3D-Sutras: A web based atlas of laser scanned Buddhist stone inscriptions in China

M. Auer, B. Höfle, S. Lanig, A. Schilling, A. Zipf

University of Heidelberg, Department of Geography, GIScience, Berliner Str. 48,
69120 Heidelberg, Germany
{auer, hoefle, lanig, schilling, zipf}@uni-heidelberg.de

KEY WORDS: Archaeology, Stone Sutras, Spatial Data Infrastructure, 3D-Visualization, Laser Scanning, Web Atlas

ABSTRACT

An important cultural heritage is located in the Chinese providence of Sichuan: about 1000 years ago, Buddhist stone inscriptions have been carved into rock – the Stone Sutras. Archiving the current state of the inscriptions, their transcription and translation into digital assets, their interpretation and provision to the public and scientific community are of a major interest to an interdisciplinary research team of art-historians, geodesists and geographic information scientists. This paper describes the innovative architecture of a Spatial Data Infrastructure (SDI) which combines standardised geospatial OGC Web Services (OWS) with an existing XML document system providing art-historic and text-scientific information. Further a web-based interactive atlas system for analysis and multimedia presentation in 2D and 3D has been realized as a sustainable solution helping art-historians and text-scientists to examine Buddhist stone inscriptions in the future. Innovative aspects comprise in particular the adaptation of the data pre-processing to enable the portrayal of terrestrial laser scan (TLS) data of relevant sites by a Web 3D Service and furthermore the integration of standards across different domains, including GIS analysis functions relevant for historians and archaeologists through several Web Processing Services (WPS).

1. INTRODUCTION

Around thousand years ago, people in the province of Sichuan carved Buddhist texts into the surface of niches and little manmade caves of stone. These texts, the Stone Sutras, are an important cultural heritage of China exhibiting the religious history and the development of Buddhism, its growth and its adaptation into the Chinese culture. More than 80 Sutras with a total number of over 600,000 characters are located at six different sites in the Chinese province of Sichuan (Schmidt et al., 2010).

An interdisciplinary research team of art-historians, geodesists and geographic information scientists developed a sustainable information system for the documentation, interpretation and presentation of the stone scriptures. For the documentation of the texts different Terrestrial Laser Scanning (TLS) technologies have been used to create three-dimensional virtual models of the carved stone surface and the surrounding environment at the archaeological sites (Schmidt et al., 2010). To provide all the necessary information for text-scientific work over a web application, a Spatial Data Infrastructure (SDI) has been developed to complement an existing XML-Document service[1] which stores and provides textual historic information with a spatial component, thus enabling new possibilities of visualisation and analysis. The visualization component is based on standardised geo web services. The interactive 2D map enables to geographically browse the available information about the archaeological inscription sites, the historical infrastructure connecting the sites, time dependent information about the development of the area of power of the Tang Dynasty from 669 to 820 AD and temporal information about the itineraries of Buddhist monks involved with the sutras and the province at the specified time. Additionally a 3D visualization component based on the Web 3D Service[2] (W3DS) is embedded in the system in order to give the user a virtual model derived by

[1] http://exist.sourceforge.net/ - An Open Source Native XML Database

[2] The Web3DService is actually an OGC discussion paper which aims for future standardisation (Schilling & Kolbe, 2010).

high-resolution terrestrial laser scanning and other modelling techniques (e.g. manual 3D reconstruction based on field investigation) enabling a realistic exploration of the archaeological inscription sites.

