

SURVEYING AND GEOINFORMATION - CONTRIBUTIONS TO AN INTERDISCIPLINARY SPECIAL RESEARCH PROGRAM ON THE HISTORY OF MINING ACTIVITIES

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ABSTRACT:

The multidisciplinary research program HiMAT (History of Mining Activities in the Tyrol and Adjacent Areas) at the University of Innsbruck is dedicated to the research of mining in the Eastern Alps. The aim of this project is together with internationally renowned partners from european universities and the German Mining Museum in Bochum the investigation of the impact of mining activities on the environment and human society from prehistoric to modern times at the highest scientific level. The effect of mining is noticeable in the settlement history and the resulting economic development of these areas up to modern times. The expansion and recession of this mining area in the eastern Alps can be studied only at a few examples like Mitterberg, the region Schwaz ("mother of all mines") and Brixlegg.

Within HIMAT the Surveying and Geoinformation Unit deals mainly with three issues. First there is the creation and use of high accuracy digital terrain models (DTMs) for archeological prospection to locate potential excavation areas. Through the survey of topography with airborne laser scanning (LiDAR) technology, even under dense vegetation, information about the terrain surface and possible archaeological structures can be achieved. A second issue is 3D Documentation. Measurement has always been an indispensable partner of any archaeological excavation activity. One of the fundamental tasks is the continuous and objective survey and documentation of three-dimensional data throughout the project duration of the SFB-HiMAT. Last but not least there is the task of integrating data within a Geographic Information System (GIS) for communication, retrieval and presentation of spatial data. To integrate the heterogeneous data of the different disciplines into one data model we choose the formal ontology of the CIDOC CRM. The IT infrastructure to provide the necessary functionalities consists of a content management system, a database and a GIS. This infrastructure allows the access of documents stored in the content management system through the GIS interface.



Fig.1: laser scanning down in a prehistoric mining site

1. INTRODUCTION

The multidisciplinary research program HiMAT (History of Mining Activities in the Tyrol and Adjacent Areas) at the University of Innsbruck is dedicated to the research of mining in the Eastern Alps. Prehistoric Europe changed extensively since the beginning of the extraction of ore and metal. By the 2nd or early 1st Millennium BC there was already an expert-based communication and economy between the valleys. This involved not only trading in commodities and goods but also an exchange of technologies and specialists. The impact of mining is also included and visible in the settlement history and the resulting economic development of these areas up to modern times. Among the former most important mining regions ranked the areas that we call now The Tyrol, South Tyrol, Salzburg and Vorarlberg. In some mining areas production priorities with industrial character already developed during the Bronze Age and Iron Age. In the late medieval and early modern times, the region of Schwaz became the leading mining area of Europe, also known as "all perckhwerck muater" (mother of all mines). The expansion and recession of this mining area in the eastern Alps can be studied only at a few examples like Mitterberg and the region Schwaz / Brixlegg. Together with internationally renowned partners from the universities of Basel, Frankfurt, Tübingen and the German Mining Museum a special research program was initiated by a team of natural and social scientists and technicians from the University of Innsbruck. The goal of this project is the investigation of the impact of mining activities on the environment and human society from prehistoric to modern times at the highest scientific level. (Hanke, 2007). Surveying and GIS have definitely to accompany the entire process of acquisition of both thematic as well as geometrical data throughout the whole duration of this special research program HiMAT. There are three main issues.

Archeological Prospection:

The goal is to locate potential excavation areas with a high accuracy digital terrain model (DTM). Through the survey of topography with airborne laser scanning (LiDAR) technology, even under dense vegetation, information about the terrain surface and possible archaeological structures can be achieved. LiDAR seem to be acutely useful to discover unidentified sites.

3D Documentation:

Measurement has always been an indispensable partner of any archaeological excavation activity. One of the fundamental tasks is the continuous and objective survey and documentation of three-dimensional data throughout the project duration of the SFB-HiMAT.

Geographic Information System and Data Integration:

A Geographic Information System (GIS) should enable integration, communication, retrieval and presentation of spatial data within the project. Basic geodata like topographic maps or orthophotos can be overlaid with data from the different disciplines. To integrate their heterogeneous data into one data model we choose the formal ontology of the CIDOC CRM.

