07 | WEB-BASED SPATIAL DATA MANAGEMENT

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OSCAR – A Web-based Multimedia Communication System for Interdisciplinary Settlement Research: Spatial & Temporal Data Organization, Manipulation & Visualization

Abstract: In the area of settlement research, scholars including archaeologists, historical geographers and historians discuss many layers of information, spatial as well as non-spatial. At present, no digital system allows the participants of such projects to satisfactorily combine the different contents and materials to enable them to discuss and document their working process digitally. At the Anhalt University of Applied Sciences in Dessau, the German Federal Ministry of Education and Research (BMBF) has funded a research project to address this topic. The project phases include the development of a methodology of cooperation, programming and the initial use of such a communication system at Marsleben, near Quedlinburg, Germany, a UNESCO World Heritage Site. It is one of the main aims of this project, dubbed OSCAR (Open Settlement Communication and Research Platform), to support researchers in evolving and verifying their hypotheses on deserted settlements, and to partially reconstruct these settlements.

Introduction

In settlement research, diverse research disciplines work on common questions about the development of settlements from the time of their construction until the present, or in some cases until the partial or complete destruction of a settlement. In this complex process, the main concern is putting the puzzle pieces of both spatial and non-spatial information together to connect the available data and materials. Whereas some researchers already do a great deal of work digitally, others use predominantly analogue tools, such as type-writers. Most scholars agree however, that only through extensive cooperation it is possible to make statements about the history of settlements or about the cultural landscape in general. This demand inevitably leads to a new kind of work and cooperation that cannot be carried out without digital means, as the researchers do not normally work in the same place.

Applied software systems currently in use are usually extremely complex and allow only isolated examination of single types of data. At the same time, many functions of these systems are superfluous for work in settlement research. It is, for example, not possible with current software to document the work continuously, to compare different data in different formats over time, or to communicate on-going research and final results to the public. The scientific community is in need of a system that fulfils these demands, among other, more concrete necessities. This article presents the current state of the OSCAR research project (Open Settlement Communication and Research). The goal of the OSCAR system is to create a working system that is easy to use while at the same time adequately meeting the demands of settlement research by linking tools and work processes. These standards will then be put into an actual project as a prototype in a digital system and tested.

The problems in current research methods will be brought to light, improving their implementation by researchers, while also making the documented project findings available in the long term to other projects. The usefulness of those tools currently in use will be evaluated and, where necessary, streamlined and reworked to be interlinked in order to allow participating researchers to work with the right tool for the right job. Existing programs are not meant to be completely replaced; rather, overlapping functions that have arisen due to the different demands of the work are to be complemented. It is for this purpose that the OSCAR system has been developed. With OSCAR serving as the foundation, it is possible to more effectively use tools cooperatively for a broad spectrum of research which means unnecessary functions are reduced and research gaps are filled.

Web-based Communication

The OSCAR software is a system to be used by those working interdisciplinarily in the field of settlement research. Geographers, historians and archaeologists are not only able to share their data, but can also interpret and discuss all the collected data to generate research information, thereby achieving a synergetic effect. First, the analog working processes are merged in order to find an overlap that can help solve some of the problems of cooperative work in settlement research. Then, digital methods are evaluated and combined to create a practical, powerful tool for researchers. Considering how widely-spread potential team members may be located, a web-based system was designed.

Client-Server Characteristics

In the case of OSCAR research, a software web-based system means the use of the TCP/IP protocol, the standard in transferring information in the World Wide Web. The protocol is implemented in a complete, newly-developed application capable of communicating beyond the boundaries of local networks via the four model layers: application, transport, internet and network.

The system consists of three components: client, server and export systems. The most important part from the user's point of view is the client, which is mainly used by the participating researchers. Selected data can be integrated and manipulated. Each research project member can generate information such as statements or hypotheses using the client. Furthermore, the client offers functions such as 2D and 3D visualizations, spatial analysis or data export. Beyond these obvious tasks, the system allows intelligent buffering. This means that all outgoing queries to the server and the results received are stored. When the same query is sent twice with the same result, the stored result on the client system is used. This feature makes possible real-time visualizations and large volumes of data. The buffering algorithm furthermore allows data to be preloaded while the application is loading. Once the software is running, work can start immediately. Another client feature is error handling which helps avoid crashes and gives some transparency to the user when problems occur. Summarizing all these features, this component can be called a "fat client" because of the large variety of functions and consequently the computing power of the processes generated.

