Towards a Mobile 3D Documentation Solution. Video Based Photogrammetry and iPhone 12 Pro as Fieldwork Documentation Tools

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Abstract

New affordable equipment suitable for 3D fieldwork documentation has appeared during the last years. Both photogrammetry and laser scanning are becoming affordable for archaeologists, who often work with limited resources and tight time constraints. This paper compares two such approaches and their workflows. Photogrammetry based on a video captured by a DJI Osmo Pocket gimbal camera and iPhone 12 Pro LiDAR scans are performed on a Finnish Early modern period archaeological project. A reference point cloud was created using a heavier terrestrial laser scanner. By comparing the acquisition processes and the accuracy and precision of the results, the potential of these new documentation methods can be evaluated. In addition to their precision and geometric accuracy, the methods are also compared in terms of ease of use and time constraints. The results demonstrate that although these technologies are still far from perfect, they provide a glimpse into the future of 3D field documentation. Archaeologists can achieve sufficiently precise 3D documentation for distinct phases of excavation in an Early modern period site without requiring an extravagant budget or special skills. However, the results indicate that the quality may not be adequate for fieldwork projects requiring more precise data, such as Neolithic period excavations.

1. Introduction

1.1 Mobile LiDAR and video based photogrammetry in archaeology

2010s and 2020s have seen rapid advances in technological means of archaeological documentation. Photogrammetry has become a mainstay in many fieldwork projects, with several

relatively easy-to-use software making the workflows streamlined and fast. Various light detection and ranging (LiDAR) equipment have become more affordable and portable – sensors are now available even on mobile phones, starting from Apple Inc.'s iPhone 12 Pro in 2020. Comprehensive point cloud data of hundreds of millions or even billions of points can be processed and inspected on relatively cheap personal computers. Storage and publication, in accordance to the FAIR principles (Wilkinson et al. 2016), of such data sets is still an issue to be solved, but in general, it can be said that the field of 3D documentation has made massive leaps during the last few years and it seems that those leaps are still to reach their climax. This article brings some experiences and comparisons of recent developments to the table, with the intention of aiding other archaeologists in choosing suitable equipment and software for their projects. Also, insights are given on the criteria of sufficient level of digital 3D documentation: for instance, the highest possible precision or point resolution can often be *too* high for the purposes of archaeological fieldwork documentation.

LiDAR has been used extensively in archaeology during recent years. Typically, this technology has been seen as either terrestrial laser scanners (TLS) or airborne LiDAR – the latter especially when talking about large scale surveys – but reliable and light weight mobile solutions have been lacking. Comparisons between LiDAR and photogrammetry in archaeological fieldwork and cultural heritage contexts have been published for some time already, (e.g., Bayram et al. 2015, Nuttens et al. 2011, Velios & Harrison 2010, Grussenmeyer et al. 2008 and Lichti et al. 2002) but examinations of handheld solutions have been limited to very restricted applications (e.g. Emmitt et al. 2021). Moreover, most of these case studies were performed on static and clearly defined targets, instead of as part of dynamic and hectic excavation process. There have also been some experiments and case studies published under other relevant fields, such as geosciences and forestry (Luetzenburg, Kroon & Bjørk 2021; Gollob et al. 2021; Mokroš et al. 2021), which also offer valuable insight for possible applications in archaeology.

Recent advances in smartphone technology have created opportunities for new developments. Apple Inc. released the iPad Pro on March 25, 2020, making it the first consumer-grade mobile LiDAR. The iPhone 12 Pro and iPhone 12 Pro Max followed on October 23, 2020, introducing a capable LiDAR device with unforeseen mobility – the operator can carry a smartphone in their pocket, with no need for cumbersome tripods or carrying cases. Apple has not released precise information about the sensors deployed on these devices, but some experiments have shown that all three – iPad Pro and iPhone Pro and Pro Max – seem to be using the same components, producing similar quality data (Luetzenburg, Kroon & Bjørk 2021: 6), the main overall difference being that the Max version has a slightly better camera lens. The iPhone 13 Pro was released on September 14, 2021, and iPhone 14 Pro on September 16, 2022, both featuring a LiDAR sensor, but significant updates on

the sensor has not apparently been made, since Apple did not publish anything in that regard when the new model was announced.

In this paper I examine some methods employed during an archaeological excavation project in Kerava region in Finland during 2022. In pursuit of an affordable and portable method for geometrically exact data acquisition, I tested a video based approach to photogrammetry and a mobile phone LiDAR solution. A DJI Osmo Pocket gimbal camera was used to shoot video footage of the target. Photogrammetry based on video frames, or videogrammetry (as per Gruen 1997), has been researched and developed already for some decades, and has seen some use in the cultural heritage field (e.g. Morena 2022, Murtiyoso & Grussenmeyer 2021, Torresani & Remondino 2019 and Alsadik et al. 2015). However, there are advantages in using a gimbal mounted pocket camera, since the more stabile shooting platform will lessen the risk of creating blurry or shaken footage. The DJI Osmo video material was imported into RealityCapture software (Version 1.2.0) for photogrammetry, where single frames were extracted and used in generating the model. Additionally, an iPhone 12 Pro with two different applications was tested on the same target. I used Pix4DCatch (Version 1.18.0) with Pix4DCloud cloud-based service, which combines the iPhone's LiDAR capabilities with photogrammetry, but also Scaniverse application (Version 2.0.3), which uses only the LiDAR sensor to collect a point cloud, which is only colored using the camera. The reference data for the comparison was collected with a Riegl VZ-400i terrestrial laser scanner (TLS), which was positioned using a high accuracy JAVAD GNSS RTK corrected antenna.

1.2 Case study

The site used for the data acquisition was Kerava Yli-Jaakkola. The site, a wooded hillside next to a 19th century wooden villa, was initially recognized as a place of archaeological interest already in the 1960s during an area survey, when some surface finds were made. However, further research and excavation became necessary only during the year 2020, when Kerava town planning decided to transform the site into a residential area. After some test trenches were dug during 2021, the final excavation was performed during the fall of 2022 (Figure 1). The process was documented according to the requirements of the Finnish National Board of Antiquities, after which the structures and archaeologically interesting strata were removed, and the area could be released for further use (Paukkonen 2022).

