Multipurpose application of digital excavation data

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Abstract: An archaeological excavation generally starts with collecting available documentation data such as maps, images, and drawings, representing both, the current as well as the historical status of the respective site. Additionally, geometrical models are nowadays often available. During the excavation, various datasets are collected including prospection data (e.g. geo-radar), thermal images (e.g. at facades or buildings), high resolution areal images (e.g. UVA-collected), close range images, or laser scanning, just to name a few. All these datasets have in common that they are likely to be georeferenced, i.e. they can be transformed into one project coordinate system for subsequent overall interpretation and analysis of the site. This may be typically realized by a GIS. Although such systems are very popular for this, they generally require expert knowledge, and they often work with 2D-data only. To overcome this, we developed an automated workflow for the generation of a 4D-multimedia application for the documentation of digital excavation data of an excavation site based on the 3D geometrical model and considering the time component as well. Using current multimedia technologies, the representation of the available documentation data is made available on multiple device classes including PC, tablets, and smartphones, thus making the data accessible while being mobile. While the collected archaeological data is generally used for the purpose of generating the archaeological expertise only, the proposed workflow, i.e. the 4D-multimedia application representing the collected data of the excavation site, enables additional possibilities for subsequent application of the results including supporting respective construction work, being the foundation for further decisions, or as medium for marketing and public relations. The applicability of the workflow is demonstrated on examples representing an excavation at the *UNESCO World Heritage Site Schloß Schönbrunn*.

Keywords: 3d modeling, documentation, archiving, visualization, multimedia

Introduction

In the past decade, digital data acquisition technologies became more and more relevant for the documentation of archaeological excavation sites. Digital cameras, tachymetric point measurement and terrestrial laser scanning are commonly used to capture shape and appearance of archaeologically relevant objects at any scale, from huge excavation sites to the smallest assets. Free software services (e.g. VERGAUWEN & VAN GOOL, 2006, DESEILLIGNY & CLERY, 2011) are available for the highly automated processing of data for documentation and visualization. The achievable results vary from image based mapping, CAD line-drawing and visual interpretation to accurate and highly detailed 3D visualization modeling (DÜFFORT et al., 2011, BRUNOA et al., 2010) and management based on 3D information systems (ALEXAKIS, 2011) providing numerous spatial analysis operations well known from geoinformation systems (GIS).

For decades, analogue images and manually generated sketches and drawings have been the only tools for archaeological documentation. Therefore, the established interpretation workflows and processes are often tightly coupled to these traditional data sources (e.g. KRINZINGER, 2010). Consequently, for many sites, time series of mappings, sketches and similar documents do exist. However, the collected datasets are often unstructured files with varying scale and coordinate system definitions, and thus, may not be analyzed simultaneously without much effort.

GIS systems can be used to overcome this. However, such systems are in general expensive considering both, the software and hardware requirements as well as the necessity for an experienced user for data collection and system maintenance. In this contribution, we propose a workflow for acquisition and preparation of digital geo-referenced datasets of archaeological sites. In combination with multimedia technology for interactive 3D visualization and interaction, a set of data layers can be shown and thus interpreted simultaneously. Supporting web access and smart devices, especially tablet PCs, makes the data accessible to anyone at any time and any place. The applicability of the proposed system is tested at a recent archaeological excavation at the *UNESCO World Heritage Site Schloß Schönbrunn*. In the following section, we give a brief overview on traditional archaeological documentation. Afterwards, the proposed workflow is described and demonstrated.

Archaeological Documentation

Typically (historic) maps, image data, and geometrical information (e.g. digital terrain models, profiles, isolines, etc.) are available, representing the historic and current status of an excavation site. Figure 1 shows exemplary datasets typically available prior to an excavation and relevant for the interpretation of the site.

Fig. 1 – Historical maps (left), (ortho)-images (center), and geometrical information (e.g. digital terrain models – right), are often used as foundation for archaeological prospection.