The central component, necessary for running the client software, is the OSCAR server, based on Microsoft SQL 2005 Express Edition. This SQL server, in tandem with our newly-designed operating logic, forms the so-called "thin server". This expression is used because the processes running are not very CPU intensive. The main functions such as data storage and querying are fulfilled by the SQL server. The limited data volume that can be saved means an additional file system is required to save large files, usually in the "BLOB" (Binary Large Object) format in the database, e.g. aerial photos, maps, digital terrain models, and pictures. The database allows nearly all queries - only spatial analysis cannot implemented directly. Those queries are taken care of by an individual index and storage format within the database. In the database, the operating logic is important for the correct functioning of the whole system. Several features are included in the data base. First, user permissions administration is necessary. As with the client, there is also error handling for the OSCAR server. A command queue is necessary to deal with the many incoming queries. This means they are sorted, put in the appropriate stack and finally, depending on the free resources of the server, processed and the response sent. The server is able to cope with queries asynchronously and buffer them as necessary. The queries are handled by running the implemented methods on the server side. Every type of SQL query has its own method coded in ".NET" with implicit further instructions.

The third component handles the export and presentation aspects of the system. It consists of the OSCAR terminal application on another computer system, and a Macromedia Flash program capable of including content generated dynamically with the OSCAR software. Additionally, the research contents can also be passed semi-automatically to a web server if it is used for the terminal application. This means that timed events can trigger transfer processes, sending the contents chosen by the researcher to the system. The OSCAR software enables a near-complete working process from uploading selected data, to interpreting and working with different media, to the presentation and the release of selected research information.

Working with Interconnected Modules

Looking more closely at the system, there is a second structure of OSCAR supporting the main application. The modules can be further subdivided into the import, working and export levels.

It is up to the user to choose a suitable module to work with, depending on the tasks to be carried out. The OSCAR software has been developed so that it is easy for anyone with a basic knowledge of Microsoft Windows, Microsoft Office, imaging, CAD, and GIS applications to fully use OSCAR.

The first level is the File/Source module, allowing the import of a variety of file formats. If a format is not supported, the user is able to use screenshots or text copied to the clipboard. The second level is a merging of the modules for creating and discussing information - the main working area. The user can variously write scientific essays, use charts for statistics or analyze and annotate images. These duties are assigned to Text, Table and Picture OSCAR. For spatial information, the Map and Model modules can be used, for example, for referencing maps, using map layers, and creating 3D objects including metadata. The two OSCAR modules work in 2.5D and 3D plus historic and research time (see below). The last level consists of the export module relevant for research releases such as papers or digital data exports: e.g. for the computer terminal application, a web site, or simply for data exchange. Viewing and working only with separate functionalities does not mean the information created or edited is limited to that particular module. Users can combine information or use it as a source or proof for other hypotheses. It is also essential that every member of the research team is able to view research results from other scientists to a greater or lesser extent. Communication and cooperation can take place either indirectly or directly by using comments or sending messages to a certain user. The researcher has the opportunity to use the search, links, comments, sources, glossary or the instant messaging client to communicate and work comprehensively.

Working connectedly also means data interchange. The software can integrate texts such as ASCII or RTF (Rich Text Format) text files. Adobe PDF is also supported but only for reading and creating new documents; editing is not possible. Pictures in JPEG, TIFF, BMP, GIF and PNG format can be used. Maps or plans in the ESRI Shape file format (SHP) are supported. Dereference pictures such as maps or orthophotos can also be imported by the OSCAR software. The output formats are text, images or 3D panoramas and 3D isometrics for the OSCAR terminal application. Considering the large collection of data and information in the software, a project-spanning interchange format would also be helpful. The International Committee for Documentation of the International Council of Museums (ICOM-CIDOC) provides a Conceptual Reference Model (CRM), which has already become an ISO standard. This model describes how any cultural heritage data can be mapped into it using semantic relations. Interchanging information published by museums, archives and libraries are the prime examples of profiting from CRM. In the field of settlement archaeology and excavations, the OSCAR project is written in a CIDOC CRM compliant format so that it is possible to ensure data exchange with other OSCAR software users or even other projects. An import-export format is planned, but will not be implemented in the first release of the software. Applied to the CRM, the database includes some special entities to ensure compatibility. The classes are “event” with “beginning” and “end of existence” or with “appellation” including “object identifier”, “place appellation” (spatial coordinates, place name). Other examples are the entities “time-span”, “place” or “dimension”.

