study even those that appear illegible due to poor preservation.

Photogrammetry through SfM is certainly a well-established practice for documenting archaeological contexts and cultural heritage (Moyano *et al.* 2020), but the same cannot be said, considering the relative lack of publications on the subject, for the documentation of smaller finds found during fieldwork or for the digitization of cultural heritage. This could be due to a variety of reasons, such as the possibility of relying on the physical object, the not-immediate necessity of the 3D models (Quattrini *et al.* 2017), but also the considerable time required for the acquisition and elaboration of the models.

For the 3D digitization of medium and small objects, Structured Light Scanners (SLS) are increasingly being used due to their speed, precision and accuracy; the only drawback of this practice is the high cost of the equipment, and the extreme specificity of the devices needed to acquire objects of different scales. Photogrammetry, on the other hand, has proven to be a solid documentation technique that, when well executed, is able to provide very precise and accurate digital replicas of the object studied, even in the case of small objects (Guerra *et al.* 2019; Ma *et al.* 2021). Photogrammetry turns out to be more affordable than SLS, and in this case the investment shifts to the time needed to produce the models. The key to all three scales is the adaptation of the enormous potential of SfM photogrammetry.

6 For an updated review of the potential of SfM photogrammetry in archaeology and an accurate bibliography, see Willis *et al.* 2016.

7 In his seminal book *Spatial Archaeology*, David Clarke (1977: 9) defined three scales for the study of human activities: *micro*, *semi-micro* and *macro*. We use here the term *meso*, often used as a synonym for *semi-micro* (e.g. Joffe 2004: 250).

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Multiscalarity of Archaeological Digital Survey: Some Reflections

One aspect of digital surveying in archaeology that requires attention is the postponement of the interpretation phase. While the pre-digital surveying methods were based on the critical selection of a number of points to be measured, and their subsequent drawing on a sheet of paper according to a given scale; the current digital techniques involves a first step of digital replicas creation of the objects of our study (entire sites, excavation sectors, trenches, stratigraphic units, or finds), and a second step of digitizing them in a GIS environment into vector geometries characterised by the attribute data.

This change is not insignificant because, in addition to the undeniable advantage of much greater accuracy and speed, digital surveying does not require the operator to simplify the geometry of the measured objects, as was the case in pre-digital procedures (everything that wasn't measured was definitely left unrecorded), but simply recreates the objects themselves in a digital environment, thus postponing the interpretation phase to a later stage, when the features are finally vectorized using different LODs.

The shift from a methodological framework (pre-digital survey techniques) in which data collection was seen as a consequence of observation, interpretation and abstraction (Limp 2016: 350) to a new one based on data collection preceding interpretation and abstraction is by no means without consequences: archaeologists risk losing the engagement with the physical aspect of the contexts being analysed (Huggett 2020: 511). The recently published results of *The Aide Mémoire Project* highlight the different perceptions of digital and hand drawing among different types of archaeologists (students, academics, commercial archaeologists, professional illustrators): when asked "Do you feel that other recording methods (photography, photogrammetry, 3D scanning) would give you the same or a different understanding of the context/feature? Why?", more than 40% of the responses were that they would give a different understanding of a context/feature (Morgan *et al*. 2021: 623, fig. 8).

When using pre-digital techniques, the impossibility of reproducing a three-dimensional scene on a two-dimensional sheet forced the qualitative-interpretive selection of the points to be triangulated or the elevations to be measured. In this respect, we can be tempted to consider digital surveying methods (and SfM photogrammetry in particular) as more objective. Nevertheless, there is a risk of uncritically documenting our site. In order to correctly vectorize an orthophotomodel, all the information about the stratigraphic sequence and the relationships between contexts, must be collected on-site; otherwise, an orthophotomodel will be difficult to translate into a vector drawing that correctly represents the stratigraphy of the context and, trivially, the survey will not be *objective*, but *wrong*.

As one participant in *The Aide Mémoire Project* survey said, "If drawing starts to be seen as more akin to transcription than to translation as a result of digital tools, I think we will lose perspective on our own processes of knowledge generation" (Morgan *et al*. 2021: 627).

