

# Design and Implementation of a Web-Based 3D Campus Information System for the University of Karlsruhe

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**Resumo:** Este artigo descreve o design e implementação de um Sistema de Informações 3D para o Campus da Universidade de Karlsruhe, baseada na Web. Através do uso de tecnologias disponíveis na Internet, como Java, VRML, RMI e JDBC foi implementado um sistema distribuído cliente/servidor, o qual é acessível através da Internet. Os objetos do sistema de informações - inclusive edifícios, ruas, etc. - são modelados em 3D e podem ser explorados em 3D em tempo real.

**Palavras-chave:** sistema de informações, modelagem 3D, modelagem de dados, VRML, interface 3D com o usuário

**Abstract:** This paper describes the design and implementation of the Web-based 3D Campus Information System for the Karlsruhe University. Using Internet technologies like Java, VRML, RMI and JDBC we have implemented a distributed client/server system which is accessible throughout the whole Internet. The objects of the information system - including buildings, streets, etc. - are modelled in 3D and can be explored in 3D in real-time.

**Keywords:** information system, 3D modelling, data modelling, VRML, 3D user interface

## 1 Motivation

Usually universities are complex organisms with a wide variety of facilities. The University of Karlsruhe for example has more than 160 buildings and more than 300 institutions all over the university campus. Hence it would be helpful for the university administration, the students, visitors and the people who work there to have an information system. Nevertheless there is another important reason to establish such a system: globalisation forces every university to face the fact that it has to compete with other universities world-wide both for students and resources. Consequently it is vital for every university to present itself in a proper way.

These reasons lead to the development of a Web-based 3D information system where the information - including geometric and descriptive data - are accessible in the World-Wide-Web by a standard Web-browser as user front end. The 3D geometry, which includes models of buildings, streets, etc., is displayed by a VRML-viewer inside the Web-browser whereas the Virtual Reality Modeling Language (ISO, 1997) is the Internet standard for describing 3D geometry and its behaviour.

As there are two different types of interactive queries inside a geo-information-system, we have implemented exactly these two types: (a) getting information about selected objects and (b) searching for objects which satisfy user defined search criterions. So if you want to get information about specific objects then every object should have one unique identifier throughout the system. This problem occurs in the 3D scene and in the underlying DBMS which manages all the objects. Therefore the objects have to be modelled in an object-oriented way which will be described in the 3<sup>rd</sup> chapter. The following chapter (2<sup>nd</sup> chapter) will give an overview about the architecture of the system.

## 2. System Architecture

The World-Wide-Web is not only a great source of information, it is also integrating standards of the underlying delivery mechanism (Rohrer, 1997). In this field the development of new technologies like Java and VRML are supporting distributed client/server applications for the Web. The advantage of the Web is also the interaction and navigation style which lets the user following associated hyperlinks and drills down to underlying information by a intuitive point-and-click paradigm (Landes, 1998). This easy to use user interface principles and the established new protocols had lead to the implementation of the 3D campus information system for the Karlsruhe University on the base of Web technologies.

Figure 1 shows the components of the system.

