# Integrated Utilization of Advanced Technologies in Archaeology and Heritage Management

**Master Course and Continuing Professional Education Course**
**23 November 2015 – 29 February 2016, Budapest**

Supplemented with the new approaches and research projects connected to digital technologies in Hungarian archaeology and heritage management

Edited by
Zsuzsanna Renner, Erzsébet Jerem,
József Laszlovszky

ARCHAEOLINGUA
CEU CENTRAL EUROPEAN UNIVERSITY

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Nemzeti Kulturális Alap

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Cross-section layers with point cloud background of the Solomon Tower, Visegrád Castle, Hungary (Mensor3D Ltd.)

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# Integrated Utilization of Advanced Technology in Archaeology and Heritage Preservation Today

## Master Course and Continuing Professional Education Course

The Archaeolingua Foundation in conjunction with the Cultural Heritage Studies Program of the Central European University offered a Master Course in archaeological heritage between November 2015 and February 2016. The series of six lectures looked back as its antecendent to the conference entitled *New Digital Technologies and Hungarian Innovations in Heritage Management – Archaeology, Historic Landscape and Built Heritage*, held form 7–12 February, 2015 and supported by the National Cultural Fund.

It was the first ever Master Course on this topic to be organized in Hungary, despite the fact that the approach and knowledge indicated in the title have become part of current archaeological practice at the international level. The program was intended to speak to a broad audience from university and doctoral students through researchers and practicing professionals to the general public.

Internationally recognized European experts were invited to speak at the Master Course who introduced the archaeological and heritage preservation applications of digital technologies according to their specific fields of research interest. The guest speakers were introduced to the audience by Erzsébet Jerem, Managing Director of Archaeolingua Foundation, and József Laszlovszky, Director of the Cultural Heritage Studies Program at Central European University, at whose initiative the Master Course had been organized. After each presentation a Hungarian expert was invited to add some remarks on the Hungarian results or scientific experience in the specific topic under discussion. The Master Course was hosted by the Cultural Heritage Studies Program of the Central European University, with the Auditorium of CEU (Budapest V, Nádor u. 9.) as the venue of the events.

The aim of this publication is to give an overview of the current state of archaeological research and address the emerging problems of the main issue of the master course, that is, the integrated utilization of advanced technology in archaeology and heritage preservation. In the first part we publish the extended abstracts of the presented topics, accompanied with illustrations, in some cases first published, as well as pictures of the events. The bibliography attached to the first paper offers a starting point for further research and can be used as orientation material for similar projects.

In the second part we have collected representative materials from Hungarian experts and teams working in the same fields to demonstrate the contribution of these projects to the application of new digital technologies. These projects were introduced as presentations or posters at the conference and exhibition *New digital technologies and Hungarian innovations in heritage management – Archaeology, historical landscape and built heritage*, jointly organized by Archaeolingua and Central European University in Budapest, 6–7 February 2015, and published in a booklet under the same title by Archaeolingua in 2015. Finally, we include here a recent case study by the Mensor3D team, one of the exhibitors, which is a spectacular example of the applications of 3D virtual reconstructions.

We hope that this publication will reflect our original intention to provide useful information on the current issues of heritage studies and the technologies facilitating their visualization and comprehension. Last but not least, we consider it worth while preserving the thoughts and problems that are being addressed by experts and researchers in the second decade of the 21st century.

# Integrated Utilization of Advanced Technology in Archaeology and Heritage Preservation Today

## Events of the Master Course

*Nov 23, 2015*

Michael Doneus
Ludwig Boltzmann Institute, University of Vienna

Non-invasive techniques for prospecting archaeological landscapes: current techniques & future developments

*Dec 14, 2015*

Knut Paasche
Norwegian Institute for Cultural Heritage Research

Major North European projects show best practices in heritage management based on high quality archaeological surveying, efficiency and the use of new non-intrusive methods

*Jan 11, 2016*

Julian Richards
Archaeology Data Service, University of York

The preservation and re-use of archaeological data

*Jan 25, 2016*

Richard Hodges
The American University of Rome

A career in ruins

*Feb 8, 2016*

Sorin Hermon
The Cyprus Institute, Nicosia

Are we there yet? 3D as a research methodology in archaeology

*Feb 29, 2016*

Adrien Olivier
Institute of Archaeology, University College London

Integrated Heritage Management: challenging values – changing attitudes

# Integrated Utilization of Advanced Technology in Archaeology and Heritage Preservation Today

## Master Course and Continuing Professional Education Course

The Archaeolingua Foundation in conjunction with the Cultural Heritage Studies Program of the Central European University is launching an English language master course in archaeological heritage. The series of lectures will continue and expand upon the work begun with the conference entitled *New Digital Technologies and Hungarian Innovations in Heritage Management – Archaeology, Historic Landscape and Built Heritage* that was supported by the National Cultural Fund.

No master course on a similar topic has yet been organized in Hungary despite the fact that the approach and knowledge indicated in the title have become part of everyday practice at the international level. We would like our program to speak to a broad audience, from university and doctoral students through researchers and practicing professionals to the general public.

Our lecturers will be internationally recognized European experts in the field who in their presentations will introduce archaeological and heritage preservation applications of digital technologies according to various topics. To each of the lectures by foreign professionals we will invite a Hungarian expert who will add further thoughts on the presentation for the Hungarian audience, as well as supplementing them with the most recent results of Hungarian research. The individual lectures and the related topics will be introduced by the organizers of the series, Erzsébet Jerem and József Laszlovszky.

We will provide interpretation for the discussion part of the sessions.

**Dates of the sessions:**
A total of six lectures will be held on Mondays at 5:30 p.m. between 23 November 2015 and 29 February 2016

**Venue:**
Auditorium of Central European University (1051 Budapest, Nádor u. 9.)

**First three lectures of the planned program:**

Monday, 23 November 2015, 5:30 p.m.
**Michael Doneus** (Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology, Programme Line 1 Archaeological Remote Sensing and University of Vienna, Austria):
***Non-invasive Techniques for Prospecting Archaeological Landscapes: Current Techniques & Future Developments***

Monday, 14 December 2015, 5:30 p.m.
**Knut Paasche** (Norwegian Institute for Cultural Heritage Research, Oslo, Norway):
***Major North European Project Shows Best Practices in Heritage Management Based on High Quality Archaeological Surveying, Efficiency and the Use of Newer Non-intrusive Methods***

Monday, 11 January 2016, 5:30 p.m.
**Julian Richards** (Archaeology Data Service, University of York, United Kingdom):
***The Preservation and Re-use of Archaeological Data***

**Further lectures:**

Monday, 25 January 2016, 5:30 p.m.
**Richard Hodges** (The American University of Rome, Italy)

Monday, 8 February 2016, 5:30 p.m.
**Sorin Hermon** (The Cyprus Institute, Science and Technology for Archaeology Research Center, Nicosia, Cyprus)

Monday, 29 February 2016 5:30 p.m.
**Adrian Olivier** (University College London, United Kingdom)

**Hungarian institutions collaborating on the lecture series:**

CEU CENTRAL EUROPEAN UNIVERSITY
Central European University, Budapest

ARCHAEOLINGUA
Archaeolingua Alapítvány, Budapest

Eötvös Loránd University, Institute of Archaeological Sciences, Budapest

FORSTER KÖZPONT
Forster Gyula National Heritage Preservation and Property Management Centre, Budapest

Hungarian Academy of Sciences, Research Centre for the Humanities, Institute of Archaeology, Budapest

The lecture series was supported by the Directorate of National Cultural Fund of Hungary.

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## Michael Doneus

Deputy Director, Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology, Vienna and Deputy Director, Department of Prehistoric and Historical Archaeology, University of Vienna


**Michael Doneus** is Professor of Landscape Archaeology at the Department of Prehistoric and Historical Archaeology at the University of Vienna. He is also Deputy Director and Key Researcher at the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology. He is specialized in landscape archaeology, archaeological remote sensing (aerial archaeology, airborne laser scanning, imaging spectroscopy), photogrammetry, surveying and GIS and has an international reputation as committee member of the Aerial Archaeology Research Group, and member of the ICOMOS & ISPRS Committee for the Documentation of Cultural Heritage (CIPA). Apart from his university teaching, he has been offering international tutorials on aerial archaeology in Hungary, Finland, Italy, Poland, Slovenia and Switzerland for the last twenty years. His most important projects include "The Celts in the hinterland of Carnuntum" (2004–2006), "LiDAR supported prospection of woodland" (2006–2008), "Aerial archaeological interpretation of the civil town and canabae legionis of Carnuntum" (2007–2008) and the "Automated georeferencing and orthorectification of archaeological aerial photographs" (2012–2014).

# Non-invasive techniques for prospecting archaeological landscapes: current techniques & future developments*


Michael Doneus[1,2] – Wolfgang Neubauer[2,3] – Immo Trinks[2]

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The term '*landscape*'comprises both physical and cognitive space, with the latter referring to the concept of its dwellers. Landscape archaeology has to cope with both aspects of space. Based on the description of its physical remains in form of archaeological and palaeo-environmental structures, an interpretation of its meaning has to be sought. There seems however still to exist a division between technical and interpretative approaches when investigating archaeological landscapes.

The mission of the *Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology* is to bridge this divide by developing systematic, high-resolution, large-scale, integrated archaeological prospection approaches while at the same time focusing on novel methodological concepts for the archaeological interpretation of the data collected in large quantity and quality. By integrating traditional methods (systematic field-walking) with near-surface geophysical (magnetics, ground penetrating radar) as well as remote sensing techniques (aerial photography, airborne laser scanning, imaging spectroscopy), entire landscapes are thoroughly documented at multiple scales. The generated data forms the basis for a four-dimensional GIS-based interpretation approach.

Considerable advancements have been made in the field of remote sensing data acquisition, both in terms of data quality as well as data quantity. For aerial photography, a cost-effective hardware solution (GNSS and IMU) allows to record all indispensable exterior orientation parameters during image acquisition for automated archiving of each photograph's footprint (Wieser et al., 2014). Airborne imaging spectroscopy (AIS) was previously characterized by an archaeologically insufficient ground-sampling distance. Only recently, a

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* This abstract is based on the following short paper: M. Doneus, W. Neubauer, I. Trinks, Exploring Europe's past landscapes: Current techniques & future developments. In: Axel G. Posluschny (ed.), *Sensing the Past - New Approaches to European Landscapes.* Proceedings of the ArchaeoLandscapes Europe Final Conference, Frankfurt, 24–26 February 2015. Dr. Rudolf Habelt GmbH, Bonn, 2015.

resolution of 40 cm could be achieved, which allowed the extraction of detailed, archaeologically relevant features. Next to problems of data redundancy and the visualization of the large amount of data generated, the increased resolution also introduced a considerable amount of noise. Therefore, a MATLAB®-based toolbox (ARCTIS –ARChaeological Toolbox for Imaging Spectroscopy) was developed for filtering, enhancing, analyzing and visualizing of imaging spectrometer datasets (Atzberger et al., 2014; Doneus et al., 2014).

Utilizing green laser sources, airborne topo-bathymetric laser scanner systems are able to measure surfaces above and below the water table across large areas in great detail using very short, narrow green laser pulses, being able to even reveal sunken archaeological structures in shallow water (Doneus et al., 2013). The radiometric calibration of full-waveform ALS data can now be achieved both for single as well as multiple wavelength data (Briese et al., 2014; Lehner and Briese, 2010).

In the course of the first four years of the LBI ArchPro several motorised multichannel magnetometer systems were developed and taken into operation. Thorough testing now permits the reliable use of magnetometry for high-resolution archaeological prospection at very large scale. Using a sample spacing of 25 cm crossline and 10 cm inline, daily coverage rates of over 20 hectares have been achieved. Two different novel multichannel GPR systems (MIRA and SPIDAR) have been evaluated (Trinks et al., 2010), motorized, adapted and optimized for their use for efficient large-scale prospection. Very dense GPR data acquisition with 4×8 cm, 4×10 cm or 5×25 cm has become possible at unprecedented daily coverage rates of up to six hectares. By April 2015 the large-scale archaeological geophysical prospection within the LBI ArchPro case studies and associated projects (Carnuntum, Gokstad) has reached a total coverage of 42.7 square kilometres at the above mentioned spatial measurement resolution (33.5 $km^2$ magnetics, 9.2 $km^2$ GPR).

On the basis of software packages developed by Alois Hinterleitner at the Austrian Central Institute for Meteorology and Geodynamcis for the processing of traditionally acquired geophysical archaeological prospection data, *ApMag* and *ApRadar*, the new software suite *ApSoft2.0* for the processing of very large prospection data sets acquired with motorized survey systems using automated positioning solutions has been realized. This new software is able to process and visualise magnetic and GPR data recorded along irregular paths and includes advanced processing steps such as GPR data migration in two and three dimensions, the output of coverage shape files and the automatic generation of geo-referenced data images for subsequent data analysis and interpretation in GIS.

For the future interpretation of all case study data, a comprehensive GIS-based interpretation workflow and tool-set '*ArchaeoAnalyst*' is being developed. It includes semi-automatic data classification algorithms for magnetic prospection data using multi-scale hierarchical data segmentation, object-oriented definition of semantic classes for data classification and an iterative classification workflow, resulting in data sets devoid of unclassified areas (Pregesbauer et al., 2014). This approach is being expanded to GPR depth-slice data, and possibly will comprise in the future even 3D GPR volume data.

All developments are systematically tested in the framework of international large-scale case studies conducted in Austria, Great Britain, Sweden, Norway and Germany (Draganits et al., 2014; Gaffney et al., 2012; Neubauer et al., 2014; Trinks et al., 2013). These case studies form an important and integral part of the LBI ArchPro research programme, for the testing of the theoretical and practical developments in regard to high-resolution landscape archaeological prospection at unprecedented scale and resolution (Trinks et al., 2012). The results demonstrate that it has become possible and affordable today to acquire high-resolution data across large areas, measuring square kilometres rather than hectares. In combination with modern interpretation techniques this novel approach heralds a new era in archaeology, where archaeological excavation no longer is the primary source of information for archaeological research.

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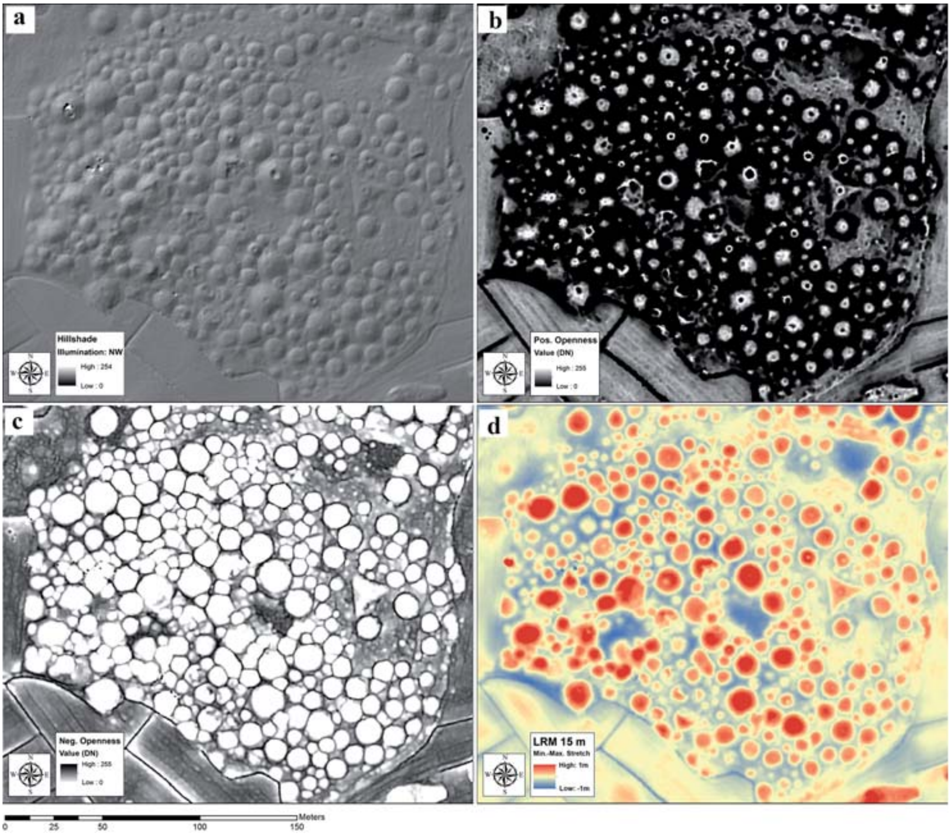


*Figure 1. Different visualizations of grave field Hemlanden at Birka (Sweden). (a): shaded relief model (light source in NW); (b): positive openness (r = 7.5 m; 2nd standard deviation histogram stretch applied); (c): inverted negative openness (r = 7.5 m; 2nd standard deviation histogram stretch applied); (d): local relief model (kernel size = 15 m)*

