Annual Report 2015

Contents

1. LBI ArchPro - Overview

1.1 Goals

Considering the massive threat of destruction and deterioration of buried cultural heritage and the need for efficient and reliable identification, documentation and interpretation methods, large-scale application of non-invasive archaeological prospection methods comprise a great potential. They are the most appropriate solution in order to provide archaeologists and planning authorities with the necessary spatial information for the protection and possible investigation of such threatened heritage at the appropriate scales: the archaeological site as well as the surrounding archaeological landscape.

Considering the state-of-the-art and the future demands for non-invasive professional archaeological prospection a consortium of European research institutes, heritage boards and public bodies supported by the Ludwig Boltzmann Gesellschaft (http://www.lbg.ac.at) established in 2010 the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI ArchPro). The LBI ArchPro (http://archpro.lbg.ac.at) is an innovative research centre for the development and application of advanced non-destructive prospection methods. It combines advanced remote sensing methods, high resolution near surface geophysics, sophisticated computer science, geomatics and archaeology. It is dedicated to the development of new and highly efficient technologies for non-invasive data capturing, data processing, virtual reality visualization and the advancement of theory and methodology of archaeological prospection. An important aim is the publication and dissemination of new developments and results of the conducted research and of exemplary international large-scale case studies in professional circles as well as to the general public.

Even though the Valetta convention (Malta treaty) has not been ratified by all member states of the LBI ArchPro consortium, it is regarded by the consortium as the major basis and guideline for the future development of archaeological research and the LBI ArchPro research programme.

1.2 Partner organizations

The LBI-ArchPro (http://archpro.lbg.ac.at) is based on a European partnership formed by:

- **LBG** - Ludwig Boltzmann Gesellschaft (A)
- **NoeL** - Province of Lower Austria (A)
- **NIKU** - Norsk Institut for Kulturminneforskning (N) - The Norwegian Institute for Cultural Heritage - Archaeology Department
- **Swedish National Historical Museums** (SHMM) - Arkeologerna (S)
- **RGZM** - Römisch Germanisches Zentralmuseum (D)
- **University of Birmingham** (GB) - The Visual and Spatial technology Centre (VISTA)
- **Uni Vienna** - University of Vienna (A) - Vienna Institute for Archaeological Science (VIAS) and Institute for Prehistory and Historical Archaeology (UHA)
- **TU Vienna** - University of Technology Vienna (A) - Institute for Computer Graphics and Algorithms (ICG) and the Institute for Photogrammetry and Remote Sensing (IPF)
- **ZAMG** - Central Institute for Meteorology and Geodynamics (A)
- **Airborne Technologies** (A)
- **Vfk** – Vestfold Fylkeskommune (N)
- **7reasons** – 7reasons Medien GmbH (A)
- **ÖAI** - Austrian Archaeological Institute (A)

- **ÖAW** - Austrian Academy of Sciences (A) - Institute for the Study of Ancient Culture (IKAnt) and The Institute for Oriental and European Archaeology (OREA)

Collaborative agreements for scientific research tasks and case studies exist with following organizations:

- **Uni Lund** – University of Lund, Department of Archaeology and Ancient History (S)
- **MALÅ** – MALÅ Geoscience AB: Ground Penetrating Radar (S)
- **Uni Gent** – University of Ghent (B)
- **Stiftung Schleswig-Holsteinische Landesmuseen** - Schloss Gottorf, Schleswig, Zentrum für Baltische und Skandinavische Archäologie (D)
- **Holstebro Museum** (D)
- **Croatian Conservation Institute** - Department for Underwater Archaeology (HR)

1.3 LBI ArchPro Board and Scientific Advisory Board

The LBI ArchPro Board

- **NoeL:**	Franz Humer, Eduard Pollhammer
- **ZAMG:**	Sirri Seren, Michael Staudinger
- **TU Vienna :**	Norbert Pfeifer, Werner Purgathofer
- **Uni Vienna :**	Gerhard Trnka, Tim Taylor
- **ABT :**	Wolfgang Grumeth, Mario Rathmanner
- **RGZM :**	Falko Daim, Detlef Gronenborn
- **SHMM :**	Christina Klotblixt, Fredrik Svanberg
- **NIKU:**	Carsten Paludan-Müller, Knut Paasche
- **Vfk:**	Terje Gansum, Anitra Fossum
- **University of Birmingham:**	Henry Chapman, Paul Garwood
- **ÖAI:**	Sabine Ladstätter, Martin Steskal
- **ÖAW:**	Barbara Horejs, Andreas Pülz
- **LBG :**	Claudia Lingner

The Scientific Advisory Board of the LBI ArchPro consists of the following distinguished scientists:

Prof. Maurizio Forte, University of California, Merced, USA

Prof. Kay Kohlmeyer, Hochschule für Technik und Wirtschaft (HTW) Berlin, Germany

Prof. Julian Richards, University of York, UK

Prof. Joakim Goldhahn, Linnaeus University, Sweden

Prof. Patrick Ryan Williams, The Field Museum of Natural History & University of Illinois at Chicago, USA

The annual meeting of the SAB was held in Vienna on December 15th 2015.

1.4 The LBI ArchPro Team

The staff of the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology comprised the following permanent employees in 2015:

- Wolfgang Neubauer (Director)
- Michael Doneus (Deputy Director)
- Immo Trinks (Head of Research and Development)
- Alois Hinterleitner (Key Researcher)
- Nives Doneus (Key Researcher)

- Christina Einwögerer (Administration Manager)
- Annemarie Steiner (Administration Manager) has joined the team in March 2015
- Karolin Kastowsky-Priglinger (Administration Manager)
- Matthias Kucera (Researcher)
- Klaus Löcker (Researcher)
- Agata Lugmayr (Researcher)
- Michael Pregesbauer (Researcher)
- Geert Verhoeven (Researcher)
- Mario Wallner (Researcher)
- Thomas Zitz (Technician)
- Georg Zotti (Researcher)
- Juan Torrejón Valdelomar (Researcher)
- Roland Filzwieser (Researcher)
- Viktor Jansa (Researcher)
- Poscetti Valeria (Researcher) was part of the team from January untill December 2015
- Lisa Aldrian (Researcher) has joined the team in September 2015
- Hannes Schiel (Field Assistant) has joined the team in September 2015
- Leopold Toriser (Field Assistant) has joined the team in August 2015
- Tanja Trausmuth (Researcher) has joined the team in August 2015
- Alexandra Vonkilch (Researcher) has joined the team in January 2015
- Nika Lužnik (Researcher) has joined the team in November 2015
- Laszlo Baumann (Technician)
- Iszolda Baumann (Facility management)

- Erich Nau (Researcher) has left the team at the end of August 2015 and will continue his scientific career at the partner organization NIKU in Norway.
- Vlad Sandici (Researcher) has left the team in November 2015 for a private company.
- Joachim Brandtner (Researcher) has left the team at the end of November 2015 for a private company.

Staff in-kind contributions:

- Christian Gugl (Researcher) contribution from ÖAW
- Rainer Schreg (Researcher), contribution from RGZM
- Erich Nau (Researcher), contribution from NIKU
- Christer Tonning (Researcher), contribution from Vestfold Fylkeskommune

- Eduard Pollhammer (Researcher), contribution from NoeL
- Helmut Schwaiger (Researcher), contribution from ÖAI

Temporary staff:

- Martin Fera (Researcher)
- Martin Gamon (Researcher)
- Jakob Kainz (Field Assistant)
- Marie Kröhl (Researcher)
- Matthias Nöster (Operations Manager)
- Klara Sauter (Field Assistant)
- Markus Schütz (Researcher)
- Tomáš Tencer (Researcher)

Initiative College for Archaeological Prospection

The University of Vienna installed within VIAS an interdisciplinary Initiative College (IC) for archaeological prospection (http://ic-archpro.univie.ac.at) at the end of 2011. Research fellows of the IC are working in the close collaboration with the LBI ArchPro staff on the archaeological analysis of LBI ArchPro case study data and various methodological developments.

IC ArchPro research assistants:

- Martin Fera
- Manuel Gabler
- Jakob Kainz
- Karolin Kastowsky-Priglinger
- Michal Ruš
- Petra Schneidhofer
- Christopher Sevara
- Tomáš Tencer
- Katalin Tolnai
- Willem Vletter

Associated PhD research fellows

- Valeria Poscetti
- Joris Coolen
- Eamonn Baldwin
- Christine Markussen
- Agata Klimczyk
- Ulrike Fornwagner

1.5 Infrastructure

In 2015 the infrastructure developments of the LBI ArchPro saw the setup of several new geophysical prospection devices as well as the initial operation of new sensor systems. For the first time a four-channel motorized 250 MHz array in SPIDAR configuration with 39 cm channel spacing was mounted in the same frame that had earlier been developed for the six-channel 500 MHz array with 25 cm

channel spacing. Since the MIRA systems equipped with 400 MHz antennae and the existing SPIDAR arrays with 500 MHz antennae cover the most commonly used frequency range for archaeological prospection with investigation depths ranging between 1.5 and 2 metres under standard conditions, the 250 MHz array offers the potential of increased penetration depth at suitable sites.
The 500 MHz motorized SPIDAR array was modified in order to guarantee greater structural strength and reliability by placing network Hubs and NICs directly on the Quadbike and shortening the tow-bar of the antenna cart.

Fig. 1: The three 16-channel MIRA systems now in use within the LBI ArchPro family.

Due to the positive experience made by the LBI ArchPro with the by MALÅ Geoscience developed multichannel GPR array MIRA, the Norwegian partner NIKU invested in 2015 into a new 16-channel 400 MHz MIRA system, which has been assembled according to the latest know-how and delivered to Norway (Fig. 1). This system is now used within a large-scale archaeological prospection pilot study in Vestfold conducted in cooperation with the LBI ArchPro partners NIKU, Vfk and ZAMG, demonstrating the exemplary use of large-scale archaeological prospection in Norwegian rescue archaeology, with direct involvement of cultural heritage managers.
A four-channel magnetometer logger for small-scale test surveys was developed and tested by Michael Pregesbauer. The new DualEM 21HS electromagnetic sensor was taken into use and a vehicle mounted survey setup tested within the project Bisenzio in Italy.
An eight-channel Caesium magnetometer sensor cart was setup with five total-field sensors at ground level, two at mid-level and on centred above at XX metre height (Fig. 2). The goal of this setup is to determine the optimum gradiometer spacing and to acquire magnetic data with improved possibilities for the estimation of the depth of buried causative structures.

Fig. 2: Caesium magnetometer cart with sensors placed at three different heights above ground.

A used Z-cooperation SPECTRUM Z™ 510 3D powder printer was purchased from the University of Applied Sciences Salzburg (Fig. 3). This printer permits the creation of detailed three-dimensional models of archaeological sites, architecture and objects. In contrast to the 3D printer based on fused deposition modelling (a.k. plastic sausage printer) the power printer permits the creation of coloured hardened gypsum models in even higher resolution. As first 3D objects the Venus von Willendorf was printed, miniature models of the Stonehenge main monument, and the Neolithic Circular ditch system of Hornsburg in nine segments. Future plans are the printing in colour of architecture models from Carnuntum and Akrotiri as well as functional architectural reconstruction models.

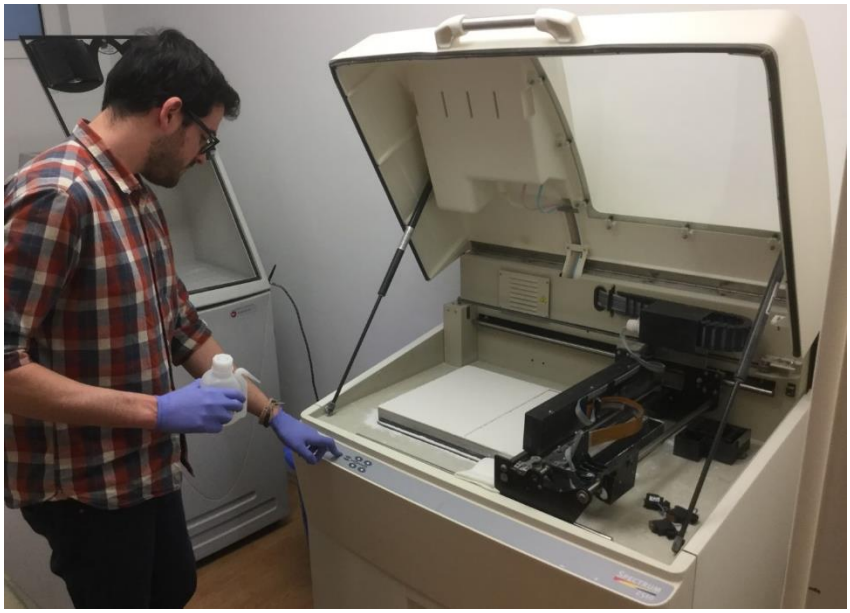

Fig. 3: Juan Torrejón Valdelomar operating the Z Cooperation SPECTRUM Z™ 510 3D gypsum powder printer. The model cleaning unit can be seen in the background.

1.6 Highlights 2015

Press conference Durrington Walls in London, GB on September 1st 2015

The press conference was organized together with the University of Birmingham and took place on Tuesday, September 1st. The focus was on the remains of a major new prehistoric stone monument in Durrington Walls, which is situated less than 3 kilometres from Stonehenge. Using cutting edge, multi-sensor technologies the Stonehenge Hidden Landscapes Project has revealed evidence for a large stone monument hidden beneath the bank of the later Durrington Walls "super-henge" (Fig. 4).

Durrington Walls is one of the largest known henge monuments measuring 500 m in diameter and thought to have been built around 4,500 years ago. Measuring more than 1.5 kilometres in circumference, it is surrounded by a ditch up to 17.6 m wide and an outer bank c. 40 m wide and surviving up to a height of 1 metre. The henge surrounds several smaller enclosures and timber circles and is associated with a recently excavated later Neolithic settlement.

At Durrington a natural depression near the river Avon appears to have been accentuated by a chalk cut scarp and delineated on the southern side by the row of massive stones. Essentially a C-shaped "arena" the monument may contains traces of springs and a dry valley leading from there into the Avon. Although none of the stones have yet been excavated a unique sarsen standing stone, "The Cuckoo Stone", remains in the adjacent field and this suggests that other stones may have come from local sources.

Previous, intensive study of the area around Stonehenge had led archaeologists to believe that only Stonehenge and a smaller henge at the end of the Stonehenge Avenue possessed significant stone structures. The latest surveys now provide evidence that Stonehenge's largest neighbour, Durrington Walls, had an earlier phase which included a large row of standing stones probably of local origin and that the context of the preservation of these stones is exceptional and the configuration unique to British archaeology.

This new discovery has significant implications for our understanding of Stonehenge and its landscape setting. The earthwork enclosure at Durrington Walls was built about a century after the Stonehenge sarsen circle (in the 27th century BC), but the new stone row could well be contemporary with or earlier than this. Not only does this new evidence demonstrate an early phase of monumental architecture at one of the greatest ceremonial sites in prehistoric Europe, it also raises significant questions about the landscape the builders of Stonehenge inhabited and how they changed this with new monument-building during the 3rd millennium BC.

List of online media reports can be found in the section on dissemination (Press releases and press coverage summary).

Fig. 4: Virtual reconstruction of Durrington Walls.

LBI ArchPro director Wolfgang Neubauer awarded Austria's "Scientist of the Year 2015"

LBI ArchPro director Wolfgang Neubauer has been awarded the prize "Scientist of the Year 2015" by the Club of education and science journalists in Austria (Fig. 5). The committee honors Neubauer's outstanding effort as director of the LBI ArchPro to make scientific research more accessible to the wide public and thus to raise the significance of Austrian research.

Fig. 5: Scientist of the Year 2015: Wolfgang Neubauer (©Roland Ferrigato).

2. Research topics and results

2.1 Integrated interpretation

INT1: GIS based data integration and data fusion

Development of a toolbox for archaeological image fusion

Introduction

Due to the constant development of new and better imaging sensors working according to different physical principles, the need arises for a meaningful combination of all this imagery. For many years, various research fields have been trying to integrate imaging data of different modalities, not at least in the geoscience and medical communities, to facilitate a better understanding and interpretation of particular phenomena. Also in the field of archaeology and more specifically archaeological prospection, the constant growth in the number and variety of image acquisition techniques creates an increasing demand for image fusion techniques to be incorporated in the analysis of these data.

Image fusion is a process in which the data from two or more images are combined in a specific way, so that a single composite output image is generated. This output image holds specific and/or substantial information from the input images. Ideally, the processing techniques used in image fusion should be efficient and reliable and the newly generated image more comprehensive and thus easier to use for a human interpreter or subsequent processing tasks. In the medical field, image fusion is often used to improve the quality of the original images and to decrease data and information redundancy so that the assessment of medical problems becomes much easier.

