S07 Integrating 3D photogrammetric data in the field: Challenges, implications and solutions

Jens-Bjørn Riis Andresen

In recent years the proliferation of image based 3D techniques has enabled very detailed archaeological recording at greatly reduced time and cost. However, this requires extensive computation time, and as a consequence the processing and interpretation of the resultant models is often disconnected from the archaeologists on site. This is problematic, as the success of any recording technique is contingent on its ability to validate and interpret data while in the field. In this session we focus on solving the theoretical and methodological problems involved in closing the gap between excavators and their data . Contributions should explore how we can optimize workflows and enable archaeologists to meaningfully engage with and use 3D data on site

S07-01 RAPID Aerial Scanning of UNESCO cultural heritage sites in the Kingdom of Saudi Arabia

Mohamed al-Farhan, Ahmad al-Hasanat, Mohamed Shalaby, Luca Passone, Thomas Levy, Neil Smith

The rapid and extensive digital documentation of cultural heritage is now being made possible through the use of unmanned aerial vehicles and photogrammetry. A joint archaeological and computer vision project called RAPID was initiated in 2014 to digitally capture several of Saudi Arabia's major cultural heritage sites throughout the country. By using a combination of non-invasive aerial and terrestrial 3D scanning techniques, the UNESCO cultural heritage sites of Al-Hijr (Ancient Dedan, Madain Saleh), ad-Dariyah and Al-Balad Historic Jeddah were digitally recorded. A major obstacle faced for each of these sites was their sheer size and complexity. In particular, Historic Jeddah's dense urban cityscape consisting of hundreds of Rowshan tower houses spans an area of 250,000 m┬▓. Each site provided unique challenges in how UAVs and time-of-flight laser scanning were integrated. The project has resulted in massive datasets and ground-breaking software just to manage and visualize it. In this paper, we present the results, methodology, learned best practices, and integrated software and hardware developed to digitally document these massive areas of cultural significance.

S07-02 Digital workflow on a selection of Danish excavations in the Århus area—With special emphasis on the use of 3D recording

Carsten Meinertz Risager

In recent years the amount of digital data recorded by Danish museums with archaeological mitigation responsibilities has increased dramatically, especially with the increased use of 3D recording techniques. Handling these data is complex, and involves reconciling locally evolved, practice-led digital frameworks with mandatory national databases. This presentation will provide an overview of these frameworks, followed by an exploration of the digital workflow Moesgaard Museum uses for its excavations by providing case-based walkthroughs of the different steps involved in 3D documentation of excavations. This will include a live demonstration of the 3D documentation process.

S07-03 The 3D photogrammetry documentation of the Mesolithic grave from Brunstad, Norway

Kristin Eriksen, Almut Schülke

In 2014 archaeologists from the Museum of Cultural History, University of Oslo, found the remains of an inhumation burial with preserved human bone material on the Mesolithic site of Brunstad, Vestfold, Norway. Preserved bone material is seldom found in Norwegian Stone-Age contexts due to very acid soil conditions, and possible grave-finds that can be ascribed

the Mesolithic period are rare. Thus the documentation of the grave was of special importance. The grave was unearthed in several blocks for excavation in the laboratory. 3D-photogrammetry was used to document the situation in the field, but also under later excavation in the laboratory, where each block was singularly documented. The aim was to later compile the different datasets to reconstruct the components of the burial. We used the software Agisoft Photoscan and ArcScene for 3D-modelling and processing. In the talk we will focus on the challenges of documenting this find and the search for practicable solutions. This involves the excavation, documentation and preservation work in the lab. We will describe the workstation that was used for a well-functioning co-operation and work-flow between the osteo-archaeologist, conservator, and the GIS-expert. Several challenges will be pointed out, like the poor condition of the skeletal material, and the fact that the burial due to several reasons had to be split into several blocks before it could put together again digitally. We will also show how 3D photogrammetric data can contribute to the understanding and interpretation of the burial.

S07-04 Using 3D photogrammetry in the field: An example from Kvåle Sogndal, Norway
Cecilia Falkendal, Ingebjørg Njos Storvik, Kevin Wooldridge
During a small excavation project at Kv ├Ñle Sogndal in the Spring of 2015, archaeologists from the Universitetsmuseet i Bergen used a pole camera and Agisoft Photoscan 'structure through motion' software as a tool for basic site data capture. This was utilised along with the Intrasis archaeological GIS programme to record a complicated structural sequence of medieval and later buildings, associated with a possible church and later forming part of a farm complex. Processing of the geo- referenced 3-D orthoimages was achieved on site by the excavation team and the results used for the detailed recording of the structures and as the annotated record for entry into the site GIS. The geo- referenced orthoimages served as the basic on-site horizontal site plan and also the vertical profile record. This paper will detail the methodology used for the initial data capture and on-site processing and the practical applications of onsite 3-D imaging.