In addition, information is collected during the excavation. In recent years, digital data acquisition allows for fast and accurate digital documentation of archaeological sites. CAD-mapping based on tachymetric measurements (figure 2, center) is commonly used. Recently, the application of Unmanned Aerial Vehicles (UAV) for photo documentation became more and more attractive, as numerous affordable micro-copters are available (e.g. BENDEA et al., 2007, SAUBRIER & EISENBEISS, 2010). By means of semi-professional camera equipment (e.g. calibrated SLR-cameras), high resolution image data may be acquired at low cost. Subsequently, such images can be rectified or, if adequate geometrical information is available, true ortho-images can be generated. Figure 2 left, shows a rectified image taken by a UAV with a resolution of 1 cm per pixel. Terrestrial Laser Scanning (TLS) enables an accurate documentation of the geometrical surface of objects at high resolution. Figure 3 shows a triangulation model as described by NOTHEGGER (2011) of a stone wall with a resolution of approximately 2 mm.

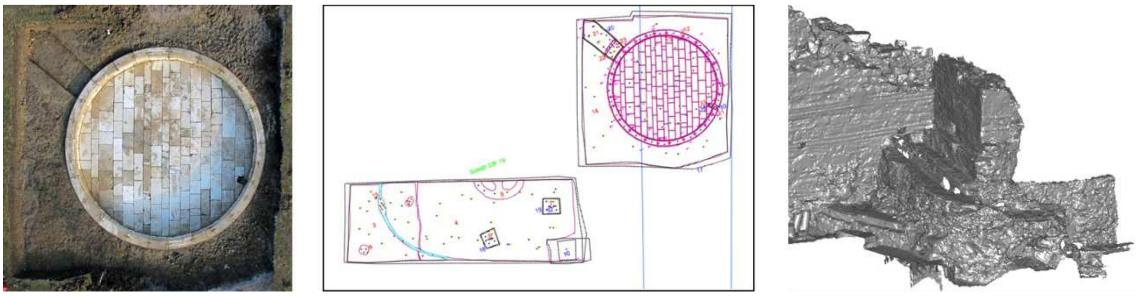

Fig. 2 – High resolution UAV-image UAV (left), tachymetric measurements (center), and terrestrial laser scanning (right) are adequate digital data acquisition technologies for collecting on-site information.

The typical workflow for archaeological documentation comprises data collection, interpretation and analysis. Figure 3 gives a schematic overview. According to this, the collected information in combination with the scientific interpretation of the given data is typically summarized in a survey protocol which is archived analogue or digital.