In remote sensing, image fusion has been used since the eighties. The variety of air- and spaceborne sensors that capture the same scene in dissimilar spectral bands and with different ground-sampling distances obviously provides a strong motivation to come up with formal solutions to combine these data. To enhance the information that can be extracted about that scene, the spectral information from an image with a lower spatial resolution is often fused (more specifically pansharpened) with the luminance data from a panchromatic image with a higher spatial resolution, thus yielding an image with different spectral bands (i.e. the colour data) as well as a high spatial resolution. Such a pansharpened image is thus an answer to the physical trade-off between spatial versus spectral resolution, since it effectively holds more useful information than could be extracted from a single sensor.

Aside from medical and remote sensing fields, image fusion has also received increasing attention by a wide spectrum of applications such as vehicle guidance or robot vision. Ideally, the fused image holds all redundant information from multiple images and additionally displays the features which are unique for one (or more) of these input images. This newly created image should thus be more suitable for human reading and analysis tasks such as image interpretation. Often, the fused image even reveals information that is not apparent in any of the separate input images. Finally, fusing different image modalities helps in reducing the storage cost.

The fusion of images can take place at different stages. Very often, these different stages are categorized as the signal-, pixel-, feature- and symbolic-level. Here, only methods that work on the pixel-level are considered.

TAIFU

Since archaeological image fusion has hardly been used, a dedicated MATLAB toolbox TAIFU (the Toolbox for Archaeological Image Fusion) has been created. TAIFU serves as a platform for testing of well-established and state-of-the-art image fusion methods (see 2.1) and facilitates the development of new data integration routines. This toolbox is thus designed to benefit archaeological interpretive

mapping of diverse prospection datasets. For example, the data from a magnetogram can be fused with an aerial image to aid the archaeologist in correlating feature locations for a more trustworthy information extraction and better interpretation of the hidden geo-cultural landscape.
The following section presents a short overview of the various image fusion approaches that are presently embedded in TAIFU (version 0.2). Three big families of methods will be explained in slightly more detail.

1. Blending modes

In many popular image editing programs such as Photoshop (Adobe), GIMP (Open Source) or Pixelmator (Pixelmator Team), the user can choose between several blending modes. These modes, which are often denoted as layer modes, change the appearance of the upper layer or image (called blend layer) based on the base image(s)/layer(s) beneath it. As such, blending modes can also be seen as image fusion algorithms.
TAIFU incorporates all (except the useless "Dissolve") blending modes which can be found in common image processing applications and even offers several others which are not found amongst the biggest players in the image editing world. Because TAIFU converts all input images to double-precision floating-point numbers in the range [0, 1], no extra normalisation step is needed when working with conventional 8-bit or 16-bit images.

2. Pansharpening

It was already mentioned above that pansharpening is an approach in which the spatial information of a high resolution panchromatic image is integrated with the spectral information from an image with a lower spatial resolution. Panchromatic fusion can be accomplished by several techniques. So far, TAIFU embeds IHS (Intensity Hue Saturation) pansharpening (the original IHS method as well as the adaptive IHS approach), wavelet-based pansharpening, Principal Component Analysis (PCA) and Brovery pansharpening. In addition, the user can choose to (de)active image histogram matching and channel normalisation.

3. Distribution fitting

Distribution fitting creates an N-band image from the input images (e.g. two three-band images deliver a six-band image). Afterwards, a histogram is computed for every image pixel (i.e. for the six-band image, a pixel-specific histogram is computed from the six samples). The user then defines a theoretical Probability Density Function (PDF) which is fitted to every pixel-specific histogram. Since every PDF is defined by one or more parameters, the parameters that define the fitted PDF for that pixel can be saved and form the new pixel values. TAIFU offers several discrete and continuous PDFs for uni- or bimodal fitting. Multi-threading (interactively customisable) is also exploited.

4. Additional fusion approaches

Aside from these three big families of fusion approaches, many other methods have been implemented: (weighted) PCA fusion; ICA or Independent Component Analysis-based fusion (see Fig. 2), (discrete stationary) wavelet-based fusion, logistic weighting, guided-filtering and gradient domain fusion.
TAIFU is currently coded in such a way that the user has to load two images (Fig. 2). Upon import, the toolbox verifies and stores the metadata of the images (such as georeferencing, Exif and IPTC tags). In addition, the user has a variety of pre-processing steps at his/her disposal: individual image channels and their histograms can be viewed and extracted, various (perception-based) colourmaps can be used to colour-code single band imagery and a handful of contrast enhancement algorithms can make certain image features better perceivable (invert, histogram stretching, CLAHE, *L** CLAHE). Moreover, colour-to-greyscale (and vice versa) conversions allow to fuse imagery for which the fusion method expects an (un)equal amount of bands.

In a next step, the above-mentioned fusion methods (often with additional options such as alpha values) can be chosen to create a fused output. When a useful result is obtained, the fused image can be saved with all the metadata embedded, although the latter can also be stored as a sidecar ASCII file. These new metadata do not only originate from both input images, they also contain data about the contrast enhancement(s), colour-map(s), channel-conversion(s) and fusion algorithm(s) that were used to obtain the final result. Finally, all buttons feature (deactivatable) tooltips, all fusion methods come with thorough explanations and a separate notification window informs the user about on-going and possible processes (Fig. 6).

Fig. 6: The main TAIFU window. A digital terrain model (upper left) is fused with a magnetogram (lower left) using ICA-based fusion.

Future additions and improvements

For the next release (0.3), many additional capabilities have been planned and are currently worked on. TAIFU 0.2 only accepts single band or three band images. From version 0.3 onwards, multi-band imagery will be supported. This, however, means that many image fusion and contrast enhancement algorithms will have to be reprogrammed so that they are flexible enough to deal with a varying amount of input bands. Second, version 0.3 will provide various image metrics that can hopefully reliably assess the quality of the fused output. Third, a few processor intensive methods will be ported to C++.

TAIFU 0.4 will be capable of interpreting several coordinate reference systems (CRSs) and offer some simple tools for dealing with images that are not perfectly co-registered or those that are expressed in dissimilar CRSs. Moreover, the possibility to interpret CRSs will make it possible to automatically or manually extract the overlapping part of the images. In this way, TAIFU will be able to deal with datasets that have a varying spatial extent and feature dissimilar spatial resolutions, something that is currently not supported.

Finally, it is hoped that TAIFU 0.4 can be released free-of-charge or at a very moderate cost, but negotiations concerning this issue are still on-going.

Relevant lectures and publications:

Verhoeven, G. (2015): TAIFU – Toolbox for Archaeological Image FUsion. Poster. AARG Annual Meeting 2015. Santiago de Compostela, Spain, 09.09.2015.

INT5: Development of interpretation workflows and tools

Evaluation of new GIS developments

In the course of the interpretation development a new ArcGIS Online and ArcGIS Pro were tested. Normally, one works with a product from the **ArcGIS for Desktop** family: Basic, Standard or Advanced (formerly ArcView, ArcEditor or ArcInfo, respectively). Any version of ArcGIS for Desktop consists of several applications such as ArcMap, ArcCatalog, ArcToolbox, ArcScene, ArcGlobe and the new ArcGIS Pro. Besides the ArcGIS for Desktop family, ESRI also offers the ArcGIS Online and ArcGIS for Server products. The following text first introduces ArcGIS Pro and afterwards ArcGIS Online.

ArcGIS Pro

ArcGIS Pro is a new application that is part of the ArcGIS for Desktop family. Just as ArcMap, ArcCatalog, ArcGlobe or ArcScene, the new ArcGIS Pro allows the user to manage geographical data, create maps and perform spatial analysis. However, ArcGIS Pro ships with ArcGIS 10.3 only for the first time. Besides, it adds many new features. In summary, ArcGIS Pro should be capable of 2D and 3D for visualization, editing and spatial analysis; modern look due to the ribbon-based interface; very fast due to the use of all possible hardware (GPU, CPU), 64-bit and multi-threaded and new graphics engine (both for 2D and 3D); powerful since all Desktop data, tools, symbology and scripts work in ArcGIS Pro, can be automated with Python and a new API and SDK, tightly integrated with Microsoft Visual Studio; tightly integrated with ArcGIS online to publish finished web maps directly to ArcGIS Online; able to run from ArcGIS Desktop 9.2 onwards.

Full 3D models are still added as before using the multipatch feature capability (see http://pro.arcgis.com/en/pro-app/help/editing/basics/create-3d-multipatch-features.htm). This works with COLLADA (.dae), OpenFlight 15.8 (.flt), SketchUp 6.0 (.skp), VRML 2.0 models (.wrl) and 3D Studio (.3ds) formats. Note that multipatch features are enclosed volumes defined with 3D rings and triangular patches that model the outer surface or shell of natural and as-built 3D features.

ArcGIS Online

ArcGIS Online is a web application allowing for sharing and searching geographic information. It allows its users to create and join groups, and control access to items shared publicly or within groups. For the LBI, it would mean that members can use, create and share maps, apps and data. Given its wide functionality, it is difficult to assess all its aspects in high detail. Sharing of maps and even complete geodatabases is simple and functional for making web maps and applications, but it is neither really a data management service nor suitable for discussing interpretations. The latter is not really possible since the editing is extremely basic. There is no real history of who edited what and why.

However, if the LBI ArchPro wants to get the case studies out on the WWW and our interpretations accessible for anybody with a browser or a mobile phone, this is a handy tool. Since one can also make custom layouts, apps and presentations, there are many options for presenting and sharing our data (in limited groups or with the whole world). When using it only to publish specific content online, there is a whole set of rules and privileges one can give to individuals, groups and everybody, so its seems rather powerful in this aspect. Data can be shared, but so far, editing seems extremely basic, which makes this tool quite inappropriate for the archaeological interpretation.

Development of integration tools: case study Oberlienz

The interpretation work has focused on the 3D Interpretation in a 3D GIS environment (ArcScene). Considering that the prospected area is dramatically sloping, the GPR data were newly processed and interpreted, including topographical correction. In order to achieve a comprehensive 3D Interpretation model in ArcScene, the workflow was improved allowing an efficient importing of large textured 3D models into ArcScene. This workflow includes preliminary cleaning and re-meshing in Meshlab. The interpretation work also involved an in depth historical research based on ancient reports and historical maps. A systematic comparison between the detected remains of the villa and excavated archaeological sites in Noricum and Raetia was conducted, with the goal to achieve a comprehensive and reliable reconstruction of the Roman villa. A more detailed reconstruction has been made according to the available collected sources. A diverse set of versions were developed as well as a distinction of the different phases. Not only buildings themselves were reconstructed but also the landscape, atmospheric conditions and flora.

Selected lectures and publications:

> *Poscetti, V.; Valdelomar, J. T.; Neubauer, W.; Müller, F. M. (2015): The Roman Villa of Oberlienz: A multidisciplinary 3D reconstruction. CAA 2015 "Keep the Revolution Going" Conference, Siena 30 March-3 April. In: CAA 2015. "Keep the Revolution Going" Conference, Siena 30 March-3 April. 43rd Computer Applications and Quantitative Methods in Archaeology. Book of Abstracts, S. 104.*

Classification of GPR data

The development of classification strategy was implemented for the case study area of Carnuntum and Birka. Due to the fact that both areas are different in terms of archaeological remains, some modification on the code had to be implemented. Special attention has been paid to the capability to process large amount of data. This was done by a tiling and stitching sequence which can be process on a server architecture which is provided by eCognition Server. The classification results are cross checked with the manual interpretation – improvements to the rule set are implemented based on the comparison.

INT6: Development of ArchaeoAnalyst 1.0

Several features were discussed and implemented in ArchaeoAnalyst in the last months. After review tools in the ArchaeoAnalyst software package have become better accessible. The Base Height Slider and the GPR Depth Composer Tools were updated, their state will now be saved in the mxd Document and the tools will automatically load when the mxd Document is opened. The tool for aerial photographs named "Creator" was also implemented. Another novelty is the development of a "Spatial Query Tool" handling the prospection data. Basically, this tool allows the users to find and load prospection data by specifying a geographical area of interest by drawing a polygon. The Spatial Query tool can also use the ArcGiS selection for the spatial query and lets the user choose the geometric relation between the query geometry and the potential results.

Further development was done in the integration of the ALS/TLS data in the ArchaeoAnalyst Creator. This includes the insertion in the prospection geodatabase, loading of data into ArcMap using optimal visualization presets. When inserting the terrain model into the geodatabase ArchaeoAnalyst offers the option to generate and insert derived visualizations based on the terrain model like hill shade and slope visualizations. This feature uses the ALS toolbox developed by the remote sensing

team to generate visualizations. ArchaeoAnalyst also offers the possibility to automatically load this toolbox into ArcGIS on demand. The ALS/TLS data are also queried by the Spatial Query Tool (Fig. 7).

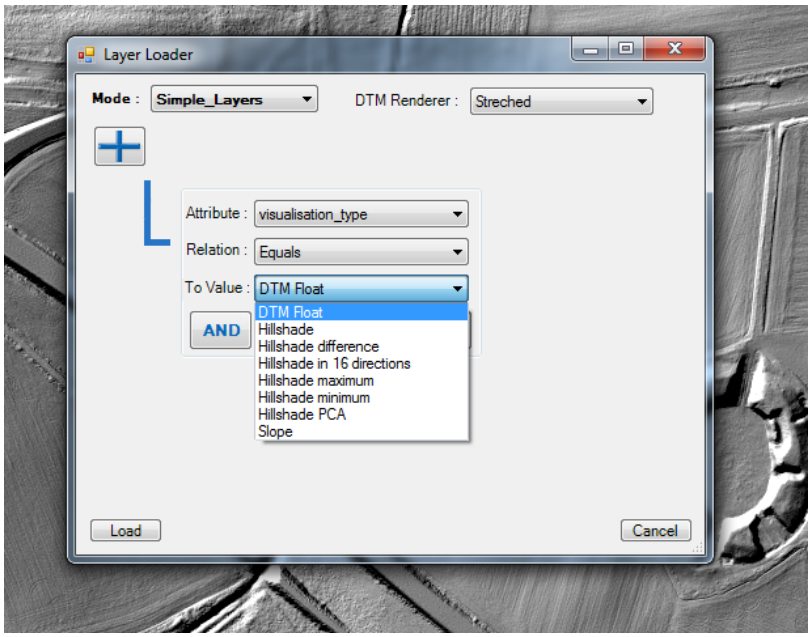

Fig. 7: Screenshot from ArchaeoAnalyst: ALS/TLS data visualization.

Last but not least, the "Create Project function" and a launcher application for the ArchaeoAnalyst have been created. In this way the ArcGIS opens with a standardized configuration suitable for archaeological interpretation.

2.2 Virtual archaeology

When Virtual Archaeology (VAR) was planned to be an important part of the LBI ArchPro research program, it was obvious, that VAR has not only to deal with reconstruction but also with visualization, exploration and simulation of archaeological datasets. For detailed definition and planning of the work packages a 2 days' workshop was planned for January 2015. The LBI ArchPro team met in Carnuntum on the 22nd and 23rd January 2015 to discuss the aim and the general characterization of VAR. As a first outcome the research program concerning VAR was defined in greater detail and presented in March 2015. The work on the packages started immediately following the recently defined tasks. In the following all work packages and projects will be described and specified.

VAR1: Review and state of the art definition of VAR

Description: Within this work package existing definitions for VA are evaluated and discussed. For this purpose literature research was done to quantify the actual and common definition of VAR within the scientific community. The outcome of this work has to be discussed within the research team. It was a preparation for the initial workshop on VAR in January 2015. Through personal communication the interest of the members of the LBI and their commitment was clarified. Due to personal workload and additional skills a core group was set up to discuss specific aspects of VAR. Every member of the core group was invited to study initial literature on the definition of VAR as a preparation for the workshop.

Results: Archive of literature and papers concerning the definition of VAR; Principles of Sevilla will be used as a basis definition; Communication with the core group started; workshop in January 2015.

Summary: Based upon the literature research it became evident, that the "Principles of Sevilla" based upon the London charter are the most elaborated definition for VAR. Nevertheless they represent to a high degree only the virtual reconstruction of archaeological sites and monuments. On several pages the principles line out the importance of interdisciplinary work and reproducibility of displayed information.

VAR2: Definition of VAR and modification of principles of Sevilla

Description: Based upon research done in VAR1 a new definition of VAR will be done including the concepts of visualization, reconstruction, exploration and simulation of archaeological data. An initial workshop organized in January 2015 has provided the primary input. The results of the workshop have been presented to all LBI ArchPro members and discussed to fulfill the demands of the research program. For a definition of VAR the workflow of the treatment of archaeological data has to be specified including the framework defined by used software and analysis procedures.

Results: Definition of VAR and "Handbook of Interpretation" (working title).

Summary: Various input including prospection data, excavation data, historical data – just to mention a few – have been collected within a geodatabase and transformed in applying the VAR toolbox. Gained output will be used in an iterative process in getting reanalyzed and further processed by VAR toolbox or disseminated. As important as virtual reconstructions of archaeological data, which is commonly seen as VAR alone, is the virtual exploration, visualization and simulation. Merging and interpreting different archaeological datasets is a task, which can only be accomplished in applying latest computer-based analysis and visualization techniques. Especially prospection data is already represented in a digital way. The most effective way of interpreting and understanding digital prospection data is within a virtual environment. Different digital visualization (e.g. using data fusion) is as crucial as new concepts of exploration of the data. New ways of exploration include the design of controllers and user interfaces such as Oculus Rift and holoscene. Different hypotheses gained through these processes can be visualized again and tested within simulations.