To paraphrase Linda Patrick, who emphasized in a seminal paper that "archaeological reports constitute archaeological records" (Patrick 1985: 30), we need to remember that archaeological survey itself is both documentation of the archaeological record and part of the archaeological record.

Focusing his attention on the relationship between material culture and how much of it ultimately becomes the archaeological record, Michael Collins identified a "sequence of

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seven contingencies" that progressively reduce the amount of behaviour resulting in material culture that archaeologists can identify during their research (Huggett 2022: 279), this list has been recently extended by Jeremy Huggett to include four further moments of data reduction entirely related to data recording and archiving workflows (Huggett 2022: 280, fig. 3). It is therefore extremely important to reflect on the potential of digital technologies to avoid any "opportunistic push-button functionality offered by the technology" (Lock and Pouncett 2017: 134) and use them to correctly document our contexts.

Macro-scale: Mapping the Ancient City of Nineveh

The topographic mapping of the ancient city of Nineveh covered almost the entire area enclosed by the city walls and 200ha between the eastern walls and the outer fortifications. The resulting DEM, orthophotomodel, and contour lines were then used in QGIS for landscape archaeology and ancient urbanisation studies.

To map the entire ancient Assyrian capital, a DJI Phantom 4 PRO UAV (Unmanned Aerial Vehicle) has been used to acquire thousands of images (12,590 images, precisely) and a Leica Zeno GG004 DGNSS to survey the ground control points (gcp) visible in the aerial photographs. This DGNSS antenna uses a PPP (Precise Point Positioning) connectivity service. PPP is a positioning technique that removes or models DGNSS system errors to provide a high level of positioning accuracy from a single receiver (Ozulu *et al.* 2018; Angrisano *et al.* 2020). A PPP solution relies on DGNSS satellite clock and orbit corrections generated by a network of global reference stations. Once the corrections are computed, they are delivered to the end user via satellite or the Internet. These corrections are used by the receiver, resulting in decimetre-level or better positioning without the need for a base station. To better understand the whole area, the first step was to collect remote sensing data from satellite and aerial imagery (CORONA, Quickbird, SRTM, Aster, aerial photographs, etc.) and load them into a GIS (Scott and McGinnis 1990). These processed images were used as a working base for the three main sectors in which the site of Nineveh is locally known: Kuyunjiq, including the acropolis mound and the village of Rahmaniye, the northern area (north of the Khosr River); Nebi Yunus, the central part, now heavily urbanised, including the mound under the mosque of the Prophet Jonah; 'Jounoub Ninawah' or South Nineveh for the southern tip of the site. For each sector, we created a regular grid of about 50 gcp on the ground visible from a height of 100/150m. Each point was surveyed using DGNSS linked to the PPP service, which allowed us to achieve an accuracy of 3cm. In some cases, such as over Tell Kuyunjiq or the Adad Gate, more gcp and closer spacing were used to achieve more accurate results. The surveyed points were uploaded into the GIS using a BingMaps base map to check their actual location on the ground. After surveying the gcp, zenithal photographs were shot by UAV from an altitude of between 100 and 150m. For some areas where more detail was needed, such as Tell Kuyunjiq, Adad Gate and Shamash Gate (Sulaiman 1971), the UAV flew at lower altitudes, between 30 and 80m.

For the macro and meso-scale, the UAV images were processed using Agisoft Metashape: the 3D model was obtained from the initial alignment of the drone photos, which resulted in a sparse point cloud. After recognizing and positioning each gcp in each photo (if present), the model was georeferenced by importing the DGNSS measured coordinates of the gcp, excluding the less precise positioning in the metadata of the UAV photos, and generated a dense point cloud. The following step was the creation of a georeferenced 3D mesh model

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and, by adding the RGB value from the UAV photos, the final generation of a textured, georeferenced 3D orthophotomodel. This workflow also produced DSM (Digital Surface Model), DTM (Digital Terrain Model) and contour lines of the entire Nineveh area, as well as various orthophotomodels, which were used as base maps in the GIS (Fig. 1).

The new survey of ancient Nineveh has already proved useful for studying in detail the urban form of this mega-site, as well as for planning its conservation and protection, also with a view to its public enhancement.