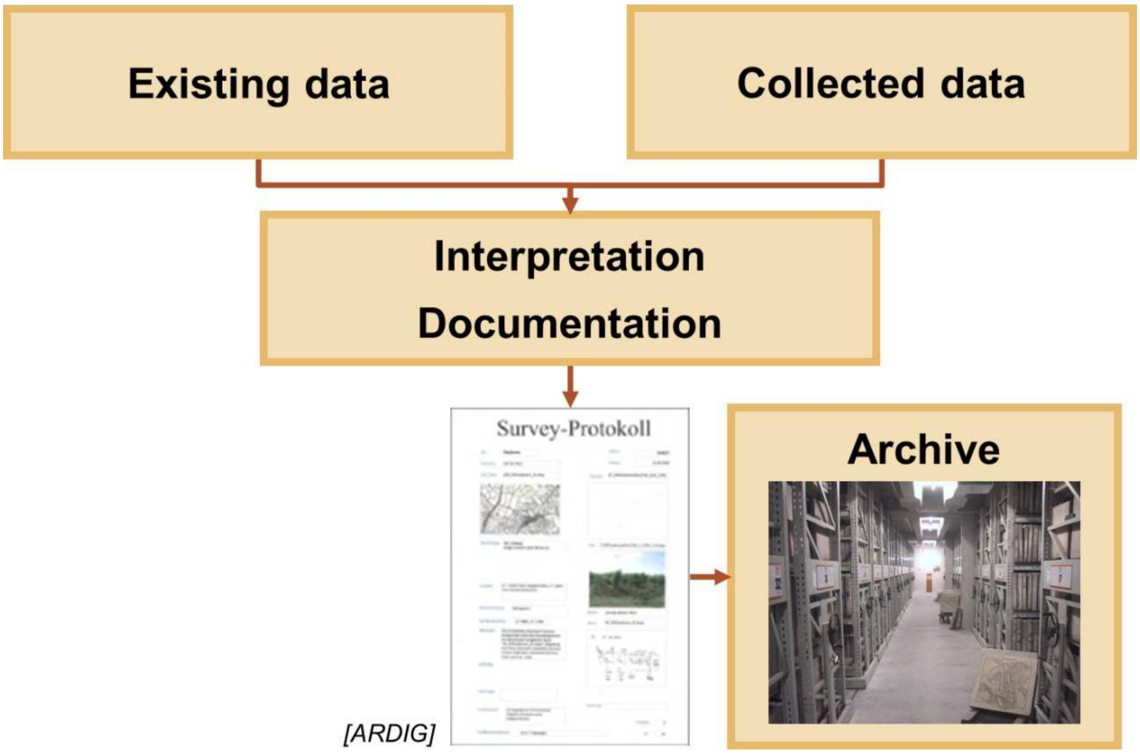

Fig. 3 – Typical workflow for archaeological documentation – Existing and collected data are combined and summarized in a survey protocol which is finally archived.

This procedure has a major drawback: Hence, the archaeologist “filters” the given data and draws a certain conclusion based on his expertise and considering the given task or purpose. I.e., the survey protocol is a (written) report summarizing the situation at the archaeological site and thus, the originally collected (geo)data is not accessible for later additional investigations of the site.

Smart Archaeology – Towards automated, digital documentation

Our approach is based on a layer concept, similar to conventional GIS-systems. Restricting the functionality of the proposed *GIS.light* to the minimum necessary for interactive visualization allows for an intuitive interaction. This is enhanced by the application of tablet devices with multi-gesture touch screens.

The geometrical foundation for the representation is a 3D-model. For this, triangulation models are used. Hence, both, 2.5D (e.g. Digital Terrain Model) or for more complex structures (e.g. buildings or sculptures) 3D models are supported. The raster layers are projected onto the geometrical model. If available, the existing geo-referencing information is used (e.g. ortho-images, digital terrain models, tachymetric measurements). For datasets without geo-referencing, we used interactive rectification based on image processing software using identical points of geo-referenced data (e.g. ortho-images). This is commonly necessary for historic maps. In order to integrate vector data, a vector-raster-conversion is required.

The basic idea of our approach called *Smart Archaeology* is to improve automatically generated "intermediate" results by means of so-called smart applications. While, as described above, traditional archaeological documentation relies on the interpretation of the given data, we propose to integrate such applications to improve the results further. By integrating smart devices (i.e. tablet PCs) as 3D-data viewing and interaction tools, on-site interpretation and manipulation of the given data is enabled. Augmented reality enables superimposing the real situation with collected data and thus supports the entire process of archaeological prospection.