The presented work is related to a pre-existing project within a similar scope described by Arnold (2008). In this project stone sutras in another province of China (Shandong) had been archived by means of photographs of the stone sutras and their respective rubbings. Rubbings are handmade copies of the inscription surface created by pressing thin wet paper on the surface and carefully dyeing the paper by manual tracing of the stone inscription (Ledderose, 1981). In the project, described in this paper, these types of artefact representations are supplemented by 3D models of the stone sutras derived from TLS data. The archive of the former project has been built up using the TEI format to encode the text transcripts with annotations, comments and references. TEI is a relevant XML standard in the humanities, social sciences and linguistics from the Text Encoding Initiative. This underpins that all parts of the project use open standards to ensure sustainability, flexibility and independence from software providers. TEI is also used to store metadata about the inscriptions and their corresponding archaeological sites. The metadata contains geographic references which enables a geographic visualisation of the data. This already existing database was the base of the system presented here and had to be integrated. Bingenheimer has shown in several projects the potential of using TEI with place references as a source for mapping applications, e.g. in his “Spatio-temporal & image database of Buddhist Temples in Taiwan”[3] or the visualisation of “Biographies of Eminent Monks” (Bingenheimer et al., 2009; Hung et al., 2010). Mainly this is done by an XML transformation from TEI into KML[4] and then visualized with the help of the Google Maps API or Google Earth. This setup works well for its purpose but as in our project the aim was to integrate a greater number of different geographic themes at various scales and the possibility of data management, visualisation and in particular analysis another approach had been chosen – the setup of an standards based SDI. Corns & Shaw (2010) emphasised the importance of developing SDIs with open standards and formats as Service Oriented Architecture (SOA) in the domain of archaeology and cultural heritage where up to now mainly areas related to environment and security are involved. With this approach it is possible to re-use and share the collected geodata with other research projects in a flexible, interoperable and future-oriented way. Within this project we combine for the first time SDI technology not only for the visualization and management of archeological 2D geodata, but also 3D spatial data from different sources, dimensions, scales and qualities and even provide OGC-based spatial analysis functionality for them. To our knowledge all these have been integrated for the first time with open text related standards relevant for the Humanities from the TEI initiative.

The main objective of this contribution is to introduce a new concept for a web-based SDI covering a large diversity of geographic data in terms of spatial and temporal scale, domain, purpose and presentation and even interactive analysis. This new concept uniquely integrates spatial data sources such as from high resolution sub-centimetre 3D laser scanning data via photograph panoramas and map of the caves up to historical boundaries and road network of the Tang Empire. It is aimed at providing a flexible and interoperable atlas for interdisciplinary scientific exploration of stone inscriptions fully based on open standards and web services.

2. ATLAS COMPONENTS

2.1 Overview

From a user’s point of view the Web Atlas consists of five major components: 1) textual description of all inscription sites, 2) inscription catalogue with metadata of the texts, 3) reading tool to explore the inscriptions in different ways, 4) search module to query the inscription database and 5) innovative multimedia map combining geographic 2D/3D visualisation with 360° panoramas, annotated photographic pictures and GIS functionality for measuring, searching and analysing (Fig. 1).

The following sections will describe the conceptual layout of the 2D/3D-Map component which is composed of the 2D-Multimedia-WebGIS and an interactive 3D-Scene-WebViewer.

[3] http://buddhistinformatics.ddbc.edu.tw/taiwanbudgis/

[4] KML – The Keyhole Markup Language is also an OGC Standard since 2008

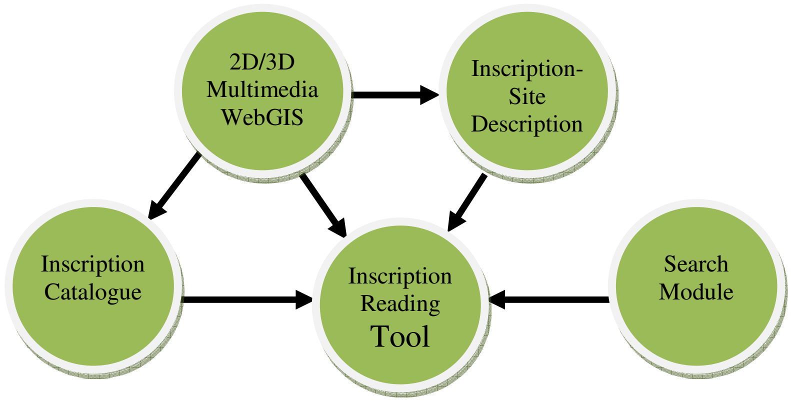

***Figure 1*:** Components of the web-atlas

2.2 2D Multimedia WebGIS

The 2D map component plays a major role in the overall atlas system. It serves as an entry point to the end-user for exploring the theme of Buddhist stone sutras in China but also as an interface for navigation through the website. It shall provide a geographic overview of the broader context of the time when the inscriptions arose. This context is depicted with the help of different selectable base maps, which can be overlaid by diverse themes such as the historical-political development, information on historical infrastructure like the historical road network of Sichuan or the distribution of important monasteries in the time of the Tang Dynasty. A user interface particularly designed for this purpose allows browsing through time where temporal datasets are available.

Besides the function of giving an overview, the 2D map provides detailed information about the different inscription sites. Especially for the largest site "Wofoyuan", where there are 125 cubic caves and niches with texts and sculptures (Lee, 2006), the map offers a site-plan with all caves, their function and status of completion. Additional information to each text-cave is linked in form of 360° flash-panoramas and annotated pictures which show the distribution of the sutra paragraphs on the cave walls.