Once the 3D model has been created, by removing objects present on the ground surface (trees, buildings, etc.) using manual procedures (involving the manual removal of individual points in the point cloud belonging to objects) and automated procedures (using dedicated Agisoft Metashape filters and GIS applications), it is possible to create the DTM, i.e. the 'bare earth' model that describes the shape of the ground filtered by anthropic or vegetation elements (Julzarika and Harintaka 2019).

Two-dimensional GIS methods are commonly used in archaeology, but archaeologists also need methods for combining different spatial data applied to three-dimensional terrain models. DTMs become particularly important when processed into slope models, where a number of landmarks such as ancient buried buildings, ancient canals, or other traces of urbanisation (both ancient and modern) are highlighted and can thus be identified (Fig. 2). Of particular interest in Nineveh is the search for ancient roads and canals within the walled city and their associated drains. This method is also well suited to reconstructing the three-dimensional walking surface of an archaeological site, even if it has been excavated and then covered by buildings or altered in some other way.

Using early topographical maps (legacy data), it is possible to digitally collect many coordinates and implement parts of the model with the original xyz data: indeed, in excavation reports one can sometimes find contour maps drawn based on a survey with an optical level (Fig. 3). The final model is thus a combination of old data and new spatial information obtained from surveying, prospecting or excavation.

Meso-scale: The Ottoman Old Bridge at Mosul

As a meso-scale case study, the topographic survey of the Ottoman Old Bridge at Mosul is here presented as an example of the use of digital methods for spatial data collection in archaeology (Marchetti *et al.* 2023).

After an initial general photographic documentation, the topographic survey took just two half days in the field. During the first day, a series of gcp were set up on the ground and surveyed using DGNSS; then two sets of photographs were taken focusing on the two better preserved piers of the bridge ('single pier survey', Fig. 4.a and 4.b). On the second day, 13 new gcp were set up on the ground and a third set of photographs were acquired covering the area for general mapping ('whole area survey', Fig. 4.c).

Pier 1 required the acquisition of 222 images with an SLR camera used directly by the operator on the ground, in a total time of 10 minutes; while Pier 3, which required the additional use of a telescopic pole due to its preserved height of more than 2.5m, required 392 images shot in a total time of 17 minutes.

A Mavic Mini UAV connected to the Dronelink app was used for general mapping of the area, allowing us to set up a programmed flight. An area of approximately 0.2ha was mapped at a constant height of 5m above the ground, using a grid pattern. The 662 photos

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obtained in a total flight time of approximately 23 minutes (for a linear distance of 900m) were processed - like the other datasets - using Agisoft Metashape software to obtain 3D point clouds, textured 3D meshes, georeferenced orthomosaics (Fig. 5.a) and a DEM (Fig. 5.b), which was then transformed into a slope map (Fig. 5.c) in QGIS.

Having two different LOD means the opportunity to strategically differentiate the efforts according to the benefit-cost ratio: the 'single pier survey' ensures the highest level of accuracy in the selected areas of the two better preserved piers; while the 'whole area survey' had a coverage that allowed good accuracy, but at the same time required reasonable post-processing times. Moreover, while the 'single pier survey' allowed to document the state of preservation and use of the individual blocks used in the construction and thus to study the construction technique more closely (Marchetti *et al.* 2023: 8-12); the 'whole area survey' allowed to reconstruct the course of the bridge and the distance of the piers.

To calculate the dimensions of the span, and therefore the distance between the piers, it has been natural to start from two of the four piers that still had the full base perimeter. Since the distance between these two piers is 37m and the total size of the pier itself is 2.7m, it was assumed that there were three missing piers. Subtracting the total size of the three piers (2.7x3m = 8.1m) from 37m and dividing by four: the resulting distance of 7.22m was obtained. Therefore, given the width of the pier (2.7m) and the distance between two adjacent piers (7.22m), the layout of the bridge and the piers was then reconstructed until the worst preserved north-eastern pier. The reconstruction coincided exactly with the edge of this pier, of which only a few blocks of the southern profile were preserved, allowing us to validate our interpretation.

The DEM, processed in QGIS into a slope raster, confirmed the presence of the missing piers, showing anomalous depressions in the positions predicted by our hypothetical reconstruction. In the DEM view near the two hypothesized piers, a depressed area is visible and thanks to the slope analysis raster, the evidence is confirmed by the darker colours near the two hypothesized piers (Marchetti *et al.* 2023: 6-8).