Figure 1: A picture of the Kerava Yli-Jaakkola excavation area from northwest.

The main interest in the area was the remains of a small wooden cottage with stone foundation from the late 17th or early 18th centuries. Plenty of finds from these periods were recovered, including various pieces of pottery, clay pipe fragments, glass beads, whetstones, and animal bones. From written sources we know that various phases of occupation and de-occupation happened during this period: the thriving farm of Jaakkola was abandoned during the Great Famine of 1695–1697, then it was resettled in 1706, only to be abandoned again during the Russian invasion (Great Wrath) of 1714–1721. In 1722 the farm was functional again and would continue to be inhabited until early 1900s (Haggrén & Paukkonen 2021). The excavated site was considered important since there have been no excavations of Early Modern Period sites in the Kerava region until now.

In addition to the experiments performed for this study, continuous field documentation was performed with DJI Osmo based photogrammetry and regular total station measurements. For the purposes of this comparison study, it was decided to document a single row of stones belonging to the northern stone foundation of the building. This provided us with simple and well demarcated structures that would feature different kinds of geometries and also allow for volumetric comparison. Additionally, inspecting the recording of the details of the adjacent small rectangular wooden structure was made possible, with various kinds of qualities needed.

Guiding principles for assessing the results are based on the updated Quality instructions on archaeological fieldwork of the Finnish National Board of Antiquities. The criteria of the document

are intentionally ambiguous, especially on such details as file formats or absolute resolutions but dictates the need for the data to be georeferenced and sufficient metadata to be archived, ⌧ for instance (Museovirasto 2020: 42–44). These requirements were respected during the fieldwork process.

2. Methods

2.1 Technical specifications for devices

The camera used for photogrammetry dataset was a DJI Osmo Pocket gimbal camera system. The camera was chosen primarily because of its stabilizing gimbal, which would assure that sufficiently slowly captured video file would remain steady, and thus all the extracted frames would be of regular quality. Additionally, the device weighs only 116 g, making it even more portable than an average mobile phone – ideal for use in e.g., field surveys in extreme conditions or locations that are difficult to reach. The device allows for 4K ultra high-definition (UHD) quality video, which was in this case shot in MOV format. The operating temperature announced by the manufacturer is 0°–40° C, but we have previously employed it successfully in temperatures under 0° C (albeit only for a few minutes at a time). The camera itself has a lens that is equivalent to 26 mm and F2.0, its ISO range is 100–3200, with maximum video resolution being 4K Ultra HD at 60 frames per second (SZ DJI Technology Co. 2022). The customization options for the settings are limited – for instance, the ISO value or aperture cannot be changed manually at all. This is usually the case when it comes to small pocket or action cameras (as noted also in Morena 2022: 179), but since the lens is fixed the automatic adjustments happening during the video shooting should not alter its geometry in regards to the photogrammetric measurements to be done in RealityCapture.

DJI Osmo Pocket was released already in 2018 and it is very affordable at the moment (Figure 2.1). A successor, DJI Pocket 2, is also available as of 2023, with a more advanced sensor and larger ISO range, making the video quality even more useful for field photogrammetry in environments with low lighting conditions.

RealityCapture software was used for producing the model. The video was imported as frames with 1.5 second intervals. This process generated 522 distinct frames, each with an approximate 80% overlap, which were subsequently utilized for model construction. Given that the camera was operated manually and on foot, the movement speed of the camera and the distance to target varied greatly – its average being 2.05 m. The resulting spatial resolution ended up beind 0.694 mm/pix. The processing was done purposefully as straightforwardly as possible: I followed the standard workflow provided by the graphical user interface of the software, without any complex configurations. This took a few hours in total, but the most of the processing was unsupervised.

Ultimately the final result was exported as a dense point cloud in LAS format with, thus making it easily comparable to the point clouds produced by the laser scanners.

The iPhone 12 Pro model I used has a 6.1-inch OLED display and 256 GB of storage space. It is equipped with A14 Bionic chip with 6-core CPU, 4-core GPU, 16-core Neural Engine and 6 GB RAM. The rear side has three 12 MP cameras, with wide (26 mm F1.6), ultra-wide (12 mm F2.4) and zoom (52 mm F2.0) lenses – and a LiDAR sensor (Figure 2.2). In total the device weighs 189 grams (Apple Inc., 2020). Apple has not published specifications of this sensor, but some details have been deduced by other research. Regardless, the sensor is a solid-state LiDAR (SSL), thus allowing a smaller size and requiring no moving parts (García-Gómez et al. 2020). Luetzenburg, Kroon and Bjørk have published detailed experiments that elucidate the technical capabilities of the sensor – the main takeaways are that the potential point density follows a linear trend on a logarithmic scale with 7,225 points at m^{-2} at 25 cm and 150 points m^{-2} at 250 cm distance and that the scope of errors in precision reside in the range of one centimeter. Their results also indicate that there are apparently no significant differences between the capabilities of iPad Pro and iPhone Pro LiDAR sensors (2021). The iPhone Pro's smaller size makes it more mobile, whereas iPad Pro features a larger monitor, allowing for closer examination and possible annotation of the data already in the field.

Many applications that utilize iPhone Pro's sensor for point cloud recording are available. These include such products as EveryPoint, Polycam, Modelar, Heges and Scaniverse. Others, such as Pix4DCatch combine the LiDAR sensor with photogrammetry and cloud-based processing. Various applications have been compared in Losè et al. (2022). Their multitude and the frequency of their updates show that there is currently high interest in developing and marketing this technology. For the purposes of this study, Scaniverse was chosen due to its free license and the possibility to easily export the data in LAS format (Figure 2.3). Pix4DCatch was chosen in turn due to its ease of use and its synergy with Pix4DCloud that could allow for instant sharing of the results.