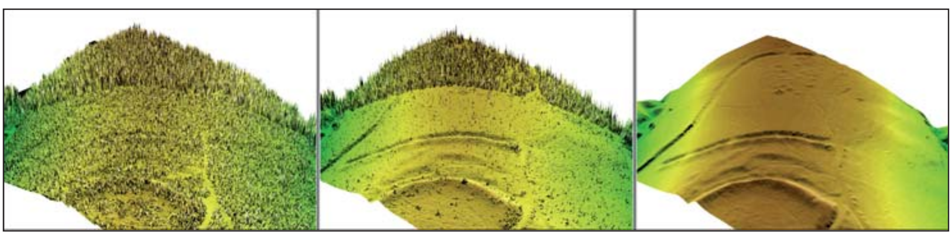

*Figure 2. Left: DSM of the first pulse data showing the canopy of the scanned area. In the foreground, the vegetation consists of dense bushes. In the background there is a dense forest with understorey. Middle: DSM resulting from the unfiltered last echo point-cloud. There are many points, which represent, tree-trunks, very dense vegetation or narrow vegetation, which do not represent the actual ground. Right: filtered DTM showing even faint archaeological traces, as e.g. round barrows with shallow depressions from looting.*

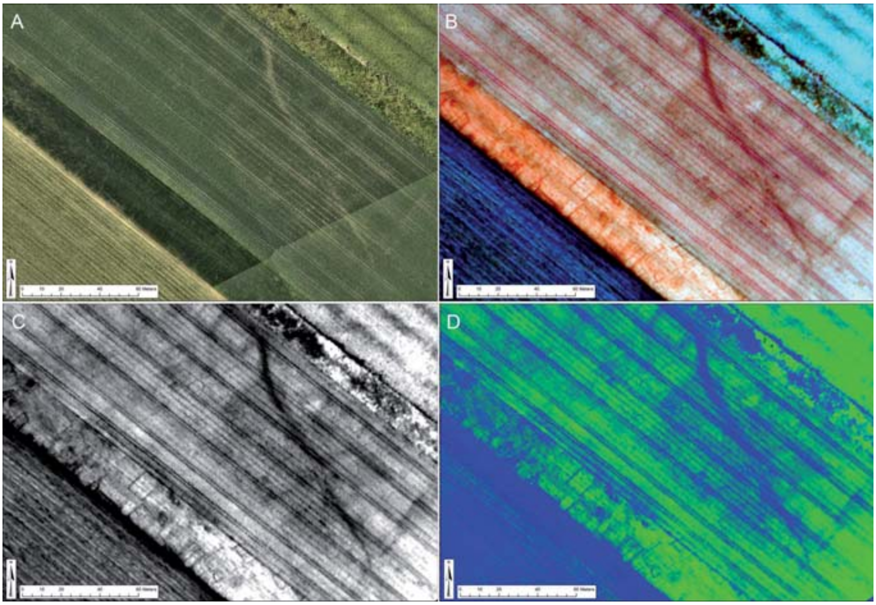


*Figure 3. Data from Carnuntum, Lower Austria, acquired on May 26 2011. (A) Conventional orthorectified aerial image, acquired in the visible spectrum. GSD of 0.1 m; enhanced using contrast limited adaptive histogram equalization (CLAHE); (B) false colour composite created by means of the REIP algorithm (R= band 1 (wavelength), G = band 2 (slope), B = band 3 (reflectance value)). (C) rate parameter b of the gamma distribution fitting; (D) normal distribution fitting ( R = NONE, G = band 2 (σ), B = band 1 (μ)). GSDs of (B), (C) and (D): 0.4 m. Figures B, C, and D were subject to the same histogram stretch by means of standard deviation.*


*Figure 4. Surface model of the Croatian Island of Palacol derived from Structure from Motion (Image: Geert Verhoeven)*


*Figure 5. Michael Doneus speaking in the Auditorium of Central Europen University*

*Figure 6. From left to right: József Laszlovszky, Michael Doneus, Erzsébet Jerem*

## Knut Paasche

Senior Researcher, Norwegian Institute for Cultural Heritage Research (NIKU), Member of Scientific Board

**Knut Paasche** is an archaeologist and researcher, he is also Head of the Archaeological Department of NIKU. He has been working as an archaeologist for over twenty years now, for four years as county archaeologist in Buskerud county. He has led many archaeological excavation and registration projects all around Norway. He has experience in the Stone Age, the Bronze Age, and the Iron Age, as well as in the Middle Ages, with a main focus on the registration of automatically protected outlying cultural heritage sites and the excavation of medieval cities. He also worked for four years on ship archaeology and deputized as collection manager at The Viking Ship Museum in Oslo. Later, in addition to creating and proposing a new reconstruction of the Tune ship, he led a research project on the new documentation and reconstruction of the Oseberg ship. His current research focuses primarily on the methodological approaches to archaeology, hence the opportunities and technical innovations for improved field documentation, namely, satellite recordings, electronic scanning and geophysical methods. Knut Paasche is Head of the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology, Norway, and the Miljø 2015-project “1537 kontinuitet eller brudd”, funded by the Norwegian Research Council. He holds a master’s degree in Nordic Archaeology with focus on the Middle Ages. His doctoral thesis is about the documentation and reconstruction of archaeological objects, with the reconstruction of the Tune ship as an example.

## Major North European projects show best practices in heritage management based on high quality archaeological surveying, efficiency and the use of new non-intrusive methods

According to Norwegian and other European legislation, developers have to ask regional authorities if there are archaeological remains in the planning area. This principle requires high quality archaeological surveying and also that archaeologists become more efficient using new non-intrusive methods. It is necessary during early planning processes that communication is concise and clear and it is also important to be able to survey large areas both when municipal master plans are at an early stage and when large building projects are planned and prepared.

High quality means better tools for surveying new archaeological discoveries. Tools that can help us prioritize at an early stage in the planning process narrow down the archaeological survey area. This is of special importance in large projects, such as road and railway construction. Tools like GIS, geophysics and airborne laser scanning will not only save the developers' money, but can also help us in the management process and further improvement of academic performance and archaeological results.

Our research so far has shown that remote sensing and geophysics can be sufficient in surveying projects, but will often have to be combined with conventional methods. In good practice conventional methods such as reviewing old historical maps, previous archaeological heritage in the area, and distribution of archaeological finds, etc. must be used as well. Also, 'old-fashioned' trenching or stripping of topsoil and traditional excavation will to some extent be necessary. Proven methods should therefore not necessarily be replaced. This approach is more about having an option that is non-intrusive, a tool that can help us in the effort to make the right priorities.

The Norwegian Institute of Cultural Heritage Research (NIKU), Vestfold County is today part of a larger international research group, The Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI ArchPro). It was established in 2010, and is dedicated to the development and application of novel, advanced, non-invasive archaeological prospection techniques and methods for landscape archaeology. LBI ArchPro combines state-of-the-art remote sensing methods, latest high-resolution near surface geophysics, sophisticated computer science, geomatics and archaeology. The goal is to develop universally applicable methods and techniques for efficient non-invasive detection, documentation, investigation, visualization and interpretation of archaeological cultural heritage.

One of the main aims of the Norwegian part of the project is to be more efficient during registration and examination of large areas with archaeological remains still intact. At the same time focus is on getting better archaeological, or if you wish, historical results out of our efforts. Today pre-excavation evaluations carried out in connection with cultural heritage management and area planning relies heavily on large-scale trial trenching which is both time-consuming for the archaeologists and disrupting to land owners which can even be damaging to archaeology. Therefore, NIKU, Vestfold County and its international partners are testing a variety of non-intrusive methods for monitoring and managing at Norwegian cultural heritage sites. So far this research has shown that destructive trenching can be limited or in some cases even completely eliminated.

Remote sensing is through the LBI-ArchPro and its partners and is fully employed in Norwegian archaeology. The experiments that have been carried out over the last few years show that these methodologies have the potential for providing archaeologists with cost-efficient tools for decision making both in the planning process and research. By covering larger areas, archaeologists will be better equipped to set archaeology in a broader context than by using more traditional methods such as trial trenching and small-scale excavations. Additionally, areas of high archaeological interest may be avoided in order to preserve archaeological sites for the future.

Previously, remote sensing techniques in Scandinavia have been applied with varying results, and as a result these techniques have, in general, been dismissed by the archaeological community in Norway. In recent years, however, a number of successful experiments have been carried out in the vicinity of the areas chosen by the LBI team, and it is argued that by using appropriate methods, it will be possible to capture the variety of archaeological remains and the connections between the different sites.

One of the many factors influencing the results of the geophysical surveys is the soil conditions at the selected test sites. For this purpose, a highly detailed soil map of the selected area has been acquired and will be used in close conjunction with the surveys. However, it is argued that in order to fully understand why these methods have worked or not, an actual physical intervention will be necessary. This will, at a minimum, include trial trenches across some of the anomalies down to the underlying subsoil. Additionally, the various soil conditions within the test areas should be tested to see if there is a correlation between the soils and the geophysical results. Methods for fast soil analyses will therefore also be assessed during the course of the project. Extensive testing under Norwegian conditions gives us a clear idea how these methods will cope with the various soil and climatic conditions as well as the types of archaeology present. An expressed aim of the project further on will be to test to what extent we succeeded with our methods, and more importantly, to explain the reasons behind.

One of the most important aspects of the project will be to assess the suitability of geophysical prospection methods in Norwegian conditions. Previous experiments in the same areas have generally been successful and it is hoped that further experimentation with these methods will prove successful. The Norse and other Scandinavian projects are case studies under the LBI ArchPro umbrella. This means that similar techniques and practices are tested out in large parts of Europe. Hopefully this will in the long run benefit us all. Non-invasive archaeological prospection techniques will if all goes well be the best practice and also the most common methodology throughout Europe.

Due to an often high density of archaeological heritage sites, combined with increasing development pressures, as archaeologist we are forced to reconsider current practice all over Europe. Developers need predictability, and therefore archaeologists have to prioritize cultural environments (cultural landscapes) considered to be of regional and national importance. Prioritizing means picking out the most important cultural environments. The cultural heritage management should have very restrictive policy for approving development proposals which are in conflict with the cultural environments and heritage values. But a good practice in management also allows areas where development projects can be conducted with a more liberal attitude towards excavating and removing heritage sites. It is all about give and take.

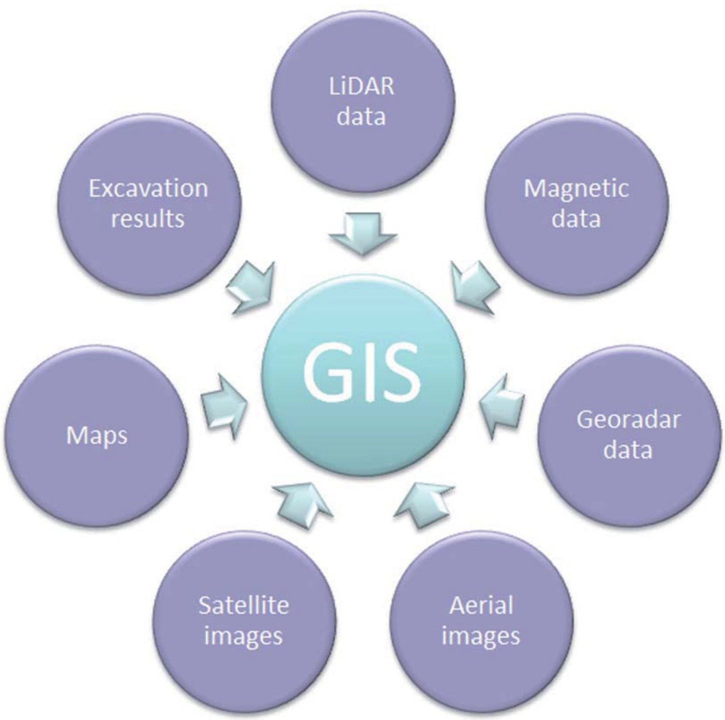


*Figure 1. Broad approach (illustration: NIKU)*

*Figure 2. Airborne laser scanning shows two of the plowed mounds (illustration: NIKU)*

*Figure 3. Large-scale prospection GPR (photo: NIKU)*

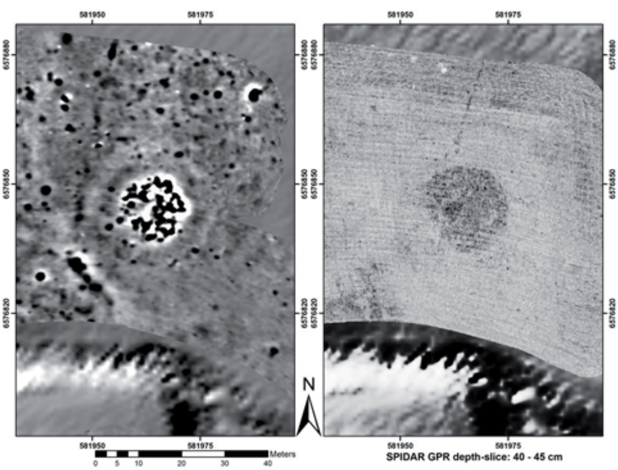


*Figure 4. Overplowed barrow shown by magnetometer and ground penetrating radar (illustration: NIKU LBI Arcpro)*


*Figures 5 and 6. Knut Paasche holding his presentation on high quality archaeological surveying at Central European University*


*Figure 7. József Laszlovszky introducing the speaker*

*Figure 8. Magdolna Vicze, Director of Matrica Museum and Archaeological Park, Százhalombatta, adding her experience on archaeological surveying*



*Figure 9. Erzsébet Jerem and Magdolna Vicze*

*Figure 10. Knut Paasche discussing with Magdolna Vicze after the presentation*

## Julian Richards

Director, Archaeology Data Service, University of York, UK

**Julian Richards** is a Professor of Archaeology at the University of York. He is Director of the ADS, and Co-Director of the e-journal Internet Archaeology. He first went to York to take part in the Coppergate Viking excavations, but after a brief spell at the University of Leeds he returned to York in 1986 to lecture on Anglo-Saxon and Viking archaeology. His direct involvement in archaeological computing began in 1980 when he started his PhD research studying pre-Christian Anglo-Saxon burial ritual using the computing power of an ICL mainframe and an early Z80 micro-computer. In 1985 he co-authored the first textbook in archaeological computing for Cambridge University Press, and has subsequently written numerous papers and edited a number of books on the applications of information technology in archaeology, as well as on Anglo-Saxon and Viking archaeology. Apart from computer applications his research interests focus on Anglo-Saxons and Viking and he has directed numerous excavations in England. He is also Director of York's Centre for Digital Heritage, and since October 2013 he has been the founding Director of The White Rose College of the Arts and Humanities (WRoCAH). He is author of *Viking Age England*, now in its third edition, and of OUP's *Very Short Introduction to Vikings*.

## The preservation and re-use of archaeological data

Heritage management tends to focus on issues surrounding the physical protection and display of archaeological sites and monuments. However, the intellectual record of centuries of archaeological research is just as precious. These resources may have been destroyed, either by the act of research itself, or by subsequent events. The concept of 'preservation by record' is deeply embedded in the archaeological process, and most countries have developed systems of heritage protection, and where destruction is unavoidable, legislative structures generally require some record to be made. Even though few archaeologists would accept that a completely objective record is possible, the primary professional ethic is still the presentation of a full record of observations, through publication and archive.

For the last hundred years the preservation of that record has largely been taken for granted. At the completion of a project the archive – including notebooks, plan and section drawings, files of recording pro-forma and photographs – would be boxed up and deposited with the appropriate museum or archive where it would be accessioned and consigned to a dusty shelf. Such archives were relatively stable, and although they might not be regularly used – if at all – it was a pretty safe bet that, short of war, fire or flood, they would still be there in 50 or 100 years. It also became standard practice that there should be a fairly exhaustive journal or monograph publication of the results of the research, although in most countries the scale of fieldwork combined with the range of data now recorded – and the cost of traditional publication – has led to a backlog, if not a crisis, in publication. Once more, however, so long as a hard copy report was published on paper its longevity was more or less guaranteed. Copies would be distributed to academic libraries around the world, and although few were read from cover to cover, the intellectual content was safe for future generations of scholars.

Consider then, the contents of an archaeological research archive in the twenty-first century: word-processed files, CAD drawings, digital photos, spreadsheets, database tables, GIS layers, and virtual reality reconstructions. The intellectual content is encoded in a complex sequence of binary information, recorded on magnetic or optical media. It is, of course, invisible to the naked eye, and requires sophisticated and rapidly changing technology to access it. Once decoded, it relies upon specialised and frequently proprietary applications software before we can make any sense of it. Furthermore, this precious archaeological resource is increasingly 'born digital', through data logging in computer-based survey systems, hand-held computers, or digital cameras. It never even touches paper between the ground and computer record. Even if it were possible to print it out, the sequence of numbers would mean little, and even a printed map falls far short of the functionality of a GIS application. Consider too, the form of the report, often available only as grey literature or distributed as a PDF file, and rarely accessible for scholarly research.