VAR3: Design of VAR toolbox

Description: The VAR toolbox has to be seen as the basic transformer of archaeological datasets within VAR. For this purpose the software components, the necessary hardware extension and the type of the data repository have to be defined. Depending on that is the declaration of used formats. VAR 3 is therefore divided into four subprojects dealing with the specific demands:

1. Definition of input formats and geodatabase design

A general geodatabase design will be generated based upon the already approved design used for archaeological interpretation of prospection data. Used formats will be defined by the data sources being integrated. The focus is not set on the specific design (see VAR 4) but on general aspects concerning which datasets will and should be added. As a result a diagram of general design of the GEODB and a list of input formats will be created.

2. Definition of software packages included in toolbox

To accomplish the tasks of visualization, exploration, reconstruction and simulation a basic preliminary list of needed software has to be worked out. Whereas some of these software packages are already used in the LBI ArchPro routines others need to be developed or – if already existing – evaluated and embedded into the workflow.

3. Definition of output formats (also web based)

Within this project output formats will be discussed and described also concerning dissemination. Necessities of format conversion between different packages of software will be elaborated. In terms of web based publishing and academic exchange different viewers (e.g. Google Earth) will be examined for additional definition of output formats

4. Aspects of (virtual) exploration may include both 3d user interaction (data glove, interfaces that may provide haptic feedback like Phantom or a 3d mouse with vibration device, Kinect system or all varieties of natural user interfaces) and interactive data editing with such interfaces, requiring of course real-time visualisation at all times. In a first step a review of existing controllers and hardware interfaces and their suitability will be done.

Results: Description of VAR toolbox and a diagram concerning workflow.

VAR4: Geodatabase design

Description: Similar to the development and implementation of the interpretational GEODB a GEODB design for overall AIS will be worked out. The interpretational GEODB will be a part of this design. In general the GEODB will consist of a primary part, which organizes input data (raster and feature classes). Secondly the interpretational part also consisting of raster and features classes will be constantly filled with results of the spatio-temporal analysis process of the datasets. A main aspect of the design is that it has to fulfill the demands of an open system, which is typical for archaeological datasets and investigations. The design has to be capable of being extended at any time to embed new types of data and information.

Results: Layout and design of GEODB and a first draft of workflow

VAR5: Software packages

Description: Within this project all software directly connected to VAR and developed by the LBI ArchPro and its partners is collected. Most of the software is necessary to develop workflows and procedures for spatio-temporal analysis. In this way a stratigraphic sequencing tool like HMC+ and interactive 3D viewers are crucial. Whereas within VAR5.1 to VAR5.5 concrete software will be tested and developed, VAR5.6 will also evaluate state-of-the-art simulation software in general.

1. HMC+

Spatio-temporal analysis, which is crucial for the examination of archaeological landscapes through time, is based upon the stratigraphic sequencing of archaeological entities at all scales. Every archaeological entity, whether it is a pit, a settlement or a process in general, is connected with a specific time interval. The superposition of these time intervals arranges space in time. HMC+ is such a sequencing tool based upon the (physical) laws of stratification and superposition. A stratigraphic sequence (Harris Matrix) reflects primary the spatial superposition. In a second step all stratigraphic units will undergo a temporal interpretation. A temporal aligned stratigraphic sequence is a perfect steering and analysis tool to arrange and visualize specific archaeological entities in time. As an extension of ArcGIS it will be a powerful tool to organize these entities in time (Fig. 8). As a result two different HMC+ versions (standalone and ArcGIS linked) should be developed as well as a user manual. Together with VRVIS new concepts to imbed a time interval based model into a stratigraphic sequence were discussed and developed. A first draft of HMC+ was tested and evaluated by the LBI ArchPro and needed changes, like the possibility to group stratigraphic units following the old concept of phases and periods, communicated to the partner.

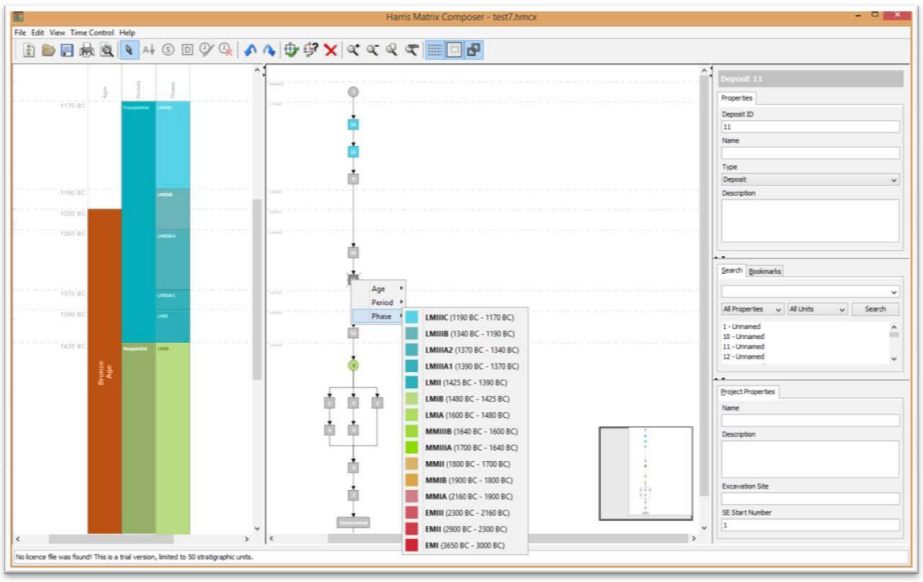

Fig. 8: Screenshot from HMC+ 1.1: every archaeological entity can be assigned to a specific time interval.

2. 3d+ viewer

To examine 3D datasets a 3Dd viewer is necessary (Fig. 9). The 3d+ viewer developed by VrVIS based upon specific archaeological demands concerning excavation data provides the possibility to explore and interpret 3D datasets. It is typical that archaeological interpretation has to be done not only upon 2D surfaces but also in 3D. Another aspect is the visualization of different excavation steps. The distribution of e.g. artifacts and samples can be displayed for further analysis. Like HMC+ the 3d+ viewer will be used connected to ArcGIS not only as a viewer but also as an interpretation engine in terms of drawing polygons. Two different 3d+ viewer versions (standalone and ArcGIS linked) should be developed as well as a user manual.

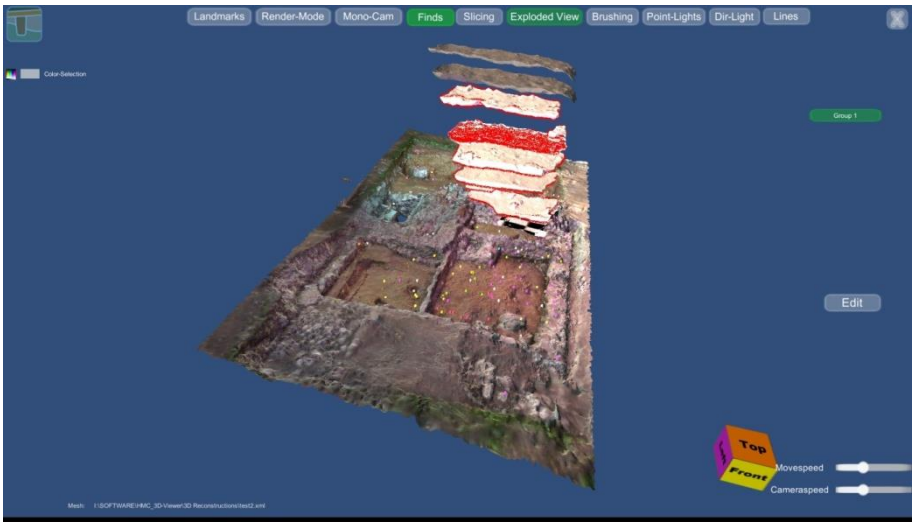

Fig. 9: Screenshot from 3d+ viewer.

3. ARCH 4dInspector

Recently developed ARCH 4dInspector should be a tool, which is capable of visualizing different archaeological hypothesis based upon various archaeological datasets. It will be used for exploring

possible interpretations in 3D. The graphic user interface is designed in a way that the creation of simple reconstructions (e.g. prolongation of presumed postholes to visualize a house structure) is done easily. By displaying different interpretations in 3D spatial and temporal conflicts and/or intersections can be examined. The software package ARCH 4dInspector and user manual/ specifications will be further developed in this work package.

4. WebViewer

3D data need usually huge storage space. For the fast exchange of information based upon or embedded within this data web based viewers are necessary to explore 3D datasets in real time without actually downloading the data. The WebViewer developed under subcontract for the LBI ArchPro purposes provides the chance to share information based upon huge point clouds (Fig. 104). As an example the Heidentor of Carnuntum was chosen to display the concept. Without downloading the datasets, they can be explored even on a smart phone. Anchor points can be set to show additional information. The WebViewer provides also the chance to explore the quality of different datasets preceding time-consuming download procedures.
http://potree.org/work/archpro/archpro_revision2/html/scene.html

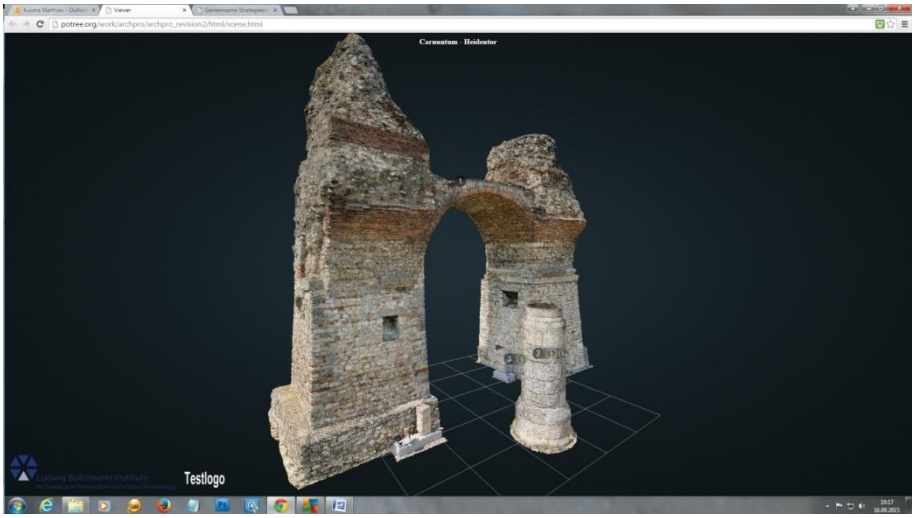

Fig. 104: Screenshot from WebViewer.

5. ArchaeoAnalyst

ArchaeoAnalyst 1.0 was developed by the LBI ArchPro as an extension of ArcGIS to support the interpretational process of archaeological datasets. Within this sub project the software will be further developed in respect of the demands of the VAR.

6. Simulation

For the simulation of transformation processes or the testing of developed models specific simulation software is necessary. Within this project different software being used for this purpose will be evaluated and displayed.

VAR6: Archaeological Information System (AIS)

Description: Archaeological research is dealing with the documentation and analysis of archaeological entities in space and time. During this process information is linked with a specific location and a time stamp. An Archaeological Information System (AIS) organizes archaeological entities and

associated information according to their specific location using a Geographical Information Systems (GIS). To end up with a stratigraphic sequence of these entities, AIS has to be accompanied by the fourth dimension – time. For this purpose the GIS-based AIS is supplemented with a time-steering tool – namely Harris Matrix Composer^{+} – to enable spatio-temporal analysis. Within this project the basic demands of AIS will be defined, software will be interlinked and implemented into GIS.

VAR7: Visualization tools

Description: Various tools and concepts for visualization of archaeological content will be developed and tested by the LBI ArchPro partner 7reasons.

VAR8: Testing and further development of AIS and VAR

Description: As soon as projects VAR3 to VAR6 are finalized the whole system of VAR introduced by the LBI will be tested with respect to usability. Based upon these results AIS including the embedded software and concepts of VAR will be modified. It has to be expected, that new ideas and concepts will arise through the work progress. This project has to be seen as a finalizing step before the whole research program of VAR will be evaluated within VAR9.

VAR9: Visualization tools

Description: The whole package of VAR including used software, workflows, AIS, GeoDB design, will be evaluated and tested in a final step. This evaluation will be the basis of the final report of the results of the LBI ArchPro research program on VAR. Future steps will be suggested.

VAR10: Case studies

Description: Several of the LBI ArchPro case studies are suited as examples to develop and illustrate tools and workflows in VAR. The results of every sub project can be used for further dissemination in terms of time and cost efficiency.

1. TED project (VAR 10.1)

Description: Most archaeological data are based upon already excavated sites. It is crucial for the comparability of archaeological datasets to integrate these existing data for contemporary archaeological data analysis. The long-term excavation at Tell el Daba (for project details see section 2.6 Case studies and third party founded projects) was chosen as a case study to evolve existing datasets within recent analysis tools using a georeferenced 4D-AIS. The basic research question is to examine the possibility of reconstructing undocumented and missing information. This approach of reverse excavating provides the chance to compare datasets of different provenience.

Results: Because of the huge amount of excavation data consisting of handmade drawings, photographs and protocols a single quadrant of area F2 was chosen to develop a custom made AIS as a basis for further archaeological interpretation of the site. All hand drawings were digitized, distorted and georeferenced to be displayed in GIS. All features documented on these drawings including bricks, walls, pits, floors, doorsteps, graves and even artifacts were redrawn in GIS resulting in about 6000 polygons. Therefore all bricklayers and walls could be displayed independent from the arbitrary level, which was documented when excavated. Additionally a grave also represented by detailed maps was reconstructed using SketchUp and imported to ArcScene. Currently the work focuses on the reconstruction of the stratigraphic sequence in correlation with stratigraphy observed by the excavators. The next steps will include the design of a geodatabase based upon gained knowledge about the type and character of the data and the implementation of HMC+ and GIS.

2. CS Kreuttal (VAR 10.2)

Description: The CS Kreuttal is the largest LBI ArchPro case study in Austria. It combines multiple datasets, ranging from Neolithic to modern times, which will be tested in frame of the virtual archaeology.

Results: For the upcoming exhibition Stonehenge (March 2016, Mistelbach/Austria) a focus was set upon the middle Neolithic Kreisgrabenanlage Hornsburg 3. Based upon the excavation and geomagnetic prospection data a 3D model was made, showing one of the latest monuments phases. The model includes also wooden constructions like the inner palisade and additional posts within the entrance to the West. The model was printed with a 3D printer (Z-cooperation), refined and prepared for the exhibition. An animation of the monument embedded in the presumed Neolithic landscape was created.
During the visualization of the data several discussions occurred concerning the "natural" character of virtual scenes and buildings. Questions arose whether one might observe a difference between a calculated model and a model which is based upon real houses and structures. For this purpose it was decided to document the reconstruction of a Linearbandkeramik house rebuild in the scale 1:1 in the open air museum in Asparn in 2014. The house was documented using TLS and IBM. Both techniques will be again compared. Nevertheless natural details seem to influence the appearance of virtual structures to a great amount. E.g. the rooftop of the real house is bending following the supporting structures below. Introducing this curve into a virtual model makes it look more natural.

3. CS Carnuntum (VAR 10.3)

Description: The CS Carnuntum provides an enormous amount of dense and detailed information based mainly on geophysical prospection (GPR, Magnetics, EMI) and accompanied by remote sensing data. Especially structures within the Roman town are very complex and therefore best suited for testing ARCH4DInsepctor and HMC+. Furthermore data fusion concepts can be tested. ARCH 4DInsepctor was initially developed to analyze the temporal relations of the different structures visible within the area of the auxiliary castle.

Results: Within the area of the civil town, the mansion, a Gallo-Roman temple, the amphitheater and surrounding area were reconstructed and visualized. During the work a spatio-temporal analysis made a differentiation of two temporal phases.

4. CS Stonehenge (VAR 10.5)

Description: Within the CS Stonehenge a main focus of VAR is set upon animation and reconstruction.

Results: Most of the work done concerns the visualization and modeling of latest results. Based upon a GPR survey the landscape of Durrington Walls was visualized. For this purpose the DTM gained by TLS was refined and combined with a general DTM. The DTM of the whole Stonehenge envelope was cleaned from modern roads and buildings representing therefore a (emotionally) non disturbed landscape. The timber circles of Amesbury 50 and 9 were also visualized and the models delivered to 7reasons. Finally the causewayed enclosure of Hambledon Hill and Neolithic pottery was modeled. For the upcoming exhibition Stonehenge survey data was prepared to be displayed within an ATV-computer game. The visitor sits on a real ATV and controls its virtual drive through the landscape of Stonehenge collecting prospection data.