To complete the atlas functionality of the map application, several tools have been added to provide interactive exploration and analysis possibilities. For example, the user can measure distances and areas or pick coordinates and export them as XML. Additionally there are possibilities to perform GIS analysis on selected datasets. For instance, to analyse the possible routes a monk may have chosen from a monastery to an inscription site, it is possible to make a network analysis and calculate isometric distances on the historic road network. Therefore, the user can define the starting point and mean daily travel distance. The visualised result allows investigation of the patterns and conclusions about how far someone could travel over a certain number of days on the historic routes (Fig. 2).

The 2D map component has been developed using the open source JavaScript library OpenLayers[5] for map display and interactive drawing functions. The user interface, i.e. the collapsible toolpanels, buttons, floating windows, time-sliders etc. is done with the ExtJS [6]library. Some special parts of the user interface like the layertree are taken from the JavaScript library GeoExt[7], which itself uses the classes from ExtJS and Openlayers and extends them. For the analysis function the OpenLayers extension from pyWPS[8] is used in combination with ExtJS-Forms to deal with the user interaction and communication with the underlying pyWPS.

[5] http://openlayers.org/

[6] http://www.sencha.com/

[7] http://www.geoext.org/

[8] http://pywps.wald.intevation.org/

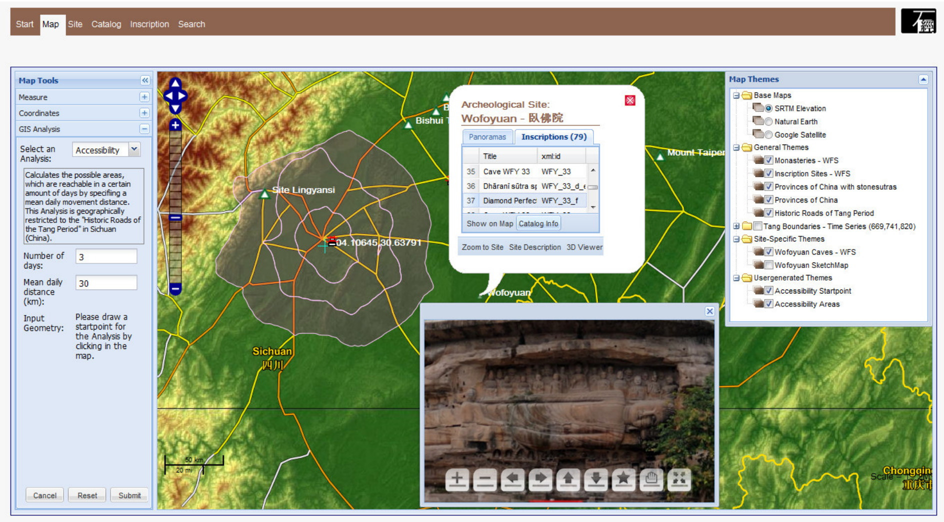

Figure 2: 2D web GIS client with analysis tools, 360° panorama views and info popup

As mentioned above the map also serves as central component for website navigation. The user is linked from a chosen feature to other Atlas parts and can get the inscription site description, an interactive 3D-Scene of the current site or can directly move to the inscription reading section (Fig. 3). The linkage is done via a popup-cloud which appears once an object has been clicked. This popup contains several nested panels with context information. Depending on the information type, the user interface provides different paths to the context information, e.g. the user selects an inscription text of a list and can directly go via the meta information from the catalogue to the reading tool. Such it is possible to perform a spatial query of the inscription texts by searching related items in the map. Other options are e.g. to open an interactive 360° panorama of chosen site or cave or explore an annotated picture of the cave walls with the distribution of the texts and their chapters.