There is, at least, a growing awareness of the fragility of digital data and a realisation that digital data require active curation. A DVD may provide a durable means of preserving a particular sequence of binary digits, but contrary to popular belief, once the drive has been rendered redundant by the next upgrade in storage technology it will be no more secure than a 5¼ inch or an 8 inch floppy disc or a punched card or even paper tape. In short, the archaeological record is now at greater risk than it ever was whilst it was buried in the ground. However, there is also a realisation that the continuing trend to digital recording and storage provides unparalleled opportunities for the online dissemination of the intellectual results of archaeological research, and that electronic publication has the potential to provide unrestricted worldwide access to heritage information, at a variety of levels, and to broaden its appreciation. As well as facing a preservation crisis, heritage managers also have an opportunity, therefore, to make their discipline more accessible than ever before.

In the UK the Archaeology Data Service (ADS) has taken a lead role in the preservation and dissemination of digital data since 1996. It hosts over 1.3m metadata records for the archaeology of the UK, over 35,000 unpublished fieldwork reports, and over 1000 data rich archives. In 2012 it was awarded the Digital Preservation Coalition's Decennial Award for the most outstanding contribution to digital preservation of the last decade. This lecture examined the issues surrounding digital preservation and access, based on 20 year's experience. Although it describes a national solution, the problems are global, and are relevant to all those involved in the management of archaeological resources. The role of the ADS is to preserve, catalogue, and describe digital data generated in the course of archaeological research and to facilitate its re-use. These activities are mutually supportive as unless digital data are actively curated they will not be available to future scholars, and unless researchers are going to re-use data there is little point in expending effort attempting to preserve them. Preservation is therefore inseparable from publication from the outset.

Other European countries are also now establishing their own digital repositories for Archaeology. In 2007 the ADS was joined by EDNA, the e-depot for Dutch archaeology, which was established as part of DANS (Data Archiving and Networked Services), and funded by KNAW, one of the main Dutch Research Councils. Agreements to deposit archaeological data at DANS were formalised in the quality standard for Dutch archaeology, making archaeology one of the largest components of the digital resources hosted by DANS. Recently, the Swedish National Data Service (SND), based at the University of Gothenburg, decided to extend its collection policy to focus on Archaeology. It has worked with the Department of Archaeology and History at the Uppsala University to archive a number of archaeological reports and has published over 200 GIS files with excavation data from Östergötland. The most recent initiative to establish a national archaeological digital research infrastructure in Europe has been led by the German Archaeological Institute (DAI), which is part of the DFG, funded via the German Foreign Ministry. In 2012 the DAI established a new project, IANUS, with an initial staff of two, to scope what would be required to set up a digital archive for German archaeology.

In North America there have been a small number of significant initiatives which seek to provide cross-institutional support for digital archiving. Although seen primarily as a data publication tool, *Open Context*, based at the Alexandria Archive Institute, has developed a relationship with the California Digital Library to provide for long-term citation and preservation, and it is now one of two repositories mandated by the National Science Foundation. The other is *tDAR*, hosted at Arizona State University, and supported since 2009 by the Andrew W. Mellon Foundation. In Australia too, there have been numerous attempts to develop a digital research infrastructure for archaeologists. The latest of these is FAIMS (Federated Archaeological Information Management System), a highly ambitious project now led by Macquarie University. FAIMS aims to 'assemble a comprehensive information system for archaeology. This system will allow data from field and laboratory work to be born digital using mobile devices, processed in local databases, extracted to data warehouses suitable for sophisticated analysis, and exchanged online through cultural heritage registries and data repositories'.

With the proliferation of national repositories there is a compelling need to bring together and integrate existing archaeological research data infrastructures to enable researchers to use new and powerful technologies. There is a need for work on standards, and mappings between national and regional ontologies and vocabularies. Consider, for example, the proliferation of archaeological period terms within different European regions and countries. The lecture concluded with an introduction to ARIADNE, a new European e-infrastructure for archaeology. The goal of ARIADNE is to turn these disparate yet valuable resources into a pan-European Integrated Research Infrastructure, with easily available and harmonised access, responding to the research needs of an emerging community of users. It has been funded for four years from February 2013 under the EU Framework 7 Infrastructures programme. The infrastructure comprises 24 European partners, including heritage agencies and organisations, universities and research institutions and specialist digital archives. ARIADNE will enable transnational access to data centres, tools and guidance, and the creation of new web-based services based on common interfaces to data repositories, availability of reference datasets and usage of innovative technologies. It will stimulate new research avenues in the field of archaeology, relying on the comparison, re-use and integration into current research of the outcomes of past and ongoing field and laboratory activity.

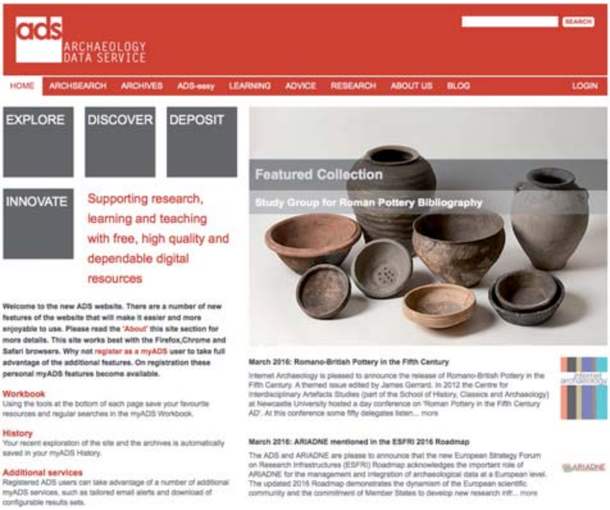


*Figure 1. Services of the Archaeology Data Service (ADS)*

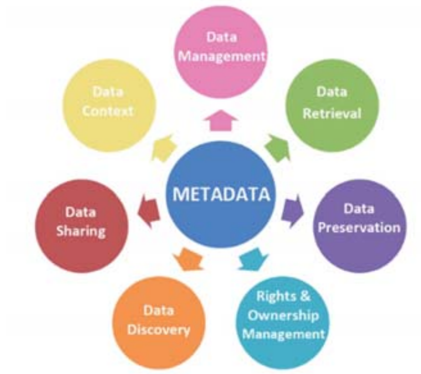


*Figure 2. Data management at ADS*


*Figure 3. Archaeology Data Service: Guides to good practice*

*Figures 4-5. Julian Richards talking on the preservation and re-use of archaeological data*




*Figure 6-9. Comments and questions: Erzsébet Jerem (Archaeolingua), Attila Kreiter (Hungarian National Museum), Katalin Wollák (Forster Institute) and Dóra Mérai (CEU Cultural Heritage Studies Program)*

*Figure 10-11. Members of the audience (Faisal Mohammed – CEU Cultural Heritage Studies Program, Katalin Bozóki-Ernyey – Construction and Heritage Office) asking questions to Julian Richards*

*Figure 12. Erzsébet Jerem and Julian Richards*

## Richard Hodges

President, The American University of Rome

**Richard Hodges** is the President of the American University of Rome since 2012. He began his career as an archaeologist with excavations in his home village of Box, Wiltshire while at high school. During that time he founded a village archaeology society which is thriving today. He studied archaeology and history at Southampton University where he completed a doctorate on the archaeology of Dark Age trade. In 1976 he joined Sheffield University as a lecturer and while there launched excavations in England and Italy at Roystone Grange (Derbyshire), Montarrenti (Tuscany) and San Vincenzo al Volturno (Molise). From 1988–95 he was Director of the British School at Rome, during which time he enlarged the excavations at San Vincenzo al Volturno with support from the Abbey of Monte Cassino, and joined the Butrint Foundation as its scientific director (1993–2012) to launch new excavations and site management strategies at the World Heritage Site of Butrint (Albania). From 1996–98 he was Director of the Prince of Wales's Institute of Architecture, then from 1998 he has been Professor in the School of World Art Studies at the University of East Anglia, Norwich. During this period, he served in the Ministry of Culture in Albania (1999) as adviser to the Packard Humanities Institute during the Zeugma (Turkey) excavations (2000), and as Williams Director of the University of Pennsylvania Museum of Archaeology and Anthropology (2007–12). He has been Visiting Professor at SUNY-Binghamton (1983), the University of Siena (1984–87), the University of Copenhagen (1987–88) and the University of Sheffield (2006–7). He was awarded the Order of the British Empire (OBE) in the Queen's honours in 1995.

## A career in ruins

This lecture set out to raise the issue of the relationship between cultural heritage and states, and illustrated this from my personal experiences in cultural heritage over the past forty-five years as a practicing archaeologist. A sub element was that I belong to a pivotal generation of archaeologists, fortunate to have worked during the great expansion of the discipline, before its recent academic contraction.

The lecture began with the premise that archaeologists are placemakers, but often do not know it. This was the case when I began excavating a Roman villa in my home village in 1967 and then made a village archaeological society around these endeavours. I described my experiences on a quintessential American excavation at Knidos, Turkey where the classical archaeologist Iris Cornelia Love was seeking trophy art in the footsteps of the Victorian archaeologist, Sir Charles Newton.

I described the nature of landscape archaeology in the Peak District, England, where with English Heritage support aided by the Peak District National Park we worked to create a trail through protected ancient farms. This successful cultural heritage intervention was contrasted with the wonderful European opportunity at San Vincenzo al Volturno, a Dark Age Pompeii, in Molise, southern Italy. Here, the chance to reframe the questions about the rise of Medieval Europe led to large scale EU funding, at which point I was removed from the project and the project goals were misconstrued as various local entities profited from the resources. The site, as a result, lacks basic conservation and makes no income from visitorship, and the accompanying museum was opened for a week in 2006, but since, the state of the collections remains unknown. This is very much in comparison to the work of the late Riccardo Francovich (Siena University) who championed public archaeology in Tuscany, Italy, and provided me with a benchmark for developing an archaeological park at the UNESCO World Heritage Site of Butrint, south-west Albania.

The Butrint project is described in my new book: *The Archaeology of Mediterranean Placemaking* (Bloomsbury 2016). Over nearly 20 years leading the Butrint Foundation, we developed a new narrative for the Greco-Roman-Byzantine port and its hinterland based upon the archaeological investigations. At the same time, working with the Albanian Ministry of Culture, we introduced a management plan and developed best practices in conservation and public outreach. Apart from many academic and popular publications, we upgraded the museum, erected a range of site information panels, worked with tour guides and collaborated with the local communities to build their stakeholdership. We were very aware of the political and social problems, but thanks to increased visitorship from about 1,000 tourists in 1993 to 100,000 tourists in 2013, Butrint has won itself an identity as an economic driver in its region.

The next project described the Zeugma rescue excavations on the river Euphrates in south-east Turkey, where I advised the Packard Humanities Institute, 2000-2004. The outline timeline was as follows:

- Biricik Dam projected from the 1930s
- Rescue excavations considered 1990s, with offer of support from GAP; rejected by government
- 1993 Rescue excavations by David Kennedy, published in 1998
- 11 May 2000 *The New York Times* featured the Zeugma tragedy
- 26-29 May 2000 RH visited for PHI; PHI project began in June and lasted until October
- 2000-4 Mosaic Conservation Project; terminated March 2004 ahead of the planned exhibition in Topkapi, Istanbul for NATO meeting in June 2004
- 2005 Gaziantep mosaic museum opened

These salvage excavations in the closing months of flooding the Biricik dam, now fully published by the Packard Humanities Institute (PHI), were intended to prefigure the making of a park and a museum where the extraordinary Zeugma mosaics might be viewed. The Packard Humanities Institute also supported Roberto Nardi and his team to conserve over 800 sq. m. of rescued pavements, but in March 2004 Nardi's team, close to completing their work, were forced to abandon the project. Little over a year later in 2005 the city of Gaziantep opened a new museum of its own, exhibiting the mosaics conserved thanks to PHI. In the lecture I examined how these outcomes might be interpreted in the short and long terms.

The last project lies in Romania, where I was invited in July 2014 to assess a gold-mining project. This caused the most discussion in the questions following the lecture.

Roşia Montană lies in the heart of the undulating Apuseni massif. A mining community since Saxon miners in the 14th century re-discovered Roman adits, it prospered under the Habsburgs and continued to be exploited under the communists in the post-war era. But with democracy following the grisly end of Ceauşescu in 1989, the galleries were closed and the miners joined the droves of Transylvanians who quit these hills and joined a disenchanted diaspora in Bucharest or further afield in Italy. On the brink of complete extinction a lifeline was thrown to the community by a Canadian mining company who fancied their chances of panning more gold from these hills using hi-tech methods. Before starting operations they followed Romanian (and international) prescriptions for meeting cultural heritage and environmental standards.

I was invited to see how competently the company had met its cultural heritage obligations because, after seventeen years of plugging away, they are on the brink of throwing the towel in, frustrated by a miasma of opponents. Roşia Montană is a modern mining landscape with isolated tracts of relic farms, a tradition shaped by almost a millennium. The modern village dates mostly from the 19th century, though its roots are probably medieval. But it is the remains of

Trajanic Dacian industrial efforts that have really brought us here. The surface Roman archaeology is provincial in character. Probed at great cost, thanks to the Canadian mining company, parts of the bath-house belonging to the administrative complex have been excavated, as have their temples and parts of their cemeteries including an ashlar-built circular tumulus imitating Augustus's mausoleum in Rome. Diligently published, the surface archaeology reveals the presence of different Roman communities, their investment in worship and the afterlife. All attests to a modest prosperity. Much the same might be said of the present village dating from the heyday of the Habsburg mines, now majestically restored. Notable for its tall-towered churches, tributes to the differing faiths of the miners, and the ample but sizeable miners' houses, Roşia Montană is a showcase historic village. An elegant museum tells the story of the mining township. But these surface remains are, of course, no more than the tip of the iceberg.

The Canadian mining company has also spent over $11 million dollars conserving the Cătălina Monuleşti galleries, created during Roman times. Their audacity is simply breathtaking: a peerless museological experience, safe and sustainable has been realized at a cost that governments will not pay. Has the mining company met its obligations, I was asked? Let me put it another way: how many other great European archaeological projects have been published, conserved and then made into museums in recent times? The elemental impact of this research upon Romanian archaeological standards cannot be overstated. As a result the Canadians, perhaps unwittingly, have entered the annals of archaeology, and possibly their greatest sin is not to know it!

The die-hard opponents of the mine say that renewed gold mining will destroy Roşia Montană, its ecology and history. How the truth has been twisted. Of course the landscape will be altered and reconstituted as in almost all Europe's heritage mining landscapes. But people matter too, as do their families. The new mines will sustain an age-old mining community in a region of high unemployment. More importantly, the re-opened mines will support the most remarkable Roman mine to be visited in Europe, and with it the later conserved Habsburg village, assuring the Apuseni mountains and Roşia are a focus of tourism during and after the projected gold mining operations (i.e. forever). Without the mining company the Roman mine of Cătălina Monuleşti will never be maintained by the penniless Romanian state.

In conclusion, this combination of real world and research projects has taught me that the academic community is barely engaged in public archaeology. More seriously, cost-benefit analyses let alone modern business practices are a mystery to many in archaeology. As a result, states and entities like the EU have under-developed notions of the importance of archaeology in an era when demand is growing rapidly from global tourism that exceeds 1 billion tourists per annum. In essence, if the discipline of archaeology is not to return to being a mere (expensive) aspect of history, it is essential that my career in ruins – and those of my pivotal generation – are used to reshape the kind of education in archaeology and cultural heritage that is taught in universities today. This then should be the bases for radical reappraisals of nation state and international approaches to cultural heritage assets with a view to supporting long-term sustainability by working with communities like those described in the lecture.

*Figure 1. Saranda 1998*

*Figure 2. Outside Carnac mine*

*Figure 3. Visitors studying a site panel at Butrint*



*Figures 1-3. Moments of Richard Hodges' presentation*

*Figure 4. József Laszlovszky's introductory remarks*

*Figures 5-6. Questions and remarks: Katalin Szende (CEU Medieval Studies), Katalin Tolnai (PhD student, University of Vienna)*

## Sorin Hermon

Assistant Professor, The Cyprus Institute, Nicosia

**Dr. Sorin Hermon PhD** is an assistant professor at STARC (The Science and Technology in Archaeology Research Center) of The Cyprus Institute (CyI), where he leads the research group on digital cultural heritage. He conducts research in the areas of domain ontologies, 3D scientific visualization, semantic structures, knowledge representation and 3D digital documentation. He is the author and co-author of more than 50 scientific publications, and a member of the scientific committee for major conferences in the field, such as Computer Applications & Quantitative Methods in Archaeology (CAA), European Association of Archaeologists (EAA), Virtual Systems and Multimedia (VSMM), etc. Sorin Hermon leads one of the major research infrastructure projects at CyI, supported from a Structural Funds Grant (STARLAB – a mobile laboratory for advanced sciences in archaeology) and is the principal investigator in several other EC funded research projects. He advises several postdoctoral fellows and PhD candidates in the field of digital cultural heritage.