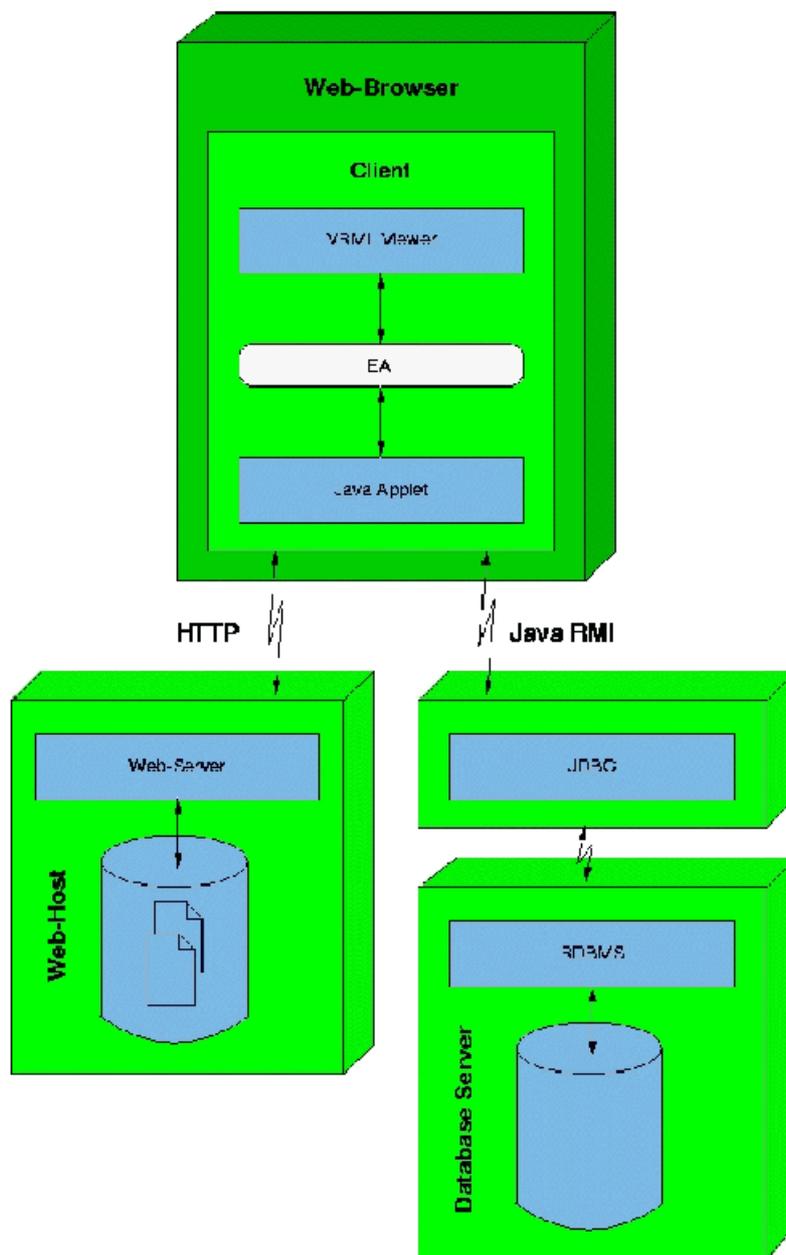


Fig. 1: System Architecture

On the top of this figure one can see the client which is running in a standard Web-browser. To use the system the only requirements are: (a) having access to the Internet and (b) a Java-compatible Web-browser with a VRML-viewer included (like Netscapes Communicator). The user simply has to load the HTML-page of the Campus System from our Web-server via HTTP (see lower left part of Figure 1). In this HTML-page the VRML-viewer and the Java-Applet of the Campus System are embedded. Both applications are now running inside the Web-browser and are communicating with each other by the External Authoring Interface (Marrin, 1997).

By the use of this interface we are able to

- control the content of the 3D scene in the VRML-viewer (by adding and deleting objects)
- receive events from object inside the scene
- animate objects from outside.

This is why we can offer an object-browser (see Figure 2) where the user is able to select the objects of interest and the desired representation type for every single object.

