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Method to Link Data in 3D Environment

Abstract: The aim of this work is to discuss a novel method to access information through an interactive 3D model that has a connection to places in the real world. This information can be textual (historical, artistic and architectural), photographic (textures, views, plans) and spatial (3D data). The geographical aspects introduce some complexities, but they allow a common and uniform access to the data. The proposed method links information to extended zones of the 3D space and can be used with 3D models that are not subdivided in logical zones, like meshes generated by 3D scanners. The use of an intuitive ranking function lets one find the relevant information by just “looking around”. The possibility to acquire, process and analyse geographic information without the need for installing proprietary GIS software or having deep GIS knowledge has been taken into account in this work, so as to make information more accessible to a larger audience. The method is applied on two case studies: the Napoleone Square in Lucca (Italy) and the crypt of the Cathedral of St. Servatius in Quedlinburg (Sachsen-Anhalt, Germany). In the case in Quedlinburg we wanted to integrate the data produced in the last seven years, during an important investigation and conservation program, that has used extensively GIS format as documentation tool.

A 3D Interface to Interact with Cultural Assets Data

Although there are several ways to efficiently present and query data related to cultural assets available nowadays, such as 2D-GIS applications which are used more frequently, novel methods (possibly web based) to deal with this kind of data are still desirable and need to be further developed.

In recent years some institutions have experimented with communication initiatives that use 3D representation as an alternative or a complement to hypertextual communication. In particular, 3D models are increasingly used for presentations related to Cultural Heritage.

The problem is that an integrated and high level management of information is missing. A growing number of applications need more advanced tools to represent and analyse the 3D world. Among all the possible types of systems dealing with spatial information, GIS has proven to be a very sophisticated system that operates with a large volume of spatial and semantic relationships while providing means to analyse them, and is still very much oriented toward 2D data. In Cultural Heritage positional information is important and the usefulness of GIS related techniques is recognized. Recent developments in computer technology have opened up new horizons for 3D visualization as these technologies are now able to handle, process,

and display a great deal of information of various kinds.

The Interactive 3D Interface

The Method

One of the main features we wanted to implement is related to making information accessible through an intuitive interface. We used an interactive 3D model that reproduces the main features of the real environment, so that the user can freely move inside it and find the parts he is interested in. The developed interactive 3D interface is currently a synthetic model. To visualize and interactively navigate 3D models on the web, we used the XVR technology (CARROZZINO et al. 2005), jointly developed by PERCRO Scuola Superiore Sant’Anna in Pisa, Italy, and VRMedia s.r.l. (<http://www.vrmedia.it>).

An important aspect in the development of this application is that it should work with commonly available hardware and possibly through the Internet, in order to allow access to a wider audience.

The method is being applied to two case studies, the Napoleone Square in Lucca and the crypt of the Cathedral of St. Servatius in Quedlinburg. The second case study in particular is related to a model which has a large amount of geo-referenced information.

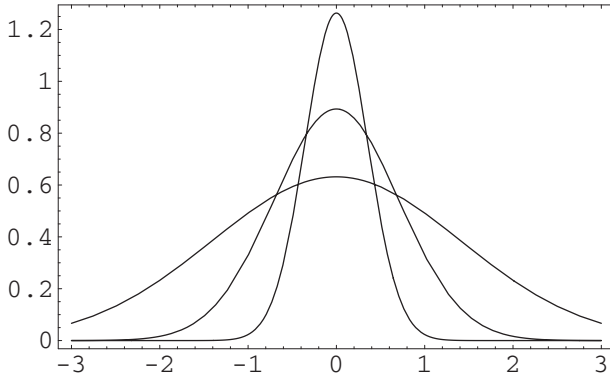


Fig. 1. Plot of normalized Gaussians with width = 0.5, 1.0, 2.0 as function of the distance from the center.

The Gaussian Information Zone

Unlike many other systems currently available, we created the information with extended 3D zones, which we call **Information Zones (IZ)**, and not just with single points in the 3D model. The simplest 3D volume is a sphere, which defines a 3D zone in a very precise and sharp way. However, the sphere is just an approximation of the information zone we desire (a better shape would be something that defines a zone with a smooth boundary). For this reason we do not use a sphere (even if in zone representations we show one), but rather a **3D Gaussian**.