## Are we there yet? 3D as a research methodology in archaeology

Virtual Archaeology (VA) and its related 3D component have shown an increased development in the scientific archaeological literature since their first introduction in the field more than two decades ago. Main topics addressed were the contribution of virtual reconstructions for the popularisation of archaeology, and, in a broader sense, cultural heritage, communication of archaeological results to the public, educational purposes or, to some extent, elucidate archaeological questions and provision of a cyber-environment where interaction with data can be done in an innovative way. Much intellectual effort has been invested in technological developments for increasing levels of realism, interactivity with digital content and its presentation through various channels (e.g. online, mobile devices, etc.).

The past few years have seen many publications dealing with proposals of innovative solutions for archaeological field 3D data capture and their related optimisation algorithms, data capturing devices or data interoperability software. Another recent line of research addresses the challenge of creating repositories for 3D data and semantically describing such 3D models.

An important development announced almost a decade ago is the London Charter (*Figure 1*). Published in 2006, it seeks to define principles and guidelines to follow when using computer-based visualization in cultural heritage. The charter does not deal with implementation, focusing instead on defining solid and everlasting principles to follow, independently of software platforms. Through its principles, it should guide the researcher aiming at using digital visualization in cultural heritage, to create an outcome that can be validated by the scientific community, is open to peer-review and provides the necessary means to investigate its components.

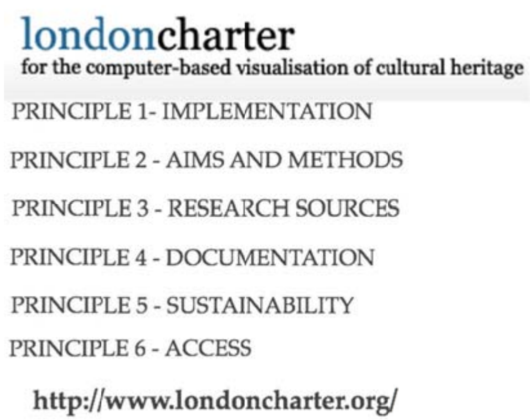


*Figure 1. The London Charter and its principles*

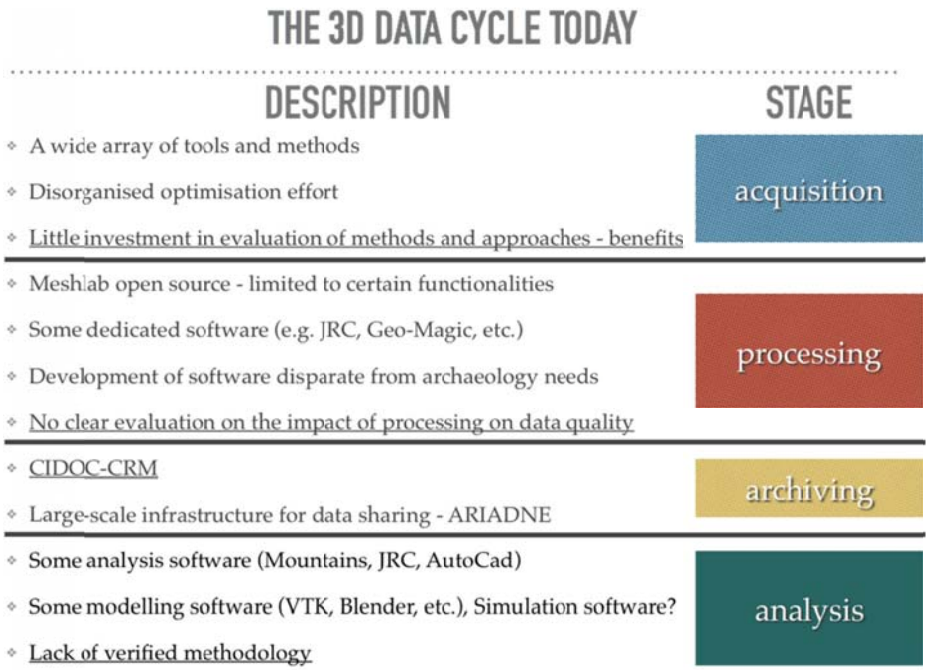


*Figure 2. The 3D research pipeline today*

Following a typical scientific pipeline enumerating the main steps of data cycle (acquisition, processing, archiving and analyzing), *Figure 2* summarizes the current state of intellectual development and tools available for researchers in archaeology aiming at adopting 3D as a research methodology.

While there are serious efforts invested in optimizing the 3D data acquisition process by proposing methods involving various sensors, such as laser or optical scanners, or image-based documentation, there is no clear analysis on how resolution and accuracy of data acquisition devices, methods or processing algorithms have an impact on the obtained 3D outcome.

Post-processing of data can be done in a relatively straightforward way using proprietary software, while open-source solutions are relatively few and limited in their proposed range of tools.

The same is true regarding tools for data analysis, such as measurements, comparisons, simulations or modeling. The few existing software are mostly proprietary and have been developed for other domains of application. In terms of archiving, CIDOC-CRM is an ISO ontology for the description of cultural heritage artefacts and their related study. Moreover, large-scale EU funded initiatives such as ARIADNE are on the right track to develop semantic-based infrastructures for archaeological digital data integration.

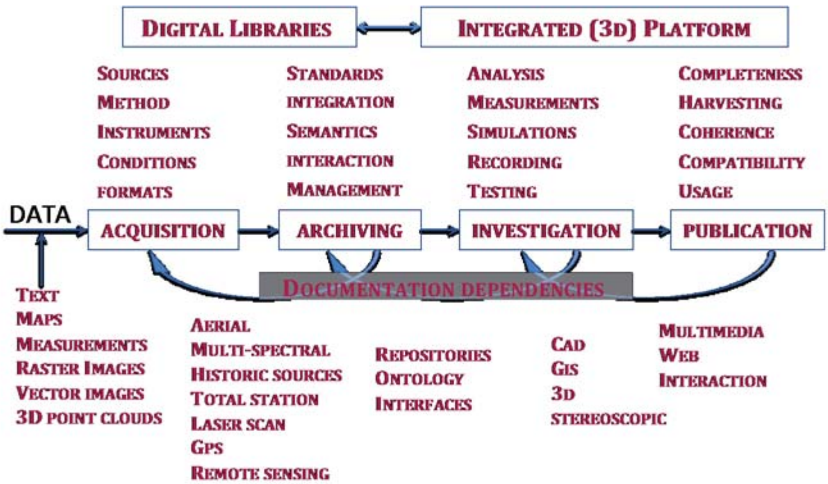


*Figure 3. A schematic diagram of a 3D research environment in cultural heritage*

*Figure 3* schematically presents a hypothesized 3D research environment, exemplifying the multitude of heterogeneous data sources and types and the inter-relationships between each step along the pipeline that transforms primary data into information embedding a scientific outcome to the community of use.

From the above, it is clear that we are 'not there yet' – much effort needs to be invested in:

- Correctly assessing the impact of 3D data collection methods and their subsequent resolutions on the available digital product that serves archaeologists as the main backbone for further reasoning.
- Developing a repository of data where heterogeneous sources are integrated and accessible for further analysis.
- Creating a reasoning environment where, through scientific visualization, researchers are able to model and simulate their research questions and test the validity of their conclusions.

*Figures 4-6. Recomposing the lost scenes of Antiphonitis Monastery (Kyrenia, North Cyprus). These photos are first published here.*

*Figure 7. Documenting architecture: 3D cloud of church interior. This photo is first published here.*



*Figure 8. Sorin Hermon talking at the event*

*Figure 9. Erzsébet Jerem introducing the speaker to the audience*

*Figures 10-12. Comments and questions from the audience: Alice Choyke (CEU Cultural Heritage Studies Program) András Patay-Horváth (Department of Ancient History, Eötvös Loránd University) and András Fehér (Mensor3D Ltd., Humansoft Ltd.)*


## Adrian Olivier

Honorary Professor, Institute of Archaeology, University College London

**Adrian Olivier** retired from English Heritage in 2012 where he was Heritage Protection Director and Head of Profession for Archaeology. Prior to that he was Director of the Lancaster University Archaeology Unit following extensive early career experience as an active field archaeologist in northern England. Adrian Olivier was the founding President of the European Archaeological Council – Europae Archaeologiae Concilium (the network of state heritage agencies), and works closely with the Council of Europe and other European institutions. He has a strong interest in wetlands archaeology and in recent years has become increasingly involved in maritime archaeology and is currently Chair of the Nautical Archaeological Society. Adrian Olivier continues to publish on heritage management issues and provide strategic and professional advice to organisations and agencies across Europe; he is an advisor to the EU funded Cradles of European Culture Project (Francia Media), and a member of the Society of Antiquaries Research Committee. He is an Honorary Professor at University College London Institute of Archaeology, and has recently been appointed Chair of the National Trust Historic Environment Advisory Group.

## Integrated Heritage Management: challenging values – changing attitudes

Heritage management across Europe continues to change and evolve. Policy instruments such as the Council of Europe Valletta Convention provide a convenient structure for the articulation of broadly agreed approaches to archaeological practice and heritage management in general – as such they are a useful tool, but they do not provide a mechanism for the direct implementation of specific national policy and practice and to deploy them in this fashion betrays a misunderstanding of their fundamental character. Nevertheless there are many problems and difficulties inherent in trying to operationalise such instruments. The nature of the relationship between heritage management and research (and other problems and difficulties) were discussed in the context of ongoing changes and developments in archaeological practices.

Much of the work that archaeologists undertake today draws on public funds and public financing and is carried out in the name of the public. The Council of Europe heritage conventions recognise the importance of building public awareness to conserve and protect the heritage and the need to engage local, community, and public values as a means of achieving public participation in heritage. Past decades have seen a real increase in the level of public awareness of, and interest in, archaeology, however, much of this communication is top down and one-way. Public benefit is easy to claim, but much more difficult to define or demonstrate in practice and there has been limited success in transforming greater public awareness into meaningful political support and these aspirations are difficult to operationalise and achieve as a matter of general practice. Approaches to delivering public benefit are changing, but there remains little understanding of, or articulation with, what the public (or publics) want from archaeologists. If archaeology is to survive and prosper, archaeologists must learn better how to fulfil a public role by engaging with communities as co-creators  placing the past at the service of the public so that it is relevant and useful in the context of their daily lives.

A new intellectual and operational matrix is required that supports integrated value-led conservation, delivers increased public benefit, and meets societal needs. This means that traditional heritage practices and attitudes need to change and adapt as heritage itself becomes increasingly democratised. Heritage professionals require a more sophisticated understanding of all the different values at play in a global context of human rights and democracy if they are to respond positively to evolving public attitudes to the heritage.

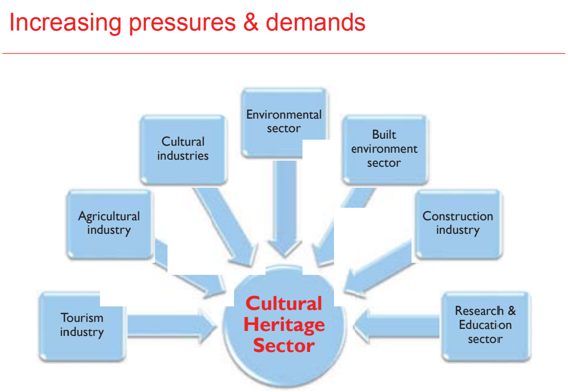


*Figure 1. Increasing pressures on the cultural heritage sector*

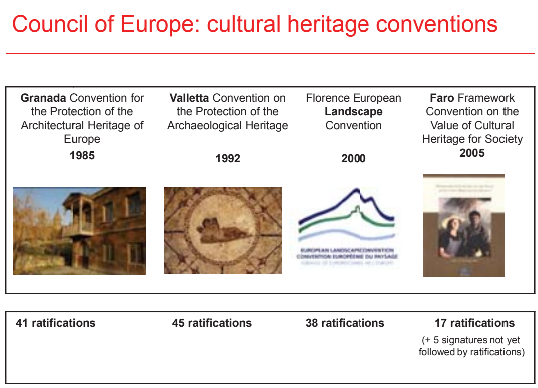


*Figure 2. The council of Europe heritage conventions*


*Figure 3. A new intellectual and operational matrix is required that delivers increased public benefit, and meets societal needs*

*Figure 4. Adrian Olivier's talk*

*Figures 5-6. Katalin Wollák (Forster Institute) and Magdolna Vicze (Matrica Museum, Százhalombatta) commenting on Adrian Olivier's presentation*

*Figure 7. Katalin Bozóki-Ernyey (Construction and Heritage Office) in the audience*

# New Approaches and Research Projects Connected to Digital Technologies in Hungarian Archaeology and Heritage Management

Hungarian archaeology and research connected to different aspects of built heritage have produced a significant number of new projects and publications related to the new approaches of digital technologies during the past few years. Even a quick survey of the on-line journal *Magyar Régészet/Hungarian Archaeology* amply demonstrates this change of focus.[1] Furthermore, workshops, conferences and exhibitions have also offered an overview of these new research directions. The present selection is based on the contributions presented at the exhibition and workshop *New Digital Technologies and Hungarian Innovations in Heritage Management – Archaeology, Historical Landscape and Built heritage*, organized by Archaeolingua Foundation and Central European University in Budapest, 6–7 February 2015.

The first group of projects represented archaeological fieldwork connected to large-scale data collection, sampling strategies in detecting sites and surveying historical monuments. Non-destructive (non-invasive) methods play a crucial

[1] Ákos Pető – Gábor Serlegi – Edina Krausz – Mateusz Jaeger – Gabriella Kulcsár: Geoarchaeological survey of Bronze Age Fortified Settlements. Kakucs archaeological expedition – KEX2. *Hungarian Archaeology*, 2015 Summer. http://files.archaeolingua.hu/2015NY/Peto_H15NY.pdf; Knut Rassmann – Carsten Mischka – Martin Furholt – René Ohlrau – Kai Radloff – Kay Winkelmann – Gábor Serlegi – Tibor Marton – Anett Osztás – Krisztián Oross – Eszter Bánffy: Large Scale Geomagnetic Prospection on Neolithic sites in Hungary. Part 2. *Hungarian Archaeology*, 2015 Summer. http://files.archaeolingua.hu/2015NY/eng_Rassmann_15S.pdf; Emília Pásztor: Hungarian Archaeoastronomical Research I. *Hungarian Archaeology*, 2014 Winter. http://www.hungarianarchaeology.hu/wp-content/uploads/2015/01/Pasztor_E14T.pdf; András Balogh – Kinga Kiss: Photogrammetric Processing of Aerial Photographs Acquired by UAVs. *Hungarian Archaeology*, 2014 Spring. http://www.hungarianarchaeology.hu/wp-content/uploads/2014/05/eng_balogh_14TA.pdf; András Balogh – Máté Szabó: RPAS – Robot planes in the service of archaeology. *Hungarian Archaeology*, 2013 Winter. http://www.hungarianarchaeology.hu/wp-content/uploads/2014/01/eng_Balogh_13T.pdf; András Fehér: Using 3D scanners in archaeology. *Hungarian Archaeology*, 2013 Summer. http://www.hungarianarchaeology.hu/wp-content/uploads/2013/07/eng_Feher_13ny.pdf; Gábor Serlegi – Knut Rassmann – Anett Osztás – Carsten Mischka – Martin Furholt – René Ohlrau – Kay Winkelmann – Eszter Bánffy: Large-Surface Magnetometer Survey of Neolithic Sites in the Kalocsa and Tolna Sárköz. *Hungarian Archaeology*, 2013 Spring. http://www.hungarianarchaeology.hu/wp-content/uploads/2013/05/eng_Serlegi_13T.pdf; Gábor Mesterházy – Máté Stibrányi: Non-destructive archaeological investigations in the Sárvíz Valley. *Hungarian Archaeology*, 2012 Winter. http://www.hungarianarchaeology.hu/wp-content/uploads/2013/02/eng_mesterhazy_12W.pdf; Máté Szabó: Non-invasive methods in the research of Pannonian villas. *Hungarian Archaeology*, 2012 Autumn. http://www.hungarianarchaeology.hu/wp-content/uploads/2012/11/eng_SzaboM_12O1.pdf.

role in this context, and institutions responsible for different aspects of heritage protection have recently engaged in these types of activities.

> *Since 2013 the preliminary tasks of archaeological excavations related to large-scale construction projects has become more and more important. This is due to the fact that investors have realised that it is remunerative to spend more on the assessment phase rather than paying more due to problems arising from an ill-planned project.*
> *It is widely known that geophysical survey methods have great potential for this task, but the integration of these methods into normal archaeological work could be even more crucial for our goal. Our job at the Forster Centre, the state office responsible for heritage assessments before large-scale construction projects, is to integrate these methods in order to improve our capabilities. The first step of integration was to be able to make our own surveys "in shop", employing geophysicists and archaeologists within individual teams that work closely with the excavation teams.*
> *In the last two years we have surveyed more than 200 hectares in areas where accurate assessments were needed to delineate archaeological sites before the planning phase. In nearly each case an excavation has followed (or will follow) these surveys; and we process both investigations on a system-wide level into a database library. It means that there is a large and expanding amount of data through which we are able to compare and validate geophysical results with actual excavations on large scale throughout the country.*[2]

Another project of the Forster Institute with similar goals and methodological approaches focuses on archaeological survey and interpretation on a regional scale. This approach has a long tradition in Hungary, best represented by the highly significant and pioneering Archaeological Topography of Hungary research program between 1966 and 2012.