Riegl VZ-400i is an industrial level TLS that can gather 500,000 measurements per second, with accuracy running around 5 mm (Figure 2.4). The measurement range is between 1.4 m and 800 m, making it ideal for large open spaces and structures. Optimal operating temperature is between 0°-40° C. Operation is almost instantaneous: the user only needs to connect the camera and the GPS to the main unit and set up a new project, after which scanning can begin. Projects with several dozens of different scan positions are supported. The file formats used are Riegl's own proprietary solutions and require RiScan Pro software for processing. Exporting the point cloud into other formats (such as LAS or E57) is supported, however, and was used in this study as well. The dataset acquired by

VZ-400i was initially processed in Riegl RiScan Pro software and then exported as a LAS point cloud.
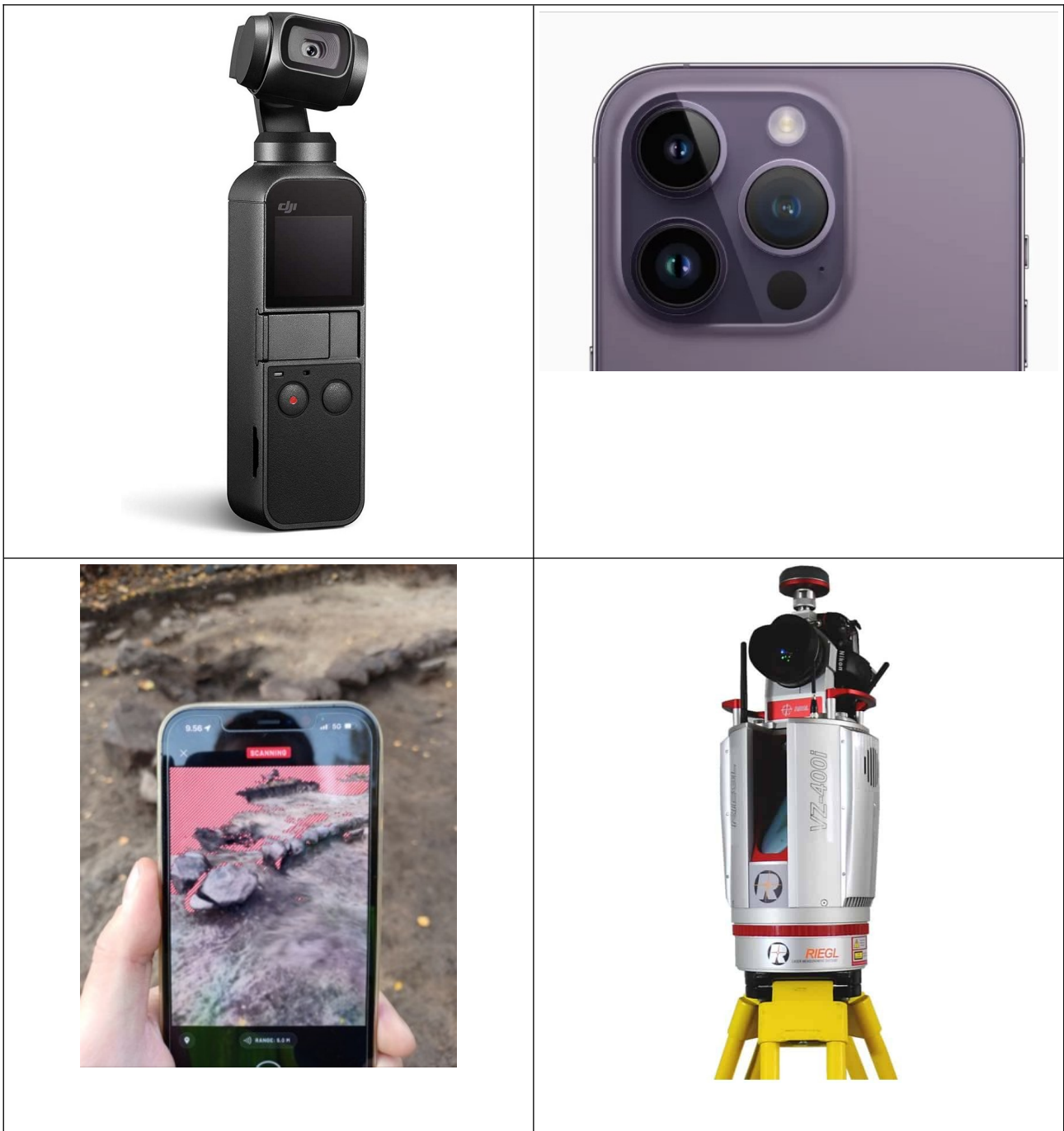

Figure 2: From left to right: DJI Osmo, iPhone LiDAR sensor location, iPhone scanning with onscreen visual feedback, and VZ-400i terrestrial laser scanner.

2.2 Data acquisition

In total, the site was documented several times using the DJI Osmo Pocket and RealityCapture method to create a continuous and total photogrammetry coverage of the whole excavation project.

However, for the purposes of this research the comparison data was recorded consequently during a single moment of the excavation on 10th of October 2022. The main target was a structural feature that consisted of several stones in a row and a small wooden structure, in addition to the main excavation area itself. This would allow for simple comparisons to be performed between the different point clouds. The documented area was situated inside a 10 m times 8 m rectangle, but due to its irregularity it had a total area of circa 53 square meters.

The recording was done during overcast weather, but, regardless, sufficiently bright light conditions. The time required for the actual shooting or scanning was written down: for DJI Osmo the filming took 13 minutes, iPhone 12 Pro with Pix4D took 6 minutes and with Scaniverse 7 minutes, whereas the Riegl VZ-400i scan took 17 minutes for nine scan positions. These timings do not include the initial setup of the equipment, but rather the time it took from turning the recording and scanning on until it was turned off. Scanning around the area of interest was done at a slow walking speed with variance in angle and height of the sensor done manually by the operator. For Scaniverse and Pix4D, the feedback on the iPhone screen was consulted to achieve sufficient coverage.