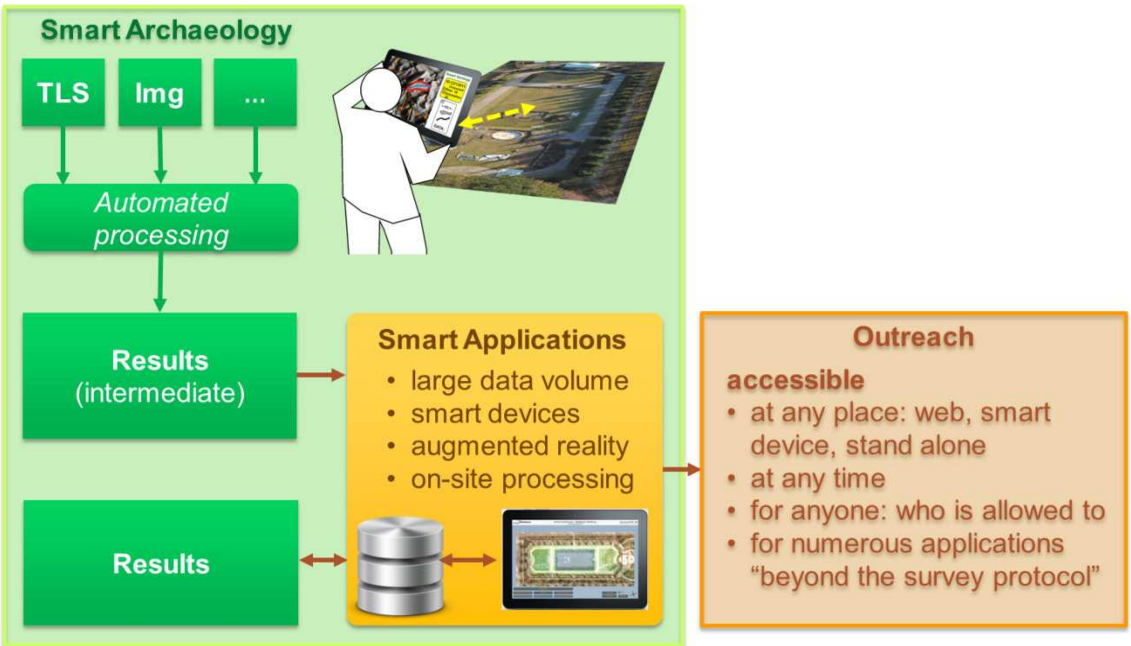

Fig. 4 – Concept of Smart Archaeology integrating smart application to improve intermediate results on-site based on expert knowledge.

In comparison to conventional GIS systems, our approach excels in its simplicity. Compared to our approach, GIS systems provide much more analysis functionality. However, for the purpose of visual interpretation of existing raster data layers, the proposed *Smart Archaeology* improves upon conventional GIS by using 3D models as data foundation. The layer based visualization technology enables an individual combination of up to four different datasets. For further processing, geo-referenced maps can be generated and exported in geo-coded raster format (GeoTIFF).

Experiment and discussion

In the *Meidlinger Vertiefung* in the park area of the *UNESCO World Heritage Site Schloß Schönbrunn*, two fountain-basins were found in January 2012. During the excavation, it turned out, that the original state of the basins has been unchanged, i.e., they were not dismantled prior to burying them. To study the history of these objects, an archaeological excavation was carried out by Archäologischer Dienst GmbH (www.ardig.at). For this, a series of historic maps in combination with recent image and terrain modeling data has been investigated. In addition, high resolution images have been acquired using a UAV. The findings of the excavation have been documented as CAD line-drawing. Table 1 gives an overview on the available datasets and Figure 5 shows the individual layers.

Type	***Number of layers***	***Date***	***Resolution***
Historical maps	6	1780-1908	25 cm
Terrain Models (DTM, DSM)	4	2007	25 cm
Ortho-images (RGB, NIR)	3	2004, 2007	10 cm
UAV images (rectified)	2	2012	25 cm / 1 cm
Line-drawing	1	2012	---

Tab. 1 – 16 datasets representing the Meidlinger Vertiefung in the park area of Schloß Schönbrunn.