> *… the void left after the discontinuation of the Archaeological Topography of Hungary project, in improving survey techniques for example, has only partially been filled by Hungarian research during the past twenty-five years and the new technical equipment has only become more widely used during recent years. Field surveys as a means of identifying new sites began to fade from Hungarian research projects despite the fact that*

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2 Máté Stibrányi – Gábor Mesterházy – Mihály Pethe: The Pudding's Proof. Integrated Magnetometer Surveys for Preventive Archaeology in Hungary. In: *New Digital Technologies and Hungarian Innovations in Heritage Management. Archaeology, Historical Landscape and Built Heritage*. Budapest: Archaeolingua, Central European University 2015, 14–15. Máté Stibrányi, Gábor Mesterházy, Mihály Pethe – Gyula Forster National Centre for Cultural Heritage Management, mate.stibranyi@forsterkozpont.hu; gabor.mesterhazy@forsterkozpont.hu; mihaly.pethe@forsterkozpont.hu.

*they were an integral part of impact assessment studies preceding major investment projects.*

*The research project […] conducted in the Sárvíz Valley of Hungary in October 2012 during the Workshop for Reading Past and Present Landscapes in Central Europe […] involved the application of non-invasive survey techniques. One of the main goals was the elaboration of a field walking methodology aimed at the accurate survey of archaeological finds. It was a necessity that the field data could be handled and assessed using GIS without the need for elaborate documentation. Meanwhile, as a result this would also enable quick and systematic surveying on a regional scale, as well as the delineation of the boundaries of different periods within any particular site.*[3]

Another research project with a regional character has focused on an area with an outstanding role and importance in the medieval period. The medieval sites of the Pilis Hills region in Hungary have been used as examples for a case study area, and at the same time to discuss methodological approaches and research possibilities. The main problem here was related to archaeological field surveys. In the research of identifying of different types of sites, the key issue was connected to different methods and their applicability in different research conditions. The research focus was aimed, at the same time, at presenting the links and connections between different scales of archaeological surveying and their methodological questions. The analysis was performed in a GIS environment, connecting data based on their geographic location. The acquisition of large digital datasets, however, raised new problems in big data management. Some of the problems were also related to transforming analog data to digital information, which is a general issue in case of regional research projects with a long history of research before the digital era.

*In general, archaeological investigations were carried out on three different scales. Most frequently larger groups of objects or features were investigated in order to understand the artifactual chronology of a given period at particular locations. As a next step, sites as compositions of archaeological features from a given geographical area were analysed. This can then be extended to the largest scale, landscape without any limits in all likelihood. This complex understanding of materials on different scales can later on lead to a bird's-eye view of various historic periods.*[4]

Remote sensing and its digital applications are also crucial for detecting new archaeological sites in different research conditions.

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3 Gábor Mesterházy: Looking behind the Dots – Methodology and Potential of Regional Scale Field Surveys in Hungary. In: *New Digital Technologies…,* 16–17.

4 Katalin Tolnai: Spades, Shovels, Computers – An Integrated Approach in Understanding Archaeological Sites. In: *New Digital Technologies…,* 18–19. Katalin Tolnai, PhD student, University of Vienna, tolnaikati@yahoo.com.

*Since Hungarian-French aerial archaeological cooperation began in the 1990s, we have become aware of the possibility of identifying the remains of burial tumuli which are impossible to explore through conventional field methods. The use of non-destructive methods proved to be the most fruitful throughout Europe in the case of this particular burial type. Recently, beyond the burial tumuli, we would also like to focus on types that are more difficult to identify, namely cemeteries with simple structures, including both inhumations and cremations.*
*Through the application of non-destructive archaeological survey methods, our aim is to enhance the efficiency of identifying burials. Begun in 2014, one of the principal aims of our program is the exploration of the cemeteries because for the predominance of settlements these seem to be a common feature of the archaeological topography.*[5]

Digital technologies have transformed not only the archaeological survey methods, but also led to crucial changes in the documentation of historical monuments. Furthermore, 3D technologies started to play a crucial role in analyzing and presenting buildings and complex built structures. One of the research projects related to these issues was carried out by the Department of the History of Architecture and of Monuments at the Budapest University of Technology and Economics. It focused on an outstanding building of the Middle Ages, the Cathedral of Saint Michael in Alba Iulia, Romania.

*The Cathedral […] was built in many phases and of course needed renovation during its eventful history several times. […] The true-to-form architectural survey of this complex building is based on the method used in "Bauforschung", the building archaeology practice developed and widely used in Germany. In this context, a survey is not only a tool for documentation but is considered a research method in itself. We discuss the importance of the on-site analysis of the building and the role and place of architectural surveys in the entire process of historic preservation, as well as the possible adaptation of the method presented under different circumstances. […] Surveys were carried out on different parts of the building such as the Lázói Chapel, the so-called Romanesque and Gothic choir, the southern aisle, the northern transept and the south-western tower. Methods covered a wide range of technologies from traditional surveying to photogrammetry and 3D laser measuring.*[6]

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5 Zoltán Czajlik: Identifying Burials through the Use of Non-destructive Archaeological Survey Methods. In: *New Digital Technologies…,* 22–23. Zoltán Czajlik – Institute of Archaeological Sciences, Faculty of Humanities, Eötvös Loránd University, Budapest, czajlik.zoltan@btk.elte.hu.

6 Balázs Halmos – Katalin Marótzy: The Adaptations of the True-to-form Survey Method in Gyulafehérvár (Alba Iulia). In: *New Digital Technologies…,* 34–35. Balázs Halmos, Katalin Marótzy – Department of the History of Architecture and of Historic Properties of the Budapest University of Technology and Economics, halmosb@et.bme.hu; mkata@et.bme.hu.

Architectural interpretation and reconstruction has also benefited from the new 3D technologies in a very significant way. One particular example of this research direction is connected to an outstanding archaeological find, the Sevso Treasure. The aim of the research presented here was to introduce the methodological approach and the first results of the reconstruction of the Late Roman period complex near Szabadbattyán in Hungary.

*Reconstructions are a matter of course in the communication of research results in archaeology, architecture and related fields. The so-called Sevso villa, located near to Gorsium, which is a well-known archaeological site and archaeological park, contains mainly Roman remains from various construction phases. This villa was built and expanded into the final complex presumably in the second half of the fourth century. This was a flourishing period in the life and history of Pannonia, only the last two decades brought a kind of decline. The almost completely excavated building is one of the largest peristyle villas in the entire Roman Empire and contains many interesting and unusual elements.*

*Nowadays, due to the development of technology, we are able through many different methods to visualize bits of the past that no longer exist or survive only in part. As usual, before 3D modeling, the representation of the volume of the complex was given in two dimensions based on drawings. Already the problem of analyzing the archaeological documentations arose, with important consequences for the final result, in particular when only the foundations or the trenches of the former foundations were found. In our case we have wall remains, only a few architectural fragments, almost all the terrazzo floors and many decorated fresco fragments from the walls and ceilings that in some exceptional cases are even in situ. In the beginning, instead of a debated and imaginative reconstruction our proposal consisted of several elevation projections and 3D sketches. Even now 3D modeling sometimes still has no scientific value, the erected remains of the superstructure and its proposed reconstruction are always just conjecture. After recalling what comprises an edifice, we collected the essential data to take into consideration for all the relevant architectural analyses and requirements. Based on these elements, we extracted the method for analysis and the steps for the virtual presentation. For this reason, the final reconstruction should no longer be just a possibility based on conjecture but the 3D product should be a representative conclusion of the current state of the scientific results. The intent of this paper is to focus on 3D visualization on the scale of large complexes, including fine details as well as the role the reconstructed "surfaces" in constructing a visual narrative.*[7]

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7 Zsolt Vasáros: A Home for Sevso? – Results and Questions from the 3D Reconstruction of the Late Roman Period Complex near Szabadbattyán, Hungary. In: *New Digital Technologies...*, 32–33. Zsolt Vasáros – Architect, Narmer Architecture Studio, Budapest, zsolt.vasaros@narmer.hu.

The second day of the conference was hallmarked by an exhibition that was not only meant to inform the audience of the scholarly presentations but to capture the attention of a wide public by providing a comprehensive overview of the ongoing activities of the various digital workshops and projects. Archaeolingua not only excelled in academic publishing, but in research too. Central to this exhibition were the posters, some of which had already been presented at important international conferences, while others gave the audience an insight into the latest results of scholarly investigations. Therefore, we consider it relevant to include a selection of them in this publication too.

*József Laszlovszky*

# Drón, holofilm, 3D

### Csúcstechnológia a régészetben és műemlékvédelemben

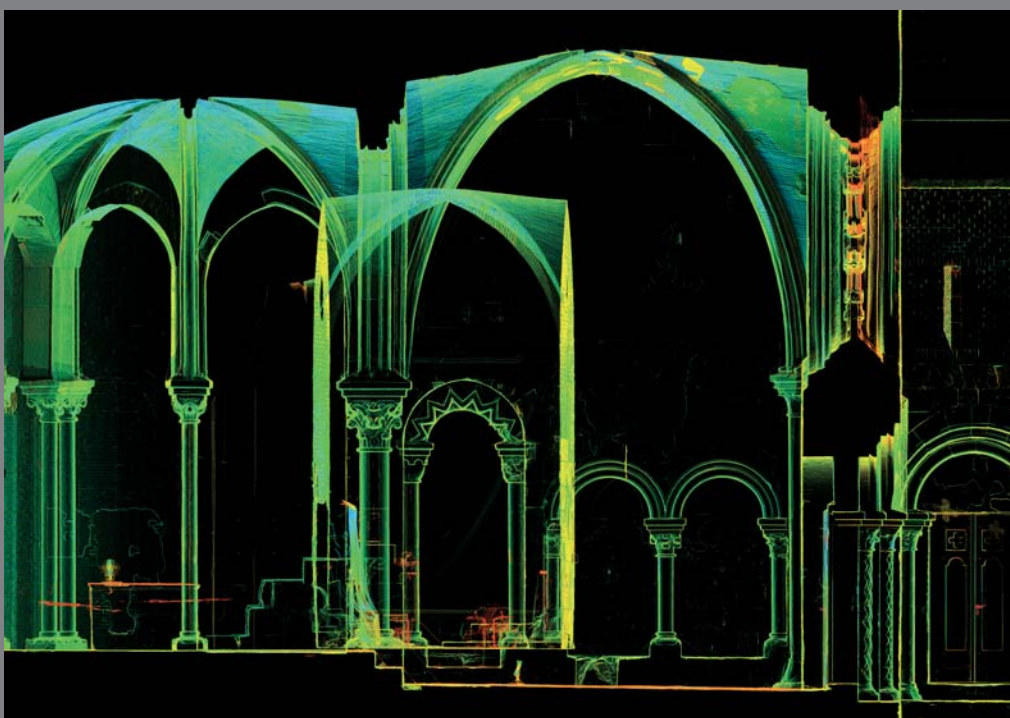
2015. február 7.

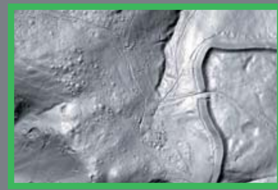
# Drones, Holo Film and 3D

### Cutting-edge Technologies in Archaeology and Preservation of Built Heritage

February 7, 2015

**Nyitva tartás / Opening hours: 10.00 – 18.00**



# Drón, holofilm, 3D

## Csúcstechnológia a régészetben és műemlékvédelemben

**2015. február 7.**

**Centrális Galéria, 1051 Budapest, Arany János u. 32.**

Eszköz- és könyvbemutatók, videó installációk: 10.00–18.00
Poszterbemutatók: 11.00–12.00 és 15.00–16.00 (a poszterek egész nap megtekinthetők)

Kiállítók:
Archaeolingua Alapítvány és Kiadó
Mensor3D Kft.,
Pazirik Informatikai Kft.
Tahiméter Kft.
Narmer Építészeti Stúdió

Antal Gabriella, Balogh András, Bertók Gábor, Borzsák Veronika, Dobai János, Gáti Csilla, Gaul Cicelle, Fehér András, Harmath András, Havasi Bálint, Lovas Lajos, Patay-Horváth András, Redő Ferenc, Sebastian Ristow, Schreiber Gábor, Tolnai Katalin, Tóth Máté, Vándor László, Varga Piroska, Vasáros Zsolt, Nagy Gábor

A régészetben es az örökségvédelemben használt legújabb technológiák bemutatása a 3D rekonstrukcióktól a drónokig – 3D szkenneles, 3D nyomtatás, holofilm, holopiramis, interaktív bemutatás, kiterjesztett valóság, mobil applikációk, Oculus virtuális szemüveg, LiDAR – távérzékelés

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## Bevezetés

A pontos térképek, részletes felmérések használata a régészetben és az örökségvédelemben is elengedhetetlen, melyek eredményeit mára további térinformatikai elemzésekre, és modellezésekre is alkalmazzák.

A **Tahiméter Kft.** 2007 óta vesz részt régészeti és örökségvédelmi munkálatokban. A cég fő tevékenysége földmérési, geodéziai és térinformatikai feladatok ellátása mind magánszemélyek, mind a beruházói oldal számára.

Örökségvédelmi célú méréseink három fő feladattípus köré csoportosultak:

1. Régészeti objektumok és környezetük felmérései a műemléki övezetek térképezéséhez;
2. Épített műemlékek környezetének felmérési-topográfiai feladatai;
3. A felmérések alapján elemzések támogatása régészek, örökségvédelmi szakemberek bevonásával.

## A mérések típusai

Terepi méréseink során a hatékony adatgyűjtés érdekében számos technológiai megoldást alkalmazunk.

A terepbejárások folyamán észlelt régészeti jelenségek helyét navigációs GPS-szel pozícionáljuk, valamint a szakemberek által rögzített adatokat egységes rendszerbe integráljuk.

A régészeti lelőhelyek területén mérőállomással és RTK GPS használatával részletes felmérést végzünk, segítséget nyújtunk a szelvények helyének kijelölésében, a korábbi ásatási helyszínek terepi visszaazonosításában.

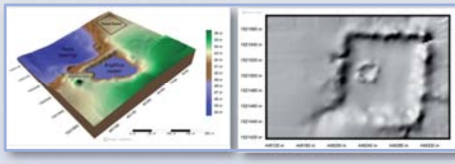
A felmérési adatokat további, szakmai adatokkal egészítjük ki. Műemléki felmérések esetén az adatokból homlokzati nézetrajzokat, realisztikus 3D modelleket készítünk.

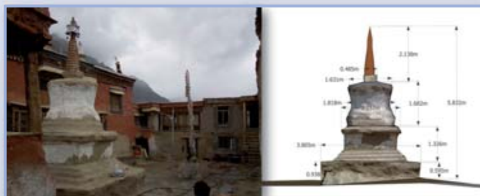
Régészeti lelőhelyek felméréseit térinformatikai rendszerek segítségével leíró adatokkal egészítjük ki, melyek használatával térbeli elemzéseket végzünk, valamint domborzatmodelleken ábrázoljuk a szakemberek által azonosított tájrégészeti elemeket.

## A mért adatok feldolgozása

A terepi méréseket követően a szakemberekkel egyezteve történik az adatok feldolgozása:

- A felmért területről alaptérkép készül, mely tartalmazza a régészeti jelenségek mellett a területen található jelenlegi tereptárgyakat is;
- A felmérést követően adatainkat térinformatikai rendszerbe integráljuk, melyhez további adatokat is csatolunk:
  - archív térképeket
  - leíró adatlistákat
- A mérések eredményeit mind digitális, mind nyomtatott formában rendelkezésre bocsátjuk.





## Referenciák

- Angkor Alapítvány: **Koh Ker, Kambodzsa** – tájrégészeti objektumok felmérése
- Stupa Onlus Alapítvány: **Ladak, India** – Épített örökségi elemek felmérésé, térképezése
- Közép-Európai Egyetem: Pomáz – Nagykovácsi puszta – régészeti feltárás és környezetének
- Magyar Tudományos Akadémia: Pilismarót-Basaharc régészeti adatainak térinformatikai feldolgozása
- MNM Mátyás Király Múzeuma: Visegrád, Sibrik-domb feltárásának térinformatikai feldolgozása
- Alsópetény, harangtorony és Werbőczy-emlékmű homlokzati felmérése



*Surveying tasks in archaeology and heritage protection (András Harmath, Tahiméter Kft.)*

Computer Application & Quantitative methods in Archaeology, Paris

# Transformation of analog data to digital information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## Introduction

In the Hungarian Middle Ages the Pilis area, being a part of the *medium regni*, played a crucial role as a royal centre, hunting domain and site of military structures. The historical sources and archaeological remains offer here a possibility to analyse primary data from several different perspectives.