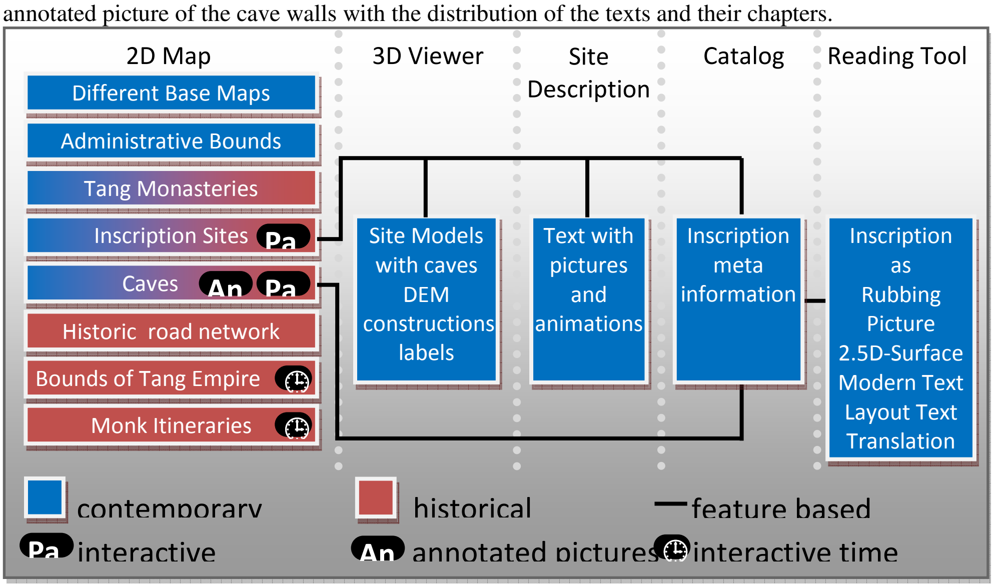

Figure 3**:** Atlas Component content with historical state of the data, additional related media and interactions, feature based linkage between atlas parts

2.3 3D Scene Viewer

Besides the 2D web GIS client, the map component also contains a 3D scene viewer which is embedded in the atlas system. It is derived from the XNavigator[9] application which is used e.g. in the

[9] http://koenigstuhl.geog.uni-heidelberg.de/xnaviwiki/doku.php

OpenStreetMap-3D[10] project (Over et al., 2009) and the city information system Heidelberg-3D[11]. This VR-presentation system provides a realistic view of the inscription sites. It aims at enabling a documentation of the archived actual state of the inscription sites measured by TLS and manual 3D reconstruction based on field investigation (Fig. 4). With the help of the 3D impression the user can develop a mental image of the situation which may be helpful for interpretation of the Buddhist texts, their positions on the site and their possible spatial relationships.

To enhance the usability and consider the different grades of experience of the users, the 3D system provides two modes of navigation. Using the free navigation mode, the user can “fly” to any preferred position in the scene to get certain visual perspectives. By using the guided navigation mode, a less experienced user can quickly get to some predefined viewpoints without the need for 3D mouse or keyboard navigation.

Like in a common 2D web application, the 3D system also provides selectable layers. Therefore, different types of objects like building constructions, vegetation, or labels are grouped together. By turning off visual obstacles or turning on virtual annotations the user can obtain insights and views which would not be possible in the real world.

As mentioned above the 3D scene viewer is based on XNavigator. This software is implemented in Java and can be installed locally, initialised via JavaWebstart or embedded in a website as a Java Applet. The stone sutra web atlas makes use of the latter. The XNavigator Java Applet provides some scripting methods to the browser via an External Authoring Interface (EAI) in a way that all the functions of layer management and navigation control can be done with the help of JavaScript and the graphical user-interfaces from ExtJS.

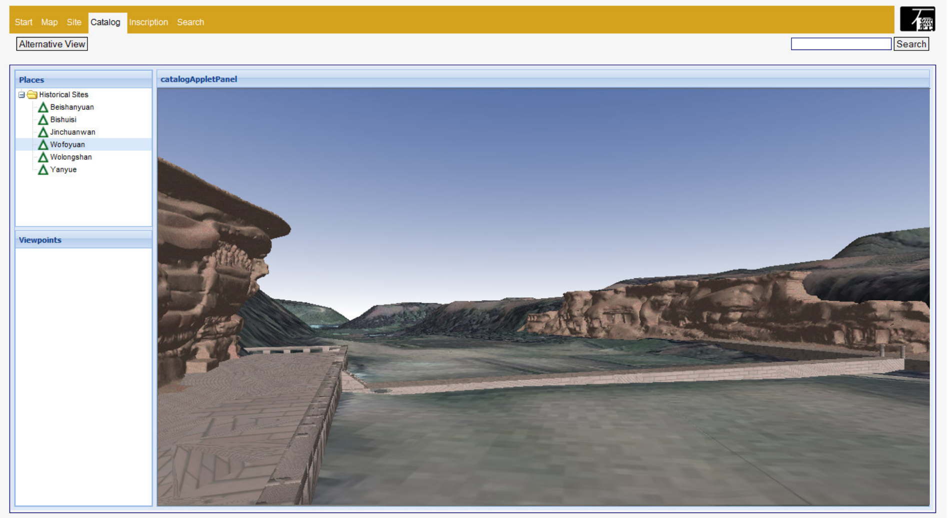

***Figure 4*:** 3D surface Model of stone walls with caves derived from terrestrial laser scanning in the Valley of Wofoyuan