Micro-scale: Administrative Documents from Ancient Nineveh

As mentioned above, the choice of SfM photogrammetry for small and medium-sized finds was mainly dictated by economic considerations, as it allowed us to use existing equipment that could be successfully used for the acquisition of objects of different scales, from small clay sealings to larger carved orthostats. During the fieldwork in Nineveh East, the acquisition was carried out with SfM photogrammetry through an already consolidated methodology (Brecko and Mathys 2020), using a Nikon D850 with an FX, CMOS sensor with 46.89 megapixels, equipped with an AF-S Micro Nikkor 60mm lens, a tripod, a turntable equipped with eight markers, a studio flash kit and a lighting cube tent. The object to be inspected is placed on the turntable and a photograph is taken every 20° of rotation, with the camera placed about 30cm from the object; after the first round, the camera is raised by 30° and another set of photographs is taken. This process is repeated four times to ensure that one side of the object is completely covered. The object is then turned upside down and the whole process repeated to capture the side that was previously on the turntable. The total number of photographs taken ranges from 150 to 300, depending on the complexity and dimensions of each object, with an estimated acquisition time of 20-30 minutes per object.

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All the images taken are processed using Agisoft Metashape 1.7.1, with an estimated error of between tenths and hundredths of a millimetre.

The elaboration process is certainly the longest operation to carry out, depending on the number of images acquired and on the machine used for the elaboration. In our case, using an HP Omen notebook with an Intel I7-8750H 2.20-4.10 GHz CPU, 32GB of RAM and an Nvidia GeForce 1070 GPU with 8GB of dedicated memory, each model takes no less than three hours to process, plus a further hour of image and point cloud adjustment by the operator.

Due to the time required, 3D acquisition is currently focused on those objects that present some criticality, such as a particularly complex morphology or a poor state of preservation, and that require a high degree of precision and accuracy combined with an extremely non-invasive acquisition methodology.

The management of the acquired 3D data sets usually differs according to the type of object acquired and therefore its use: the model of an archaeological site will necessarily be treated differently from the model of a cuneiform tablet, simply because each model needs to be studied differently to obtain different types of information. In addition, due to the narrow specificity of the capabilities of 3D graphics software, it is currently not possible to identify a single software that can handle all the tasks required for each specific request.

For the category of small finds, models are mainly used for visualisation purposes, to obtain graphical enhancement through filtering algorithms (*v. infra*), to produce drawings, renderings and digital impressions (Fig. 6), but also for digital integration of different fragments belonging to the same object. Most of these tasks are carried out using Blender, a powerful free open-source software capable of covering a wide range of tasks. In particular, the fact that it is an open-source software allows users to adapt Blender by developing specific tools and add-ons to address specific needs (Bossema *et al.* 2023).

The case of the inscribed tablets found in the buildings of Area C and Area E of eastern Nineveh is emblematic. The poor state of preservation made these objects very fragile and difficult to decipher. The acquisition of the three-dimensional models proved essential to provide Assyriologists with accurate digital replicas of the objects that could be consulted anywhere without the risk of damaging the original finds, and also, thanks to the use of a series of digital post-processing techniques, to provide an additional tool for improving the legibility of the finds (Fig. 7). Some of these techniques include, for example, the possibility of changing the orientation of the light source, removing the original colouring of the object, which in some cases can interfere with the interpretation of certain signs, and changing the colouring of the surface of the fabric to better highlight inscriptions and impressions (Diara *et al.* 2024). This can be achieved by using a filtering tool available in several modern 3D software: for this project we used the Cavity filter in Blender and the MSII filter in another open-source software called GigaMesh (Mara *et al.* 2010).

The 3D representations in themselves constitute a complete graphic documentation, capable of providing researchers with an overview of the object under study, thus allowing a series of elaborations that would otherwise be impossible by relying solely on drawings and photographs. This is the case of the inscribed fragments of the Sennacherib cylinder (Fig. 8) found scattered inside the building under investigation in Area H during the archaeological campaigns of 2021 and 2022. Since some of the recovered fragments had already been sent to the Iraqi Museum in Baghdad at the end of the 2021 campaign, the integration of these

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fragments during the 2023 campaign was only possible thanks to the joint work of several experts, from restoration to the study of the cuneiform characters, using the 3D digital copies of the fragments obtained.