With the help of the different data sets is it possible to give a complex topographical analysis of the main medieval complexes in the area. Their spatial distribution pattern can be investigated as a part of environmental-historical research based on former archaeological investigations and on recent prospection methods.

As a result of the research from the past 60 years several types of data are available for further analysis. These data sets can be grouped, according to the scale of investigation.

## Landscape research – Pilis area

On landscape scale historical maps, digital elevation models are available or can be created to reconstruct the land use patterns of Pilis. To achieve this goal military survey maps, compiled in the 18th century, were georeferenced and digitized into an integrated GIS database.

On site scale cadastral and topographical maps let us the possibility to create a more detailed digital elevation model which can be joined with historical small scale maps.

In Visegrád a 19th century map shows a road, *Via Antiqua*, leading from the Danube bank to the town. The excavators presumed that the location of the road is identical with a watercourse on the side of the hill.

With the help of the detailed elevation model it is now possible to visualize the location of the road within the watercourse.


## Intra-site research – Visegrád Sibrik

To go further within the analysis, at intra site-scale, plans and drawings of an excavation documentation were scanned and digitized into the database with detailed description of the features.


Here an early royal administration centre was identified the main structure of a Roman fortification built in the fourth century A.D. and rebuilt in the tenth century.

## Visegrád Sibrik

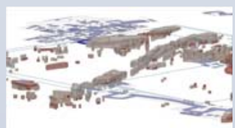
An early royal administration centre was identified in this area, the main structure of which was a Roman fortification built in the fourth century A.D. and rebuilt in the tenth century.

The excavations on site were held in several field seasons with precise documentation and land survey geographic measurements. Drawings and description of the trenches followed the traditional archaeological methodology. After combining the different kind of data and finding matching units in the description it was possible to build up the overall excavation plan.

Besides archaeological excavations geophysical measurements were also conducted at site. The inner part of the castle area was measured with magnetometer and with ground penetrating radar.

As the prospection data is also georeferenced into the same system excavated features and interpreted anomalies can be analysed simultaneously.

One possibility for the analysis the use of different visualization methods present the features layer by layer at their depth or to create volumetric models in 3D, based on depth information.



As a result of the above presented data acquisition a systematic database is now available for further research and various combinations of the digitized data helps the investigation and study of the area on different scale, starting from a large scale approach to a more detailed intra-scale research.

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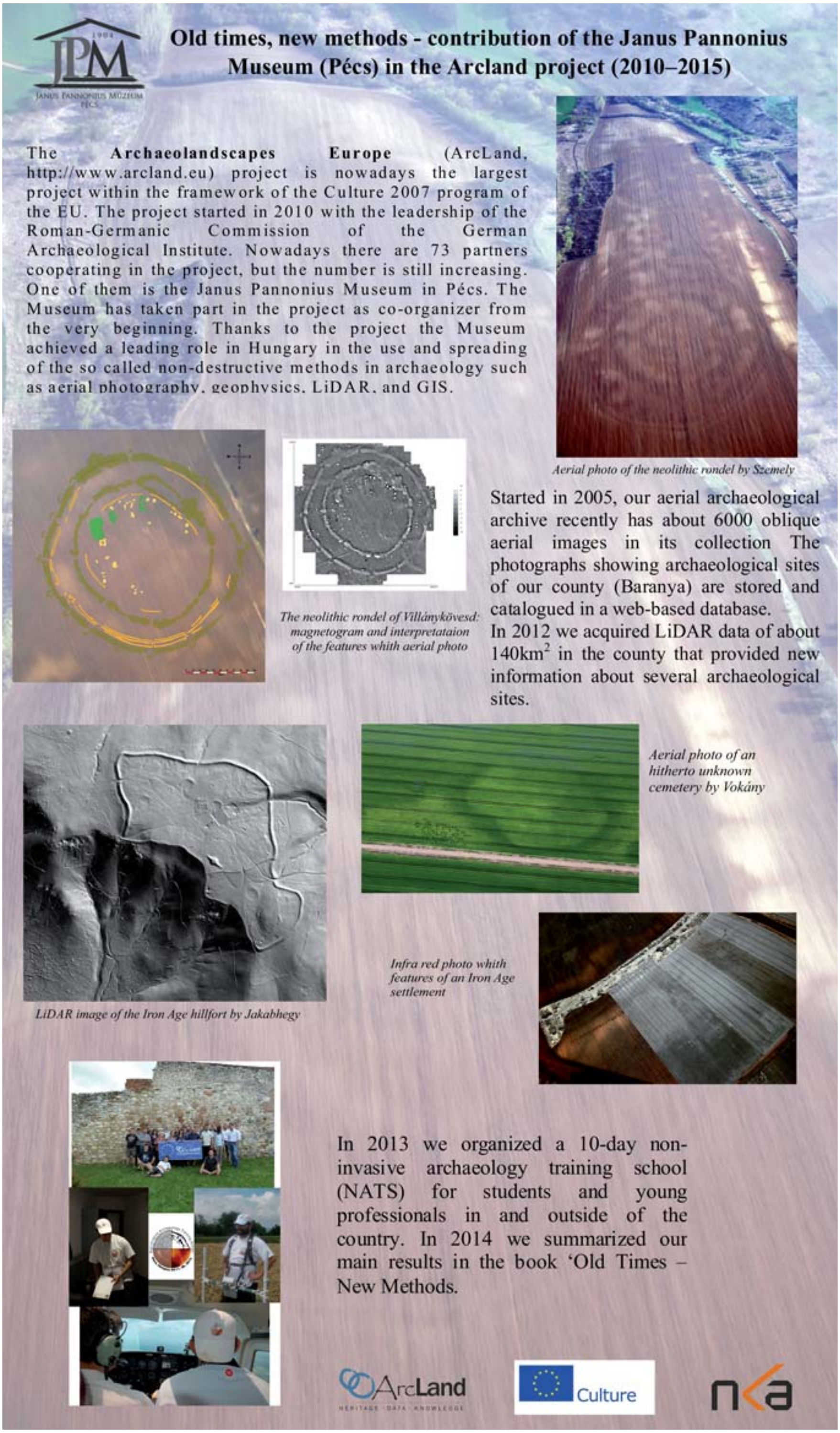
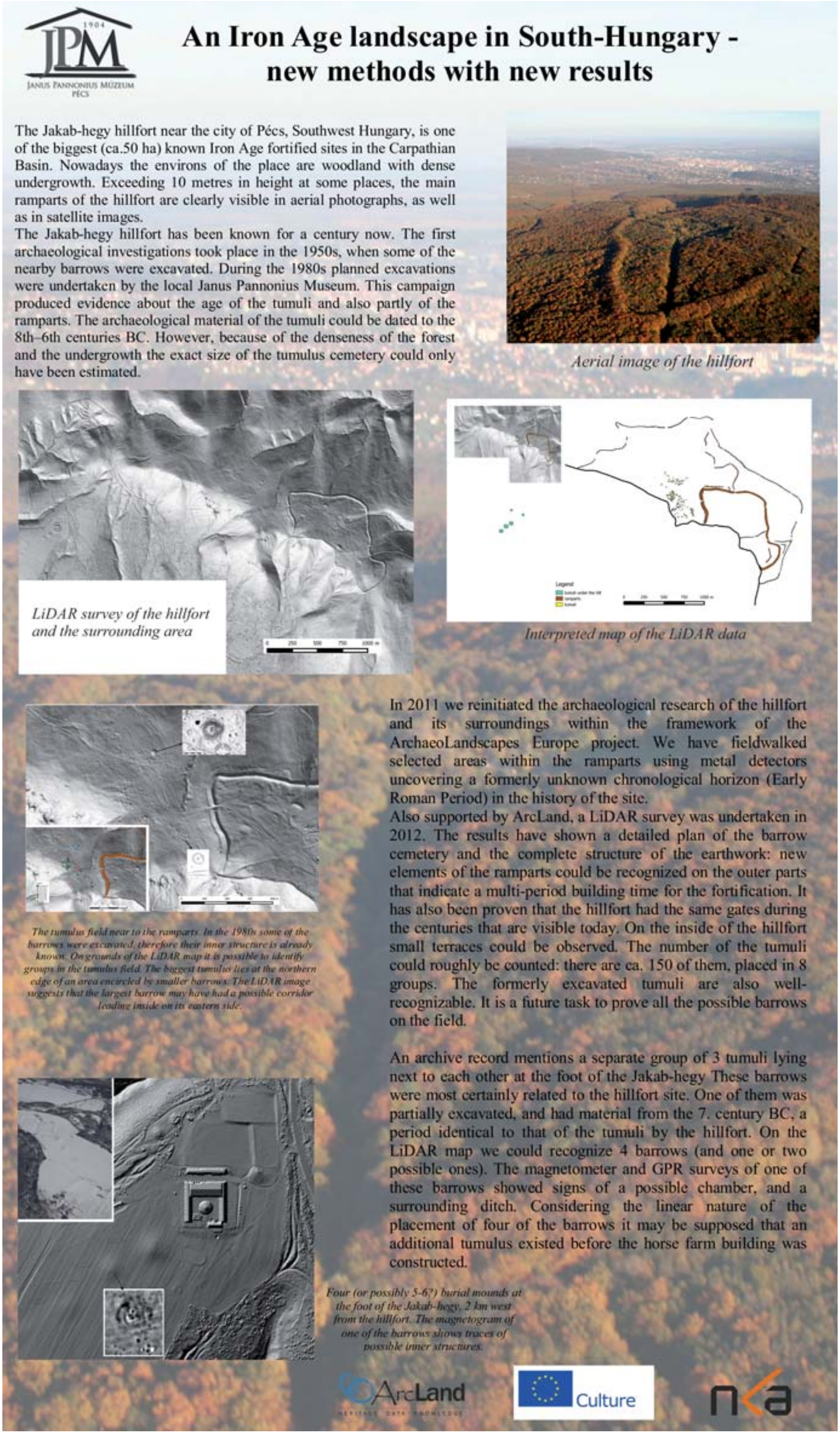
*Transformation of analog data to digital information (Katalin Tolnai, University of Vienna)*

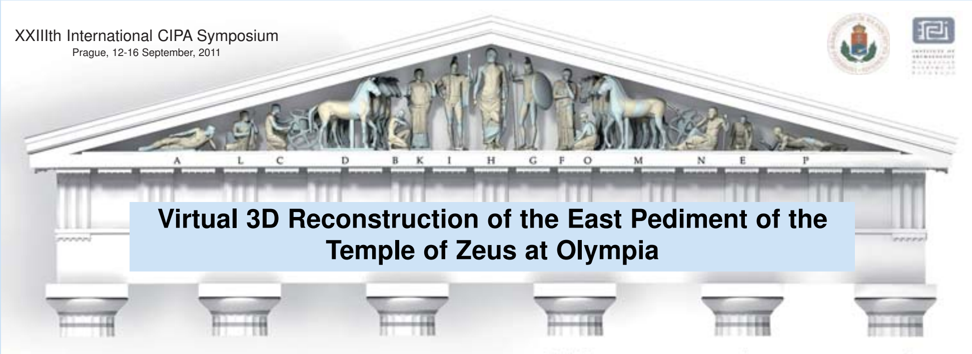



*Old times, new methods – Contribution of the Janus Pannonius Museum (Pécs) to the Arcland Project (2010–2015) (Gábor Bertók, Pázmány Péter Catholic University, Budapest and Csilla Gáti, Janus Pannonius Museum, Pécs)*




*The iron-age hillfort of Pécs-Jakabhegy – Results of a LiDAR survey (Csilla Gáti, Janus Pannonius Museum, Pécs)*

XXIIIth International CIPA Symposium
Prague, 12-16 September, 2011




# Virtual 3D Reconstruction of the East Pediment of the Temple of Zeus at Olympia

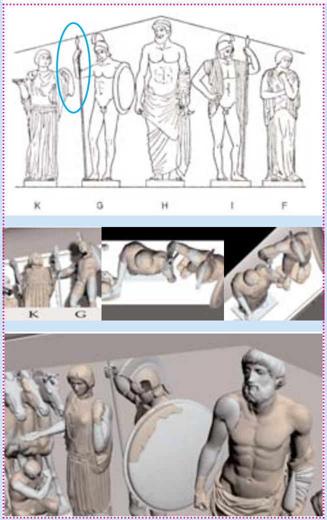



*Fig. 2. Different views of the open arrangement Type A. This reconstruction was declared to be physically impossible by G. Treu in 1897, but features as the most probable one in most recent publications. The area, where the arm of K and the spear of G would come in collision according to Treu is highlighted in the drawing (after H.-V. Herrmann, Olympia. Heiligtum und Wettkampfstätte, München, 1972, fig. 96). The 3D model shows that the arm and the spear do not necessarily cross each other, but since their distance is very small, it is very unlikely, that this would have been the arrangement intended or realized by the ancient artists.*

## The new approach

Instead of the expensive and troublesome experimentation with plaster casts and models, highly accurate virtual 3D models of the statues were produced by scanning the original fragments and then modelling the missing parts virtually. Inserted in the virtual model of the pediment, these 3D models can be easily used to test the technical feasibility and aesthetic effects of the different reconstructions.

## Results

In the case of both "open" arrangements, one can observe, that the spears fit the available space only if both heroes grip the shaft directly under the spearhead. (Fig. 3)

In the other two "closed" cases, we have no such problem with the spears.(Fig. 4)

The 3D models created during the project and the full documentation can be consulted on the multimedia documentary CD-ROM ISBN 978-963-284-196-0.


*Fig. 1. The virtual 3D model showing the four main possibilities for the reconstruction of the central part of the pediment. Figure H in the middle is Zeus, the identification of the other figures is doubtful. Original fragments are grey, reconstructed parts are rendered in pale blue. The two "open arrangements" (male figures turning away from each other) are marked with a pink, the "closed arrangements" (figures G and I arranged in the opposite way) with a blue frame. These borders also indicate differences in the position of the female figures: Type A (dotted) means F standing to the north and K to the south of Zeus, in Type B (dashed) they are arranged inversely (K - north, F - south). The virtual reconstruction of the entire pediment (on the top) conforms to the closed arrangement Type A, because this variant is considered by the present author as the most probable one.*

## A brief history of research

The main problem of the reconstruction concerns the relative position of the five figures in the centre of the pediment (Fig. 1) and results from the following facts:

1) The *fragments themselves* can be arranged in four substantially different ways.
2) Each reconstruction can be easily presented in *drawings* or *miniature plaster models*.
3) There are *no other obvious clues* for choosing the most probable reconstruction.

At the end of the 19th century in Dresden, plaster models of the fragments were produced on their original scale and lost body parts, arms, etc. were reconstructed in plaster as well. After several years of experimenting with these plaster models, Georg Treu the archaeologist, who published the sculptures of Olympia, claimed in 1897 that one of the four conceivable arrangements is physically impossible, because the left hand of figure K and the spear in the right hand of G would run across each other in the limited space (Fig. 2). To support this argument, Treu added that with the help of the plaster models, anyone could verify his statement. During the following decades, several archaeologists exploited this possibility and experimented with the life-size models: they concluded that the reconstruction proposed by Treu had to be modified at some major points, but no one advocated the option excluded by him.

After World War II, the results of these experiments have been largely ignored and an absurd situation emerged: nowadays the most widely accepted reconstruction is precisely the one (open Type A), which was deemed technically impossible by Treu (Fig. 2).

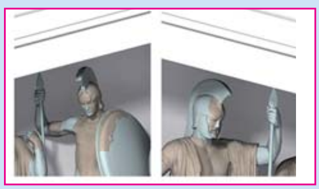


*Fig. 3. The main problem of the two open arrangements. The spears of the two male figures can be accomodated within the pedimental frame, only if they hold the weapon in a most unusual way, which is otherwise hardly attested in ancient Greek art.*

*Fig. 4. The central part of the composition according to the closed arrangement. There are no iconographic problems, the spears can be held correctly. The closed arrangements should be therefore preferred instead of the open ones.*

## Conclusions

1) The reconstruction, which is most widely accepted today (open Type A), is technically the most difficult to realize and therefore highly improbable (Fig. 2).
2) Both open arrangements would be feasible only, if we ignored a general pictorial convention of ancient Greek art (i.e. the way spears are shown in similar cases). The closed arrangements should be therefore preferred (Fig. 3 and 4).

It must be stressed, however, that the virtual reconstruction does not enable us to establish the right arrangement, i.e. the one actually realized in antiquity, but only to exclude two options. Considering every piece of available evidence, the **closed arrangement Type A** can be regarded as the most probable reconstruction (large picture above Fig. 1).