S07-05 Mobile 3D scanning: Non-disruptive site recording
Lutz Schubert, Frank Griesinger, Thomas Guderjan
3d scanning and visualisation have gained increasing interest over recent years, as scanning technology becomes more readily available and as first virtual and augmented reality devices appear on the market. As a method for inspecting prospective sites, to document excavation process, to involve the public and to share data about excavated objects, 3d scanning also becomes increasingly interesting for archaeology before, during and after excavation. However 3d scanning is still either expensive or not very precise and generally difficult to set up and disrupts the work on the site. Lighting conditions must typically be considered and an according period of time planned for executing the scan. Within this paper we present an algorithm that allows on the fly scanning with mobile, potentially head-mounted devices in a non-disruptive fashion, e.g. during site surveying. Though this could allow for a 4d documentation, the presented approach focuses on scanning one constant site only, i.e. without taking time into consideration. The work presented here is part of a larger development of an application to identify occluded structures, i.e. to identify hidden archaeology using "live" 3d scans and to integrate the information in excavation records.

S07-06 Supercomputing at the trench edge: Expediting image based 3D recoding
David Stott, Matteo Pilati, Carsten Meinertz Risager, Peter Jensen, Casper Skaaning Andersen, Jens- Bjørn Riis Andresen

Image-based 3D reconstruction with Structure From Motion (SFM) techniques are increasingly used for documenting archaeological excavations. They afford an inexpensive means of recording accurate, detailed spatial and radiometric data, but there are a number of challenges presented by these methods. Foremost among these is the time it takes to produce a finished model. Due to the computationally intensive nature of these techniques processing often takes hours to complete. This is problematic, as archaeological excavation is by its nature a destructive practice where success is contingent on the quality of the record. Validating and interpreting these data in the field, while the subject still exists is essential. Thus, rapidly processing the models and making them available to archaeologists as they excavate is of crucial importance.
In this presentation we demonstrate how the process of model generation can be expedited to occur in near real-time, from the field. This is achieved using three approaches. First, by remotely processing the images over a 4G mobile internet connection to the High Performance Computing (HPC) cluster at DeIC Abacus 2.0 we can dramatically increase the computational power available on site. Second, we examine the effect different parameters have on processing speed and quality of the finished model. Third, we argue that data transfer and processing time can be further optimised by appropriately constraining image size to the scale of the objects being recorded.

S07-07 Creation of an Early 19th century Siberian ship 3D model
Andrei A. Pushkarev, Olga V. Zaytceva, Mikhail V. Vavulin, Anna Y. Skorobogatova
The Northeast Passage played a great role in the colonization of Siberia. However, we know almost nothing about design and specific features of Russian ships of the 17thÔÇô19th centuries that sailed through the Northeast Passage and gave rise to the very first Russian settlements on the Ob river. Due to the absence of drawings and the inadequacy of written sources, dependable reconstruction of historic vessels is virtually impossible if no archeological data is used. Archaeological investigation of a 19-century wooden ship was performed in 2015 on the bank of Kiryas, an arm of the Ob river. At the moment, this is the only large wooden ship in Siberia explored using archaeological methods. Another unique feature of the ship is its almost undamaged condition, which will ultimately allow for complete reconstruction. The flat-bottomed ship measures 34 Đà 7 x 1,7 m. The planks of the bottom and the side slopes are connected with more than 50 frames made of stump wood. In order to save as much information about the unique discovery as possible, a computer reconstruction project was developed. The first stage was launched in September 2015 and included two types of surveying:
1) Digital orthophotography of the ship location. The photos were made using Octocopter UAV Zala 421-22 and Sony RX1 camera.
2) High-precision digital photogrammetry of the wooden ship. Surveying was performed using Nikon D800 digital photo camera. The resulting photos were then processed with Agisoft Photoscan software. The works performed provided for:
- An overview ship location 3D model, 10 cm resolution;
- A textured ship 3D model, 0,4 cm resolution. In the course of works, the following new techniques were used:
- Overlapping of land survey data and UAV images;
- Survey of ill-lit areas:
- Combining images of individual ship parts into a whole model;
- Reconstruction of the missing ship elements using photos from earlier years.