The IZ is realized associating information with a Gaussian centered on the object that we want to link the information to, and with a width comparable with its size. It is important to note that the Gaussian does not define an exact zone, but just an approximated one. A 3D Gaussian is a function which assigns a value to each point of the space like a continuous distribution. To illustrate this concept, a Gaussian can be considered as a charge distribution (or a “fog”) that is more concentrated at the center and the decay rate is determined by the width (standard deviation). As can be seen in Fig. 1, the width controls how fast the Gaussian decays. The use of a continuous distribution of information also makes it clear that there is no coupling between the zone size and the amount of information. The quantity of information is not connected with the size of the Gaussian. It depends purely on the size of the object of the information which is realized by normalizing the distribution. The zones do not necessarily coincide with a 3D object represented in the model, they might be just a part of it, or they might contain many objects at the same time.

Associating the information with zones, and not directly with the 3D model, frees from the subdivision of 3D models into logical sub-elements to which information must be attached, which represents an important advantage. For instance, one can directly use meshes generated by 3D scanners without needing any particular post-processing in order to identify sub-portions of the models.

The View Zone

The portion of the 3D model, which is being “looked at” in the interactive 3D Viewer (**View Zone – VZ**) is also approximated with a normalized 3D Gaussian. The center of the Gaussian is chosen on the point P, representing the first intersection between the 3D scene and a ray cast from the current point of view towards the center of the view plane. The width is proportional to the distance of the center P from the view point, so that it is similar to the size of the viewed area (Figs. 2, 3). This method has the advantage that View Zones and Information Zones are described similarly. This symmetric treatment of VZs and IZs let us use the interactive 3D viewer to visually insert the IZ of a piece of information, or to “jump” immediately to the view related to some information.

The Relevant Information

To find the relevant information we look at the relationship between the view zone VZ and the information zones IZ. Intuitively the relevance should decrease if the zones are very far apart or have very different sizes. To implement this, we need a precise definition of *relevance*. It turns out that given two normalized Gaussians:

$$g_A(r) = \frac{1}{(2\pi\sigma_A^2)^{3/4}} e^{-\frac{|r-R_A|^2}{2\sigma_A^2}} \quad g_B(r) = \frac{1}{(2\pi\sigma_B^2)^{3/4}} e^{-\frac{|r-R_B|^2}{2\sigma_B^2}}$$

the overlap S_{AB} between them, defined as:

$$S_{AB} = \int g_A(r) g_B(r) dr = \left(\frac{\sigma_A \sigma_B}{\sigma_A^2 + \sigma_B^2} \right)^{3/2} e^{-\frac{|R_A - R_B|^2}{2(\sigma_A^2 + \sigma_B^2)}}$$

has exactly the properties we want.

We determine the relevance using the *overlap* between the IZ of the information stored in the database with the current VZ. As can be seen in Fig. 4, the overlap is highest when the Information Zone IZ coincides with the Viewed Zone VZ ($R_A = R_B$ and



Fig. 2. Interactive 3D Viewer with the viewed area VZ represented as green wire frame sphere.



Fig. 3. Interactive 3D Viewer with the viewing zone VZ represented as a "green sphere" and two information zones IZ represented as "red spheres".

$\sigma_A = \sigma_B$), and gets smaller if the IZ is far away or of a very different size. Making use of the zone sizes, as well as of their positions, makes this method well suited for high densities of data.

When browsing the 3D model an ordered list (**List Data**) of the most relevant information related to the current VZ is built and visualized following the schema shown in Fig. 5.

The Prototypes

Our research focuses on developing a method to connect information with an approximate zone in a 3D model and to find the information related to the current view. Our interactive 3D interface called ArchApp is applied in both case studies. For Piazza Napoleone in Lucca we have created a georeferenced 3D model using real information from topographical data. The related information data is represented by architectural and historical information about the urban development that we had to link to its geographical position.

The work in Quedlinburg, which is still in progress, has to keep the connection (relation) between the existent information (a cloud of points corresponding to the ceiling where rectified images were mapped, on which further information was inserted by conservators using a GIS program) and a simplified 3D model to be used in real-time. To accomplish this task, we

are using a parametric surface, defined as the maximum of a series of piecewise half-elliptic tubes, to describe the ceiling of the crypt where the paintings are located. This surface was best-fitted to the points retrieved from a 3D scanner, in order to directly generate the mesh for XVR from this surface. Having this parametric surface will enable us to map the coordinates of the orthophotos to texture coordinates and vice versa (Fig. 6). The resulting parametric surface and a sample of the scanner points are shown in Fig. 7.

ArchApp

ArchApp is a prototype that uses the method we have presented. It is a dynamic web based application written with the web framework Rails which, using a database and a file-based archive, lets the user insert, modify and browse the information using a web based 3D viewer that uses XVR technology (Figs. 8, 9).