The IT infrastructure to provide the necessary functionalities consists of a content management system, a database and a GIS. This infrastructure allows the access of documents stored in the content management system through the GIS interface.

2. ARCHAEOLOGICAL PROSPECTION

The survey of topography at the target areas is a very important part in the workflow of archaeological sites' identification, excavation and documentation. One of the major tools of archaeological prospection is airborne laser scanning (LiDAR) which helps to depict micro-topographic details in shaded relief. It creates high accuracy digital terrain models (DTMs) that could detect the potential excavation locations by providing information about the fine structure of the surface. Archaeological prospection therefor could be the first step to conduct. The position of the potential archaeological structure can be determined by this method and can be compared with other (historical maps, aerial photos, etc.) sources to aid more exact site selection. This process therefore could assist the planning of archaeological fieldwork.

The mapping of historic mining places can be carried out efficiently by utilizing airborne laser scanning (LiDAR), especially on largely vegetated mountain areas. In these regions, there is no other feasible methodology that can provide us with sufficient data regarding the assessment of micro-topographical relief. The obtained measurements can be post-processed with a precision of 15 cm (Large and Heritage, 2009). In addition, the speed of data collection represents a very high level. A further advantage of the LiDAR technology in this region is that the federal states of Tyrol and Vorarlberg have already decided – and by 2010 Salzburg, Bavaria and South Tyrol will follow their examples - to have area-wide LiDAR-based DTMs for their own governmental applications, which are available for our projects, as well. This signifies an enormous opportunity for the HiMAT program as all of the investigated regions will be scanned by the hereby mentioned federal states. This is particularly crucial since the costs of LiDAR data collection are remarkably high and mostly governmental projects can afford it. However, in many key locations further measurements are needed to ensure higher resolution in order to generate more accurate DTMs.

For instance, the Mitterberg mining site in the federal state of Salzburg, one of the key areas of the HiMAT project, has been scanned with high resolution (raw data: 11 points/m²), and modelled with a focus on archaeological prospection. In spite of the dense vegetation coverage the geographical position and the structural formation of the historic mining activities can be evidently recognized based on the high accuracy shaded relief (Fig. 5).

There is another example of additional site surveying where at the already existing LiDAR dataset of the Tyrol government is completed by terrestrial laser scanning and total station data. After data acquisition at the excavation site of Mauken near Brixlegg, Tyrol, a high quality DTM was created by the fusion of the different data sets. The results indicate various external mining forms as well as a well-defined mine entrance (Fig. 2).

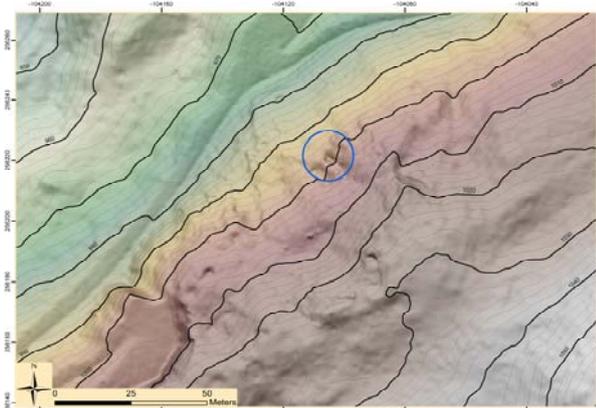


Figure 2. DTM of excavation sites Mauken, blue circle mining entrance, © Land Tirol

Further studies also point out that this method of archaeological prospection has been already proved extremely beneficial in the detection of previously unknown archaeological sites. Consequently, the airborne laser scanning and its utilization in the future are exceptionally essential in exploration of archaeological places (Doneus et al., 2006, 2008).

3. DOCUMENTATION OF ARCHAEOLOGICAL EXCAVATIONS AND FINDS

Surveying is a significant part of every archaeological excavation. The advantage of a three dimensional and comprehensive recording using a laser scanner is not only in the contactless and non-destructive data acquisition of sensitive and complex objects. The high resolution of modern equipment makes an accurate and objective 3D documentation of excavations and finds feasible (Hanke et al., 2008; Moser et al., 2009a).