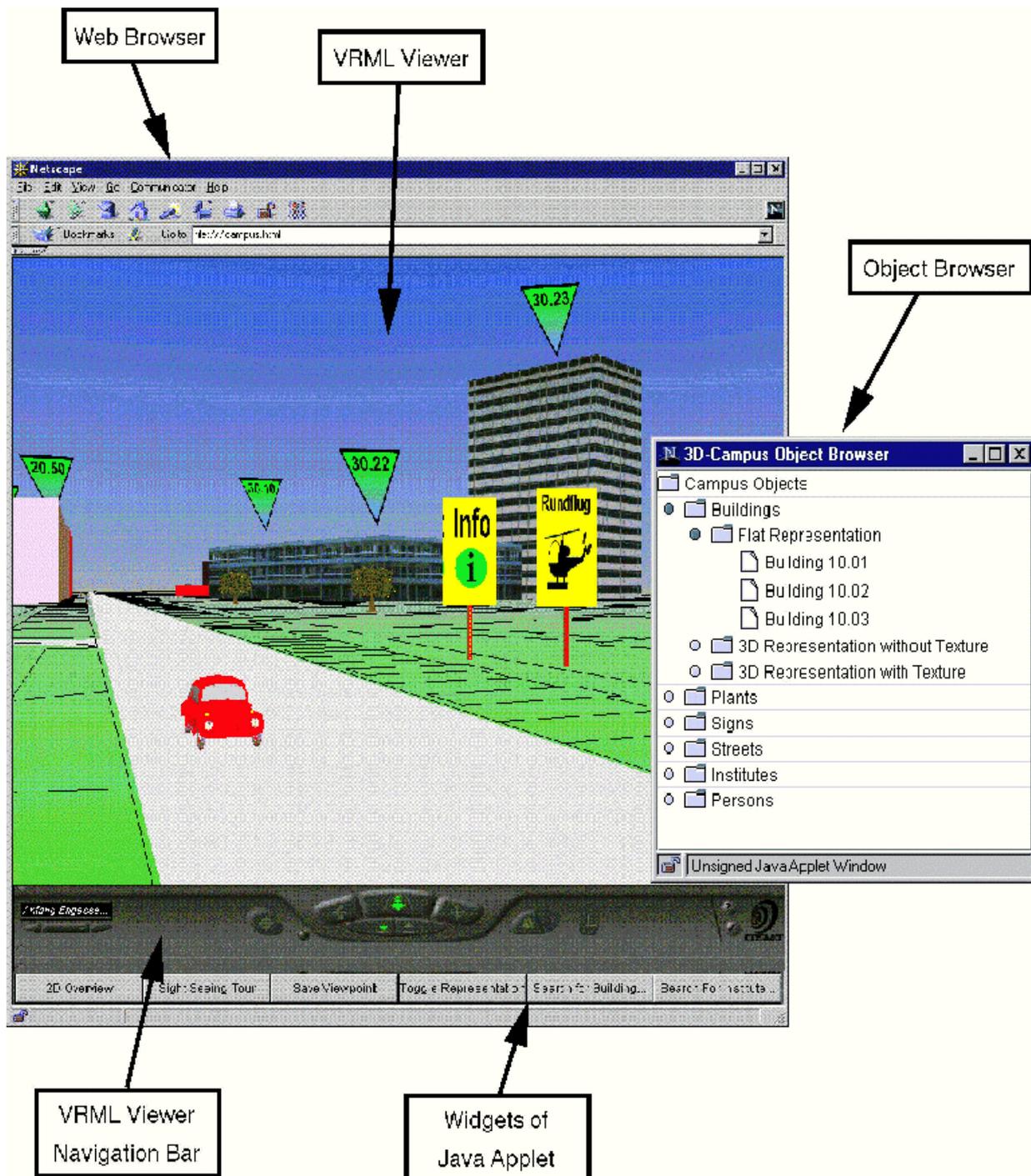


Fig. 2: 3D user interface with object browser

Therefore every geometric object has to be available on the Web-host as a VRML-file. To manage all this different files belonging to the objects and the attributes for the objects a database management system is running on a special database server (see lower right part of Figure 1). Here the Java-Applet plays the central part: it is not only communicating with the VRML-scene but it is also communicating with the DBMS. It is implemented in a three-tier-architecture, where the Applet is not connected directly to the DBMS. Via Java's RMI (Gosling, 1998) the Applet is querying a middleware layer, which is communicating in a secure environment via JDBC (Hamilton, 1997) with the database server. With this approach we are able to use different DBMSs - which can be distributed across the Internet - without changing the whole system.

### 3. Data Models

The information system deals with different classes of objects. To handle all this different kind of objects it is important to have a common approach. This common approach is object-oriented and collects similar objects in classes. In such a class objects have the same set of attributes and the same set of operations. The attributes describe the data respectively the properties of the object whereas the operations are defining the functionality of the object. The attributes of the objects are stored in a data base management system (DBMS). Therefore every class has to offer a set of operations for the access of this data. The access to the DBMS is handled by the system in a three-tier-architecture described in chapter 2.