To cope with the huge amount of data of the laser scanning models and the high-performance 3D visualisation, the data is prepared in several Level Of Details (LODs) and afterwards cut into several tiles with different sizes. This approach allows the presentation system to load and display just those parts of the 3D model which are in the field of view. Additionally, only the nearest parts of the model are shown in the highest quality. This procedure optimizes the size and transfer of the data, and therefore the time the user has to wait for the presentation.

10 http://www.osm-3d.org

11 http://www.heidelberg-3d.de/

3. A SUSTAINABLE SPATIAL DATA INFRASTRUCTURE

3.1 Standardised Web Services

An important issue in developing data infrastructures in general and SDIs in particular is to achieve sustainability. This means that in many cases of temporary limited research projects the collected data gets lost when the project is finished because of the absence of the persons who know where the data is, which formats are available etc. To avoid these kinds of problems the spatial data for this Web Atlas is stored in a standardised way and provided by different geo web services. With the use of the standards of the Open Geospatial Consortium (OGC) it is possible to gain interoperability, which means that the data can not only be used by our web application but it can also be accessed with any GIS system supporting OGC standards. This guarantees flexibility in further usage of the data beyond project duration. The web atlas is fed by four different OGC-Web-Services (OWS) which are: 1) WMS for the 2D map presentation, 2) WFS for vector data, 3) WPS for analysis processing and 4) W3DS for the 3D scenes, while the latter one is in the state of an OGC discussion paper on the way to become a new standard (Schilling & Kolbe, 2010).

3.2 An Integrating Data Infrastructure Design

One of the challenges on the service infrastructure level was the integration of an existing XML document database and service used and maintained by the historians into the SDI design. This XML database stores the text-scientific results, transcriptions, catalogue meta-data of the inscriptions, context data about inscription sites and caves and other information. The XML documents about the inscriptions sites, caves and the metadata documents have been supplemented with a spatial component in form of geographic coordinates. This opens up the potential of spatial analysis and visualisation of the stored information. As the XML documents do not make use of geographic standard formats it cannot be distributed by OGC Services directly. To enable a standardised access to the data as well as to support the given structure of the XML database, an automated conversion step has been integrated which pulls new documents, whenever they are available, from the XML database and writes them as Simple Features into a spatially enabled PostgreSQL[12] database with PostGIS extension (Fig. 5). From this source the information can be distributed easily by the different OGC services to the web client or any other GIS client. This approach allows archiving of new XML data by the text-scientists in a familiar way using a desktop XML Editor with database connection and ensures, through the automated update of the PostGIS database, that new features will be automatically shown on the map client and are available for GIS analysis through standardised geodata interfaces. In this case the OGC-WMS and OGC-WFS interface is provided by the opensource software Geoserver. The OGC-WPS has been realised with pyWPS using GRASS-GIS processes behind it while the W3DS is an implementation of the University of Heidelberg (Basanow et al, 2008).

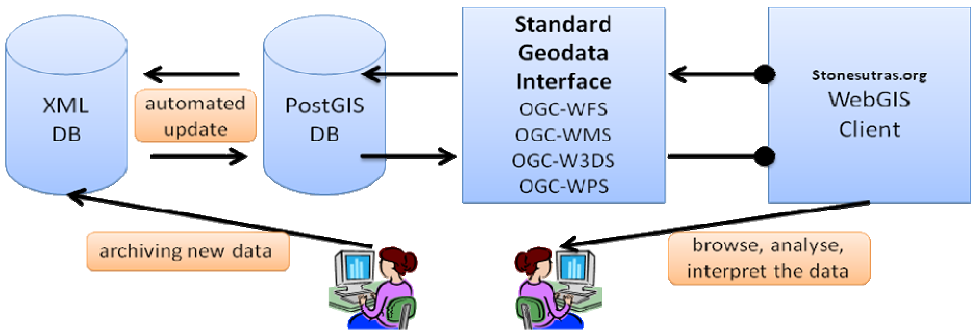

Figure 5**:** Integration of an XML-Document Service into the spatial data infrastructure