3D Data Publication: The Case Study from the 'Gli Assiri all'ombra delle Due Torri' Exhibition and Future Perspectives

In addition to their use for internal study and conservation, some of the small find models acquired were 3D printed, painted to match the original colour schemes, and exhibited during the 'Gli Assiri all'ombra delle Due Torri' exhibition at the Museo Civico Medievale in Bologna from June to September 2023. This project introduced a new approach to sustainable exhibitions, where the models are not intended as mere replicas of the originals, but as tools to convey historical content about the Neo-Assyrian Empire. These physical models were complemented by freely accessible online versions, enriched with information obtained during the study and acquisition phase.

The publication of data is a cornerstone of open science, serving as a fundamental tool for dissemination, but also to ensure transparency, review, and verification of research findings. For this reason, the entire collection of objects acquired during the excavation campaigns will be made freely available online. This will be achieved through a publication platform that will allow users to explore the 3D models, associated metadata and all related documentation. Key features of the platform will include user-friendly functionality and customizable tools tailored to the specific needs and challenges of each object. To support this initiative, the team selected 3DHOP, a well-established open-source framework specifically designed for the rendering of 3D content in the cultural heritage field (Potenziani *et al.* 2015). 3DHOP is highly intuitive and capable of managing extremely complex 3D geometries, ensuring fast data transfer and efficient rendering, even in areas with slow internet speeds, making the models accessible to users in regions with limited internet connectivity.

Conclusions

Particularly in the case of excavations carried out in foreign countries, where the researchers have only limited time to manipulate the finds under study, have quality documentation available is essential to complete the work, especially when consultation of the physical object would require, at best, a long and expensive journey, or, at worst, the impossibility of reaching it. This documentation must be as accurate as possible to guarantee an efficient study.

We may be tempted to think of photography as an extremely objective form of documentation, but we fail to take into account that the perspective from which the images are taken, the focus and the angle of light are all factors that profoundly affect the final result. In other words, the direct relationship with the object of study is held by the operator who produces the documentation, not by the scholar who is bound by the documentation produced by others for their work. It's not necessarily the case that the operator's perspective is the same as that of the scholar, who may find it necessary to focus on certain details that the operator may consider secondary. Such problems can be minimised by 3D acquisition of large assemblages from an excavation campaign. We are not suggesting that archaeological photography and two-dimensional surveying should be replaced by 3D surveying, but we may be open to testing new documentation outputs that complement those long used. When

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talking about drawings or pictures, their subjectivity provides important value when combined with the point of view of professional illustrators, whose experience can guide other users along a cognitive path. Nevertheless, the value of 3D documentation is undeniable, as it further reduces the subjectivity of the acquired documentation and allows the end user to explore the model in detail in ways that the operator may not have considered.

Furthermore, aerial photography has proven to be very useful in the planning of geophysical surveys, offering faster implementation and wider coverage. While the data obtained may not be as detailed as that from magnetometer or GPR analysis, it can still provide valuable insights to guide these more targeted methods. It is likely that the future of archaeological research will involve combining both solutions on UAVs, allowing the same aircraft to take photographs and perform geophysical analysis simultaneously (Schmidt *et al.* 2024).

To date, the greater accessibility of photogrammetry compared to other types of 3D technologies has allowed for the widespread adoption of 3D documentation by a diverse audience and has enabled an unprecedented multi-scalar digitization path, but despite this, SfM photogrammetry presents some issues that cannot be overlooked.

One of the most problematic is certainly the processing time required to complete the reconstruction of the object under investigation. This factor could lead to several other related problems, such as the inability to process models in parallel with acquisition due to the large discrepancy between acquisition and processing time. This is particularly the case when the acquisition is aimed at large collections of objects, so that the processing has to be postponed for several days, if not weeks, with the real risk of having to deal with problematic image datasets and consequently problematic models, invalidating all or part of the work and forcing the operator to repeat the acquisition with all the inconveniences (partially excavated areas, objects not immediately available, etc.). In such cases, it is advisable to process the models, especially the most critical ones, promptly to minimize the risk of losing valuable data and to ensure the preservation of the information acquired. Although this problem can be mitigated by the experience of the operator and the use of a rigorous acquisition methodology, it is impossible to completely eliminate this risk component and must therefore be taken into account.