There are, however, some drawbacks in using CIDOC CRM (Sugimoto 2006). The conceptual reference model has only been assigned to a few practical projects, with the majority in theoretical projects. Especially for the field of archaeology, it has not been tested enough. In general, the model is more suitable for museum communities exchanging cultural data. Another common problem is the interpretation of the CRM because of its implicit character. Having the same aim to map the same data, different users could come to different results in modeling. This, combined with complex archaeological mapping data, could lead to some chaos. Going into further detail, the user would have problems bringing geographical data, especially in the third dimension, into a CIDOC CRM compliant format. The Centre of Archaeology of English Heritage experienced such a complication when trying to use the model. Because of the lack of properties for geographical information, they had to resort to other properties normally not used for those data. In short, there are some disadvantages and unknown factors which lead us to hesitate to implement CRM in the OSCAR software.

Spatial Aspects of OSCAR

The fact that pictures, maps, orthophotos, and 3D models as well as digital terrain models will be used requires the implementation of 2D and 3D or summarized spatial data. Spatial models are essential for the virtual working process and subsequent digital representation. The different types of data and usage in the OSCAR system make particular demands on the OSCAR database model and program code.

3D Objects – Creation, Indexing and Analysis

3D objects generated hypothetically by the researcher play an import role in virtual modeling. To make this process accessible to non-experts, the OSCAR software has implemented a parametric object generation technology (Koppers 2002).

This method was chosen because of its simple use, the low volume of data, and fast transfer process. Another advantage is the blurring of facts and time so there is no need for highly detailed models. More generalized objects with a good selection of editable parameters are more practical and support essential settlement research as a science of interregional considerations without using overly detailed information that is hypothetical by nature. The OSCAR user can choose between four types of objects: vegetation, development, and terrain surface and terrain paths. All structures can be created with only a few parameters, some already preset by the OSCAR project administrator and the rest adjusted by the individual researcher. Vegetation includes trees, bushes, or other plants in simple 3D. Every plant is pictured as a mapped image texture with pixel transparencies on a rectangular face. Properties or parameters that can be changed are the minimum distances between the single plants or the minimum and maximum height in order to give a realistic area of vegetation. Textures for alpha, bump map and color, with a given size in meters can also be changed. Structures or buildings (Mueller 2007) are described by their height, roof type and roof slope, and textures for the walls and roof. All textures are further divided into alpha, bump map and color. Simple textures or terrain surface are another creatable object type. These can be used to illustrate meadows or fields, for example. This object type is determined by the three textures and a blending factor for the realistic and gradual blend between different areas. The last object type is complex textures or terrain paths. Here, in addition to the three textures, the width parameter can be adjusted.

All four types of objects have several predefined subtypes for different objects. For instance, the development object can have as subtypes pit houses, medieval wooden framework houses, walls or towers. The user is able to choose from a predefined object library and can change some enabled parameters. Administratively, this library can be enlarged or replaced, depending on the requirements of each research project. Apart from the creation of objects, the question of spatial organization arises. Popular indexes are the Quad tree in 2D and the Octree (Doctor / Torborg 1981) in 3D with bounding rectangles and boxes. They separate the model's space in every level into four equal regions. Regions containing objects are continuously divided while the empty regions remain undivided. This algorithm stops when every geometric object is in only one single region. The OSCAR software uses spatial indexing via bounding spheres (Garcia / Sappa / Basanez 1999). It is a special bounding volume defined by a centre and a radius. The central point of the bounding volume is the centre of the object to be covered. The origins of this algorithm are game engines with collision detection. Indexing with bounding spheres follows a bottom-up strategy resulting in an n-array tree.