5. CS Akrotiri

Description: Within the CS Akrotiri a main focus of VAR is set upon animation and reconstruction.
Results: For the CS Akrotiri several Digital Terrain Models of the surrounding areas were generated

based on Terrestrial Laser Scanning data and Image Based Modelling. Some of the data were collected using Kite Aerial Photography. A first focus was set on the relocated archaeological excavation site of Robert Zahn in the Potamos valley some 500 m to the north-east of the Akrotiri excavation site dating to 1899. The location of Zahn's excavation site, which had been roughly known from reports mentioning it in a ravine to the east of the ravine where later the Akrotiri site has been discovered, and a photograph, has been determined using Image Based Modelling and Terrestrial Laser Scanning. With help of a set of 31 excavation photos from 1899 found in the collection of the German Archaeological Institute at Athens and the concept of involuntary photogrammetry it was possible to partly reconstruct the relocated excavation in 3D. Additionally, in December 2015 the excavation diary of Robert Zahn, containing drawings and detailed maps as well as descriptions was located in the Antikensammlung in Berlin. A working copy of the diary was made.

Relevant lectures and publications:

Aspöck, E.; Kopetzky, K.; Kucera, M.; Horejs, B.; Neubauer, W.; Bietak, M. (2015): A puzzle in 4d - Digital preservation and reconstruction of an Egyptian palace. Digital Heritage 2015. Granada, Spain, 01.10.2015.

Verhoeven, G.; Karel, W.; Štuhec, S.; Doneus, M.; Trinks, I.; Pfeifer, N. (2015): Mind your grey tones – examining the influence of decolourization methods on interest point extraction and matching for architectural image-based modelling. In: D. Gonzalez-Aguilera, F. Remondino, J. Boehm, T. Kersten und T. Fuse (Hg.): Virtual Reconstruction and Visualization of Complex Architectures. 6th International Workshop "3D-ARCH 2015. 25–27 February 2015, Avila, Spain (ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., Vol. XL-5.

2.3 Underwater archaeology

UWP1: State of the art prospection for underwater archaeology

A description of the state-of-the-art of geophysical underwater prospection was finalized. A list of preferred acoustic sensor systems for high-resolution large-scale archaeological prospection of shallow underwater sites was compiled, including multi-beam sonar for the generation of detailed bathymetry models, sub-bottom profilers for the investigation of structures of archaeological interested embedded into the sediment, and side scan sonar for the imaging of the seafloor. In collaboration with Vienna University as well as the government of the region of Upper Austria the required shared funding amounting to €550.000 was secured by the LBI ArchPro. Discussions commenced with the University of Natural Resources and Life Sciences (BOKU) in Vienna concerning collaboration for the setup of the underwater survey systems. First instrument demonstrations by the manufacturers are scheduled for May 2016. First archaeological prospection tests are estimated to take place in autumn 2016. The initial focus will be on the mapping and investigation of Austrian pile dwellings in lakes in Upper Austria.

Relevant lectures and publications:

Doneus, M.; Doneus, N.; Briese, C.; Verhoeven, G. (2015): Airborne laser scanning and Mediterranean environments - Croatian case studies. In: Izdanja Hrvatskog Arheološkog Društva (30), S. 147–163.

Doneus, M.; Miholjek, I.; Mandlburger, G.; Doneus, N.; Verhoeven, G.; Briese, C.; Pregesbauer, M. (2015): Airborne Laser Bathymetry for documentation of submerged archaeological sites in shallow water. In: Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci. XL-5/W5, S. 99–107. DOI: 10.5194/isprsarchives-XL-5-W5-99-2015.

2.4 Unmanned aerial systems

No activities during the year 2015.

2.5 Data acquisition and processing

Development of new camera kit for aerial archaeology

For test-flights in project areas with new camera kit a new hardware based on Xsens MTi-G-700 GPS/INS (provided by Partner UNI Vienna) has been tested. The results show that the accuracy is better than 0.5° in each angle (roll, yaw, pitch). Small software (based on Matlab) was written to automatically transform the images on a plane surface using the GPS and IMU data. The results were better than expected and the hardware can in future be used for automated archiving of aerial photographs as well as for providing initial values for the automated orthorectification (Fig. 11). Further test-flights with the Xsens MTi-G-700 GPS/INS (provided by Partner UNI Vienna) were done on 26th June and 2nd July 2015 in the case study area Kreuttal.

Fig. 11: Result of automated transformation images on a plane surface using the GPS and IMU data.

DAP1: Induced EM system method and testing

The novel DualEM 21HS EMI system was tested with the aim to acquire experience how this system behaves under measurement conditions in the field (Fig. 12). The following tests were conducted in order to gain experience with the instrument, sensors and acquired data:

1. long term drift: stationary measurement in order to determine the long term drift of each coil configuration

2. roll/pitch dependency: determination of the roll/pitch factor in order to dynamically correct data for roll/pitch sensor movements
3. repeated measurements of a single profile for determination of instrument accuracy and repeatability
4. measurement in presence of a noise source: testing the influence and effect of a vehicle on the sensor with the perspective to mount the sensor on a motorized vehicle

Since it was intended to mount the EMI sensor in front or rear of a motorized vehicle, the influence of the machine on the data was investigated. It is obvious that the machine induced noise increase when approaching the vehicle. On low conductivity terrain the influence is particularly visible on the 0.5/0.6 m dipole, which reduces the capability to resolve near surface anomalies.

For dynamic test measurements the sensor was mounted on the front hitch of the tractor. A profile was measured several times in order to specify the repeatability of a measurement and to compare the measurement with "undistorted" measurement recorded by towing the sensor on a sledge behind the vehicle.

First test measurements were performed within the case study Kreuttal and the data have been processed. During a first fieldwork test problems with the sensor configuration occurred and the auxiliary data (roll/pitch) was not recorded. Additional problems have been detected in case of higher sampling rates (>2Hz). The vehicle mounted EMI setup was as well tested within the case study Bisenzio.

Fig. 12: The DualEM 21HS mounted in front of the Kubota tractor and alongside a Quad bike for the survey in Bisenzio.

DAP5: Extension of APSoft 2.0

The processing software for motorized geophysical prospection has been slightly changed in the last twelve months to better meet the needs of the LBI ArchPro. The ApRadar software was further developed to handle the new Mira firmware and to enhance positioning for Mira Systems without PPS input. The functionality of ApRadar was extended to export GPR fields to the 3D visualization software "Voxler" and to import an "area of interest" from ArcGIS permitting the cropping of GPR data sets. Furthermore, a special method to detect and filter traces superposed by high frequency noise was implemented. The ApMag software was extended to eliminate single magnetic sensors from the processing, which is necessary if they are erroneous. The visualization of the magnetic prospection data was enhanced by reducing the influence of periodic interferences. ApMag was also extended by a robust function for optimized visualization of magnetic data in ArcheoAnalyst.

The functionality for GPR and magnetic hand held systems was enabled to process many small areas in one pass by simply compiling the raw data of all areas in one directory.

Enhancement of LoggerVis data acquisition software

The measuring system settings in LoggerVis got a user interface design review, resulting in a new feature namely the “preset systems”. As depicted below, the user can choose from a dropdown list of predefined systems. By doing so all metadata settings regarding the measuring system, display settings and user interface settings relevant to the specific measuring system are automatically set. Also, the user has the option to save the current measuring system configuration as a pre-defined system, which then becomes loadable through this feature.

Furthermore, in this version of LoggerVis a navigation tool was implemented. The user can now pinpoint a destination trough clicking on the screen and a screen arrow guides the driver to the destination point (Fig. 13).

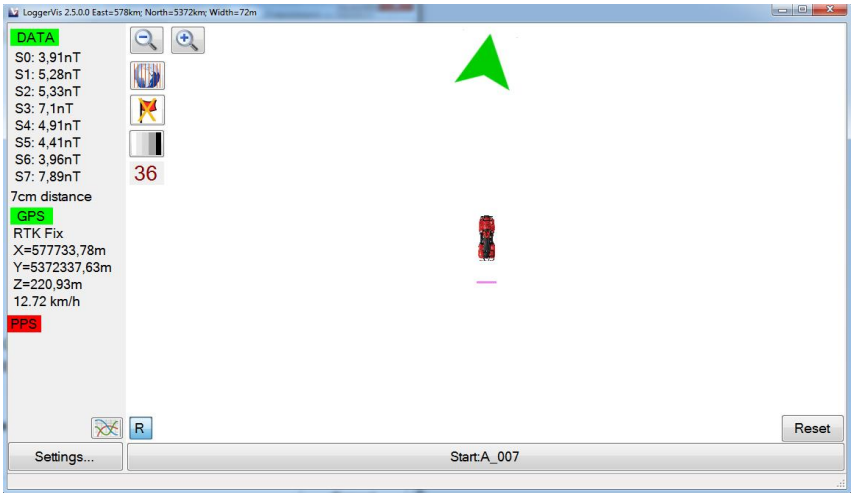

Fig. 13: Screenshot from LoggerVis.

Another addition to the LoggerVis software is the “Gladiator operating mode”. This operating mode is designed for archaeological excavation sites with the purpose of recording GPS points of finds, stratigraphic unit outlines, photogrammetric points and other positions relevant to the excavation. LoggerVis also uses the “Gladiator software” developed last year to process all these points and to export them into file formats required by the software packages used to process the excavation data.

DAP9: Development of a Fluxgate Magnetometer Data Logger

The goal of the development of a Fluxgate magnetometer data logger was the intention to investigate the possibility for optimized in-house developed data acquisition systems. Therefore a prototype for a four-channel magnetometer data logger was developed. Fig. 14 shows the front and rear connector panel of the prototype data logger. The logger uses the 7 pin LEMO connector of the existing Förster probe cables. The output is implemented via a standard USB cable. In case of successful testing the system can be upgraded to an eight channel logger. Besides the logger hardware the necessary logging software (in beta stage) was also developed.

Fig. 14: Prototype for a four-channel system.

2.6 Case studies and third party funded projects

Kreuttal, A

In 2015 several campaigns and tests have been carried out. A major project was the supervision of the excavation at Kreisgrabenanlage Hornsburg 2 run by the University of Vienna. During this campaign several other investigations linked to the LBI ArchPro research program were realized, namely tests of hand operated multi-channel cesium gradiometer run in RTK mode (HELGA) and the motorized Caesiumgradiometer, the application of LoggerVis for geodetic surveys, soil sampling strategies and a comparison of Image Based Modeling and TLS for surface documentation.

Excavation and geoarchaeological investigations: KGA Hornsburg 2, Area B

At the site of the Middle Neolithic Kreisgrabenanlage Hornsburg 2 an area of about 30 by 15 m was examined during an archaeological excavation. The specific area is located about 50 m North West of the western entrance of the KGA. It was examined using magnetometry twice: for the first time with a Caesiumgradiometer with inline spacing of 50 cm (HELGA 1992) and again in 2011 using a motorized 10 channel Fluxgate magnetometer with inline spacing of 25 cm. Due to a high grade of erosion it could be observed that some anomalies are partly destroyed.

The results show the presence of a settlement surrounding the KGA with a focus on a faint ridge heading in western direction from the KGA. Several structures indicate a multiphase settlement consisting of large houses and Grubenhäuser belonging to the same time period as the KGA.

Area B was chosen for the excavation. The observed anomalies are quite clearly separated from surrounding ones and indicate possible settlement features. Several large pits are arranged within an area of about 10 by 10 m. The excavation started on the 11th of June with the setup of the infrastructure and ended on the 17th of July. During the excavation a vineyard from the 19th century was revealed intersecting with most of the prehistoric features. All observed features were already very shallow, which was also indicated in advance by the two geophysical datasets gained within 20 years. Several kilns, probably for cooking, were observed grouping around a couple of larger pits. From the huge central pit (approx. 4 m in diameter) a lot of well elaborated artifacts were gathered including fine micro-silices, ceramic spoons (Tüllenlöffel), painted pottery and also very rare pieces of ornamented pottery indicating an early phase of Middle Neolithic Lengyel. The interpretation of the function of the complex is still in progress.

Fig. 15: Impression of the excavation of area B.

Excavation and geoarchaeological investigations: Habersfeld, Area A

Another area – Habersfeld, Area A – was investigated in the summer of 2015. Large scale survey from the year 2011 has revealed four pits, arranged in a T-shaped symmetric way with approx. 2 m in diameter (Fig. 16). Without a large scale prospection approach this site would hardly have been detected. The excavation trench has covered an area of 5 by 5 m and the most southern pit was closely investigated. After the manual excavation of the topsoil the pit with a rectangular shape of 1.2 by 1.8 m was located in 45 cm depth. Whereas no artifacts were found to date the feature, the impact of high temperatures cause by one or more fires within the pit was evident. An unexpected huge amount of stones from 10 to 25 cm in diameter was found, which show scorch marks. Pieces of charcoal will allow radiocarbon dating.

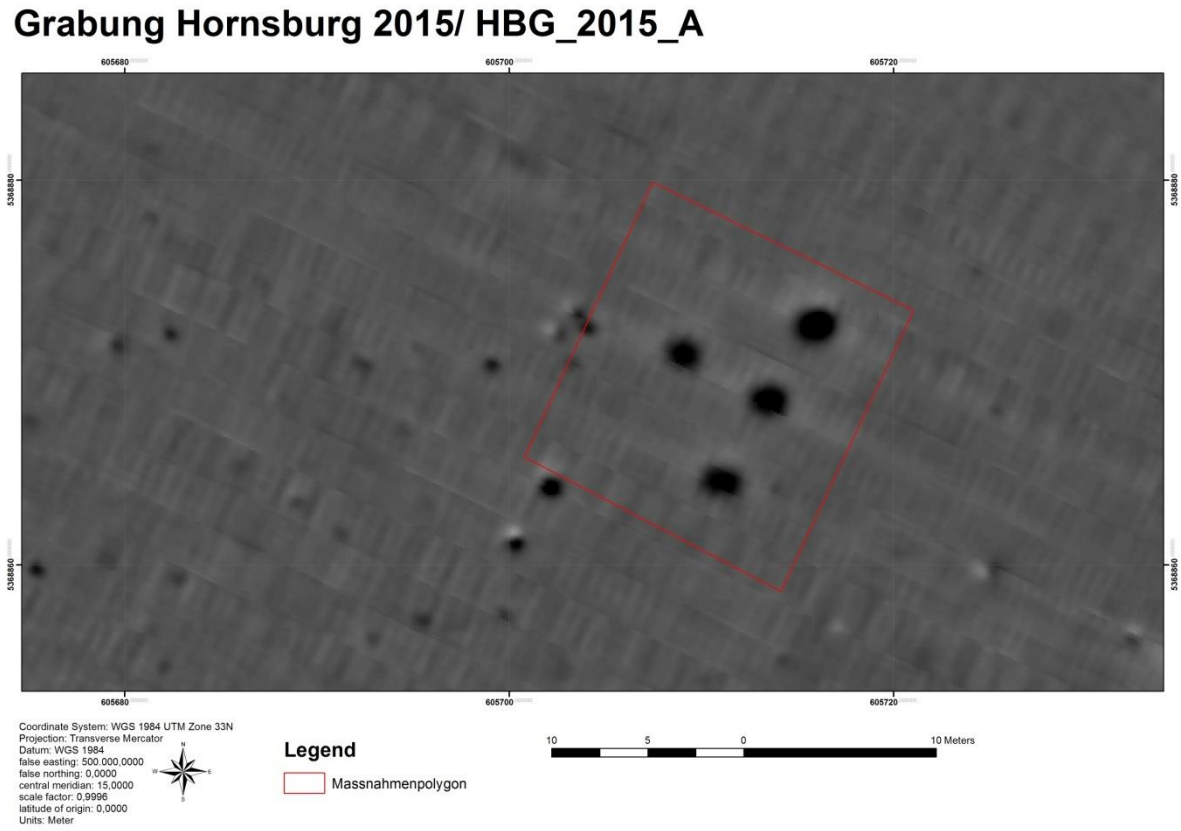

Fig. 16: Magnetic data of Haberfeld, area A showing the t-shaped arranged pits.

IBM and TLS

Besides purely chronological research questions several aspects of the LBI ArchPro research program were enlighten. For the documentation process of a stratigraphic excavation Image based Modelling using coded target points was applied. The results will be analyzed in comparing them to TLS data within a separate study. Most of the surfaces of the stratigraphic units will be statistically evaluated concerning their local differences of both methods using the software Cloud Compare.

LoggerVis for RTK geodetic survey

Another test concerning RTK survey using LoggerVis was carried out. LoggerVis was prepared in advance for single points and polygon measurements based upon JAVAD systems (Triumph base and rover). Already last year Gladiator software was developed to automatically separate differently coded measurements done with a total station. The same codes will be implemented for LoggerVis. The big advantage is the usability and a straight forward approach for geodetic surveys fulfilling our specific demands.

RTK mode for hand operated systems

Additionally a field close to excavation area B covering the Northern part of KGA Hornsburg 2 was geophysical examined with the old gradiometer system HELGA being operated in RTK mode and the motorized cesium gradiometer. The operation of HELGA in RTK mode worked satisfyingly.

Drilling

During the campaign also a recently bought drill was tested on the site. A first practical introduction of the usage was carried out by R. Peticzka and E. Draganits (Uni Vienna), introducing the system.