In summary, SfM photogrammetry is undoubtedly an invaluable tool for the documentation and conservation of archaeological objects and contexts and has significantly improved the quality of documentation for many archaeological teams. However, it is important to remain aware of the potential challenges and limitations associated with this technology. This is particularly relevant for archaeological sites that are constantly evolving, as well as for digitization projects carried out abroad.

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Introduction written by JM, CP, MV, Multiscalarity of archaeological digital survey: some reflections by CP, Macro scale by MV, Meso-scale by CP, Micro-scale and 3D data publication by JM, and Conclusions by JM, CP, MV.

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Links to 3D models:

- Tell Beirut Late Bronze-Iron Age glacis: https://sketchfab.com/3d-models/tell-beirut-late-bronze-iron-ages-glacis-bf269678c4f14fdea90ce91e898654a4
- Neo-Assyrian impressed clay sealing from Nineveh: https://sketchfab.com/3d-models/neo-assyrian-impressed-clay-sealing-from-nineveh-a8eb4b23b5d748ee82702f-0a745195a4
- Bronze amulet with the demon Pazuzu from Nineveh: https://sketchfab.com/3d-models/bronze-amulet-with-the-demon-pazuzu-from-nineveh-6b22c571d0b948dfa-fa702ab5bb1e1a1
- Inscribed cylinder of Sennacherib from Nineveh: https://sketchfab.com/3d-models/inscribed-cylinder-of-sennacherib-from-nineveh-b681354fdf424ea7888f5fc0ab87475d

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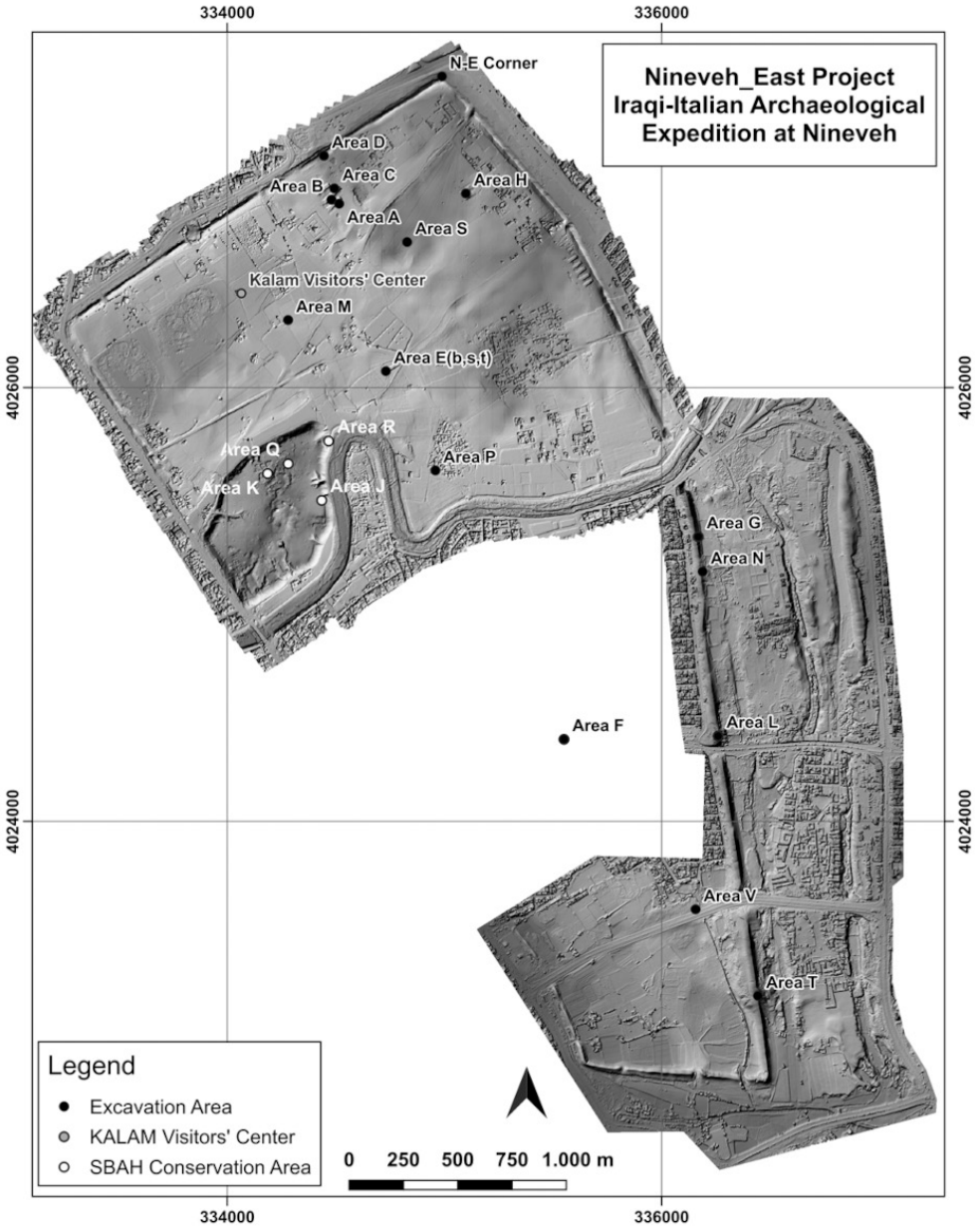