All point clouds were imported into CloudCompare software, where they could be compared using the Multi-Scale Model-to-Model Cloud Comparison tool (abbreviated as M3C2) (Lague et al., 2018). Subsampled clouds would be colored by Scalar Fields (SF) based on the distance of each point to the reference point cloud, which could then be visualized either through showing the resulting point cloud with SF colorization, or by exporting the data itself and showing it as a histogram, for example. M3C2 was used instead of the more straightforward Cloud-to-Cloud distance plugin (C2C), also available in CloudCompare and used in many other comparison studies (e.g. Murtiyoso & Grussenmeyer 2021: 489; Morena 2022: 181. Cf. Luetzenburg, Kroon and Bjørk 2021), since M3C2 results in signed distances, whereas C2C is able to present only absolute values. This means that M3C2 is better for detecting systematic bending or warping of the pointclouds.

The data collection was performed without the use of ground control points (GCPs) to minimize the requirements for equipment and setup. Instead of GCPs, the Multi Station Adjustment (MSA) plugin of RiScan Pro was used for aligning the data sets with the reference point cloud (Figure 3). MSA is based on the Iterative Closest Point algorithm (ICP), which was introduced already in 1992 (Besl & McKay; Chen & Medioni).
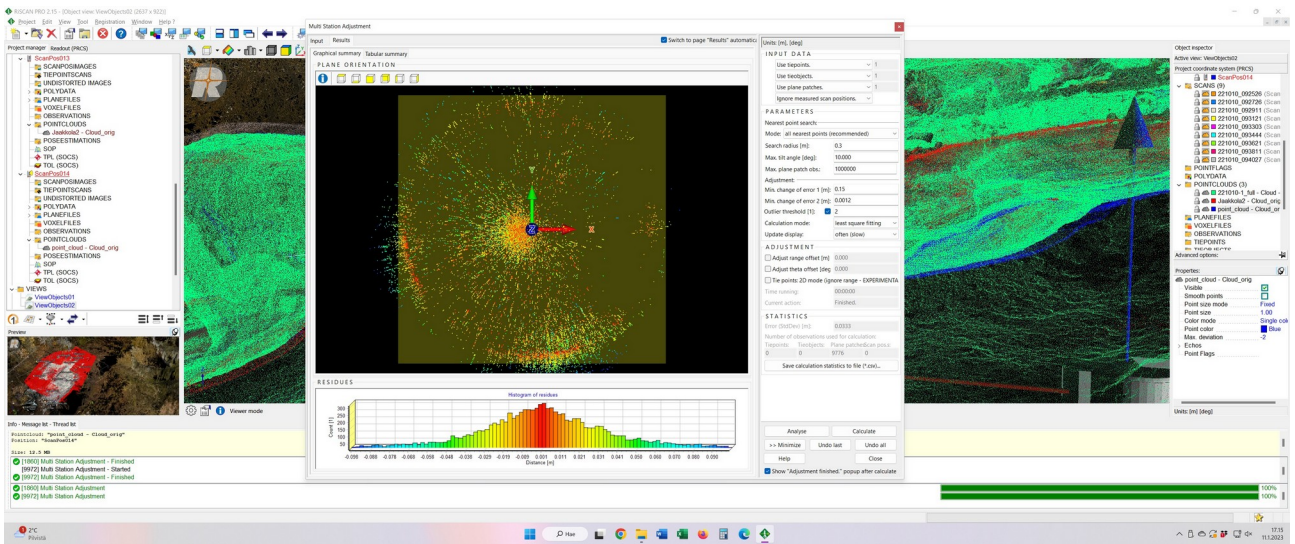
Figure 3: A view of Multi Station Adjustment tool in RiScan Pro software.

To demonstrate the capabilities of MSA, a M3C2 comparison was performed on two different scans from different positions collected using the Riegl VZ-400i (Figure 4). This example showed that the MSA is an accurate and efficient tool for point-set registration and that M3C2 provides homogenous and even results.
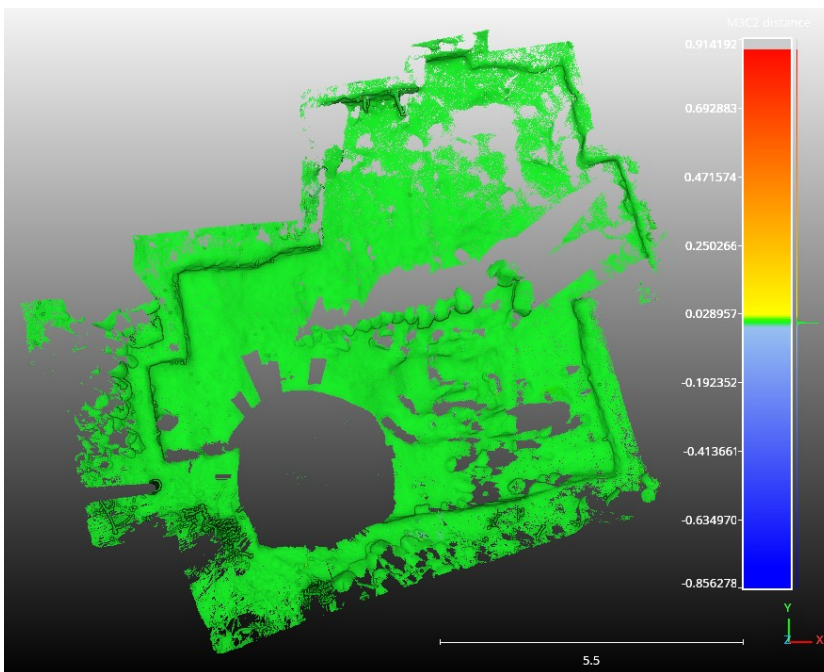

Figure 4: Comparison of two Riegl VZ-400i scanning positions using M3C2 plugin.

Volumetric comparison of a chosen single feature was also performed in CloudCompare to attain another view of the possible discrepancies in the datasets. This was done using the Compute 2.5D Volume tool and comparing the point cloud volumes with the reference point cloud from Riegl VZ-400i.