S07-08 3D spatial analysis: Beyond extrusion and sectioning

Martijn van Leusen, Gary Nobles

Over the last 5 years, the fields of 3D archaeological data capture and visualisation have seen a quick development, both in terms of the technology involved (hardware and software) and in the numbers of groups involved and conference papers and articles produced. A similar development has been ongoing in many neighbouring disciplines. This paper, after briefly setting out the current state of the field, focuses on future needs and current limitations to the analytical use of 3D data in archaeology. It then sets out a proposal for an R&D agenda that aims to achieve mature 3D spatial analytical (GIS) functionality within 5 years.

S07-09 Enhancing evidence and re-evaluating interpretations with 3DGIS and image-based 3D replicas: The case of Borggade (Denmark)

Matteo Pilati

This paper illustrates a 3DGIS solution for the integration of image-based 3D recording in the investigation process at the medieval site of Borggade (Denmark). This experience reveals some methodological strengths and theoretical implications of using accurate and detailed 3D replicas of archaeological contexts for the managing of information in the field. Thanks to the reliance on a powerful offsite processing computer and a 4G data transfer connection, it has been possible to dispose of 3D replicas of the documentation surfaces and document them contextually to the excavation process. An entire library of over 150 replicas could be visualized and databased in ESRI's ArcScene, reproducing documentation surfaces (plans and sections) the way they were shaped, perceived and initially interpreted by the archaeologists in the field. Furthermore, 3DGIS poses the archaeologist also in the position of representing, thus analyzing, the site as it never had existed in reality: the replicas can indeed be rearranged according analytical needs. As concluding remarks, given the accuracy and detail of true-to-reality 3D replicas their implementation can deliver a great amount of information about the site's structure and the onsite interpretation work; integrated in a 3DGIS environment, this information enhances the evidential and analytical value of documentation, promoting processes of data validation and re-evaluation of interpretations.

S07-10 In the fields and on the screens. 3D documentation for the excavations at Paphos Agora, Cyprus

Kasper Jan Hanus, Łukasz Miszk, Wojciech Ostrowski, Weronika Winiarska

Paphos Agora Project's fieldwork revolve around (currently) four trenches. The nature of excavations at ancient classical city makes the documentation extremely challenging task due to vast quantity of unearthed portable antiquities, mostly pottery shreds and complicated stratigraphical relations of the architecture. There are some universal requirements for the field documentation: it should be as close to "the reality" as possible, yet the recording process can not be too time consuming. Furthermore, acknowledging the digital revolution in archaeology, the documentation shall be easily transferable to GIS software. Thus, in order to og "beyond" the limitations of drawing documentation we have decided to test the utility of close range photogrammetry while documenting successive stratigraphic lots. This approach was tested during the excavations at the site of Paphos, Western Cyprus. The following pipeline was implemented: archaeological exploration - digital documentation - field interpretation. This workflow proved to be both accurate and time effective. Achieved accuracy of the models made out of close range photogrammetry were accurate enough to be directly imported to GIS software, furthermore the quickness of this method resolved the problem of the "bottleneck" - as usually drawing documentation is quite time consuming. 2D (ortophotoplans) and 2.5D (DEMs) documentation of every excavation lot was uploaded into GIS database, creating the base for further interpretation. As well the interpretation process

can be supported by creation of textured 3D models of the trench, that could be prepared for every stage of the excavations. This integrated approach is in our opinion a powerful tool to create a digital representation of the archaeological site for documentation and interpretation purposes.

S07-11 Closing a gap with simple toy. How using a tablet affected documentation workflow on the Rozprza ring-fort excavation

Jerzy Sikora, Piotr Kittel

The use of digital documentation, including image-based 3D techniques allows to reduce the role of traditional and time-consuming manual drawings. However it significantly shortens the process of obtaining data in the field, it also need long time for digital processing of images. In fact, this situation is nothing new. Older researchers probably still remember that similar challenges were connected with a traditional archaeological photography of pre-digital era. During the excavation on the medieval ring-fort and motte in Rozprza 2D and 3D photogrammetric documentation and integration of the results in GIS was widely used, eliminating traditional forms of field documentation. It was particularly important in extreme wet conditions of work in the bottom of Luci─à┼╝a river valley. Popular Agisoft PhotoScan software and QGIS georepherence module as well as a set of open source graphical raster and vector applications were used. The key role was the appropriate organization of the field work involving the parallel excavation of several sections by limited team. As a result, it was possible to flip explorers and equipment in situations where it was necessary to suspend work in the section, until the end of documentation process. An important facilitation was to support the process by using popular tablet on Android OS. It allowed the application of interpretation layers directly onto earlier prepared orthophotos, with direct contact with documented structures. At the same time descriptive documentation and registration of stratigraphic relationships were performed, using a custom Strati5 app, based on a spreadsheet. This way the field documentation based on 3D techniques became a series of actions implemented routinely at the completion of the exploration of the another layer or preparation of the another cross- section. Simple and cheap tablet helped to close the gap between gathering of field data and later processing and interpretations.