Figure 1. DSM of the ancient city of Nineveh showing the location of the excavated areas and heritage preservation sites.

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Figure 2. DSM of the Acropolis of Nineveh with contour lines at 2m.

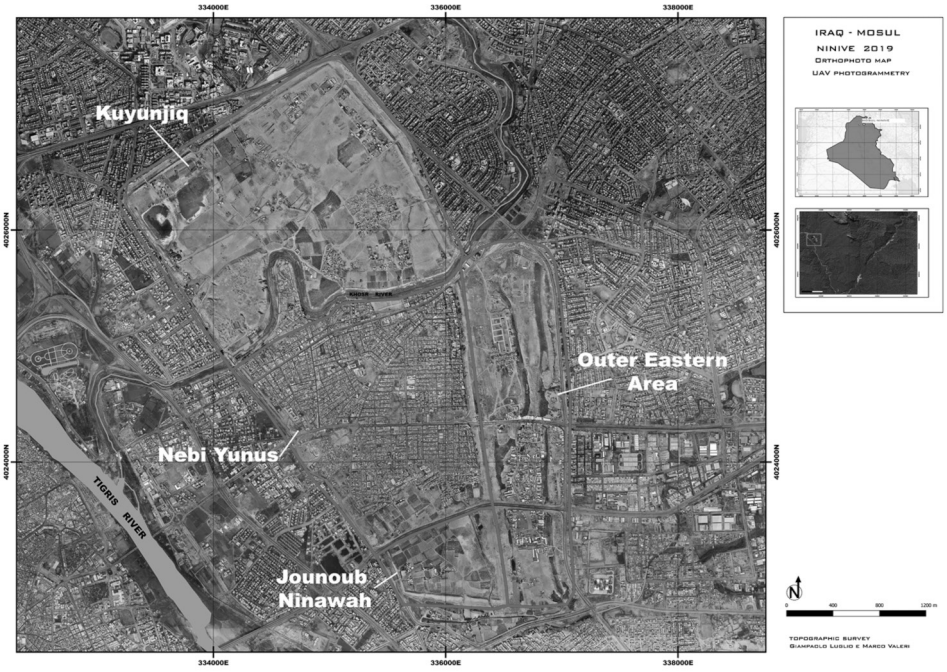

Figure 3. Orthomosaic of the ancient city of Nineveh projected over a satellite basemap. In white are the names of the four main sectors into which the archaeological site is divided.