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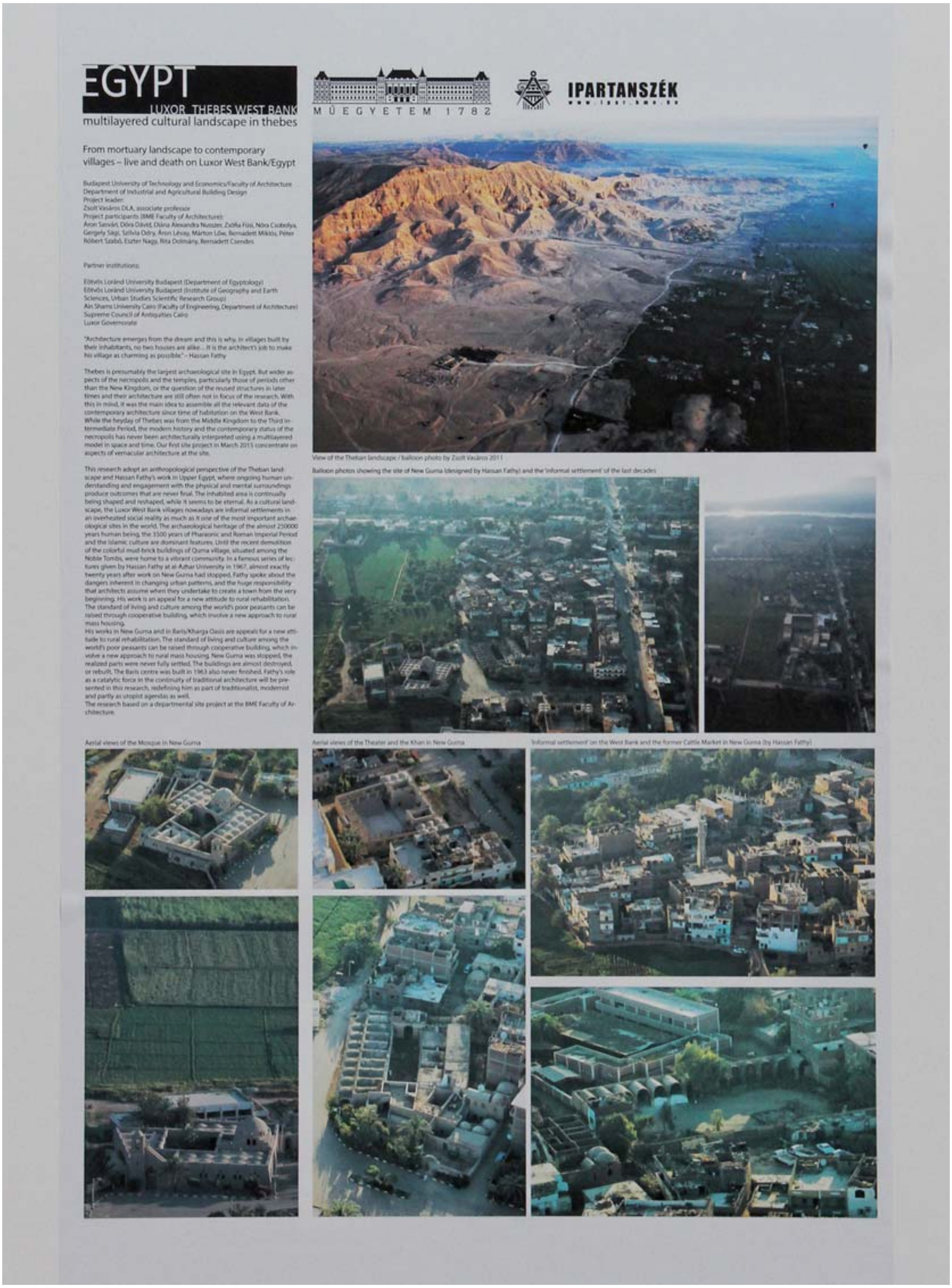
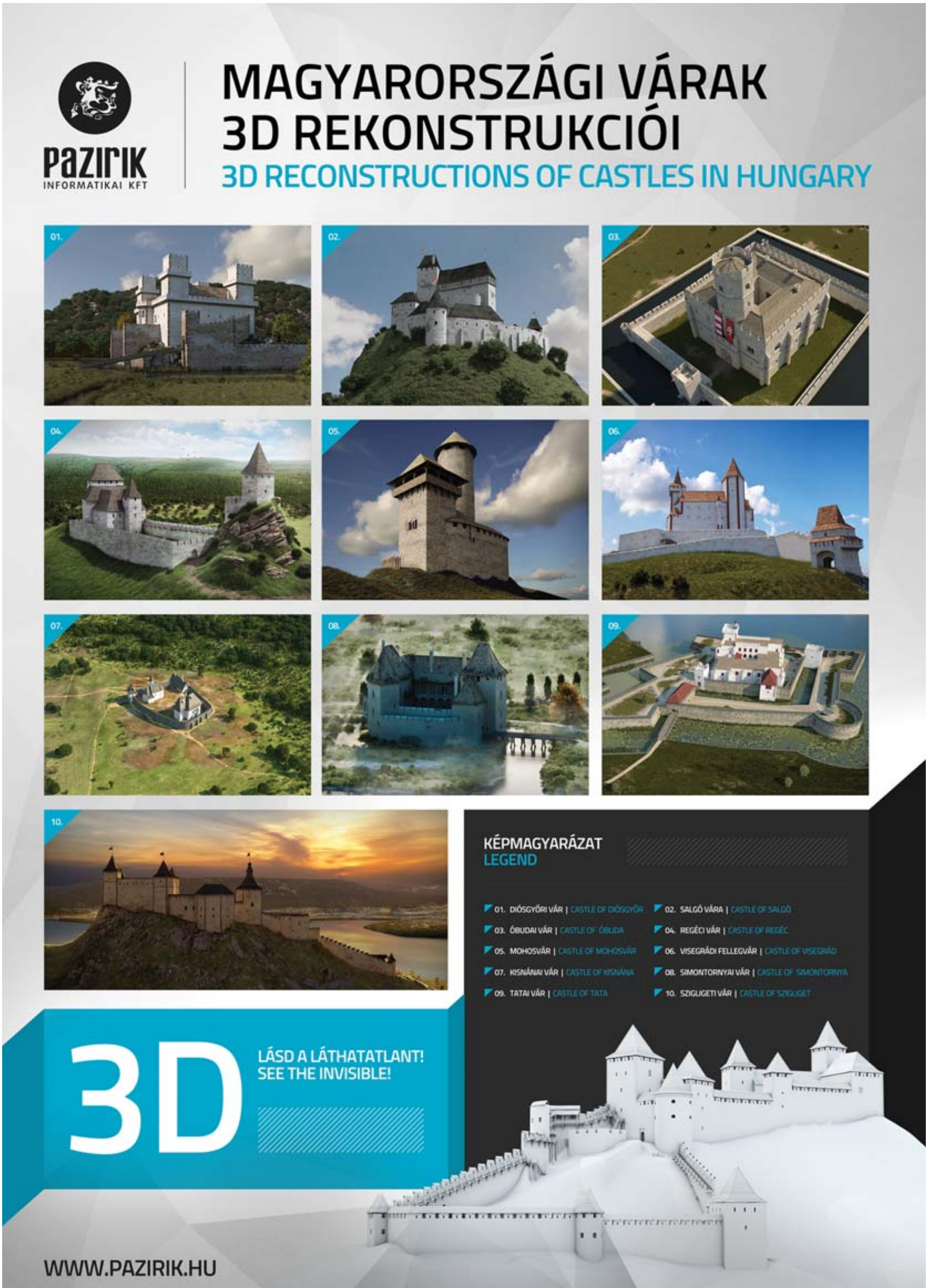
**Sponsors:** norway grants, OTKA

**Collaborating institutes:** 3D FOR ALL

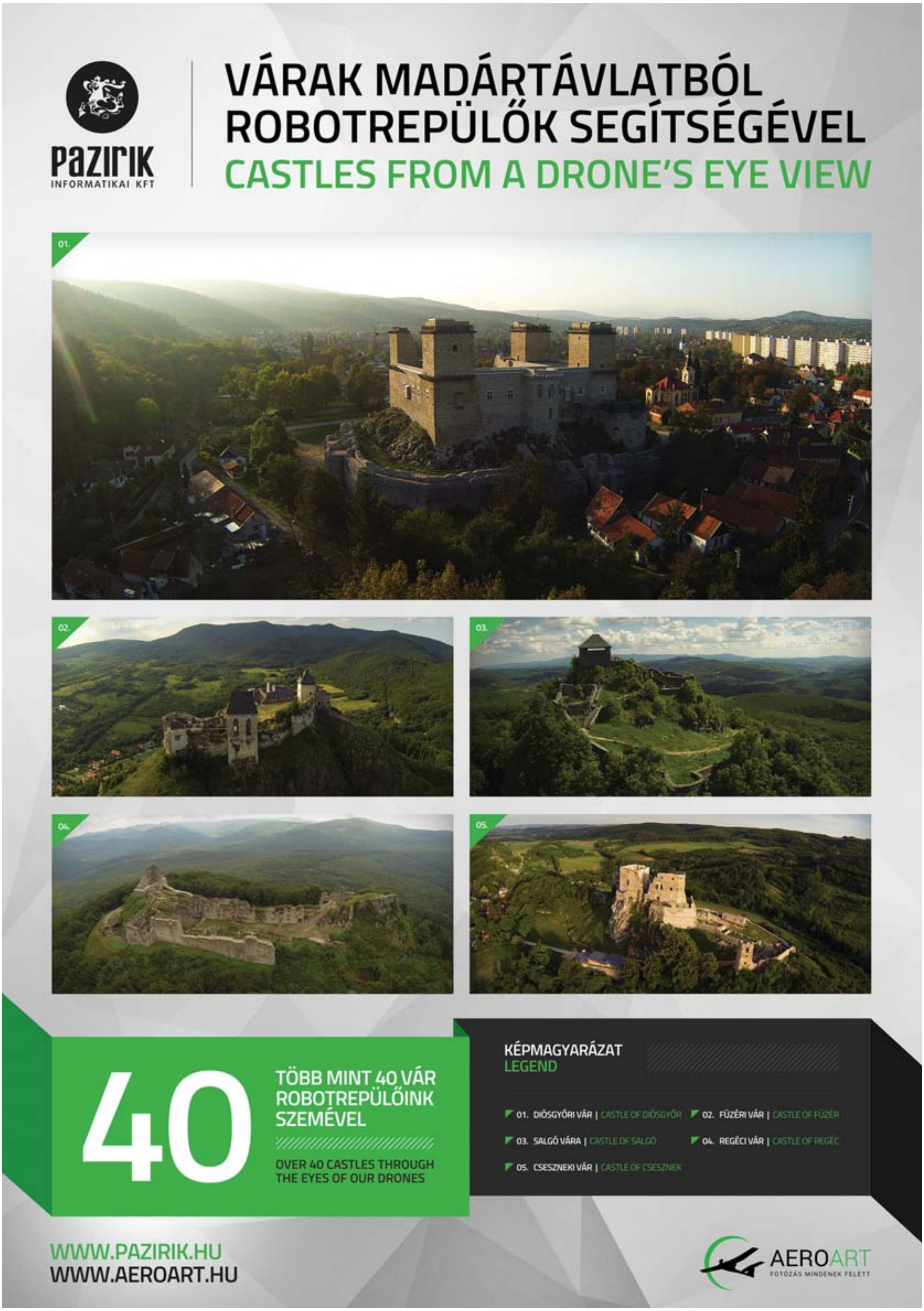
*Master hand attributions for classical greek sculptors by 3D analysis at Olympia – Virtual 3D reconstruction of the east pediment of the temple of Zeus at Olympia (András Patay-Horváth, Department of Ancient History, Faculty of Humanities, Eötvös Loránd University, Budapest)*




*Egypt – Luxor/Thebes West Bank: 3D thinking – 3D objects. Selected visual results of 20 years fieldwork (Narmer Architecture Studio, Budapest. Field director: Gábor Schreiber PhD, ELTE Department of Egyptology. Architect: Zsolt Vasáros DLA, Narmer Architecture Studio. 3D expert: Gábor Nagy, Narmer Architecture Studio)*




*Application of photo-based 3D modeling in the exploration and documentation of sites in Hungary – 3D reconstructions of castles in Hungary (Pazirik Informatikai Kft.)*




*Application of photo-based 3D modeling in the exploration and documentation of sites in Hungary – Castles from a drone's eye view (Pazirik Informatikai Kft.)*

# Integrating point clouds to support heritage protection and VR/AR applications*

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## Abstract

The current paper discusses the surveying of a ~30 m high tower in a Hungarian castle; since it is a protected monument, its documentation is of national interest. Besides surveying and data processing, the paper provides details on the procedure of sharing the collected data in virtual/augmented reality environment.

Due to the tower's complex geometry (uneven wall surfaces, irregular shapes) and size, multiple surveying techniques have been applied. The gate, the near environment of the building and rooms have been mapped by terrestrial laser scanning, while structured light scanners have been used for small objects to capture the fine details. Aerial images have been taken by UAV to acquire information on the tall parts of the building. The paper gives an overview on the applied data acquisition procedures.

Data from different sources have been merged and handled in a unified system that enables the integrated analysis of all surveyed objects. The result product can be further used to derive data for architectural purposes, e.g. views, sections or numerical values. The high density point cloud supports virtual/augmented reality applications; both experts and tourists can take a virtual walk in the tower, the practical solutions and future options are also presented in the paper.

Our investigations proved how the state-of-the-art spatial surveying technologies can support heritage protection, and, by merging multiple types of data, the results can be used in virtual/augmented reality applications.

Keywords: *terrestrial laser scanning, structured light scanning, unmanned aerial vehicle, augmented reality, virtual reality, architectural modeling, head mounted display.*

* This paper was presented at the ASPRS Annual Conference, 2016, Fort Worth, Texas and can be reached at http://conferences.asprs.org/Fort-Worth-2016/Conference/Proceedings.

# 1 Introduction

The Humansoft Ltd. was founded in 1989, and has been operating as a member of 4iG Plc. since 2014. With its high level services and high quality solutions it is a prominent player of the Hungarian IT market. Income from sales was 60 million USD (2015), number of employees is 300.

The Mensor3D Ltd. was founded by Humansoft Ltd. in 2014. Our main profiles are technical testing and analysis in architecture and mechanical engineering based on 3D scanning.

Hungary is incredibly rich in cultural heritage. Its preservation, digital documentation and spectacular preservation is of common interest. Mensor3D employs the most advanced 3D technologies for the purpose of 3D digital preservation of the monuments in the country and artifacts of national importance. We strive to make our products used in museums, and for tourist and educational purposes. We know that the researchers, educators, students, tourists and those roaming in the virtual space would like to get and see the different set of the opportunities offered by these technologies.

Several companies and scientific projects can be found worldwide with similar goals, mainly cultural heritage preservation, architectural survey and documentation, mechanical engineering and visualization. CyArk, one of the most remarkable non-profit organizations, is dedicated to digital heritage protection. Mensor3D Ltd. is the successor to the project SziMe3DAR which was selected by the CyArk 500 challenge to digitally document the Medieval Palace of Visegrád in Hungary.

# 2 Historical background

## 2.1 The Solomon Tower

The Solomon Tower is one of the most important Árpád-era relics in Hungary. It was the main fortification of Visegrád Castle. The five-storey, 32 meter high hexagonal tower was built in the 13th century (*Figure 1*). Its southern side collapsed during the Turkish battles in the 16th century. It was rebuilt several times between 1870 and 1960. The building is currently facing a number of technical problems; renovation of the building cannot be further postponed. The planning procedure requires an accurate and comprehensive survey documentation. Surveyed data also support scientific research: in addition to the exact geometry of the building structures, texture is recorded and it is presentable as a colored point cloud.

## 2.2 The fountain

The largest fountain of Visegrád was built by Louis I of Hungary in the inner courtyard of the residential building of the Visegrád royal palace. The octagonal, originally two-storey, tower-like fountain's ground was based on the archway on the eastern side of the courtyard (*Figure 2*). The fountain's upper rectangular structure was standing on its balcony-like second floor. Except the parts made of red marble, the fountain was painted in colors (Buzás, 2010).

## 2.3 The stove

The stoves of the Visegrád palace are exceptionally important in the development of the stoves of the medieval Hungarian kingdom (*Figure 2*). The archaeological artifacts of the last years enabled the detailed documentation of the stoves from the period concerned. The current statically appropriate stove model reconstruction provided valuable information about the real historically correct layout (Kocsis, 2016).