4. CONCLUSION

The development of a web atlas for laser-scanned Buddhist stone scriptures in China was a challenging task. The interdisciplinary character of the project demanded a special integrating design

[12] http://www.postgresql.de/

of the data infrastructure to combine a non spatial XML database, which provides texts in standardised format for the humanities (TEI), with the spatial-aware SDI components standardised by the Open Geospatial Consortium (OGC). This could be realised using a PostgreSQL-script regularly checking for updates in the source database. This automated process and the consistent use of OGC-Standards makes the system interoperable with other systems and sustainable beyond the duration of the project. No GIS-experts are needed to add new data with geographic reference to the system. Furthermore, an online system could be launched which enriches a text/image information system with a GIS component combining classic 2D layers with interactive time-browsable layer series, linked multimedia features like 360° panoramas and a 3D visualisation component for a realistic impression of the historically important inscription sites. The OGC WPS specification has been used to provide several analysis functions for geographic data from different scale (China to Millimetre) to the web client. Altogether the Web Atlas with its GIS component gives the users the opportunity to develop new hypotheses by graphically revealing spatial distribution patterns and relationships between the inscriptions and the available related context data.

ACKNOWLEDGEMENTS

This work was funded by the Federal Ministry of Education and Research (BMBF), Germany, in the framework of the project "3D-Sutren".

REFERENCES

Arnold, M., Buddhist Stone Scriptures from Shandong, China.- In: Stuart Dunn, Suzanne Keene, George Mallen, Jonathan Bowen (eds.), EVA London 2008. Conference proceedings, London: The British Computer Society, pp. 1-8, 2008.

Basanow, J., Neis, P., Neubauer, S., Schilling, A. & Zipf, A., Towards 3D Spatial Data Infrastructures (3D-SDI) based on Open Standards - experiences, results and future issues.- In: Oosterom, P., Zlatanova, S., Penninga, F. & Fendel, E. M. (Eds.), Advances in 3D Geoinformation Systems (Lecture Notes in Geoinformation and Cartography),Springer, pp. 65-86, 2008.

Bingenheimer, M., Hung, J.-J., Wiles, S., Markup meets GIS - Visualizing the ‘Biographies of Eminent Buddhist Monks’.- In: Proceedings Information Visualization IV 2009. Edited by E.Banissi et.al. Published by the IEEE Computer Society, DOI: 10.1109/IV.2009.91, pp. 550-554, 2009.

Corns, A.J. & Shaw, R., Cultural Heritage Spatial Data Infrastructures (SDI) – Unlocking the Potential of our Cultural Landscape Data.- 30th EARSeL Symposium 2010 Remote Sensing for Science, Education and Natural and Cultural Heritage, pp. 1-8, 2010, (Conference Manuscript at http://www.conferences.earsel.org/system/uploads/asset/file/48/earsel-symposium-2010_1-01.pdf)

Hung, J.-J., Bingenheimer, M., Wiles, S., Digital Texts and GIS: The interrogation and coordinated visualization of Classical Chinese texts.- In: Proceedings International Conference on Computer Design and Applications ICCDA 2010,vol 1, pp.453-458, 2010.

Ledderose, L., Rubbings in Art History.- In: Walravens, H. (Hrsg.) Catalogue of Chinese Rubbings from Field Museum.- (Fieldiana Anthropology New Series, vol. 3) Field Museum of Natural History, Chicago, USA., pp. XXVIII-XXXVI, 1981.

Lee, S.S., The Buddha’s Words at Cave Temples: Inscribed Scriptures in the Design of Wofoyuan.- In: Ars Orientalis, 36, pp. 36-76, 2006.

Over, M., Schilling, A., Neubauer, S., Lanig, S. & Zipf, A., Virtuelle 3D Stadt- und Landschaftsmodelle auf Basis freier Geodaten.- In: Angewandte Geoinformatik 2009. Beiträge zum 21. AGIT Symposium Salzburg, pp. 608-617, 2009.

Schilling, A. & Kolbe, Th.H., 2010 Draft for Candidate OpenGIS® Web 3D Service Interface Standard.- OGC Discussion Paper, Ref. No. OGC 09-104r1

Schmidt, N., Schütze, R. & Boochs, F., 3D-Sutra - Interactive analysis tool for a web-atlas of scanned sutra inscriptions in china.- In: International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, XXXVIII, 5, 532-537, 2010.