Laa an der Thaya, A

In 2015 two fieldwork campaigns have been conducted in framework of the Case Study Laa an der Thaya. The CS area (8 km^2) is located in the north of Lower Austria, next to the Czech-Austrian border and the city Laa an der Thaya. Archaeological finds from the plough soil suggest long settlement history beginning with the middle Neolithic period; a temporary used Roman field camp was found just a few years ago by aerial archaeology. Lately discovered historic map of the court mathematician Johann Jakob Marinoni from 1711 mentions, next to different landmarks, also three deserted villages from the medieval times in the CS area.

Fig. 17: Left: Multi-phase settlement at Schmalzberg. Right: Multi-phase settlement at Grafenwasen.

During the first prospection season three main areas have been selected for systematic geophysical prospection: Schmalzberg (flood plain of the river Thaya), Ruhhof (Roman field camp) and Rothenseehof (medieval settlement). The campaigns took place in the period from March 3rd to April 14th 2015 and from August 4th to September 16th 2015. A total coverage of around 230 ha with the magnetic systems could be obtained within 24 days of fieldwork. Additionally 3.3 ha have been measured with a SPIDAR GPR system.

In the GPR data, the temporary Roman field camp and the deserted village of Rothensee could clearly be observed. Additionally on the Schmalzberg a settlement with various archaeological structures (double ditch fortification system, pit alignments etc.) was found (Fig. 17). In the northern part of the surveyed area, northwest of the Mitterhof, a long round ditch with several possible entrances was documented. It is cut by a younger, N-S oriented ditch. Inside these two enclosures, numerous prehistoric house plots and pits could be observed. The magnetic data shows that an artificial elevation called "Runder Berg" in the West corner of the area has initially been encircled by a ditch as well. A possible grave chamber cannot be seen in the data, the most likely interpretation of this elevation would therefore be a motte-and-bailey castle.

Carnuntum, A

The interpretation of the GPR data was focused on the eastern part of the survey area (Burgfelder, Mühläcker). The area was already investigated by aerial photography and published by the partner organization ÖAW. So the new information of the area was limited but the infrastructure of the Roman city layout and the buildings became clearer. North of the prominent "grave street" a new settlement area was identified with buildings which are orientated along a massive defense ditch. To the east a new military camp was identified. It belongs to the latest phase of the area and seems to have a relation with the nearby campus and the palace of the city governor.

The interpretation of the radar data from the military town (*canabae legionis*) of Carnuntum is showing similar picture as known from remote sensing interpretations. Combining the aerial photo interpretation with the GPR data, we now have the possibility to re-evaluate the old excavations maps of the early 20th century. The settlement is structured by three main roads, one – generally known as amber road "Bernsteinstraße" – is coming from the south-west and separates a settlement district in its north from the rest of the *canabae*. The southern extend of this district is limited by a substantial ditch, which was interpreted as water cannel. To the west of this area the eastern walls and earthwork of the auxiliary castell is also visible in the GPR measurements. To the East, between this district and the legionary camp, lies an area with two huge rectangular structures identified as two slightly shifted phases of roman campus. A second road leading from the SE into the *canabae legionis* shows the typical Roman road layout, while as closer to the settlement graves start to emerge on both sides and then small houses guiding the way to the legionary camp. The settlement here has two distinguishable layouts, one is formed by rectangular roads, almost perpendicular to the main road, and the other consists of narrow winding roads with pointed angels. The third road is leaving the legionary camp in its east and forms the Roman limes road, leading along the shores of the Danube to Hungary.

A new area of the Roman town of Carnuntum is being virtualy reconstructed based mostly on GPR and aerial prospection results. The area, in the surrounds of the amphitheater II and the civil town, contains several buildings which have been interpreted as *tabernae* and storage buildings. Since the area was used as a graveyard and some of the graves were still visible in later times, also grave monuments are part of the virtual reconstruction. Some work has been done on the volumetric model and DTM that are suitable for a further refined version: textures, more detail geometry, animation, etc. The visualization has been developed together with 7Reasons.

The GPR data around the *mansio* (civil town) shows traces of a complete change in the town layout during the city wall building phase. Therefore it was necessary to define the temporal relations within this area and to separate the different building phases. Some of the walls are running perpendicular to the city wall and can be dated to the later building phases. Some other parts with a different orientation belong to an earlier phase of the civil town.

Selected lectures and publications:

Gugl, C., Neubauer, W., Doneus, M., Wallner, M., Löcker, K., Die Canabae von Carnuntum. Luftbildarchäologie – Oberflächensurveys – Geophysik. Internat. Konferenz „Legionslager und Canabae legionis in Pannonien", Budapest, Ungarn, 16.11.2015.

Gugl, C., Archäologische Prospektion in Carnuntum, Vortrag Universität Basel, 1.12.2015 / Vortrag Universität Bern, 3.12.2015.

Humer, F.; Neubauer, W.; Konecny, A.; Nau, E.; Fuchshuber, N. (2016): Die Grabungen 2014 im Bereich der Gladiatorenschule von Carnuntum. In: Carnuntum Jahrbuch 2014, 167–172.

Wallner, M.; Torrejón Valdelomar, J.; Neubauer, W.; Kucera, M.; Brandtner, J.; Sandici, V. (2015): Application of Georeferenced Archaeological Information Systems for Archaeological Digital Heritage - The Auxiliary Fortress of Carnuntum (Lower Austria). In: Second Digital Heritage International Congress. Volume 1: Digitization & Acquisition. Computer Graphics & Interaction. Granada, Spain, 28.09.-02.10.2015. 2 Vol., 159–162. DOI: 10.1109/DigitalHeritage.2015.7413859

Velm, A

On October 27th and 28th 2015 a geomagnetic field campaign was conducted to resurvey the "Kreisgrabenanlage" of Velm (Lower Austria) and its closer vicinity. In total an area of about 14.4 ha was investigated with a motorized Fluxgate magnetic system.

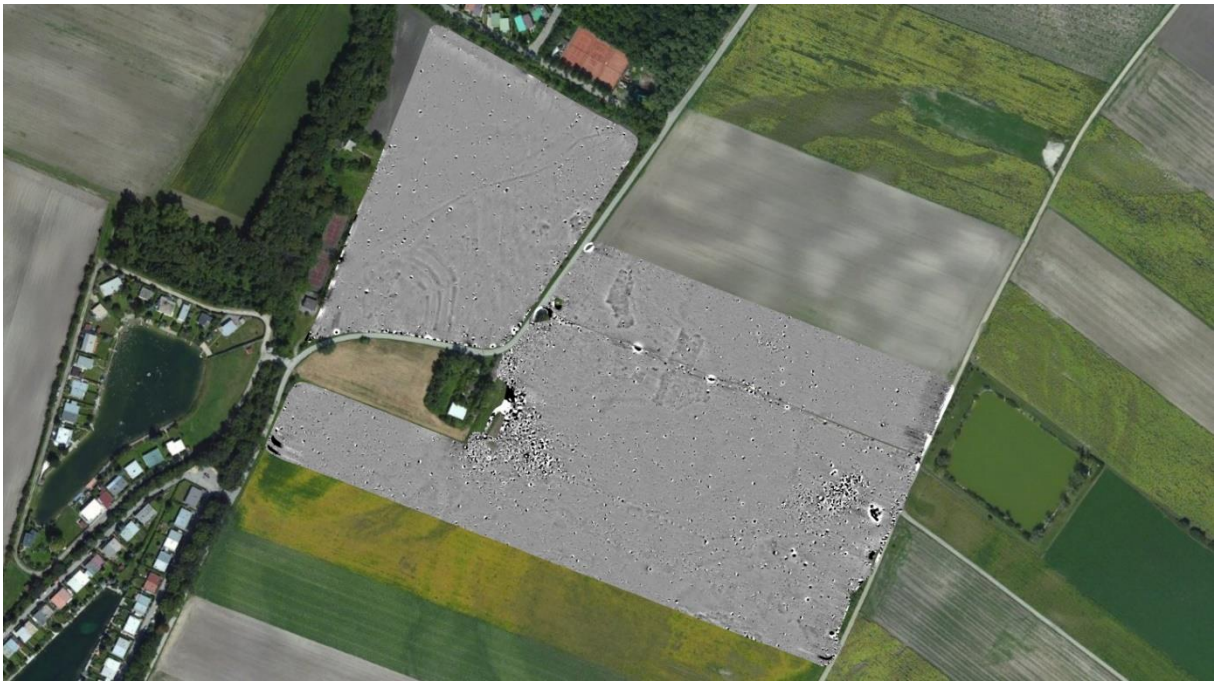

Fig. 18: Geophysical prospection in Velm.

The Neolithic circular enclosures of Velm were documented on the field 371/5 (Fig. 18). NE of the ditch system several rectangular structures were detected and represent probably the remains of prehistoric houses.

Birka, S

The interpretation focused on a building in the south-western part of the Black Earth area, which was subsequently used to create a 3D reconstruction model for use within visualizations for the WIKINGER! exhibition at Schallaburg. The house itself has been included in a movie produced for the exhibition. Not only the outside of the building is presented but also the GRP data and the different layers of the construction process.

For the central settlement area of Birka newly acquired drone photographs were processed and orthophotographs rectified (Fig. 19). Since the images were taken over the course of two days, the shadows and illumination had changed constantly. Several orthophotos were created and afterwards merged in PhotoShop in order to obtain the best overall fit.

Fig. 19: High-resolution orthophoto generated for Birka.

The final spatial resolution (2.4 cm) lies between the lowest (5 cm) and highest (1.4 cm) resolutions possible. Normally, proper ground control for any photogrammetric processes is in the order of 1/2 to 1/3 of the spatial resolution. In the case of the photos from Birka, ground control points (GCPs) were extracted from Bing Maps. This means that there are still some absolute and relative errors contained in the orthophotos, which only can be removed with better GCPs. The biggest problem is related to the most interesting zone (i.e. the stones related to the hall buildings just above the town wall), because flights were executed at several altitudes and with different lenses. As such, the difference between the photos made during the lower flights and those from the higher flights is sometimes over one metre.

Vestfold, N

An interpretation workshop took place in Vienna from January 7th to February 13th 2015. Next to LBI ArchPro staff also colleagues from Norway were represented (Christer Tonning, Lars Gustavsen, Monica Kristiansen and Vibeke Lia). The interpretation was focused on a GPR survey with a high density of small pits (probably fire-places) along a ridge with a few gravemounds.

For the Viking Exhibition in Schallaburg a Viking house, based on the results from the Viking settlement of Borre, was reconstructed.

Between September 21st and October 7tha team of the LBI ArchPro, supported by the Vesfold fylkeskommune and NIKU, carried out a fieldwork campaign in the framework of the CS Vestfold. The main focus lied on the GPR survey area in Slagendalen / Oseberg. For this purpose, the SPIDAR 1 and

the MIRA 1 GPR systems were in use. Additionally NIKUs MIRA 3 system was applied during four days of fieldwork. Additionally, a magnetometer system (EAL 1) was brought to Norway and used to survey selected areas. A total area of 42 ha was surveyed using GPR and about 3.5 ha using magnetometry.

The GPR survey areas around the modern settlement of Basberg revealed a vast number of new archaeological remains. Almost the entire surveyed area shows archaeological features of different types. Based on the GPR data from 2013, some features were excavated in 2014 and consequently interpreted as Iron Age burials and settlement structures. These results together with the newly acquired GPR data speak for the area of Basberg as an important Iron Age settlement and burial site. Among other structures, a number of new burial mounds, cairns and cooking pits were detected. In the northern part of Slagendalen, just south of the burial mound of Rom Vestre, GPR surveys led to the discovery of a new settlement area. The remains of at least two longhouses (including walls, postholes and fireplaces) and several smaller buildings were detected. The finds are preliminarily interpreted as a complete Iron Age farmstead.

During the field work an area at Rom Østre previously surveyed by SPIDAR in 2014 was excavated by archaeologists from Vestfold fylkeskommune. This data were used to evaluate previous GPR survey results. A total correspondence between the GPR interpretation and excavation results was achieved.

Stonehenge, UK

Between August 30st and September 6th 2015 an additional geophysical archaeological prospection fieldwork campaign for the LBI ArchPro case study Stonehenge, the so-called Stonehenge Hidden Landscapes Project, was conducted under the direction of the British partner organization VISTA, Institute of Archaeology and Antiquity at the University of Birmingham and the LBI ArchPro. The purpose of the field work campaign was to survey missing areas surrounding Durrington Walls with GPR (SPIDAR) in order to find possible stones of the row of stones found under the bank of Durrington Walls in 2013. We measured bits in the south of Durrington Walls, just east to the car park of Woodhenge, the field north of the henge and the missing pieces in the Cuckoo Stone Field as well as surrounding Woodhenge.

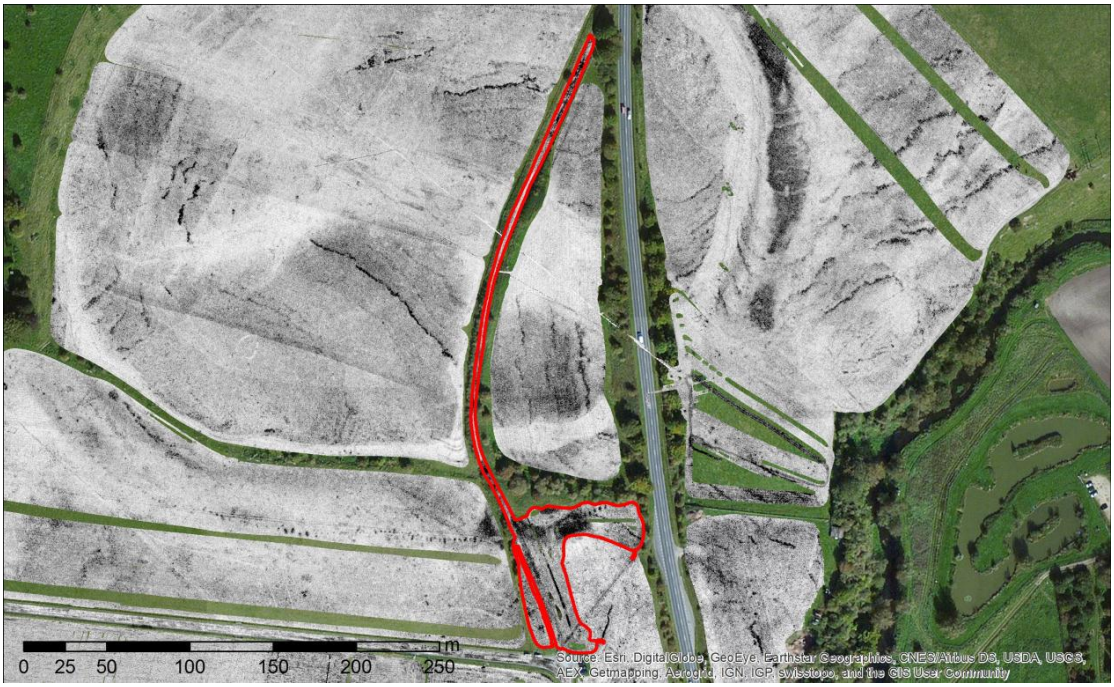

Fig. 20: Coverage of September 2nd 2015.

Fig. 21: Coverage of September 3rd 2015.

The central area of Durrington Walls was measured with the Spidar system and shows a very densely populated interior. There are several field boundaries (possible form medieval times) and more modern disturbances by deep plowing visible. Beside these more modern linear structures also prehistoric ring ditches and enclosures are recognizable. The most important structures within the interior of the “super henge” are several hundred rectangular pits of some 1.3 m x 1.5 m. These features have a very similar appearance to the Neolithic houses found by the “Riverside project”

under the bank of Durrington Walls and might be the last remains of the central areas of a huge Neolithic settlement.

Schwäbische Alb, D

In February 2015 a short interpretation workshop was organized for the CS Schwäbische Alb. The interpretation focused on the area called “Dietlinsweiler”, where several settlement areas and a possible grave field could be identified. During the workshop the new features of ArchaeoAnalyst – such as the "Iron Locator" were also tested.

Osor and Vižula, HR

From October 21st to 26th 2015 a second geophysical prospection season was conducted in Croatia. The fieldwork campaign focused on large-scale Georadar prospection (Mira I System) in Mediterranean landscape.

The ancient city of Osor was founded in the Iron Age, and has developed during the Roman and Byzantine period to one of the most important centers in eastern Adriatic. Located at the isthmus between northern the Adriatic islands Cres and Lošinj, Osor is often mentioned as very important for the sea travel. The man-made channel between the two islands is dated to Roman or even pre-Roman time and its position is seen as a major advantage for control the sea route between the islands. In 2015 an area of approximately 2 ha was surveyed (Fig. 22). The first analysis of the data shows a well preserved plan of a Roman town with *insulae* and city streets.

Fig. 22: Geophysical prospection in Osor (2014-15).

The *villa maritima* of Vižula is located in the Medulin Bay, at the southern end of peninsula of Istria. The importance of this geographical region in the Roman times is underlined by the extraordinary rich Roman architecture. Istria, a key link between the provinces of Dalmatia, Noricum and Italic Julian regions, was in Roman period of imperial organization particularly important. This period is characterized by the establishment of a new spatial arrangement model (development of cities), the development of transport communications and administrative-territorial organization. Traffic networks on land and sea have enabled increased production and large-scale settlement activities, which has resulted e.g. in complex *villae maritimae* from 1. and 2. century, closely associated with the emperor, the inner circle of relatives and friends. Vižula, with nearly 24 ha, is the largest of its kind in Istria. In cooperation with the Croatian Conservation Institute, Department for underwater archeology, in 2015 some 2 ha have been surveyed, resulting in plans of yet unknown buildings and complexes from the Roman period.