3. Results

3.1 Visual inspection

The number of points in the point cloud was the greatest in Riegl VZ-400i scan and the photogrammetric model created with RealityCapture, 33,142,943 and 88,023,719, respectively. Scaniverse scan had 2,296,711 points and Pix4D 1,883,721. These results immediately show that the quickest and the most mobile methods also yielded the sparsest point clouds, which was expected. It is unclear whether increasing the scanning time with Scaniverse or Pix4D would improve the resolution – both applications show visual feedback for sufficiently scanned areas, and sweeping them again with the scanner might not have an effect on the results The Riegl scan was cropped to remove the unnecessary surroundings, whereas neither of the point clouds acquired with iPhone 12 Pro reproduced the whole of the excavation area, with the results concentrating on the center of the scanned area, the foundation stone structure. This was unexpected, since the application screen for both of the products implied that the whole area had been scanned with sufficient coverage.

Regardless, through initial visual inspection one can notice that at least all the principal features can be discerned from all the point clouds (Figure 5.1–4). The variation in the RGB coloring of the data was notable. All three point clouds created by mobile solutions had a considerably lighter color range when compared to the point cloud extracted from the Riegl TLS data. On a subjective note, it seems that the three mobile techniques reproduced the colors more accurately.
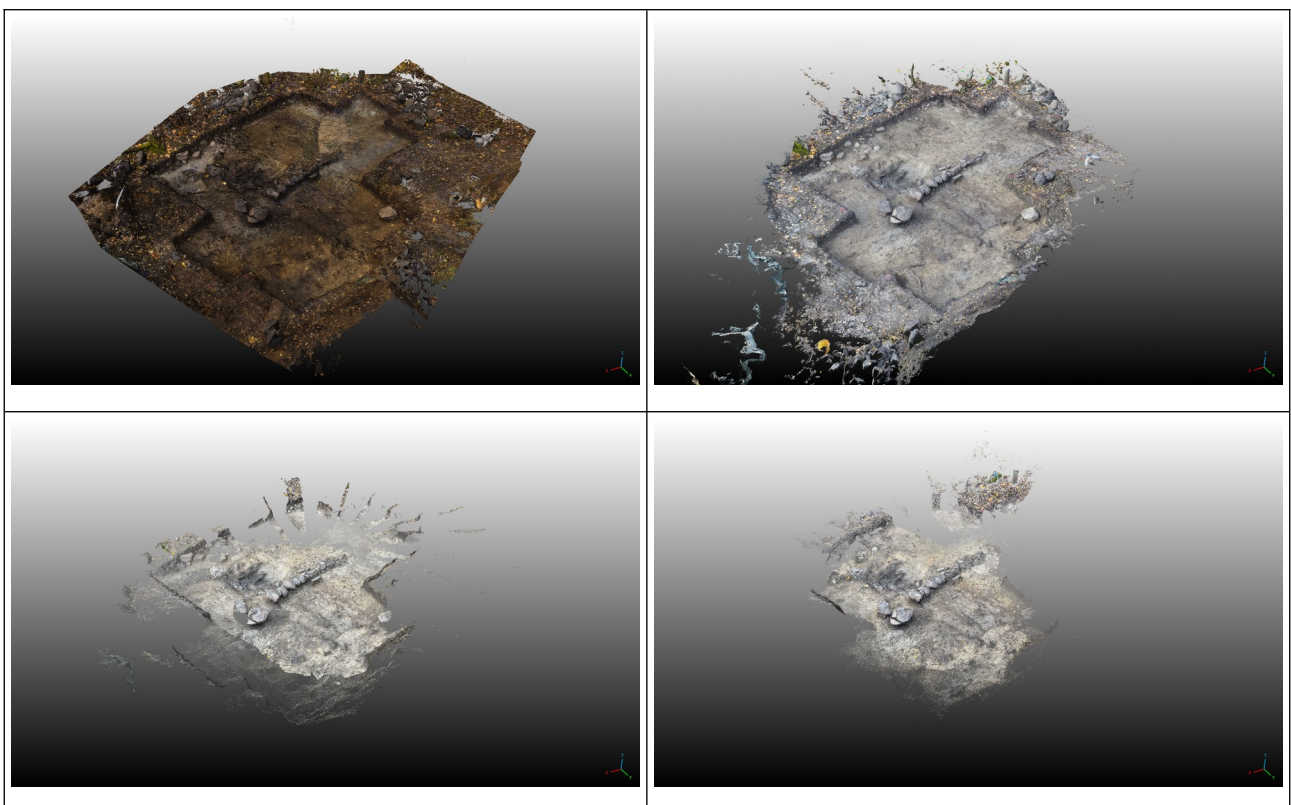
Figure 5: Textured views of four clouds. From left to right: Riegl VZ-400i (cropped), DJI Osmo + RealityCapture, iPhone 12 Pro + Pix4D and iPhone12 Pro + Scaniverse.