Besides of the differences among the classes, every class has to offer the same basic functionality. This is why we have created an abstract super class. The super class of our system is called *Campus\_Objects*. All the other classes of objects are derived from this class. The class diagram which is modelled by using the Unified Modeling Language (Rumbaugh, 1998), shows the structure of our system and the relations among the classes (see Figure 3).

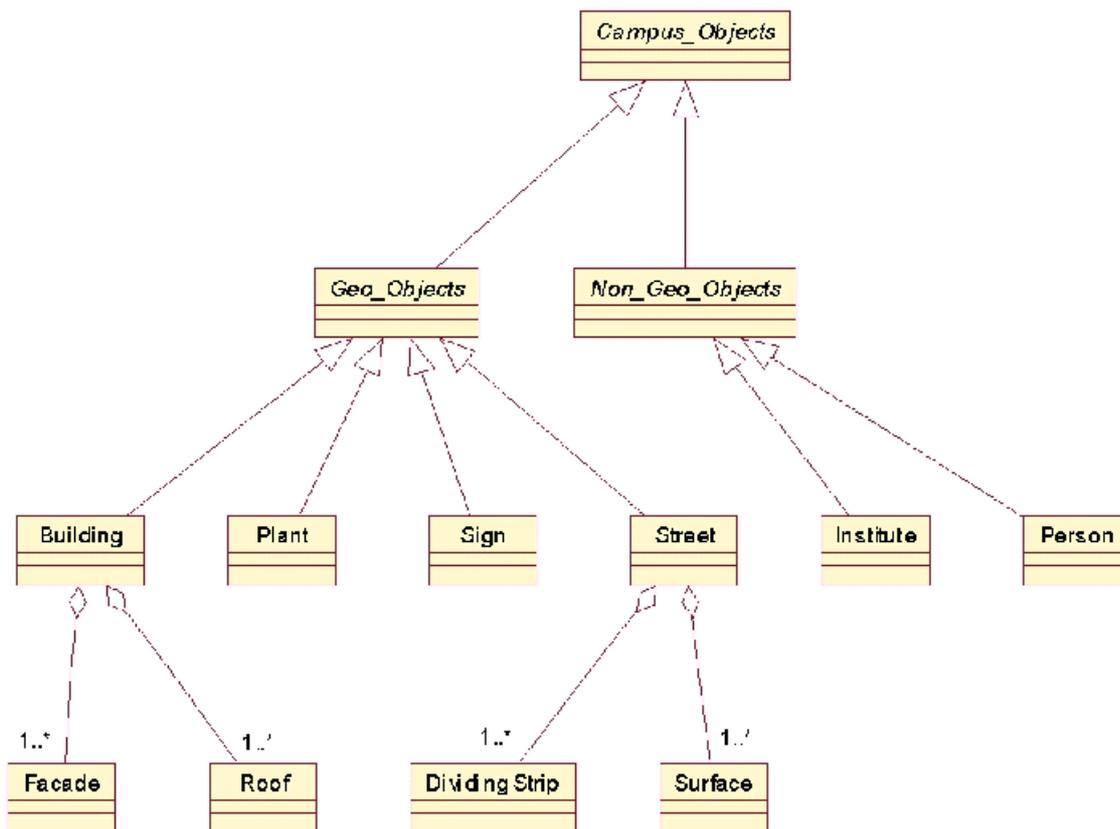


Fig. 3: Class diagram

The derived classes can be subdivided into two other abstract classes: one for objects with no geometric representation (see the *Non\_Geo\_Objects* in the class diagram) and one for objects with a geometric representation (*Geo\_Objects*).

#### 3.1 Non-geometric objects

Representatives for this class of objects are the institutes of the University and the persons working in the University. In the class diagram (see Figure 3) this is the right branch including "Person"-class and "Institute"-class. These classes deal with all the specific attributes. For the "Person"-class the attributes are: name, title, function, telephone number, etc. and for the "Institute"-class it is the name, address and etc. Special methods of these classes retrieve the values of the attributes from the underlying DBMS.