Caričin Grad, SRB

Between March 17th and March 26th 2015 a team of the LBI ArchPro supported by the RGZM Mainz and the Archaeological Institute Belgrade carried out geophysical fieldwork in Caričin Grad (Justiniana Prima) in Serbia. The main objective of the campaign was to conduct GPR prospections in the area of Caričin Grad. A total coverage of 7.6 ha with the SPIDAR system could be obtained within six days of fieldwork. Another important task was the survey of several smaller and more difficult accessible fields in order to obtain a better picture of the whole archaeological site, where additionally 0.66 ha have been measured with a single channel GPR system (Fig. 23).

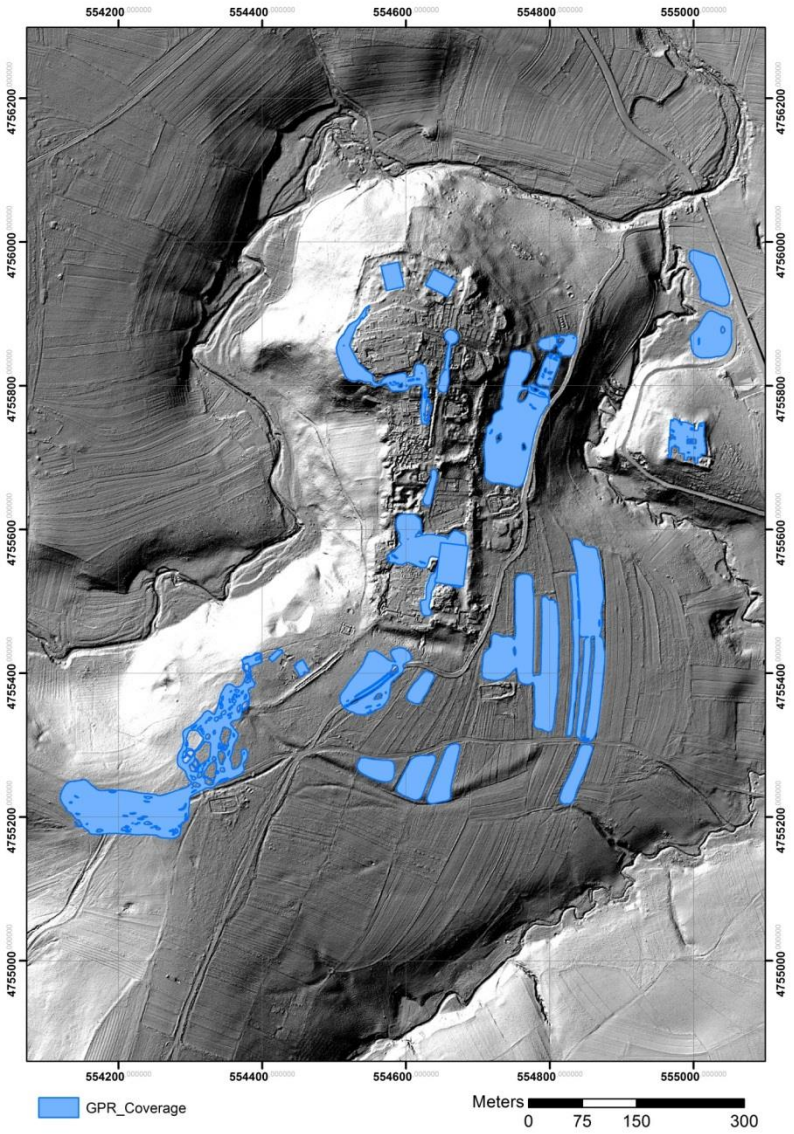

Fig. 23: GPR coverage in Caričin Grad.

Ephesos, TR

All data collected by the LBI ArchPro partner organization ZAMG have been reprocessed. Set up of the Geo Database is in progress.

Selected lectures and publications:

Seren, S.; Totschnig, R.; Hinterleitner, A.; Löcker, K.; Ladstätter, S. (2015): Archaeological prospection results in the surroundings of the Serapeion at Ephesos, Turkey. In: A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 502-505.

Bisenzio: Multi-Disciplinary Research on a major Etruscan center from the Late Bronze Age to the Archaic Period

In cooperation with the RGZM Mainz and Johannes Gutenberg-Universität Mainz a project with a title "Multi-disciplinary research on a major Etruscan center from the Late Bronze Age to the Archaic Period" has been granted by the DFG (2015-2017). As part of this research project conducted by Dr. Andrea Babbi and Prof. Markus Egg from the Römisch Germanische Zentralmuseum in Mainz in collaboration with Prof. Christopher Pare from the Johannes Gutenberg-Universität Mainz a team of the LBI ArchPro conducted a non-invasive geophysical archaeological prospection survey at Bisenzio in Lazio region, Italy, from July 5th to 26th 2015. The target of this fieldwork campaign, which had been planned as the first of three three-week campaigns to be conducted between 2015 and 2017, was the prospection of Etruscan settlement traces and burials in the area surrounding Monte Bisenzio at the southern shore of Lago di Bolsena. Earlier archaeological research in form of field walking and excavations had indicated settlement remains and revealed rich Etruscan burials. Using two motorized ground-penetrating radar systems, a 16 channel 400 MHz MALÅ Imaging Radar Array with 8 cm crossline spacing and a six channel 500 MHz Sensors & Software SPIDAR array with 25 cm crossline spacing, a total area of 42 hectares was covered within three weeks (Fig. 24, Fig. 25). Due to deep ploughing the state of preservation of the archaeological remains in general was poor. Some graves and few buildings have been detected.

Fig. 24: GPR survey at Bisenzio with the 16-channel MIRA system (left) and the 6-channel SPIDAR system (right).

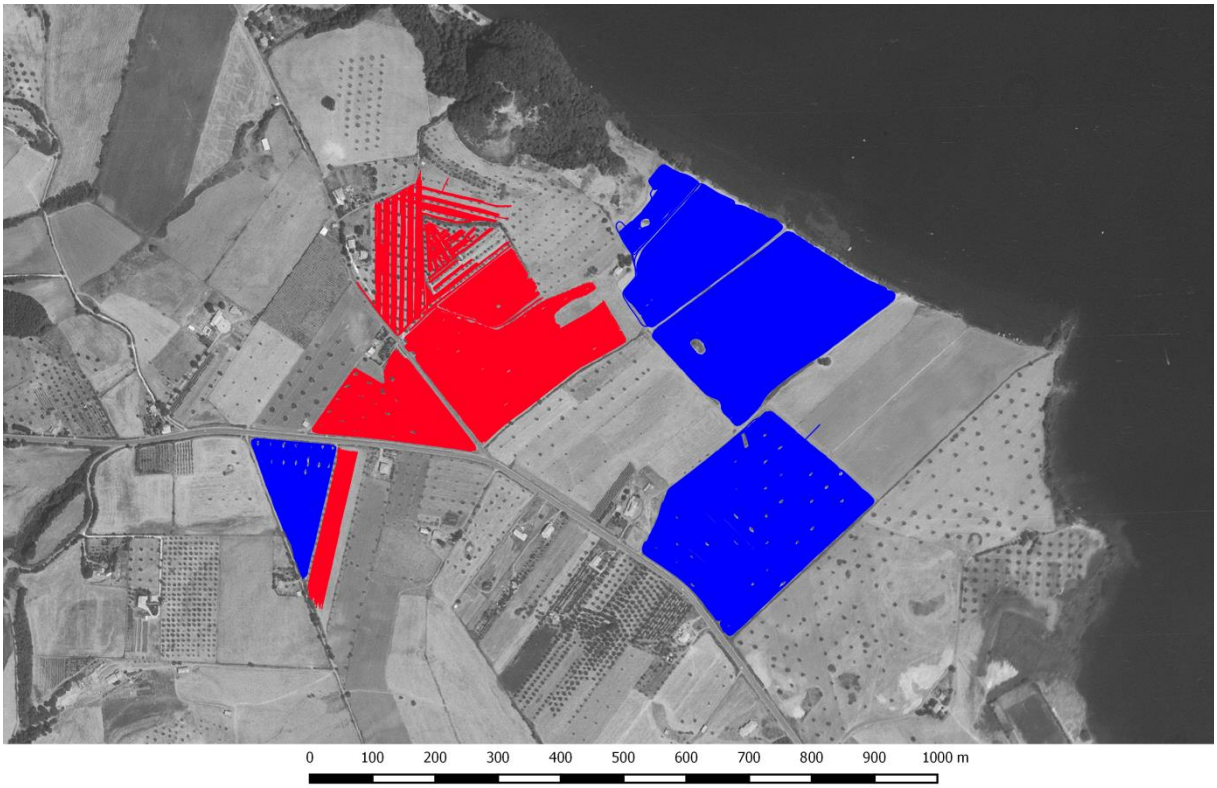

Fig. 25: Coverage with MIRA (red) and SPIDAR measurements (blue) in 2015.

A puzzle in 4D: Digital Preservation and Reconstruction of an Egyptian Palace (TED Project)

A project together with Austrian Academy of Sciences/OREA proposal has been started in spring 2015. Next to the LBI ArchPro several International cooperation partners are involved: Austrian Center for Digital Humanities, Universität Bochum, Chicago University, ÖAI, Archaeology Data Service and PIN Scri - Polo Universitario "Città di Prato".

The project will provide long-term preservation for the rich archaeological resources of the Austrian long-term excavation project at Tell el Daba in Egypt. Digital and non-digital excavation data will be integrated according to stratigraphic, i.e. archaeological spatio-temporal principles, enriched with metadata and prepared for long-term archiving and open-access online publication. A visualization of the resulting integrated site model will allow researchers as well as the interested public to experience the ancient site and its colourful and world-famous Minoan wall paintings. The LBI ArchPro is involved in the development of a 4D Archaeological Information System (AIS). Archaeological research is dealing with the documentation and analysis of archaeological entities in space and time. During this process information is linked with a specific location and a time stamp. Whereas Geographical Information Systems (GIS) organize and segment geographical space and associated information, the term Archaeological Information System (AIS), which is commonly already in use, aims to reflect the close engagement with a GIS. An AIS has to be based upon GIS, which results in the assignment of archaeological entities and the information associated with them to a specific location. To end up with a stratigraphic sequence of these entities, AIS has to be accompanied by the fourth dimension – time. For this purpose the GIS-based AIS is supplemented with a time-steering tool – namely Harris Matrix Composer+ - to ensure spatio-temporal analysis. Most archaeological data are based upon already excavated sites. It is crucial for the comparability of

archaeological datasets to also embed these existing data into recent concepts of analysis. For this purpose the long-term excavation at Tell el Daba was chosen as a case study to evolve existing datasets within recent analysis tools using a georeferenced 4D-AIS. A basic research question is to examine the possibility of reconstructing undocumented and missing information. This approach of reverse excavating provides the chance to compare datasets of different provenience.

Selected lectures and publications:

Aspöck, E.; Kopetzky, K.; Horejs, B.; Bietak, M.; Kucera, M.; Neubauer, W. (2015): A puzzle in 4D - Digital preservation and reconstruction of an Egyptian palace. In: 2015 Digital Heritage International Congress. Vol. 2: Analysis & Interpretation. Theory, Preservation & Standards. Digital Heritage Projects & Applications. Granada, Spain, 28.09.-02.10.2015, 675–678. DOI: 10.1109/DigitalHeritage.2015.7419596

LBI ArchPro Carnuntum

Final report was submitted to the county administration of Lower Austria in September 2015.

Selected lectures and publications:

Wallner, M.; Löcker, K.; Neubauer, W.; Doneus, M.; Jansa, V.; Verhoeven, G.; Trinks, I.; Seren, S.; Gugl, C.; Humer, F. (2015): ArchPro Carnuntum Project: Large-scale non-invasive archaeological prospection of the Roman town of Carnuntum. A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 400–403.

Hallstatt

In the last months the goals were to 3d reconstruct the staircase of Hallstatt and provide rendered images for further use. The artistic guidelines stated a simple depiction with an explaining animation. For the 3D reconstruction the SFM model of the staircase and high resolution scans of every single piece have been used. Afterwards an animation and a render setup was prepared and executed for a final image-sequence output.

Denmark

Over the past 30 years Aerial Archaeology has become an established tool in Danish archaeology. Especially in the region of West Jutland, repeated flights have resulted in the discovery of hundreds of new archaeological sites. Based on this successful approach, additional new research avenues are emerging, focusing on the complementary use of near-surface geophysical prospection and remote sensing techniques. The benefits of this integrative approach in this part of Denmark are attributable to very favourable environmental conditions, since Jutland is almost entirely covered by glacial sands, deposited along the melting glacier during the end of the last ice age. The very uniform sandy soils and the flat agricultural landscape offer ideal conditions for aerial archaeology, as well as large-scale motorized geophysical prospection. Crop- and soil-marks find perfect conditions to develop and depict the buried archaeology due to high contrasts between the archaeological structures and the homogenous soil matrix. Even though aerial archaeology works very well under the present conditions, new research avenues emerged as a result of recent technological and methodological developments regarding large-scale, high-resolution geophysical prospection methods and their

potential arising from the complementary use of both remote sensing and ground-based geophysical techniques.
Therefore, in summer 2014 the LBI ArchPro joined an ongoing aerial archaeological research project (*Fortiden set fra himlen*) conducted by Holstebro Museum with the added goal to investigate the complementary use of GPR and magnetometer prospection in a first pilot study.
To be benefit from these experience five sites dated from the Iron Age to the Medieval Period (Stadil, Skarum Mølle, Vesterager, Rysensten, Norreby, all within 50 km radius from Ringkøbing, were chosen for a first test run in West Jutland. Due to extensive aerial archaeological prospection surveys conducted by experienced archaeologists from Holstebro Museum solid archaeological reference data and considerable experience already existed for all of the chosen sites.
Fieldwork in West Jutland was carried out within two campaigns in 2014 and during 2015 data was processed and interpreted; the first results were presented at the Archaeological Prospection Conference 2015 in Warsaw.

Selected lectures and publications:

Nau, E.; Helles Olesen, L. Helles; Schneidhofer, P.; Gabler, M.; Filzwieser, R.; Schlosser Mauritsen, E (2015): Large-scale high-resolution GPR and magnometry prospection in West Jutland, Denmark. A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 485–488.

Iceland: Harbours in the North Atlantic (AD 800-1300)

The LBI ArchPro team has carried out GPR measurements in Iceland from May 18th to June 5th 2015. The surveys were part of the research project 'Harbours in the North Atlantic (AD 800–1300)', which is conducted by the Centre for Baltic and Scandinavian Archaeology in Schleswig (Germany). The project is funded by the German Science Fund DFG and forms part of its special research programme 1630 on harbours from the Roman Period to the Middle Ages. Apart from the LBI ArchPro staff, the project team consisted of Joris Coolen (ZBSA Schleswig), Ronny Weßling (Crazy Eye Perspective, Vienna), Mark Gardiner (Queen's University Belfast) and Marianne Nitter (Arkeologisk Museum Stavanger).
Five sites with tentative remains of medieval harbour sites or associated (temporary) settlements were studied. Due to the mostly rough terrain and logistical constraints, the surveys were carried out with a manual system, the Pulse Ekko Pro, using 500 and 250 mHz antennas. In Mariuhöfn in Hvalfjörður, western Iceland, the GPR survey revealed stone structures of a tentative late medieval trading site. In Þingeyrar in northern Iceland, the remains of a large boathouse, possibly dating to the settlement period, as well as a medieval church and a circular enclosure known as 'dómhringur' (judges' ring) – possibly an older church site – were surveyed. Excavation by Icelandic archaeologists during the summer of 2015 has shown that the church revealed by the GPR measurements was probably part of Iceland oldest monastery. Furthermore, GPR surveys were carried out at the medieval trading/harbour sites of Gautavík (eastern Iceland) and Gásir (northern Iceland) as well as at a Hanseatic trading site in Kumbaravógur (Snaefellsnes peninsula, western Iceland).

Fig. 26: View of Mariuhofn, Iceland.

3 Training and teaching

3.1 LBI ArchPro software workshop: ArchaeoAnalyst

Two internal workshops on the ArchaeoAnalyst have been organized in recent months. In spring 2015, the specification was discussed, in fall the training workshop was held on the premises of the partner organization Uni Vienna (Fig. 27).