In comparison to conventional methods the number of accurate details can be increased in the same period of time. The processing of huge amounts of data is a known problem in modelling. The continuous development and improvement of hardware and software makes it possible to calculate even larger amounts of data and to produce the 3D models to the highest quality level (Grimm-Pitzinger et al., 2009). For the subsequent analysis and interpretation by various experts, using high-resolution images for texturing the model can increase the information from 3D objective documentation significantly. Such high-tech equipment and the corresponding evaluations of the data are normally used for dam monitoring or quality assurance in aircraft and mechanical engineering, but also will be important in the archaeological and historical monuments in the future. Because of the different available resolutions and accuracies of measurement the development of appropriate work processes is necessary (Hanke et al., 2009). The aim is to support the different project parts in their documentation as well as possible, to transfer the evaluated data in a common coordinate system and to give project partners the results in an appropriate manner (Moser et al., 2009b).

Many finds are not available for an indefinite period of time, because of the protracted conservation procedures. The following analysis of geometry and texture with digital models can be done in two different ways.

Using a 3d-plotter or a milling-machine, copies can be produced in different scales and materials. With these replicas it is feasible to use ordinary methods of analysis or reconstruction.

The copies can also be used as exhibits, museum and teaching purposes.

The second method is a true digital one. With a spatial model every view is possible and there are more and easier options of analysis available. A huge advantage, if the finds and places are no longer accessible. This is also important for countries with rigid export rules to transfer examination work to home.

For the understanding of complex forms it is very helpful to construct sectional drawings (Figure 3) and counter lines for respectively developed views of the surface.

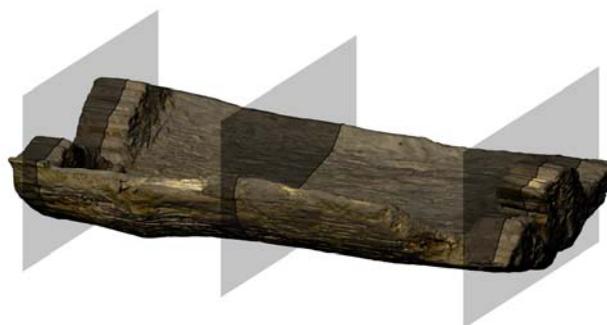


Figure 3. High-resolution 3D model of a 3000 year's old (Middle European Bronze Age) wooden washing trough, approximately 80 cm long

Maybe not all external forms are visible. They can be hidden by a texture or are just too small for human eyes. With a monochrome view, a slowly changing illumination or an enlarged view hidden structures can be studied (Figure 4).



Figure 4. Photo documentation vs. 3D model

In addition to the analysis of the surface and texture, also the volume and volumetric weight can be determined.

A further benefit is superimposing different development steps and data types. Due to the possibility to include all spatial information into the digital model, a combined analysis is very easy. By the three dimensional documentation of the excavations all different layers and ages could be combined to a total model. A reconstruction of the position of the digitized finds is also possible (Figure 6).

A digital reconstruction of objects shows advantages compared to analogue methods. For a replica it is not necessary to produce a mould from the original find. By the assembling of sculptures and pottery fragments, all different versions can be non-destructive simulated with the computer. Dimension and weight is irrelevant for the work. The digital model can be varied anytime during its reconstruction and visualisation.

The last step is the visualisation of the spatial models. To increase the public interest it is possible to generate an easy interpreted graphic image of all the various results of research. The data and findings of the different levels of development are available on the internet for a favoured audience (Moser et al., 2009a).