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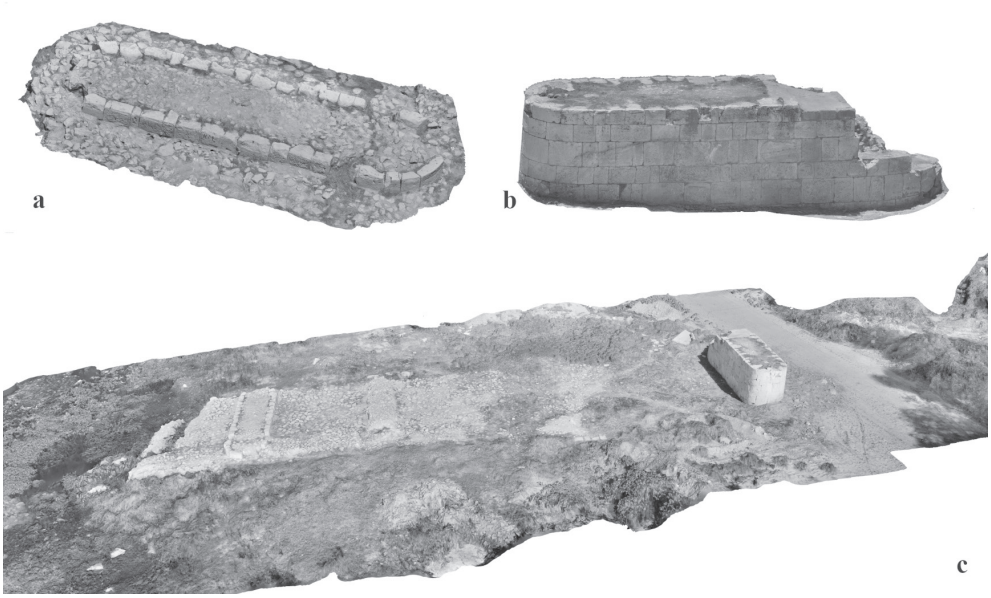

Figure 4. 3D textured models of the 'single pier survey' (a, b) and the 'whole area survey' (c)

Figure 5. Different digital layouts of the investigated area: orthophotomodel (a), DEM (b), slope map (c).

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Figure 6. The impression of the NE.22.O.600 cylinder seal was digitally created using the open-source software Blender.

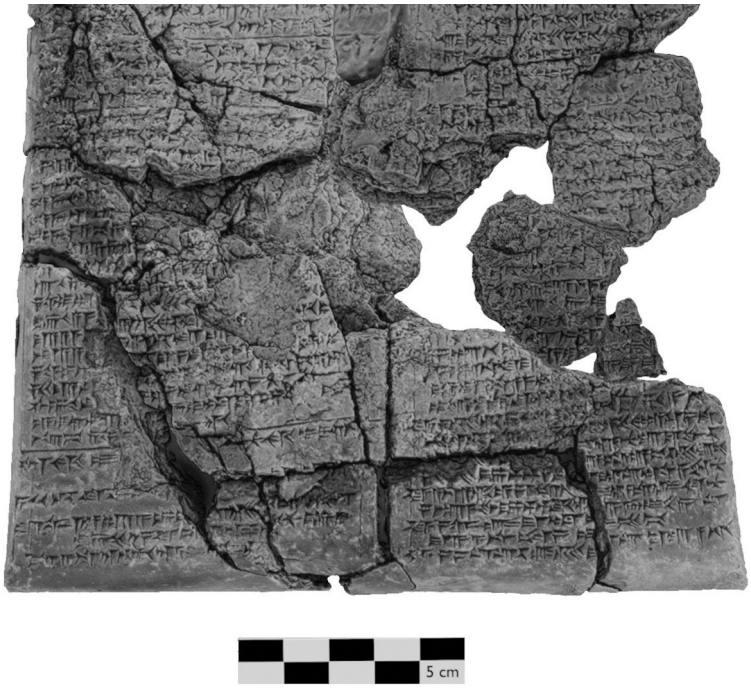

Figure 7. The use of geometric functions on the NE.21.O.368 incantation tablet can help to highlight details that are otherwise difficult to see.

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Figure 8. The integration of the floating fragments of the Sennacherib cylinder, as well as the fragments already handed over to the Iraqi authorities, was made possible digitally through the joint efforts of experts from different fields of study.

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