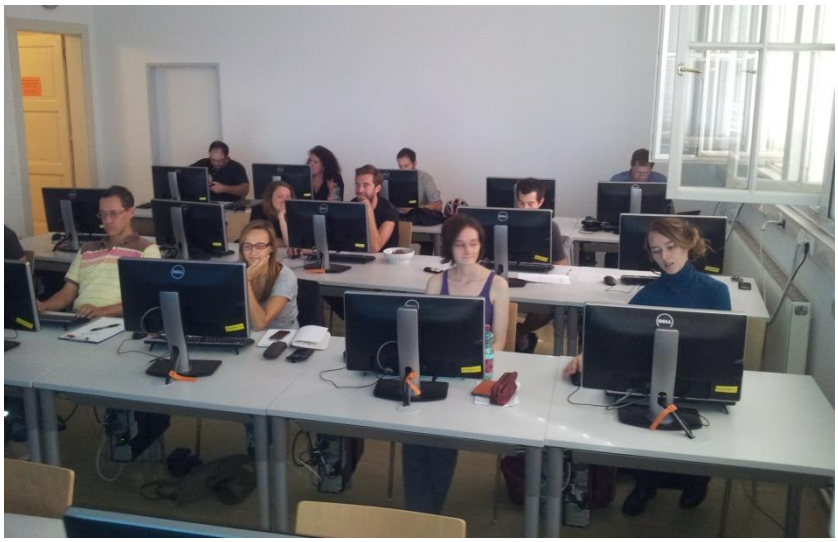

Fig. 27: LBI ArchPro workshop in September 2015.

3.2 FFG Internships

FFG Talents Award

The report on a geophysical prospection survey with the LBI ArchPro in summer 2014 has been elected among the top 20 internship reports in the FFG Young Talents program. In April 2015 the Austrian Ministry for Innovation and Technology presented the award to the team.

Fig. 28: FFG Young Talents program

FEMtech Internships for Female Students – Entry into a Research Career

FEMtech Internships for Female Students supports and mentors female students to take up scientific and engineering positions in industry in order to meet the future demand for researchers and R&D experts. It aims to encourage young female undergraduates in the area of science and technology to take up a career in research as well as to encourage companies to integrate women in R&D projects and activities. The internship lasts one to six months and is supported by the Austrian ministry of Transport, Innovation and Technology.

Milena Nowak and Rebecca Nowak spent a six-month FEMtech internship at the LBI ArchPro. The two Visual Computing students (TU Vienna) have mainly been contributing their programming skills to the development of TAIFU (Toolbox for Archaeological Image Fusion) under the supervision of Geert Verhoeven. While it is Milena and Rebecca's first job in a scientific research setting, the experience has extended beyond mere software programming, the two students say: "Watching the group dynamics within the team, learning about all the exciting fieldwork that produces the data we are handling, focusing on one specific long-term project and seeing it unfold and – last but not least - facing the discipline of getting up and to work every day, are some of the lasting impressions we have gathered during those six months."

3.3 Teaching activities

As part of the project ArcLand a summer school was organized in June 2015 in Poznan, Poland. Geert Verhoeven gave six lectures on aerial photographs and 3D landscape modelling. The project ArchaeoLandscape Europe (ArcLand) is funded by the European Union within the framework of the Culture 2007-2013 framework (CU7-MULT7, Strand 1.1 Multi-Annual Cooperation Projects).

For the summer school "Scuola di Dottorato in Storia, critica e conservazione dei beni culturali", Padova, Italy, Geert Verhoeven gave in October 2015 lectures on theory of SfM + MVS, SfM + MVS cultural heritage examples, hands-on with Agisoft PhotoScan Pro etc.

Lectures at the University Vienna

Wolfgang Neubauer	Summer 2015	060105 UE Stratigraphische Praxis

	Summer 2015	060073 PV Privatissimum
	Summer 2015	060088 SE Die Landschaft um Stonehenge
	Summer 2015	060097 SE Archäologische Prospektion
	Sommer 2015	060071 PR Lehrgrabung Hornsburg
	Winter 2015	060087 PV Privatissimum
	Winter 2015	060105 PR Practice of Archaeological Stratigraphy
Michael Doneus	Summer 2015	060063 UE Vermessungskunde für Archäologen (with W. Neubauer)
	Summer 2015	060064 UE GIS-Anwendungen in der Archäologie
	Summer 2015	060099 PV Privatissimum
	Summer 2015	060064 PR Lehrgrabung I Hornsburg
	Winter 2015	060072 UE GIS-Anwendungen in der Archäologie
	Winter 2015	060034 VO Grundlagen - Luftbildarchäologie
	Winter 2015	060080 PV Provatissimum
	Winter 2015	060074 UE Luftbildarchäologische Interpretation
	Winter 2015	060077 SE Seminar Urgeschichte: Klima, Umwelt und Kommunikation in der Urgeschichte der Südägäis
	Winter 2015	060071 PR Flugzeuggetragenes Laserscanning (LiDAR) für ArchäologInnen
Immo Trinks	Winter 2015	060035 VO Einführung Theorie Geophysikalische Prospektion
Matthias Kucera	Summer 2015	060076 PR Experimentelle Archäologie in der Praxis
	Winter 2015	060083 VO Grundlagen der Experimentellen Archäologie

Supervison

- Łukasz Banaszek, PhD student at the Institute of Prehistory, Adam Mickiewicz University in Poznan, who will be part of the LBI ArchPro team until September 2016 (scholarship from Polish Ministery of Science and Higher Education)

4. Dissemination

4.1 Internal LBI ArchPro dissemination

Internal dissemination activities have been concentrating on following topics:

- LBI ArchPro personal reports
- Maintenance of LBI ArchPro bibliographical database
- Cataloguing and labeling of the LBI ArchPro library (books, periodicals, papers, CDs, etc.)
- Archiving of data on LBI ArchPro server
- Tracking of media coverage and archiving of media reports (online, print)
- Provision of information and PR material to media
- LBI ArchPro homepages

4.2 Scientific dissemination

2.1 Articles in journals

2.1.1 A1 (articles published in journals listed in the ISI Web of Knowledge restricted to article, review, letter, note, proceedings paper)

Draganits, E.; Doneus, M.; Gansum, T.; Gustavsen, L.; Nau, E.; Tonning, C.; Trinks, I.; Neubauer, W. (2015): The late Nordic Iron Age and Viking Age royal burial site of Borre in Norway: ALS- and GPR-based landscape reconstruction and harbour location at an uplifting coastal area. In: Quaternary International (367), 96–110. DOI: 10.1016/j.quaint.2014.04.045.

2.1.3 A3 (articles with peer review published in national journals (i.e. Austrian, Belgian) not included in A1 or A2)

Gugl, C.; Neubauer, W.; Nau, E.; Jernej, R. (2015): New evidence for a Roman military camp at Virunum (Noricum): the garrison of the governor's guard (singulares)? In: Caiete ARA (6), 79–90.

2.1.4 A4 (articles published in journals without peer-review)

Doneus, M.; Doneus, N.; Briese, C.; Verhoeven, G. (2015): Airborne laser scanning and Mediterranean environments - Croatian case studies. In: Izdanja Hrvatskog Arheološkog Društva (30), 147–163.

Verhoeven, G.; Doneus, N.; Doneus, M.; Štuhec, S. (2015): From pixel to mesh - accurate and straightforward 3D documentation of cultural heritage from the Cres/Lošinj archipelago. In: Izdanja Hrvatskog Arheološkog Društva (30), 165–176.

2.2 Books & book chapters

2.2.1 B1 (author or co-author of books (limited to books published by a scientific publishing company, no syllabi, no thesis)

Gugl, C.; Radbauer, S.; Kronberger, M. (2015): Die Canabae von Carnuntum II. Archäolgisches und GIS-analytische Auswertung der Oberflächensurveys 2009-2010. Wien: Verl. der Österr. Akad. der Wiss. (Der römische Limes in Österreich, 48).

2.2.2 B2 (author or co-author of chapters in books - no proceedings of conferences)

Doneus, M. (2015): Das Luftbild als Grundlage für Siedlungs- und Landschaftsarchäologie. In: M. Doneus und M. Griebl (Hg.): Die Leitha - Facetten einer archäologischen Landschaft. Wien: Verlag Österreichische Gesellschaft für Ur- und Frühgeschichte (Archäologie Österreichs Spezial, 3), 25–38.

Doneus M.; Janner M.; Fera M. (2015): Flugzeuggetragenes Laserscanning im Leithagebirge. In: M. Doneus und M. Griebl (Hg.): Die Leitha - Facetten einer archäologischen Landschaft. Wien: Verlag Österreichische Gesellschaft für Ur- und Frühgeschichte (Archäologie Österreichs Spezial, 3), 51–62.

Neubauer, W. (2015): Neu entdeckt – Die mittelneolithische Kreisgrabenanlage von Au am Leithaberge. In: M. Doneus und M. Griebl (Hg.): Die Leitha - Facetten einer archäologischen Landschaft. Wien: Verlag Österreichische Gesellschaft für Ur- und Frühgeschichte (Archäologie Österreichs Spezial, 3), 39–50.

Pásztor, E.; Barna, J. P.; Zotti, G. (2015): Chapter 113: Neolithic Circular Ditch Systems ("Rondels") in Central Europe. In: Ruggles, C. L. N (Hg.): Handbook of archaeoastronomy and ethnoastronomy: Springer Verlag, 1317–1348.

Zámolyi A.; Draganits E.; Doneus M.; Fera M. (2015): Paläoflusslaufentwicklung der Leitha (Ostösterreich) – eine Luftbildperspektive. In: M. Doneus und M. Griebl (Hg.): Die Leitha - Facetten einer archäologischen Landschaft. Wien: Verlag Österreichische Gesellschaft für Ur- und Frühgeschichte (Archäologie Österreichs Spezial, 3), 11–23.

Zotti, G. (2015): Chapter 29: Visualization Tools and Techniques. In: Ruggles, C. L. N (Hg.): Handbook of archaeoastronomy and ethnoastronomy: Springer Verlag, 445–458.

2.2.3 B3 (editor of books, including editor of proceedings)

Doneus, M.; Griebl, M. (Hg.) (2015): Die Leitha - Facetten einer archäologischen Landschaft. Wien: Verlag Österreichische Gesellschaft für Ur- und Frühgeschichte (Archäologie Österreichs Spezial, 3).

Holzer, G.; Newby, V.; Svatek, P.; Zotti, G. (Eds.) (2015): A World of Innovation. Cartography in the Time of Gerhard Mercator. Newcastle upon Tyne: Cambridge Scholars Pub.

2.3 Conference proceedings

2.3.2 C2 (full articles - no abstracts - in proceedings of scientific conferences, not included in A1, A2, A3, A4 or P1)

Doneus, M.; Miholjek, I.; Mandlburger, G.; Doneus, N.; Verhoeven, G.; Briese, C.; Pregesbauer, M. (2015): Airborne Laser Bathymetry for documentation of submerged archaeological sites in shallow water. In: Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci. XL-5/W5, 99–107. DOI: 10.5194/isprsarchives-XL-5-W5-99-2015. DOI: 10.5194/isprsarchives-XL-5-W5-99-2015

Gugl, C.; Neubauer, W.; Nau, E.; Jernej, R. (2015): New evidence for a Roman military camp at Virunum (Noricum). In: A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 289–292.

Hinterleitner, A.; Löcker, K.; Neubauer, W.; Trinks, I.; Sandici, V.; Wallner, M.; Pregesbauer, M.; Kastowsky-Priglinger, K. (2015): Automatic detection, outlining and classification of magnetic anomalies in large-scale archaeological magnetic prospection data. In: A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 296–299.

Lindberg, E.; Briese, C.; Doneus, M.; Hollaus, M.; Schroiff, A.; Pfeifer, N. (2015): Multi-wavelength Airborne Laser Scanning for Characterization of Tree Species. In: S. Durrieu und C. Véga (Hg.): Proceedings of SilviLaser 2015, 271–273.

Löcker, K.; Kucera, M.; Trinks, I.; Neubauer, W. (2015): Successfully falsified… On epimestological problems of archaeological excavations and geophysical surveys. . In: A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 222–224.

Nau, E.; Helles Olesen, L. Helles; Schneidhofer, P.; Gabler, M.; Filzwieser, R.; Schlosser Mauritsen, E (2015): Large-scale high-resolution GPR and magnometry prospection in West Jutland, Denmark. A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 485–488.

Poscetti, V.; Zotti, G.; Neubauer, W. (2015): Improving the GIS-based 3D mapping of archeological features in GPR data. In: A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 603–607.

Schneidhofer, P.; Nau, E.; Hinterleitner, A.; Lugmayer-Klimczyk, A.; Bill, J.; Gansum, T.; Neubauer, W.; Paasche, K.; Seren, S.; Draganits, E.; Trinks, I. (2015): Geoarchaeology as essential supplement for large scale, high resolution archaeological geophysical prospection: the case study Gokstad in Norway. In: A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 499-502.

Seren, S.; Totschnig, R.; Hinterleitner, A.; Löcker, K.; Ladstätter, S. (2015): Archaeological prospection results in the surroundings of the Serapeion at Ephesos, Turkey. In: A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 502-505.

Trinks, I.; Neubauer, W.; Doneus, M.; Hinterleitner, A.; Doneus, N.; Verhoeven, G.; Löcker, K.; Kucera, M.; Nau, E.; Wallner, M.; Seren, S. (2015): Interdisciplinary archaeological prospection at unprecented scale and resolution. The first five years of the LBI ArchPro Research Initiative 2010-2015. A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 144–147.

Trinks, I.; Tsokas, G.; Verhoeven, G.; Löcker, K.; Kucera, M.; Nau, E.; Wallner, M.; Tsourlos, P. (2015): Mapping the Bronze Age settlement of Akrotiri on Santorini: digital documentation and archaeological prospection. In: A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 518–521.

Zotti, G.; Neubauer, W. (2015): Astronomical and Topographical Orientation of Kreisgrabenanlagen in Lower Austria. In: F. Pimenta, N. Ribeiro, F. Silva, N. Champion, A. Joaquinto und L. Tirapicos (Hg.): SEAC2011 Stars and Stones: Voyages in Archaeoastronomy and Cultural Astronomy. Proceedings of the SEAC 2011 conference. Evora, Portugal, 19.-22.09.2011: Archaeopress (BAR International Series, 2720), 188–193.

Verhoeven, G.; Karel, W.; Štuhec, S.; Doneus, M.; Trinks, I.; Pfeifer, N. (2015): Mind your grey tones – examining the influence of decolourization methods on interest point extraction and matching for architectural image-based modelling. In: D. Gonzalez-Aguilera, F. Remondino, J. Boehm, T. Kersten und T. Fuse (Hg.): Virtual Reconstruction and Visualization of Complex Architectures. 6th International Workshop "3D-ARCH 2015. 25–27 February 2015, Avila, Spain (ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., Vol. XL-5). Online verfügbar unter http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-5-W4/307/2015/isprsarchives-XL-5-W4-307-2015.pdf.

Wallner, M.; Löcker, K.; Neubauer, W.; Doneus, M.; Jansa, V.; Verhoeven, G.; Trinks, I.; Seren, S.; Gugl, C.; Humer, F. (2015): ArchPro Carnuntum Project: Large-scale non-invasive archaeological prospection of the Roman town of Carnuntum. A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 400–403.

Wess, M.; Atzberger, C.; Doneus, M.; Verhoeven, G. (2015): ARCTIS – analysing hyperspectral datasets. A. Rzeszotarska-Nowakiewicz (Hg.): Archaeological prospection. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 15.-19.09.2015: The Institute of Archaeology and Ethnology, Polish Academy of Sciences (Archaeologia Polona, 53), 403–407.

2.3.3 C3 (Abstracts of conference papers, lectures)

Aspöck, E.; Kopetzky, K.; Horejs, B.; Bietak, M.; Kucera, M.; Neubauer, W. (2015): A puzzle in 4D - Digital preservation and reconstruction of an Egyptian palace. In: 2015 Digital Heritage International Congress. Vol. 2: Analysis & Interpretation. Theory, Preservation & Standards. Digital Heritage Projects & Applications. Granada, Spain, 28.09.-02.10.2015, 675–678. DOI: 10.1109/DigitalHeritage.2015.7419596

Wallner, M.; Torrejón Valdelomar, J.; Neubauer, W.; Kucera, M.; Brandtner, J.; Sandici, V. (2015): Application of Georeferenced Archaeological Information Systems for Archaeological Digital Heritage - The Auxiliary Fortress of Carnuntum (Lower Austria). In: Second Digital Heritage International Congress. Volume 1: Digitization & Acquisition. Computer Graphics & Interaction. Granada, Spain, 28.09.-02.10.2015. 2 Vol., 159–162. DOI: 10.1109/DigitalHeritage.2015.7413859

Torrejón Valdelomar, J.; Brandtner, J.; Kucera, M.; Wallner, M.; Sandici, V.; Neubauer, W. (2015): 4D investigation of Digital Heritage an interactive application for the auxiliary fortress of Carnuntum. In: Second Digital Heritage International Congress. Vol. 2: Analysis & Interpretation. Theory, Preservation & Standards. Digital Heritage Projects & Applications. Granada, Spain, 28.09.-02.10.2015, 81–84. DOI: 10.1109/DigitalHeritage.2015.7419457

2.4 Miscellaneous

Talk invited

Doneus, M. (2015.): Flugzeuggetragenes Laserscanning (LiDAR) in der Archäologie: Möglichkeiten, Einschränkungen und neueste Forschungen. Bergbaumuseum Bochum. Bochum, Deutschland, 13.01.2015.