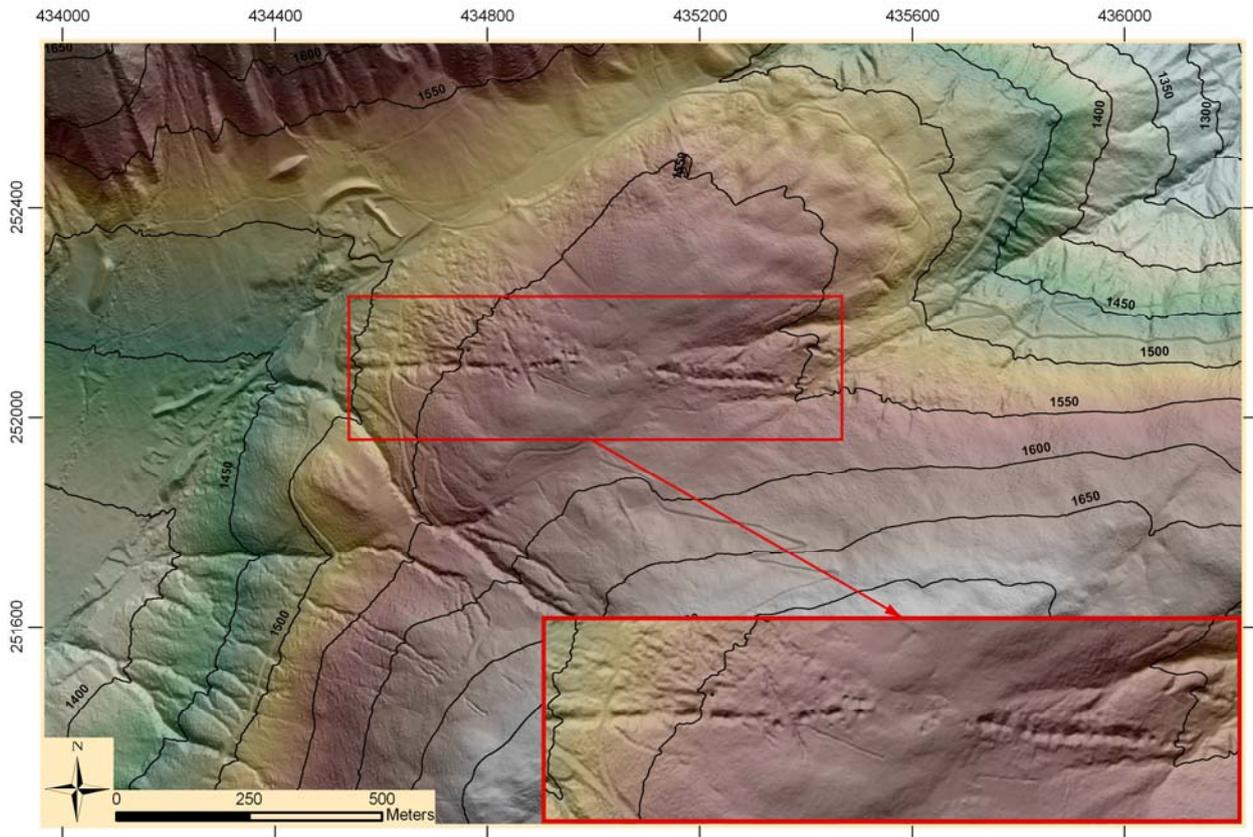


Figure 5. High accuracy shaded relief of the Mitterberg mining site for archaeological prospection, © Land Salzburg