3.2 M3C2 comparisons

When it comes to precision and accuracy, visual inspection of the unprocessed point clouds shows no clear distortions or significant amounts of noise. Comparing point clouds with the reference point cloud by using the M3C2 plugin in CloudCompare, however, brings the problems to light. By inspecting the histograms based on the SF's generated by M3C2 the differences are instantly visible (Figure 6.1–3). The green color represents +-2 cm difference in regard to the reference data. Gray color means that the representative area was not present in the data under evaluation. The steepest histogram can be seen in the DJI Osmo / RealityCapture data, but Pix4D and Scaniverse seem also relatively good.
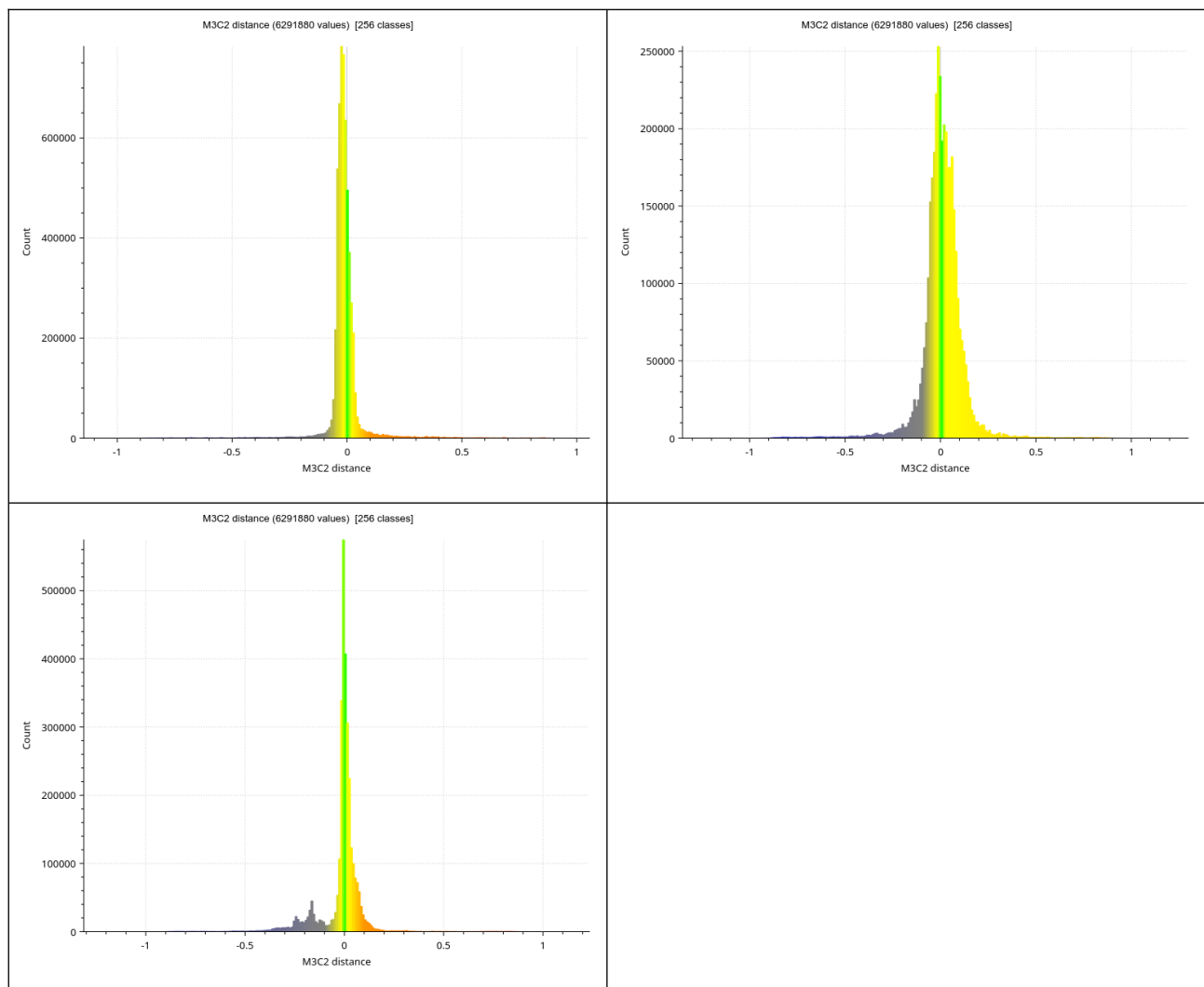

Figure 6: Histograms in descending order: DJI Osmo and RealityCapture, iPhone 12 Pro and Pix4D and iPhone 12 Pro and Scaniverse. M3C2 distance signifies the difference to the reference cloud in meters, whereas Count signifies the amount of points falling into that M3C2 range.

Table 1 presents the clustered results, categorized into five groups based on their potential applicability in archaeological studies. In Finnish archaeology, there are no officially established

fixed margins of error for precision in field measurements (Museovirasto, 2020). However, from our experience, measurements with a precision of less than 0.02 (2 cm) can still be considered acceptable, as they fall within the range of potential errors that may occur due to human error or differences in interpretation during activities such as total station measuring or manual drawing. It is essential to note that the appropriateness of this level of accuracy depends on the specific context of the research; for example, a two-centimeter accuracy may be grossly insufficient for the requirements of paleolithic excavation projects.

The subsequent cluster of points, with an error range of 0.05–0.02 m, can still serve as ad hoc measurements suitable for high-frequency documentation of large stratigraphical units and prominent architectural features during the excavation process. Nevertheless, it is important to acknowledge that this level of inaccuracy already highlights the limitations associated with the data quality achievable using these mobile devices.

Error	Max – 0.5	0.5 to 0.1	0.1 to 0.05	0.05 to 0.02	Less than 0.02
DJI Osmo + RealityCapture	0.79 %	4.68 %	4.32 %	45.43 %	44.77 %
iPhone + Pix4D	1.08 %	15.39 %	25.13 %	34.54 %	23.86 %
iPhone + Scaniverse	1.60 %	25.13 %	14.16 %	16.62 %	42.49 %

Table 1: Errors in point cloud precision by single point according to M3C2 comparison performed in CloudCompare.

Together these two first groups consist of 90.2% of all measured points for DJI Osmo, 58.4% for Pix4D and 59.1% for Scaniverse. Clusters with errors larger than this – 5 cm or more – contain points that are not sufficiently precise for other uses than simple visualizations. Considering these results, it seems that only DJI Osmo and RealityCapture offer any kind of promise for precision in this kind of field documentation. Significantly, one quarter of all the points measured with iPhone 12 Pro and Scaniverse combination have an error of 50 cm or more. One has to take into account the possible errors in M3C2 comparison for this kind of discrepancies, but regardless, this means that a major portion of all data collected with Scaniverse was virtually useless.

However, when the point clouds themselves are inspected with the SF coloring activated, one can see how and where this variation of precision occurs. Generally, the edges and borders of the documented area have the most difference in comparison to the reference point cloud, especially when it comes to features outside the excavation area. These could still have a difference of even tens of centimeters. Otherwise, it seems that due to the MSA alignment the large even soil surfaces match closely with the reference data. This is important considering the possibility of 3D-documenting stratigraphical development of the excavation, where different stratigraphical units

need to be accurately demarcated, and thus vertical error of several centimeters could cause problematic overlap.