Searching is done in a recursive way. Spatial analyses necessary for the system include querying areas or bounding volumes, some distance calculation and whether a point is on a plane. When searching by envelope with coordinates, a top down algorithm is used. The tree is passed node by node, level by level. If a node contains the region of coordinates, the further steps concentrate on this branch and the search algorithm goes deeper from this node as starting point. After having found the right node, the geometry involved can be transferred from the SQL database onto the OSCAR server. The spatial index for the particular model is always stored on the central database and a copy transferred to the client. When the index is changed, e.g. by inserting a new geometric object into the scene or into the model, it is created twice and the result passed to the database. The general advantage of this procedure is the ".NET" optimized algorithm. The 3D objects as parametric bounding spheres are put into an array and then the index is built as described above. Every object is taken only once and not paired by statistical parameters as in other procedures. This speed advantage in the creation of the spatial index is caused by the need for real-time presentation of the scene. Distance calculations between bounding spheres and planes or points are also made quickly, taking into account the discrete character of the index. This also enables fast visibility detection because when the viewing angle of the scene is increased, the distances of objects relative to the former view have to be calculated quickly. Another advantage is the simple data structure of the bounding sphere in comparison to Octrees: a sphere is defined by two parameters while a box used by an Octree (Saona-Vazquez / Navazo / Brunet 1999) needs 8 points or 6 planes. Therefore a box needs more operations than a point does. The simplicity of the bounding sphere means the data volume to be transferred is optimized for a client-server scenario. The index and the 3D objects are only connected by an index number. Geometry and the spatial index are not transferred together.

History and Hypothesis as 4th and 5th Dimensions

By adding two additional dimensions to 3D digital terrain models, they gain the historic context necessary for research purposes. Both dimensions are formed by time. Extending the storage model of database reveals the need for saving changes to do with time and different hypotheses. Database-time issues are dealt with by several different theoretical models. The OSCAR software makes use of two of them, combining the Snapshot and Update models (Berka 2000). The term "Snapshot" describes the condition or shape of a model at a specific point in time: all objects created or changed are stored. "Update" entails storing only the changes between different points of time. The OSCAR software stores, creates and changes features according to the Snapshot model. An argument for using the Update model is that objects valid for different settlement models which also have the same time relation are not stored twice. If only a time relation changes, but the object shape remains the same, the object is not stored twice, only the new date is given and a new hypothesis based on the former with the new information is created. The Update model used is based on the so-called "topology of time". This concept of time and space allocated to spatial objects stores them with a given validity. Defined by two events in time an object version or state is assigned. Using a time slice, all objects valid for this point in time are considered. The OSCAR storage model saves different attributes, all belonging to the main category of geometric objects. Every single instance has a spatial reference, three coordinates, a temporal relation for historic and research context, the indexing parameters, and features classifying the object. Features are the object category, the name, and an annotation.

All attributes form an object that is situated in place, time and semantic context. The so-called "4th and 5th dimensions" are necessary for scientific hypothesis *(Fig. 1)*. In the OSCAR software, a hypothesis is defined as the condition of a (whole or partial) settlement model at a specific time of research. This settlement interpretation by an individual researcher with temporal relation is described by parameters for the different hypothesis objects: the position in 2.5D or 3D, the shape, the condition in an indirect way, the usage, function or appellation of the hypothesis geometry, and the time. Temporal aspects are history and time of research. Historic issues are defined using a time-span with tolerances for start and end. This time-settlement relation of the scientist is the "4th dimension". An example would be to give a church a date of existence from 1530±1 year to 1570±20 years.