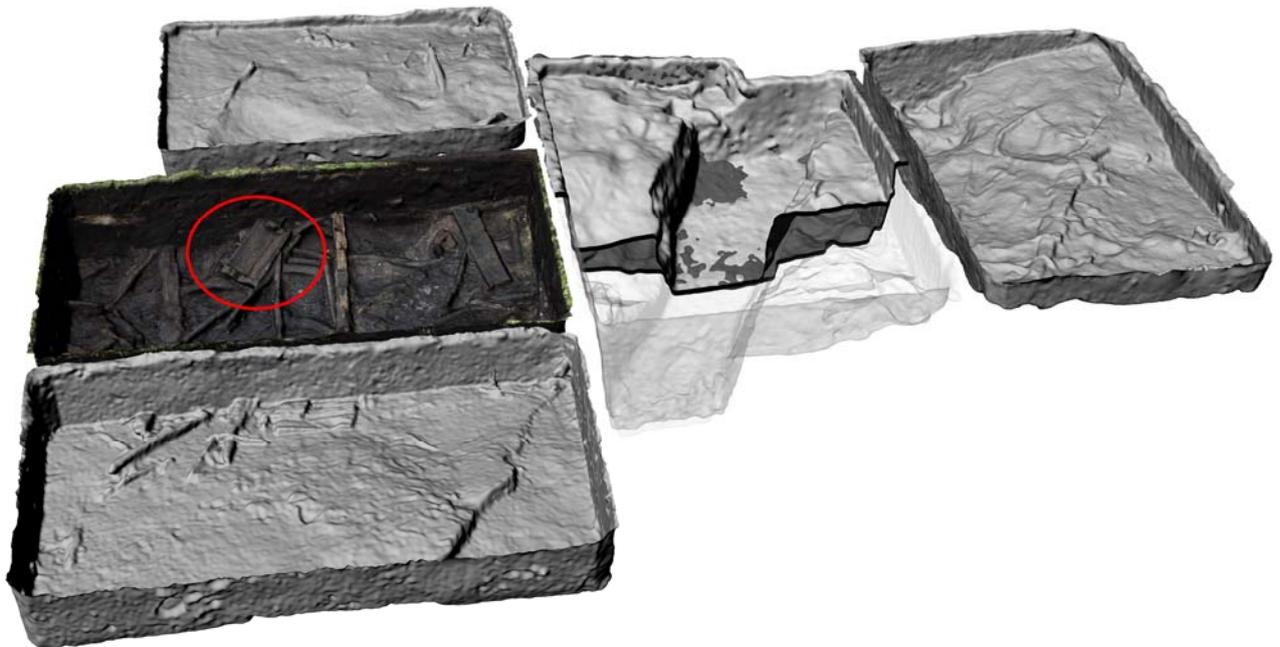


Figure 6. Spatial documentation with several excavation layers and the reconstructed position of the digitized trough

4. GIS, DATA MODEL AND IT ARCHITECTURE

Another task of the Surveying and Geoinformation Unit was to build a Geographic Information System (GIS) to enable integration, communication, retrieval and presentation of spatial data within the project HiMAT. The GIS offers basic geodata on the regions, like orthophotos topographic and historic maps or digital terrain models (DTMs) as shown in Fig.7.



Figure 7. Orthophoto, topographic map, historical map and DTM © Land Tirol and BEV

These basic geodata could be overlaid with data gathered by the different disciplines, for example the surnames of people that have their origin in a certain profession (Fig. 8).

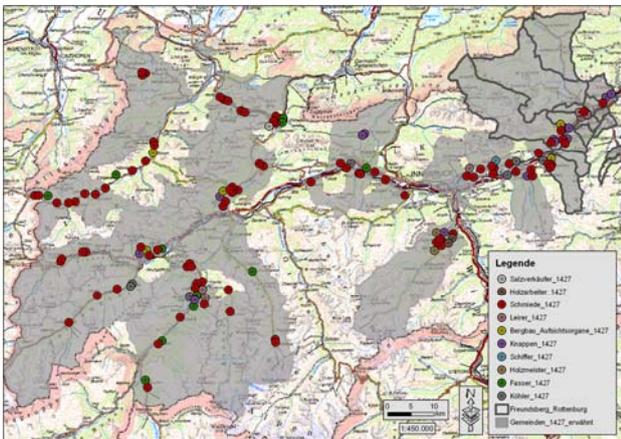


Figure 8. Names of people that have their origin in a certain profession, © BEV, HiMAT (Kathrein)

Another example of overlaying spatial information with the extension of making spatial analysis and including GPS data is shown in Fig. 9. Sites of mines that were extracted from a historical map were buffered with 30 meters and overlaid on a high resolution DTM. In addition a GPS track of a field prospection with waypoints for archaeological surface structures is shown.