S07-12 The documentation of Neolithic flint mines—An experimentation of methods

Åsa Berggren, Anders Gutehall

What is the best method to document a site of numerous pits, the result of a complex sequence of digging and filling, cutting and reopening holes in the ground in search of flint during the Early Neolithic?

During an excavation of Neolithic flint mines in 2014 in the area of S ├Âdra Sallerup in Malm ├Â, Sweden, we experimented with various methods to document the mines in plan. These methods are now being evaluated. In addition a comparison to methods used to record the mines during the decades long history of excavations in the area is also executed.

The methods used were hand drawing on paper, digital planning with GPS, orthophotography, and photogrammetry. This paper discusses the evaluation of these methods and the impact of the methods on the process of interpretation.

Archaeological documentation methods have developed quickly during the last decades, digital techniques have become increasingly accessible and affordable. The increased use of these methods affects the prerequisites of archaeological interpretation and consequently the knowledge that is produced. However, this shift is seldom problematised or analysed.

The development of methods often takes place within research projects, with carefully chosen objects. However, we were able to use a choice of methods within a contract archaeology project, albeit with additional means from a research fund supporting the evaluation. The

objects are typical of developer funded archaeology, not visible above ground, quite different from standing remains of architecture often regarded as suitable for research experiments of digital documentation.

n addition to adjusting the method to the recorded object, our results show that quite low tech digital solutions can go a long way towards achieving a detailed and relevant record. As each method seem to capture slightly different aspects, a combination of methods also seems preferable.

S07-13 Back and Forth through the contexts: 3D Geographic Information Systems in support of field documentation

Nicolo' Dell'Unto, Giacomo Landeschi, Jan Apel

The use of three-dimensional (3D) models in support of intra-site investigation activities represents an important novelty in archaeological practice. Unlike interpretative drawings, which provide a schematic and symbolic description of the site, three-dimensional models have the capacity to display the full qualities of a context immediately upon exposure, providing a high qualitative geometric description of the site at any specific time frame of the investigation activity. Among the different workflows of 3D data acquisition that have been presented in literature, a very few case studies actually discussed the impact that this new typology of data has on archaeological practice. Since 2014, archaeological investigation activities have been carried out at the Mesolithic site of K ├ñmpinge (Southern Sweden) by the department of Archaeology and Ancient History at Lund University. The documentation activity performed so far has been completely recorded in three dimensions and managed in the field by a 3D Geographic Information System (3D GIS). In specific, by employing tablet PCs and field laptops, 3D models (as a result of image-based 3D modelling techniques) were georeferenced and used in the trench in aid of the field documentation. The possibility of taking advantage of a 3D real time platform capable of providing a spatio-temporal overview of the sequence of contexts retrieved at different stages of the investigation allowed the achievement of a completely different perception of the site. This paper will present and discuss the results of this experimentation, focusing on how the systematic use of a fully-3D visualization system in support of archaeological practice affects field interpretation, excavation strategies and knowledge production.

S07-P2 Questions and bottlenecks: The precariousness of computation heavy documentation in the field

George Alexis Pantos

Archaeological excavation is often a complex business that requires constant interpretation and reappraisal that is well catered for by traditional documentation tools of the pen, pencil and eraser. While, photogrammetric recording methods offer many benefits, they currently lack the same immediacy, flexibility and adjustability of traditional methods. Furthermore these recording techniques promote a different way of interacting with the archaeological record during data capture and represent a fundamentally different record to traditional forms. The poster draws on the experiences and experiments with single context and multi-scale 3D recording - successful and otherwise - carried out as part of excavations at Shubayqa, Jordan. The poster seeks to emphasise the complex interrelated variables that can affect 3D recording and its use on site - from decisions on what and when to record (or re-record) to technical dependencies and environmental limitations that can lead to bottlenecks in workflow. While solutions to some problems have been overcome in the examples given, the main aim of the poster is to provide a frank account of the use of an imperfect technology in the field and to raise and to highlight important questions at each step of the process.