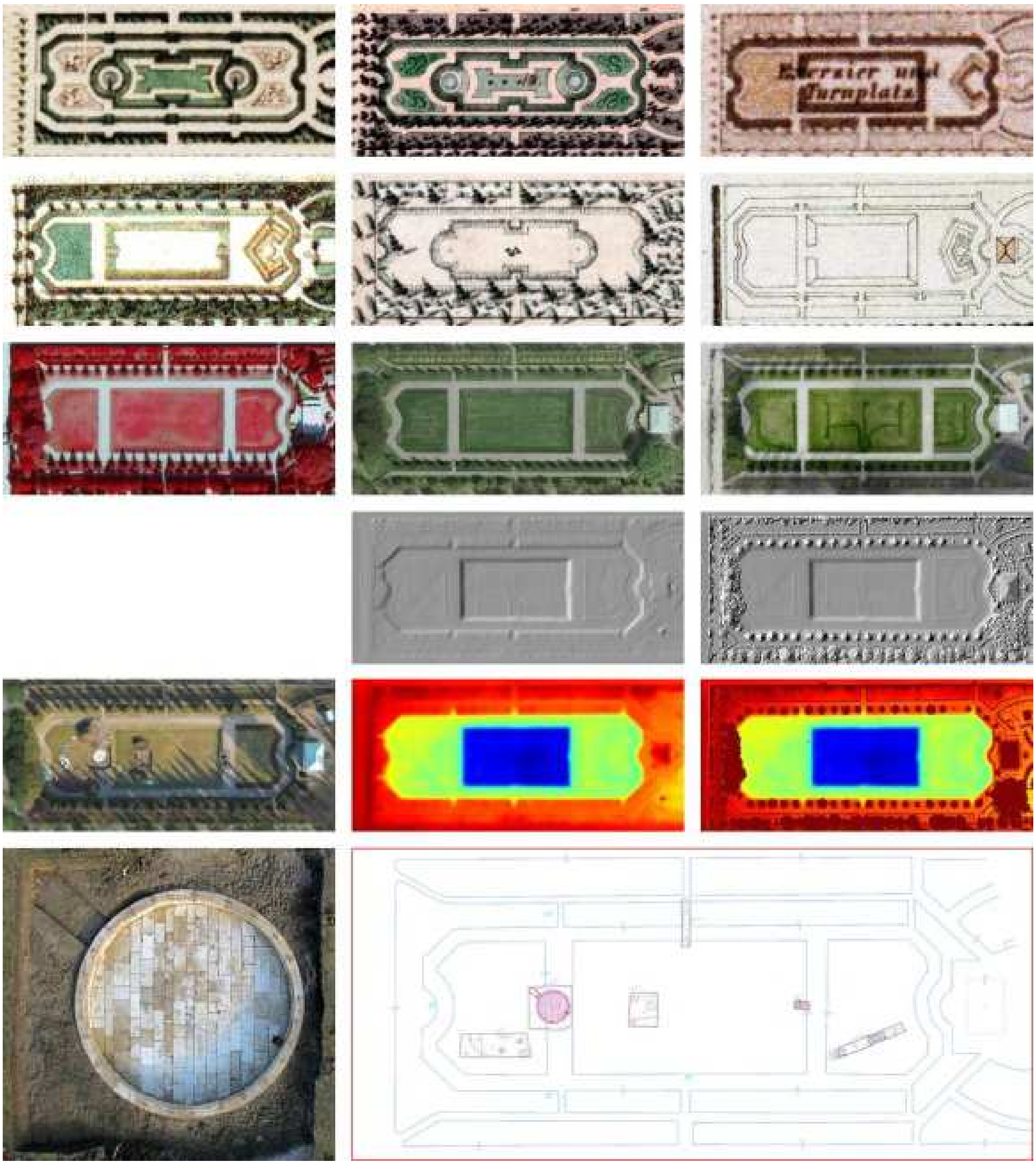

Fig. 5 – 16 datasets representing the Meidlinger Vertiefung in the park area of Schloß Schönbrunn. 6 historic maps (1780, 1819, 1860, 1860, 1968, 1908), true color and NIR ortho-images (from 2004 to 2007) and airborne laser scanning data (Digital Terrain Model and Digital Surface Model, 2007) were available prior to the excavation. A CAD line-drawing and rectified high-resolution images based on UAV-data were created during the excavation.

The Digital Terrain Model (DTM) is used as geometrical foundation. Up two four raster layers can be superimposed as texture maps to the DTM simultaneously using layer transparency. DTM and ortho-image data had a proper geo-location, i.e. a well-known resolution and position. The UAV images were rectified with respect to the DTM. To provide the line-drawing as raster layer, a vector-raster conversion was necessary. The historical maps were available as scanned images with varying scale and referencing. Partially, they were randomly distorted. In addition, in some cases the information represented by the historical maps is not observable in recent datasets. In order to achieve an acceptable referencing of those datasets, an interactive rectification, based on numerous control points determined of the so far referenced data, has been applied.