The problems in the photogrammetry results might be due to issues with the automatic camera calibration performed in RealityCapture. This may cause a so called "bowl effect". where the resulting point cloud distorts by protruding its sides vertically. Examining this further, it was noticed that RealityCapture had calculated slightly different calibration for each frame – this, in turn, seemed to happen due to a possible bug in the software, since the metadata of the video file does not transfer into the extracted frames, thus making the program process each frame separately. In addition to improved calibration, the use of GCP's could help with these errors (the bowl phenomenon has been described in e.g. Jaud et al. 2019).
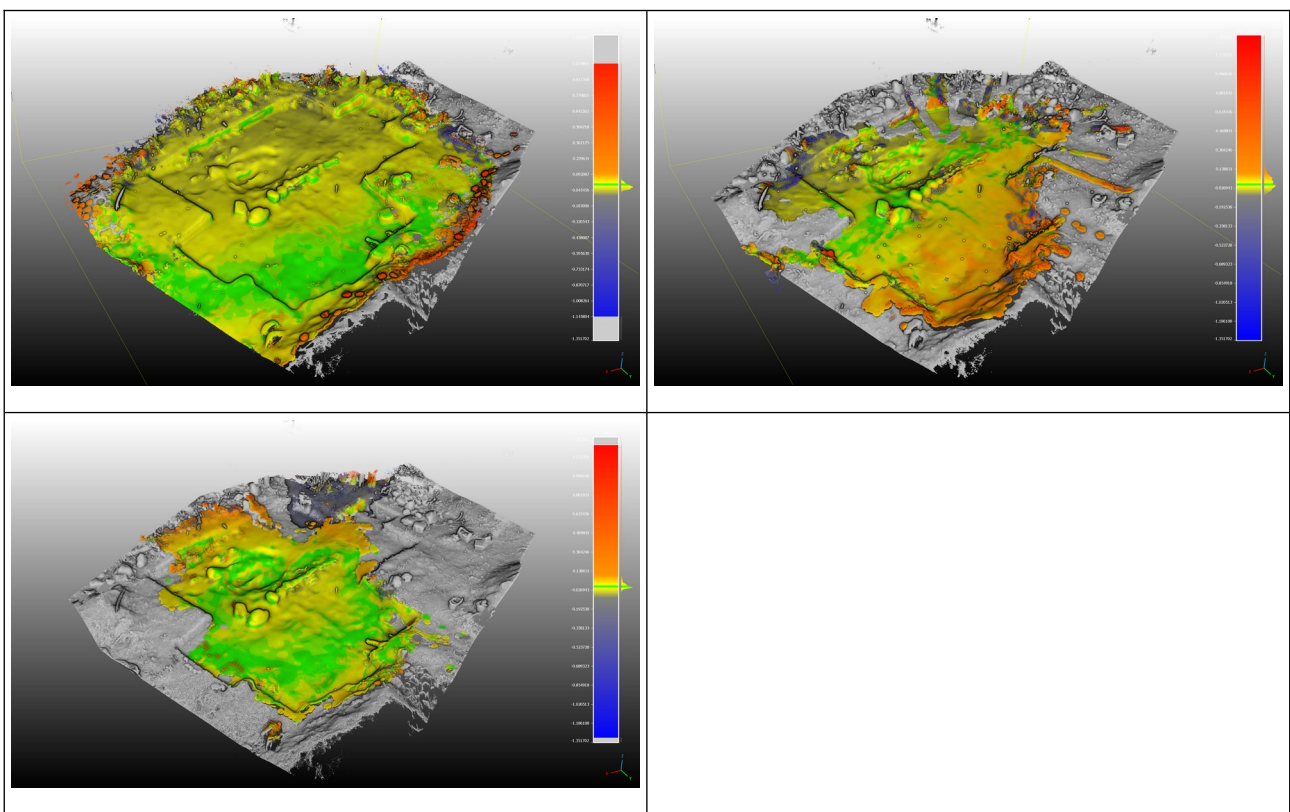

Figure 7: Point clouds colored using Scalar field values of M3C2 comparison. In descending order: DJI Osmo and RealityCapture, iPhone and Pix4D and iPhone and Scaniverse.