The research aspect forms the "5th dimension". It is simply the date when the scholar releases a hypothesis. Bringing all the facts together, the user of the OSCAR software can create or change models and give them a time span while the point in time when the hypothesis was made is automatically stored. A released hypothesis of the settlement model can be viewed by all other research team members. Models that are only internally stored can be seen, but it is not possible to relate another

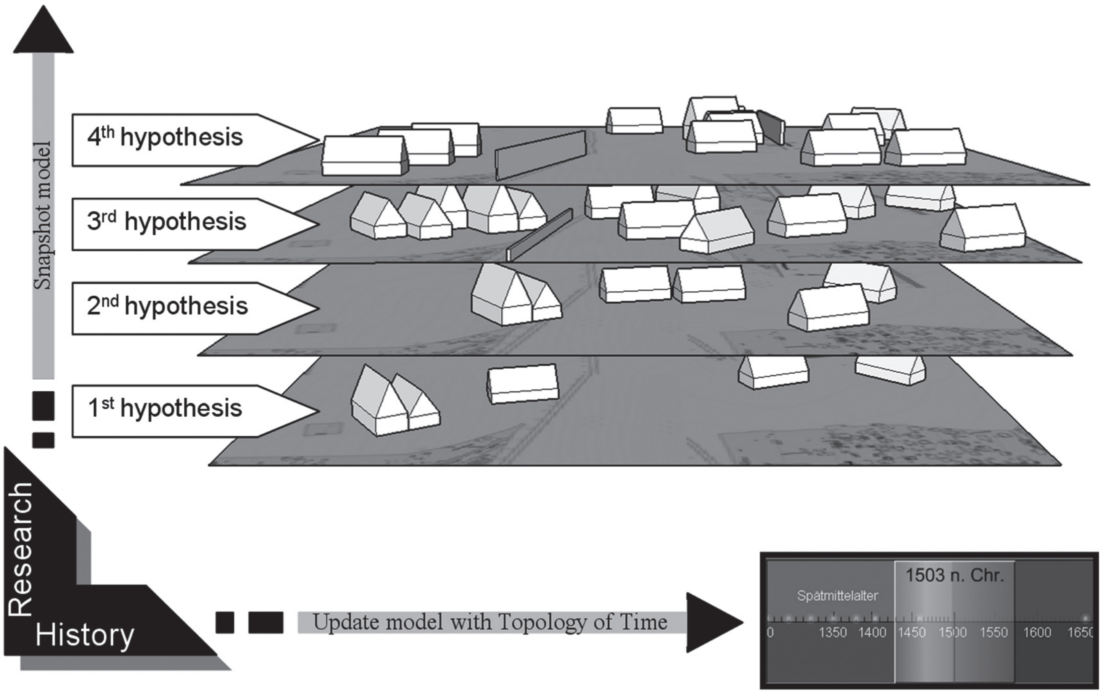

Fig. 1. 4th and 5th dimension representation concept in OSCAR.

model to these, whereas released hypothesis can be linked or quoted.

This mechanism gives every member of this team the ability to profit from other research information so that discussions and the members' own work are better linked to a broader knowledge base. Misleading interpretations can be discovered earlier and the digital working process is improved.

Conclusion

In this article, the status of the current research project OSCAR with its emphasis on spatial organization and working of data was presented. The already existing and planned program technology and the relationship and main focus from the technical perspective were explained. As the "classic" component for data processing and administrating, Microsoft SQL databank has been used. In order to meet the special demands for communicating different levels of information, a system for hypotheses and time in combination with program overlapping functions (linking different media) was developed. In the area of 3D presentation, parametric object generation and the "Bounding Sphere" approach are used. This work phase is based on the extensive preparation work of surveys and analyses of requirements. This was carried out with the help of expert and lay people opinion polls to determine the real needs in the area of cooperation in settlement research. Thanks to the cooperation of many experts when interviewed and in responding to various surveys in the areas of content, technology and tools, a solid basis for the current phase of work could be established. The main aspect lies in the unique way of connecting all components of the system to a newly structured general system for the researcher's working process.

By the end of 2007, the programming phase should be completed so that a working model will exist. This will then be used for the project of the settlement in Marsleben. The results of this will be used to further improve the system. At the same time, the first reconstruction of Marsleben should be completed by September, 2007. At the end of the project, a digital communications tool with an integrated presentation system should exist that can be used in other settlement research projects and which will continually be further developed and expanded.

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Illustration Credits

Fig. 1. 4th and 5th dimension representation concept in OSCAR, created by the authors.

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