The proposed system enables two different visualizations of the given data. Based on a predefined data bundle containing all 16 raster layers and additional attributive information, an interactive real-time rendering, texturing the geometrical model (i.e. DTM) can be generated. The interactive visualization is based on a game engine (Unity – www.unity3d.com). Therefore, various platforms can be supported including mobile devices and web based representation. Figure 6 left shows the user interface using a tablet PC. In the perspective view of four superimposed raster layers (ortho-image 2007, height-coded DSM 2007, historical map 1819, line-drawing), the local geometrical structure can be seen clearly. The achievable accuracy of the referencing of the datasets covering a time series of almost 200 years is approximately 1 to 2 pixels. For generating a "conventional" map, each interactively defined combination of superimposed layers can be exported as geo-referenced orthogonal projection with a defined scale (Figure 6, right). To support high resolution plotting of such maps, the originally available high resolution datasets (up to 1 cm per pixel) are used, whereas for the real-time rendering, accordingly resampled datasets are provided.

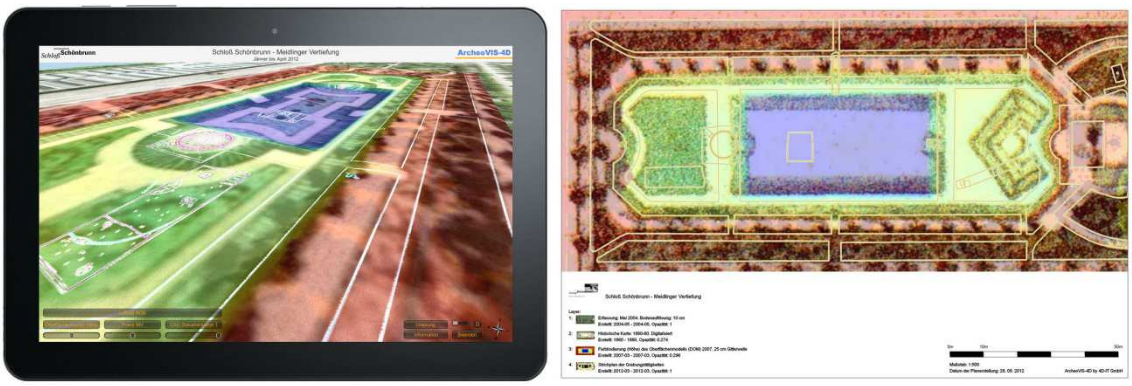

Fig. 6 – 3D-multimedia application for visualization and inspection of digital documentation data of the excavation site Meidlinger Vertiefung in park area of Schloß Schönbrunn, Austria.

Conclusions

We presented a concept for digital documentation and presentation of excavation sites. It is based on the collection and visualization of datasets representing the current and past situation of an excavation site. Datasets representing the respective site prior to the excavation (e.g. maps, terrain models, ortho-images, etc.), and data collected during the excavation (e.g., high-resolution image data (UAV) and tachymetrically determined CAD-drawings) can be integrated. All respective datasets are transformed into a common project coordinate system. For visualization, they are superimposed to a digital terrain model, thus enabling a 3D-representation of the original 2D-information.

The system is based on a layer concept, similar to conventional GIS-systems. Restricting the functionality of the proposed *GIS.light* to the minimum necessary for interactive visualization allows for an intuitive interaction. This is enhanced by the application of tablet devices with multi-gesture touch screens. The proposed *Smart Archaeology* concept, based on server-side bundle hosting enables an unlimited accessibility to the data to anyone at any time and any place, while giving the data provider the possibility to control and, if necessary, restrict data access. By this, the data provider may track exactly, which maps were requested by a user while giving the user the possibility to create individual maps of the excavation site considering his individual purpose. This flexible concept of data providing makes a multipurpose application of the data, originally collected for archaeological prospection, possible. The data may not be used only for generating a survey protocol, it may serve for numerous subsequent applications including supporting respective construction work, being the foundation for further decisions, or as medium for marketing and public relations, in addition.

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