3.3 Volumetric comparisons

To support the observations reached through the M3C2 analysis, some volumetric measurements from two segmented areas were compared with the reference point cloud using the Calculate 2.5D Volume tool in CloudCompare. The objects – two large rocks in the northeastern corner of the structure, and the row of stones that was in the middle of the documented area, were segmented simultaneously from all the aligned point clouds. Resulting comparisons can be seen in Table 2.
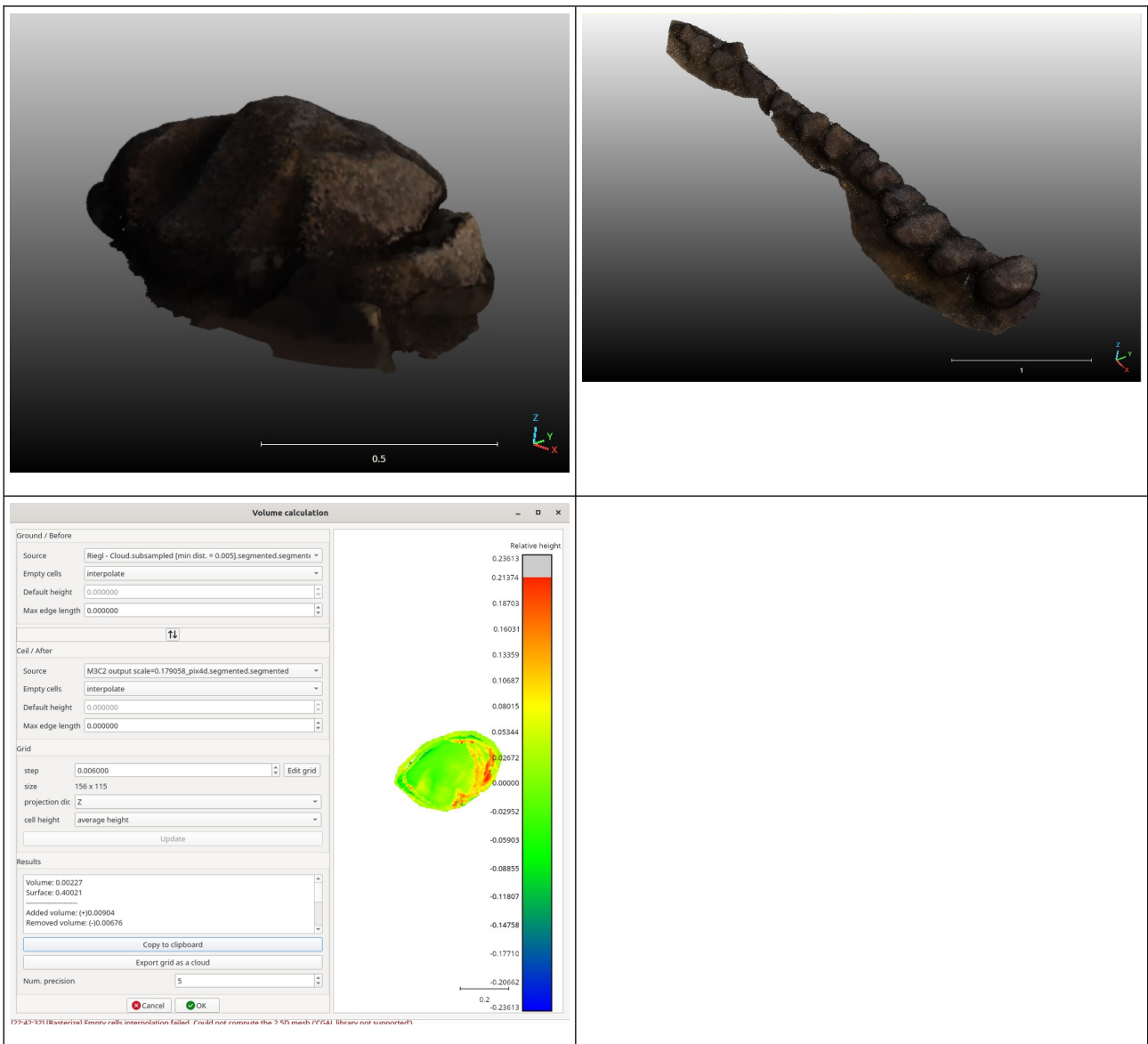
Figure 8: From left to right: The Riegl point cloud of a rock used in the comparisons; the Riegl point cloud of the stone row used in the comparisons and a view of the Calculate 2.5D Volume tool.

The differences are not massive, but still significant, depending on the intended use of the data. For example, in the case of single rocks their shape is not captured accurately in all three dimensions in this kind of sweeping scans. Differences are in the range of 0.0083–0.001 cubic meters depending on the methods used, which still means an error of even 8300 cubic centimeters, or 8.3 liters.

Object	Rock 1	Rock 2	Stone row
DJI Osmo + RealityCapture	-0.0083	-0.050	-0.0080
iPhone + Pix4D	0.0023	-0.008	-0.001
iPhone + Scaniverse	-0.0060	-0.020	-0.006

Table 2: Results of volumetric comparison of difference to the reference point cloud in cubic meters.

Surprisingly DJI Osmo + RealityCapture method seems to perform worse than the others in this section. However, this may be partially explained by the technical differences between the three methods. The CloudCompare output shows both added and removed volume separately and DJI Osmo generated point cloud shows a systematic tendency for the removed portion to be always larger, whereas for the two iPhone 12 based methods the amounts are always roughly balanced. This is possibly because all the LiDAR point clouds had some noisy outlying points around the documented objects, whereas the cloud generated by photogrammetry did not feature this phenomenon. This would mean that the reference data, being also captured using LiDAR, would have the same noise issues as the two iPhone 12 point clouds, whereas the DJI Osmo + RealityCapture point cloud would appear volumetrically smaller. Performing an aggressive denoising and filtering of all the laser scanning data might have lessened the differences, but it was not performed here to make the workflow more straightforward, since the motivation was to test quick and mobile methods with minimal postprocessing.

All in all, it seems that the variance of the data indicates that none of the three methods can be relied upon for really precise volumetric analysis of this kind of subjects. Visual inspection shows that the general shape and size are replicated sufficiently, but the measured volume is not accurate in the end. However, for the purposes of drawing 2D vectors and mapping for the field excavation report, high volumetric precision is not essential.

4. Conclusions

All equipment and methods were successfully employed to attain a point cloud of the target area, but significant differences were observed regarding their usability and precision, in addition to variation in possibilities and usability of processing, sharing and further analysis. In general, both iPhone applications lacked precision and scope required for this kind of recording. They show a lot of promise and can be used in more limited cases, where precision smaller than few centimeters and accurate geometry are not required. Swift production of rudimentary models for visualization and communication purposes might be such situations, for example. However, currently they are significantly lacking in quality if they were to become the main tool for measuring archaeological features during the excavation process.

Generally, when it comes to all kinds of mobile laser scanning approaches, it still seems that LiDAR sensors integrated into mobile phones are far behind TLS devices and other kinds of equipment. This applies to archaeology only to a certain degree, however. Whereas industrial applications might require sub-millimeter precision, many applications in archaeological fieldwork (especially

when recording non-architectural features) can suffice with an error of few centimeters. The example from Kerava presented in this article is a good example: when it comes to documenting mixed stratigraphical layers and damaged stone structures from the 16th or 17th centuries, a difference of few centimeters is sufficient. This applies especially to continuous and high-frequency systems of documentation, where several scans could be performed daily to record the stratigraphical development of the excavation process and where the physical stratigraphical delineations, especially on the horizontal plane, are already products of interpretation done by the excavators themselves.

Especially photogrammetry is being already used extensively and intensively in large excavation projects, but often its precision has not been sufficiently evaluated, or at least the results have not been published (e.g., Boyd et al. 2021). As has been shown in this paper, simple visual inspection might not reveal the problems in geometry and precision of the data. The photorealistic quality of the results can be deceiving – if no systematic evaluation of these methods is performed, archaeologists might end up with measurements that look beautiful and realistic but are significantly more imprecise than ones that could have been done with more traditional methodology, such as total station measurement. At the moment, these lightweight and mobile tools share many problems, but their low price and easy accessibility are a welcome sign of quick democratization of these technologies.

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