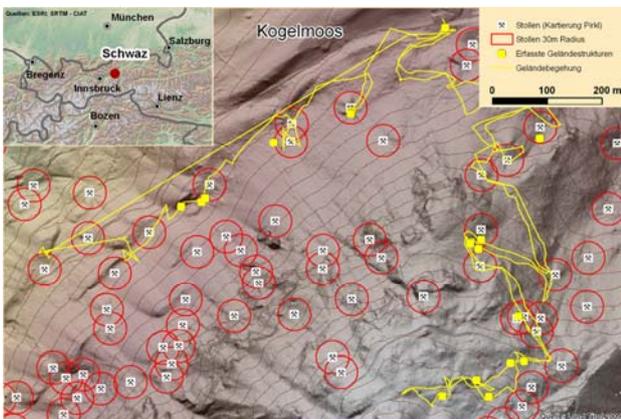


Figure 9. Sites of mines, Buffer, DTM, GPS data © Land Tirol, HiMAT (Rampf)

In addition to spatial overlays and analysis we wanted to relate the different data within the project to each other. In order to do this we encountered the need for a concept of knowledge representation. The information available in HiMAT should be represented using metadata and the formal ontology of the CIDOC CRM (Crofts et al, 2007) serves as data model. The CIDOC CRM was developed for cultural heritage documentation and became an ISO standard in 2006. It provides the necessary semantics to handle the types of heterogeneous data encountered within the project and relate them to each other. Examples for the classes of the CIDOC CRM that are used within HiMAT to model our universe of discourse are 'Physical Feature', 'Physical Object', 'Information Object' or 'Research Activity'. Another challenge was the creation of a common list of terms to be used within HiMAT. After the process of selecting a list of terms that all disciplines agreed upon we organized them in a hierarchical thesaurus. The upper levels of the thesaurus correspond to the classes of the CIDOC CRM. It is expected to be extended as the project develops. Not only in humanities is knowledge often transferred with documents that are not formalized. In order to make this information accessible to all disciplines a content management system was implemented at the start of the project to provide the infrastructure to handle these data like PDFs, MS Word documents, photos, maps or interviews. These documents have to be enriched with metadata based on the CIDOC CRM standard using the terms from our thesaurus. Spatial objects are stored in a database and the metadata and links to the documents from the content management system are transferred to the database and linked to the spatial objects. Figure 10 shows the basic IT architecture with its components and interfaces.

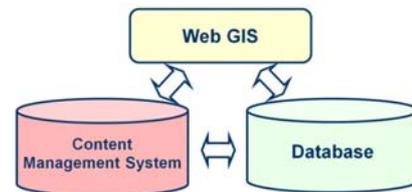


Figure 10. Basic IT architecture

Through this type of data storage all documents related to a spatial object can be retrieved using the GIS interface. In Figure 11 you can see the amount of objects available at a certain archaeological site in the area of Mauken in the form of a pie chart. Each slice of the chart represents a number of objects of a certain kind that are accessible through the GIS interface. Out of the slice of 'Physical Objects' we choose a wooden trough and accessed its 3D model which is an 'Information Object' stored within the Content Management System.

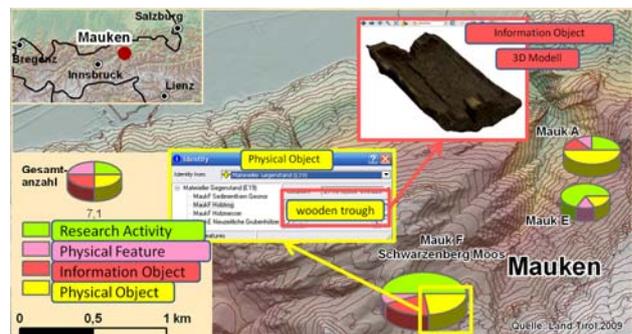


Figure 11. Access to a 3D model of a wooden trough through the GIS interface, © Land Tirol

5. CONCLUSION

The contribution of new technologies like LiDAR to archaeological prospection is very important and offers new opportunities. Also 3D documentation is essential for archaeological fieldwork and GIS has the ability to integrate data from such different disciplines as found in this project. The forthcoming of the entire project can be followed up at the HiMAT website: <http://himat.uibk.ac.at/>

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