### 3.2 Geometric objects

Representatives for this class of objects are buildings, streets and plants. These objects treat their descriptive data like non-geometric objects. In addition to this descriptive data all classes derived from *Geo\_Objects* have also special attributes reflecting their geo-references, like bounding box, centre, etc. Besides of these data they also manage references to their geometric data. These references are organised in lists where the different geometric parts of the objects are handled. This is necessary because most of the geometric objects consist of different parts. For example a building is implemented as an aggregate and has different parts. These parts are façades and roof (see the lower left branch in the class diagram, Figure 3).

The streets are also compositions and have a part structure represented by a dividing strip and the street surface.

Geometric objects have three lists of that kind. Every single list handles one representation type. The representation types are:

- Flat representation
- 3D representation without texture
- 3D representation with texture

This means that a geometric object is represented by three different models in the system. These models stand for the different levels in complexity of the resulting 3D scene. With this approach the user of the information system is able to choose the adequate model. For a quick overview of the whole campus the flat representation or the 3D representation without texture is the best choice. But for photo-realistic impressions one can choose the more sophisticated models including texture.

## 4. Geometric Models

The 3D campus information system for the University of Karlsruhe includes 3D models of real-world objects. In addition to the models of these "physical" objects we also include geometric representations of abstract data in the scene by using real-world metaphors like signs, etc. In terms of comprehension, navigation and exploration it is necessary to give a significant aid to the user. With the help of such artificial signs we can easily provide the user with the names of the buildings or the name of the streets within the scene. In addition to this advantage these signs may be used as widgets which can be activated by the user to establish a link to information about the specific object.

### 4.1 Real-World Objects

We consider the area of the university campus as flat because the city of Karlsruhe is located in the Upper Rhine Valley. This is why we are digitising the contours of the streets, footpaths, parking places directly from an existing map of the campus.

From this map we also get the ground plans of the approximately 160 buildings. The height of each building is gained from the analysis of aerial images and/or from the digital elevation model of a laser scanner flight. The solid 3D models of the buildings are created by an orthogonal projection of the ground plan using the height of the building as the distance of the projection. After some refinements in a CAD system the models are converted to VRML. In VRML textures are mapped on the façades of the buildings. These textures are gained from images of the buildings after a projective transformation (Landes 1996). The roofs of the buildings are generated automatically by the four corner points and the roof type as input parameter. This workflow guarantees the step by step acquisition of the three desired representation types for every building.

### 4.2 Virtual Objects

In terms of comprehending a 3D scene it should be extended by geometric objects which have no physical equivalence in the real-world scene. The instances of this class of objects are signs, blackboard, etc. Most of these items are generated in a special 3D modeller which are able to generate VRML code. These geometric elements are integrated into the VRML scene. Examples of these signs are building numbers levitating above the corresponding buildings, or several signs next to the street signs which can be activated to perform actions like a sightseeing tour.

## 5. Conclusion

Since the early 90s there have been big changes within the Internet. It has changed from a communication system to a global information system. This development has been initiated by the introduction of World-Wide-Web (WWW) technologies, which provide an easy access for everybody to the variety of multimedia resources. Especially the integration of new standards in programming (Java) and 3D visualisation (VRML) are leading to a new type of distributed client/server applications for the WWW.

These features had a vital influence on the design and implementation of the 3D-Campus-Information-System of the Karlsruhe University. At the moment the Federal University of Santa Catarina in Florianópolis, Brazil, is also in an acquisition process of gaining data for a Campus Information System. The assumption of activities is embedded in the PROBAL<sup>1</sup> project "*Joint development of Campus Information Systems for the universities of Karlsruhe (Germany) and Florianópolis (Brazil)*".

In addition to the joint development mentioned above there is another co-operation project between Karlsruhe and Florianópolis concerning the acquisition of urban 3D data in Laguna, Brazil. This project, "*Architectural Photogrammetry and Digital Image Processing for the Acquisition and Documentation of a Brazilian Town Ensemble*"<sup>2</sup>, provided us with substantial know-how of great impact on our work with the Campus Information System (Landes, 1996; Renuncio, 1998, Martins 1998; Westphal 1998).

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<sup>1</sup> Funded by DAAD (Germany) and CNPq (Brazil).

<sup>2</sup> Funded by DFG/GTZ (Germany) and CNPq (Brazil).

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