Doneus, M. (2015): Prospektion – Geoinformation. Anwendungen in der Archäologie. Österr. Gesellschaft für Vermessung und Geoinformation. Wien, Österreich, 21.01.2015.

Doneus, M. (2015): Exploring past European landscapes: current techniques - future developments. Keynote. 'SENSING THE PAST - New approaches to European landscapes' – final conference of the ArchaeoLandscapes Europe project (ArcLand). Roman-Germanic Commission of the German Archaeological Institute. Frankfrut, Germany, 25.02.2015.

Doneus, M. (2015): ALS-Bathymetry in Archaeology. Workshop on Laser Scanning Applications, University of Cologne, in cooperation with the annual conference of the German Society for Photogrammetry, Remote Sensing and Geoinformation. Köln, Deutschland, 16.03.2015.

Doneus, M. (2015): Non-invasive techniques for prospecting archaeological landscapes: current techniques & future developments. Master Course and Continuing Professional Education Course: „Integrated Utilization of Advanced Technology in Archaeology and Heritage Preservation Today. The Archaeolingua Foundation and the Central European University. Budapest, Hungary, 23.11.2015.

Gugl, C. (2015): Prospektion archäologischer Landschaften. Research Framework DLAB (Danube Limes in Austria and Bavaria). Passau, Deutschland, 15.10.2015.

Gugl, C. (2015): Archäologische Prospektion in Carnuntum. Universität Basel. Basel, Schweiz, 01.12.2015.

Gugl, C. (2015): Archäologische Prospektion in Carnuntum. Universität Bern. Bern, Schweiz, 03.12.2015.

Gugl, C.; Neubauer, W.; Doneus, M.; Wallner, M.; Löcker, K. (2015): Die Canabae von Carnuntum. Luftbildarchäologie – Oberflächensurveys – Geophysik. Internat. Konferenz „Legionslager und Canabae legionis in Pannonien“. Budapest, Ungarn, 16.11.2015.

Lindberg, E.; Briese, C.; Doneus, M.; Hollaus, M.; Schroiff, A.; Pfeifer, N. (2015): Multi-wavelength Airborne Laser Scanning for Characterization of Tree Species. SilviLaser 2015, La Grande Motte, France, 28.-30.09.2015.

Neubauer, W. (2015): Prospection and virtual archaeology. 13: Wahrheit und Wirklichkeit: Zur Bedeutung von Modellen in Ökonomie, Wissenschaft und Philosophie. Europäisches Forum Alpbach 2015. Alpbachtal, Österreich, 28.08.2015.

Neubauer, W. (2016): Das Stonehenge Hidden Landscapes Project. 7. Tagung der Fachgruppe Archäologische Ausgrabung im Verband der. Berlin, Deutschland, 14.04.2016.

Verhoeven, G.; Doneus, M. (2015): Airborne remote sensing - breaking new ground from the air. 2nd ITN-DCH Workshop: Handling massive and complex datasets for multimedia information fusion and high resolution 2D/3D/4D surveys. Carnuntum, Austria, 23.03.2015.

Verhoeven, G.; Trinks, I.; Neubauer, W.; Löcker, K.; Hinterleitner, A. (2015): GPR and magnetic prospection - Large-scale, non-invasive mapping of buried archaeology. 19. Tagung der Österreichischen Restauratoren für archäologische Bodenfunde. Universität für angewandte Kunst. Wien, 17.04.2015.

Zotti, G. (2015): Archaeoastronomical simulation in a desktop planetarium. Cultural Heritage and New Technologies (CHNT) 20. Vienna, Austria, 02.-04.2015.

Zotti, G. (2015): Virtuelle Methoden der Archäoastronomie. Jahrestagung der Gesellschaft für Archäoastronomie 2015. Berlin, Deutschland, 01.10.2015.

Summer schools and conference workshops

Verhoeven, G. (2015): ArcLand Training School: Aerial photographs & 3D landscape modelling. 6 lectures. Poznan, Poland, 15.06.2015. Summer school.

Verhoeven, G. (2015): Scuola di Dottorato in Storia, critica e conservazione dei beni culturali. Padova, Italy, 30.10.2015. Summer school.

Zotti, G. (2015): Open Source Virtual Archaeoastronomy. SAEC 2015. Société Européenne pur l'Astronomie dans la Culture. Rome, Italy, 09.11.2015. Conference Workshop.

Talk

Doneus, M. (2015): Automated archiving of oblique and vertical aerial photographs. AARG Annual Meeting 2015. Santiago de Compostela, Spain, 09.09.2015.

Doneus, M.; Miholjek, I.; Mandlburger, G.; Doneus, N.; Verhoeven, G.; Briese, C.; Pregesbauer, M. (2015): Airborne laser bathymetry for documentation of submerged archaeological sites in shallow water. ISPRS / CIPA workshop "Underwater 3d recording and modeling". Piano di Sorrento, Italy, 17.04.2015.

Doneus, N. (2015): Archaeological prospection: the know-how behind the nice pictures. XXI International archaeological workshop. Centar za arheološka istraživanja, Institut društvenig znanosti Ivo Pilar. Medulin, Croatia, 10.12.2015.

Ettinger-Starčić, Z.; Doneus, N. (2015): Geoarheološko istraživanje Osora. XXI International archaeological workshop. Centar za arheološka istraživanja, Institut društvenig znanosti Ivo Pilar. Medulin, Croatia, 10.12.2015.

Neubauer, W.; Löcker, K.; Kucera, M.; Nau, E.; Flöry S.; Verhoeven, G.; Lugmayer-Klimczyk, A.; Trinks, I. (2015): Multi-scale digital landscape documentation and archaeological prospection of Stonehenge. Riegl Lidar 2015. Hong Kong, China, 05.05.2015.

Schneidhofer, P. (2015): Geoarchaeology as essential supplement for geophysical prospection. XXI International archaeological workshop. Centar za arheološka istraživanja, Institut društvenig znanosti Ivo Pilar. Medulin, Croatia, 10.12.2015.

Trinks, I. (2015): Geofysiske undersøkelse. Frokostseminar på NIKU: Fremtidsarkeologi. Oslo, Norway, 02.02.2015.

Trinks, I. (2015): Digitale Dokumentation der bronzezeitlichen Siedlung von Akrotiri auf Thera. Institut für Klassische Archäologie, Universität Wien. Wien, Österreich, 28.04.2015.

Trinks, I. (2015): State-of-the-art geophysical archaeological prospection and virtual archaeology. Workshop "Sensing soil condition and functions". 4th Global Workshop on Proximal Soil Sensing. Hangzhou, China, 12.05.2015.

Trinks, I.; Kucera, M.; Verhoeven, G.; Nau, E.; Sevara, C.; Neubauer, W. (2015): Digitally safeguarding ancient Akrotiri on Santorini, Greece. Riegl Lidar 2015. Guangzhou, China, 07.05.2015.

Poster

Lugmayer-Klimczyk, A.; Floery, S.; Kucera, M.; Neubauer, W.; Löcker, K.; Baldwin, E.; Gaffney, V. (2015): Terrestial laser scanning of the landscape around Stonehenge. 11th International Conference on Archaeological Prospection. Warsaw, Poland, 18.09.2015.

Verhoeven, G. (2015): TAIFU – Toolbox for Archaeological Image FUsion. Poster. AARG Annual Meeting 2015. Santiago de Compostela, Spain, 09.09.2015.

4.3 Public relations

Exibition "Vikings!", Schallaburg, Lower Austria

http://www.schallaburg.at/en/exhibitions/2015-wikings

The LBI ArchPro is an official cooperation-partner of the "Vikings!" exhibition at the Schallaburg castle. The castle hosts the most comprehensive exhibition on Vikings ever shown in Austria from 28th March to 8th November 2015. The LBI ArchPro has contributed to the exhibition with a large-scale milled relief model of the Viking Age site Birka. Based on the cleaned high-resolution airborne laser scanning data acquired within the case study Birka-Hovgården a milled model of the northern part of Björkö was created, including the Black Earth area, the hillfort and large parts of the cemetery Hemlanden with many hundreds of Viking Age burial mounds. A large number of thematic maps were transformed for exact projection onto the 3D model, displaying the burials, excavations, as well as the first results from the large-scale archaeological prospection case study Birka (Fig. 29). In the outdoor area of the castle the LBI ArchPro team has set up a custom-made exhibition container where visitors can learn more about non-invasive prospection techniques in archaeology and their field application at Viking Age sites like Borre in Southern Norway.

Fig. 29: 3D projection model of Birka within the Schallaburg exhibition.

"Stonehenge Underground" at the Royal Society's Summer Science Exhibition in London

https://royalsociety.org/summer-science/

The LBI ArchPro was part of the UK's most prestigious science exhibition (29th June to 5th July 2015) at the Royal Society's Summer Science Exhibition in London. The institute was be showcasing its ground-breaking work at Stonehenge in an exhibit set up together with partner University of

Birmingham at the Summer Science Exhibition 2015, which is an annual display of the most exciting cutting-edge science and technology in the UK. It is organized by The Royal Society.

Meet Science! 2015, Vienna

http://www.lbg.ac.at/en/node/3856

On April 16th 2015, the Ludwig Boltzmann Gesellschaft gathered their research institutes and clusters Semper Depot in Vienna in order to present themselves and their latest activities to numerous guests from the Austrian research community.

The Vienna Research Festival 2015

http://www.wien-event.at/events/weitere-events/wien-event/forschungsfest-2015/

The LBI ArchPro participated in this year's Vienna Research Festival (12th to 14th September 2015) organised by the The Vienna Business Agency, which was founded in 1982 as the Vienna Economic Development Fund (Wirtschaftsförderungsfonds) by the City of Vienna, the Vienna Chamber of Commerce, the UniCredit Bank Austria AG (formerly the Zentralsparkasse) as well as the Erste Bank der Österreichischen Sparkassen AG (formerly the Erste Österreichische Sparkasse). The Vienna Business Agency prioritises and promotes the defined focal strengths of the city: life sciences, urban technologies, creative industries and ICT. Innovations are the key to commercial success and ensure the long-term development of the business location. The goal of the Research Festival is, together with Viennese companies, universities and research facilities, to demonstrate to a wide cross-section of the public what type of research is being conducted in Vienna, and how it is being done. This year's theme was the path from research to the finished product. An entertaining framework program (experiment reviews, research workshops, children's programs, etc.) has accompanied a large hands-on exhibit (Fig. 30).

Fig. 30: The Vienna Research Festival 2015.

Forum Alpbach

http://www.alpbach.org/de/session/breakout-session-13-wahrheit-und-wirklichkeit-oekonomische-modelle-der-innovation-am-pruefstand-der-praxis/

LBI ArchPro director Wolfgang Neubauer has been invited to speak at the Technology symposium at this year's European Forum Alpbach on 28th August 2015. The European Forum Alpbach is a non-profit association based in Vienna, Austria. The EFA takes place in Alpbach (Tyrol, Austria) every year attracting around 4000 participants from all over the world. Established in 1945, the EFA addresses relevant socio-political questions of our time connecting international scientists, decision-makers, intellectuals and opinion leaders from all sectors of society with an interested audience and committed young people. Former participants of the EFA include Sir Karl Popper, Viktor Frankl, Ban Ki-Moon, Yitzak Rabin, Indira Ghandi, Josè Emanuel Barroso etc. The work of the LBI ArchPro was presented in the section 13: Truth and Reality: The Importance of Models in Economy, Science and Philosophy.

Coming 2016: "Stonehenge - A Hidden Landscape" exhibition at MAMUZ Museum Mistelbach

http://www.mamuz.at/de/das-museum/museum-mistelbach/ausstellungen-museum-mistelbach/3-stonehenge-verborgene-landschaft

New discoveries and insights into Stonehenge landscape made possible by the LBI ArchPro's intensive research over the last five years will be – for the first time - presented in a comprehensive exhibition in Austria. Starting on 20th March 2016, the "Stonehenge – A Hidden Landscape" exhibition at the MAMUZ Museum Mistelbach will take the visitor on a journey of more than 8.000 years through Stonehenge and its surrounding landscape including the newly discovered stone monument at Durrington Walls and original finds from the Salisbury -, Wiltshire- and Dorchester Museum.

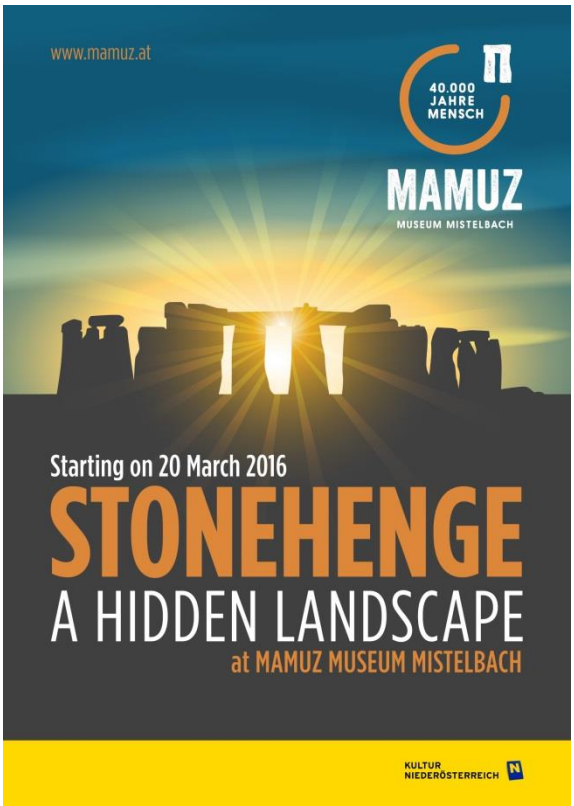

Fig. 31: Announcement of the exhibition at MAMUZ Museum Mistelbach in 2016.

4.4 Press coverage summary

LBI ArchPro

- http://www.golem.de/news/drohne-bodenradar-3d-drucker-nur-geeks-koennen-archaeologen-sein-1502-112335-3.html
- http://archpro.lbg.ac.at/sites/files/archeo/wiener_zeitung_die_wilden_horden_aus_dem_norden_1.4.2015.pdf
- http://archpro.lbg.ac.at/sites/files/archeo/die_furche_in_die_tiefe_der_vergangenheit_23.4.2015.pdf
- http://archpro.lbg.ac.at/sites/files/archeo/noen_talente_auszeichnung_1.6.2015_1.pdf
- http://archpro.lbg.ac.at/sites/files/archeo/noen_archaeologie_ohne_zu_graben_9.6.2015.pdf
- http://archpro.lbg.ac.at/sites/files/archeo/universum_magazin_step_by_step_11.6.2015.pdf
- http://archpro.lbg.ac.at/sites/files/archeo/die_presse_werkzeuge_fuer_die_suche_nach_der_wirklichkeit_29.8.2015.pdf
- http://archpro.lbg.ac.at/sites/files/archeo/kronen_zeitung_schicht_fuer_schicht_geschichte_11.9.2015.pdf
- http://archpro.lbg.ac.at/sites/files/archeo/wien.at_forschungsfest2015_4.9.2015.pdf
- http://archpro.lbg.ac.at/sites/files/archeo/noen_auf_den_spuren_der_wissenschaft_5.10.2015.pdf

Kreuttal, A

- http://archpro.lbg.ac.at/sites/files/archeo/noen_dorf_der_erbauer_wird_ausgegraben_30.6.2015.pdf
- http://www.meinbezirk.at/mistelbach/chronik/party-in-hornsburg-vor-6000-jahren-d1410816.html
- http://www.noen.at/nachrichten/lokales/aktuell/mistelbach/Die-aelteste-Hornsburgerin;art2689,650770#galerie/121510/8
- http://archpro.lbg.ac.at/sites/files/archeo/bezirksblaetter_noe_mega-party_in_hornsburg_vor_6000_jahren_5.8.2015.pdf

Carnuntum, A

- http://archpro.lbg.ac.at/sites/files/archeo/wiener_zeitung_mit_dem_auge_nicht_mit_dem_spaten_18.12.2015.pdf
- http://www.noen.at/nachrichten/lokales/aktuell/bruck/Doku-Gladiatoren-erobern-Kulturfabrik;art2674,696582
- http://archpro.lbg.ac.at/sites/files/archeo/universum_history_niederosterreichs_gladiatoren_-_kurier.pdf
- http://www.noe-news.at/news/index.php?option=com_content&task=view&id=11282&Itemid=1
- http://noe.orf.at/news/stories/2748751/
- http://science.orf.at/stories/1765633/
- http://tv.orf.at/program/orf2/20151222/769001501/405925
- http://archpro.lbg.ac.at/sites/files/archeo/universum_magazin_neuer_blick_auf_die_stadt_der_kaiser_15.12.2015.pdf

Oberlienz, A

- http://archpro.lbg.ac.at/sites/files/archeo/osttiroler_bote_roemische_spuren_in_oberlienz_26.11.2015.pdf

Stonehenge, UK

- http://archpro.lbg.ac.at/sites/files/archeo/discover_magazine003.pdf
- http://archpro.lbg.ac.at/sites/files/archeo/zmescience_22.6.2015.pdf

Durrington Walls, UK (selected)

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