# 3 Surveying the Solomon Tower

Several technologies were combined during the data acquisition procedure. The goal of the survey was to create a dataset that enables deriving architectural 2D products (views, layouts, sections) and a detailed 3D model for virtual reality presentations. The survey had two stages: first the fountain and the stove (both from the Anjou era), then the building and its environment were captured. There was a one-year gap between the two survey stages. We used the following data acquisition equipment:

- Z+F Imager 5010C and Leica HDS7000 terrestrial laser scanners (TLS)
- Nodal Ninja + Canon EOS 600D
- Leica TCR803 Total station
- Leica Viva GS14 GNSS receiver
- Artec EVA and Breuckmann structured light scanners (SLS)
- DJI Phantom unmanned aerial vehicle equipped with GoPro Hero3 (UAV)
- Bosch laser distance measurer

The tower has five floors, 350 $m^2$ each, the directly connected environment is 400 $m^2$. Since the tower is 32 m high, and below the top of the tower an external ramp/corridor and its rail structure blockes the line of sight, its upper area cannot be captured by TLS (*Figure 1*).

Therefore UAV was used to complement the TLS datasets and to survey the environment in a distance from the tower. TLS was used indoors to capture large spaces, the rooms and stairways, while SLS was applied to survey the fine details. The main geometry of the fountain inside the tower was captured by TLS, but

*Figure 1. The 32 m high Solomon Tower with the external ramp at the top*

*Figure 2. The Anjou stove (left) and fountain (right) of the Solomon Tower*

SLS was used for the inner parts of its columns and for the basin (*Figure 2*). Note that for architectural analysis mm-level point density and accuracy was required. ArtecEVA was widely used to survey the details but for small objects with fine details the Breuckmann SLS was applied, e.g. the extremely decorated stove covered by shiny tiles was only captured by Breuckmann (*Figure 2*).

During the TLS measurements tie points were used to join the point clouds acquired from different scan stations, but a part of them was also used as control points to transform the point cloud into geodetic reference system (Lovas, Berényi, & Barsi, 2012). Registering the point cloud into a high level coordinate system also enables to merge the dataset with the results of other surveys carried out earlier or later. Moreover, these control points support the connection between the TLS and UAV data. The control point coordinates were obtained by conventional surveying methods, such as total station and GNSS measurements.

The tower floors inside are connected with narrow spiral staircases, therefore point cloud registration was supported by measuring the tie points with total station. In particularly small areas and narrow spaces tapes and laser distance measurer were used to capture the geometry, which was joined to the 3D model during post-processing.

Since the tower's layout is very fragmented, instead of creating scan stations very close to each other, some small rooms were captured without using tie points; these point clouds were merged with cloud-to-cloud registration.

The entire tower was surveyed with two scanners, from 96 scan stations in two days. The UAV flight took 2 hours, the total station survey required 4 hours, manual distance measurements lasted 6 hours, while SLS measurements with two instruments needed a whole day; 8 people worked on the site during the project.

39 panoramic images of high priority areas were captured during laser scanning for presentation purposes, while intensity measurements were used otherwise. Since several different kinds of instruments producing big data were used, the applied point density values had to be selected carefully on the site to optimize data storage, handling, management, and processing.

## 4 Surveying the fountain and the stove

The goal was to support the reconstruction procedure of the particular artifacts. By modeling the fragments and small parts of the object, it can be virtually reconstructed by the experts.

In case of the fountain the SLS and TLS technologies were used combined; the artifact was captured from 15 scan stations. In the further stages of the project, when the fountain's environment was surveyed, these point clouds were reused, saving 3-4 hours on the site. Since no permanent tie points were deployed, cloud-to-cloud matching was used to register the point clouds captured in different times.

The fountain's area of base is 25 m$^2$, its height is 5.5 m. The main body's geometry was captured by TLS, while Artec EVA SLS scanner was used for acquiring data from the fine details (*Figure 3*). The inner parts of the fountain can only be surveyed from inside, here also the Artec scanner was used due to size limits. Some separated parts, fragments of the fountain were surveyed by SLS in their

*Figure 3. TLS survey of the fountain*

current storage location; these datasets were merged with that of the fountain during the post-processing procedure supported by art historian experts.

The primary issue in surveying the details is the surface of the particular area. Too porous surface results in limited reflectance. Too smooth and shiny surfaces have similar effects that could be eliminated by using a thin layer of marker dust that doesn't change the object's geometry, easy to remove and improves the reflectance capability.

The stove is covered by glazed ceramic tiles. Breuckmann 3D structured light scanner was used to capture its geometry. The result is a TIN surface model complemented with texture by using images taken during the scans. Each stove element was surveyed separately, and the integrated model was created according to the instructions of the art historian expert (*Figure 4*).

*Figure 4. Separated stove elements and the integrated model*

These elements differ in size, shape and decoration; there are sizeable but simple tiles and small but finely detailed parts. These have been separated and surveyed using different scanner optics. If its size allowed, the object was put on a rotating stand and was scanned from a fixed scanner position. The accurate survey of the objects required 20 to 100 scan positions. The scanner's own software was used to register the scans by manually marking the tie points. The integrated surface model was corrected, e.g. by filling holes on the mesh. The separately modeled elements were merged using reconstruction plans and instructions, eventually resulting in an integrated stove model. This model has been put in a virtual environment that enables its presentation. Additional products have also been created: augmented reality card, 3D print, poster, video footage that are also part of the museum's presentation (SziMe3D, 2016).

## 5 UAV measurements

During complex surveys UAV measurements do not replace but complement terrestrial laser scanning by measuring inaccessible areas. Compared to laser scanning, the major advantages of UAV are the small size of the equipment and the less on-site measurement time. However, as a shortcoming, UAV cannot be used indoors. Although the accuracy and resolution provided by the UAV is sufficient for multiple purposes, these parameters depend on light and weather conditions. The laser scanner as an active remote sensing technology is capable of surveying in dark environment, and is not sensitive to shadows (Hadzijanisz, 2014).

To estimate the required flying time and number of images, the flight was planned in a Google Maps-based software. Take-off location is to be selected with good GPS visibility and without objects disturbing the take-off and landing; the tower top (2 take-offs) and the open area next to the tower (1 take-off) were reasonable options (*Figure 5)*.

Camera settings have to be adjusted before take-off, no changes are enabled during the flight. To ensure overlap between the images, 0.5 fps capture rate

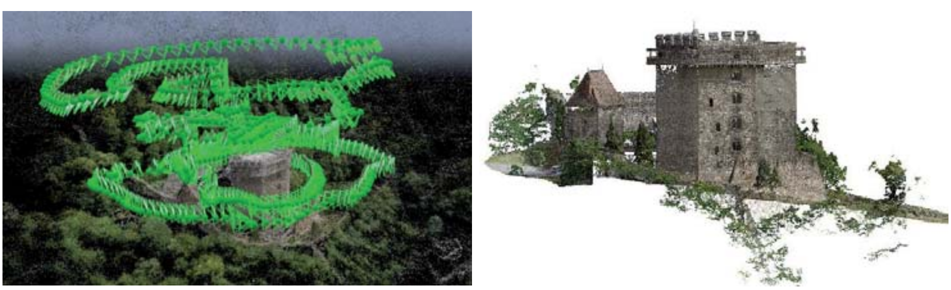

*Figure 5. Aerial image positions (left) and derived point cloud (right)*

*Figure 6. Original and exposure corrected aerial images*

was set considering the flying speed (6 m/s). The UAV captured 968 images with 12 Mpixel resolution in jpeg format.

Image correction was carried out in two steps, first is the exposure correction. The GoPro camera does not save raw files, only compressed jpeg images, but with exposure corrections the details of the too dark or too bright images can be revealed (*Figure 6*). The second step is adjusting color temperature that was done by each RGB channels.

Images taken during take-off and landing, and those with too much overlap or with motion blur have been removed; 914 images remained for further processing. The UAV's OSD (on screen display) cannot record navigation data, therefore the GNSS coordinates of the ground control points were used for registering the image in a geodetic reference system.

Generating and filtering the point cloud from 914 pieces of 12Mpixel images is time consuming and requires high computation capacity; the result is a colored, geo-referenced point cloud that consists of 47 million points (*Figure 5*).

## 6 CAD modeling

To support heritage protection, the thorough documentation has to be based on the acquired data discussed previously. The architectural documentation contains 8 floor plans (6 main and 2 intermediate ones), 3 ceiling plans, 2 sections, 1 top view and 6 façade views. Multiple section planes were defined to derive from the floor plans and sections to ensure the representation of all the required objects on the drawings (*Figure 7*). The resolution of the data acquisition enabled 1:50 scale representation of the details.

To achieve additional thematic information, the orthogonal point cloud image was used as a layer under the vector drawing that provided valuable information

*Figure 7. Cross-section layers with point cloud background*

on the texture of the surfaces. Based on these data the different building periods could be separated and indicated with different hatch patterns.

The 3D model of the building was also created on the basis of the survey. The building is part of the museum, and a realistic, high resolution 3D model can be part of the exhibition. Such a model can be the base for BIM (building information modeling) that would support the building operation. To achieve this goal the point cloud was cut into separate parts before modeling. The building environment (courtyard, gate) was not modeled, therefore was cropped from the dataset. The outer shell of the building, the staircase and the floors have also been separated. The high point density enabled to create a mesh from the tower walls without gaps which is perfect for visualization purposes (*Figure 8*). Being a historical site, no objects from CAD repository (e.g. window, wall) can be used in the modeling procedure.

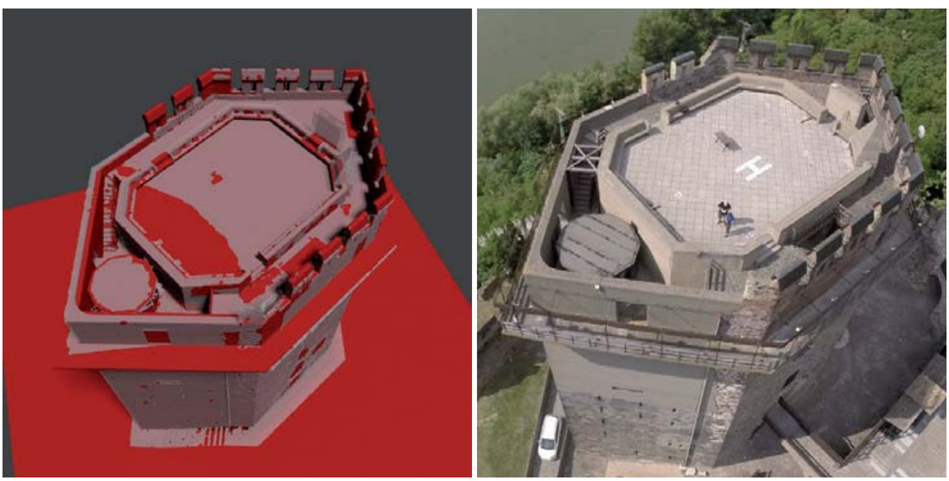

*Figure 8. 3D mesh and model representation (left) of the Solomon Tower (right)*

## 7 Using the surveyed data for augmented reality

The primary objective was to digitally document the Solomon Tower's historical site and its artifacts in 3D with high fidelity and precision. The applied technologies are capable of providing multimedia (i.e. AR – augmented reality, VR – virtual reality) experience for the general public and tourists (*Figure 9*).

Aerial photogrammetry, terrestrial laser scanning and structured light scanning devices have been used successfully to capture real-world sites and objects. These methods provide reliable results, but are considered expensive. The output of current scanners are not yet ready for direct analysis or real time interaction on generic platforms. Usually some minor data continuity issues have to be addressed, and basic editing is necessary. There are robust tools to correct these deficiencies. Specialized, independent virtual working environments provide solutions from the initial steps (processing raw captures) to delivering the final results – Augmented Reality (Bödő, 2015).

Our objective is to share and introduce these scanned datasets and models (reconstructions) with non-researchers, and to create an interactive presentation based on research and design data. We intend to introduce current display and motion capture technologies (HMDs – Oculus Rift; stereo sensors – Leap Motion) and explore how to apply these devices in open or confined spaces.

The scanned spatial data can be converted into a high resolution mesh or complex digital model of the objects which can be further processed. Creating high resolution meshes requires high computation power and capacity, thus optimization is required. Optimized meshes with high resolution textures are visually undistinguishable from high resolution scan data. The model can be just

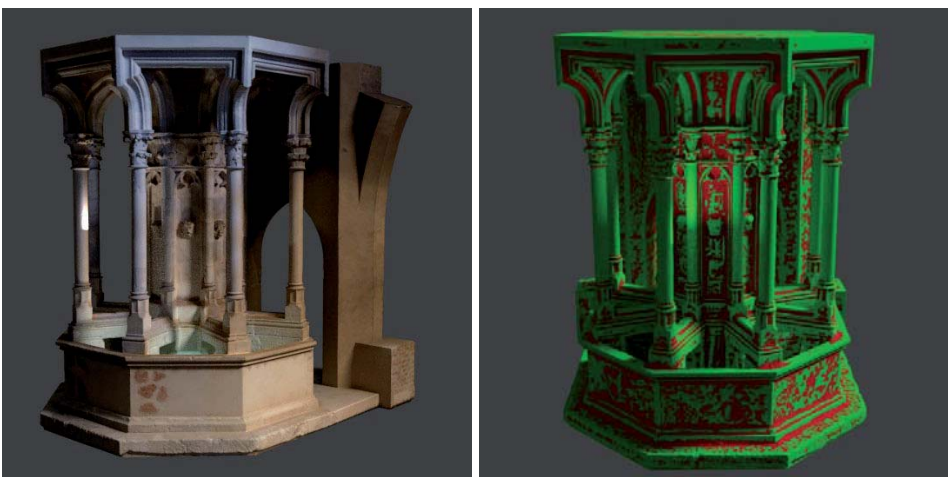

*Figure 9. Anjou-era ornamental fountain rendering (left).*
*High (green) and low (red) resolution mesh composition (right)*

a virtual reconstruction of the present state but can also be used to reconstruct former structures. It is measurable, and can depict the object in different stages of construction or decay. By coupling other imaging technologies, e.g. photogrammetry, the original visual surface of the object can be recreated in impressive details with the help of recorded textures (Magnor, Grau, Sorkine-Hornung, & Theobalt, 2015).

For research purposes high accuracy scanners have to be used to achieve the maximum precision, to find subtle but potentially important information. With basic pre-processing tools, high polygon count surface models can be created on the basis of scan data. These high polygon count models then can be used to create (fluid) simulation ready parametric models. They also serve as a foundation for reconstructions or even to make low polygon count models for real time AR experience (*Figure 10*). Based on the lower resolution models, an entertainment and educational AR application can be developed. By overlaying images on the visible reality, for example populating a historical place with virtual figures, or providing sound effects and/or narration, the augmented reality application can offer not just the sense of presence but also give a touch of time travel back to imaginary but historically correct scenes. This approach also creates new opportunities for impaired people who may have difficulties in visiting remote historic places.

To fully experience the surroundings in 3D and right scale, a special hardware has to be utilized. There are many ready-to-use and in development technologies to display virtual content. The HMD (Head Mounted Display) technology can seamlessly involve visitors in visual scenarios. The tracking and display technology should work together. The limbs are kept free to be able to walk and browse the exhibition and initiate interaction with virtual and real-world objects in the same way. Real time image processing has to be utilized to virtually track human motion, and interpret it to help interaction with virtual surroundings.

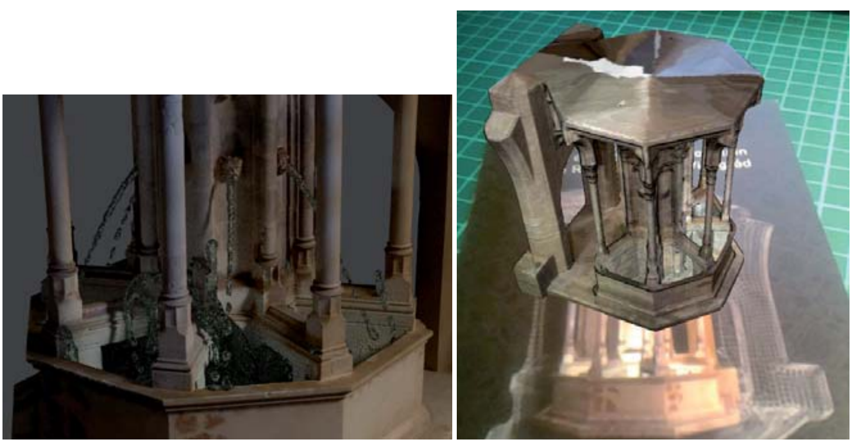

*Figure 10. Simulated water splashing in the fountain (left), AR experience (right)*

## 8 Conclusions

3D scanning is a powerful tool to measure objects with exceptional precision, from tiny ones to entire buildings. In our project we proved that the applied spatial surveying technologies (i.e. TLS, SLS, UAV) can effectively complement each other and are therefore capable of providing a complete, state-of-the-art solution for engineering or archeological documentation tasks. Our investigations proved how the accurate, dense point clouds can support creating virtual models that can be used in VR/AR environment.

The applied technologies and the derived products can remarkably support heritage protection through the documentation of selected areas and artifacts. Cutting-edge visualization techniques enable the realistic and interactive presentation of the current and past objects.

## 9 Acknowledgement

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