ISEE

In the case study of Lucca square, we tested a real world application, called ISEE, using a GPS Compass (Vector CSI Wireless), providing 2D heading and positioning data, connected to a laptop (Pentium IBM ThinkPad T42) (Figs. 10, 11). ISEE allows one to move in the real environment and, on the ba-

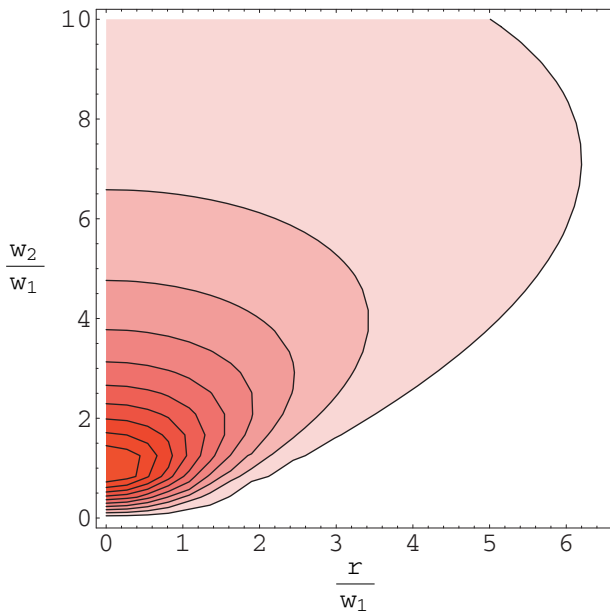


Fig. 4. Contour plot of the overlap of two normalized Gaussians with width w_1 and w_2 and a distance r between the two centers.

sis of the data provided by the GPS, it automatically provides the information related to the portion of the real world that is being observed. The information is achieved by translating the GPS data in the reference system of our 3D model. This allows us to realize an exact overlap between the “real ambience” and the “virtual” one. In this first experiment we used a “cumbersome” prototype which made use of a notebook and of a large GPS device. Our target is to use a portable device, such as a palm computer with GPS features including an electronic compass or a gyroscope, in order to produce an interactive electronic smart guide. The actual prototype equipment was quite awkward to use, but the results have been very pleasing.

From our first experiments, the major issues which arose for a real world application were the accuracy of the instrument and a way to robustly cope with periods of poor GPS signal.

Conclusions

We have presented a method to link the information to 3D space that has many interesting and innovative aspects. The association of the information with 3D zones (and not directly with the 3D model),

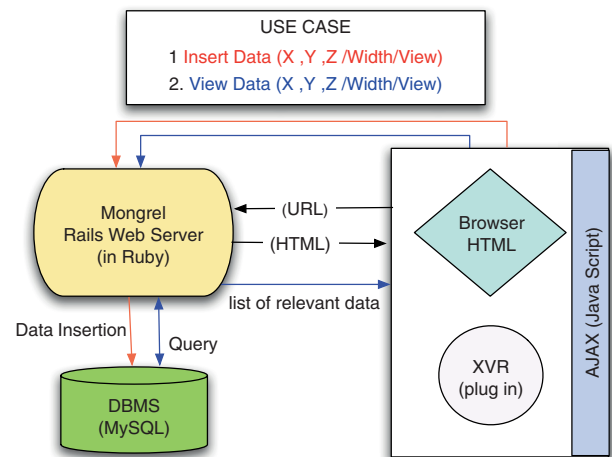


Fig. 5. Interaction scheme of two use cases of ArchApp.

allows an immediate use of 3D data coming from various sources (e.g. 3D scanners). The use of Gaussian functions gives an efficient implementation of relevant information zones with a smooth distribution of information and of the ranking algorithm. Our proposed ranking method (using the overlap of Gaussian functions) copes well with high densities of information and, together with the symmetric treatment of view and information zones, enables an intuitive interface.

The method was applied to a web application that uses an easy XVR-based 3D interface to access and manage the information through the Internet and without the need of special software and knowledge. This type of web GIS is able to share historical, artistic data in a circumscribed place, though it is not suitable for global data. The information is stored in a way that should be accessible also in the future. This method has a favorable scaling for large quantities of data (that might not be visualized all at the same time in a 3D model)

Currently we are working on extending the ArchApp application, especially in regard to automatically integrating the existing GIS data of Quedlinburg in the application.

We think this method may assist in closing the gap between different user levels when dealing with Cultural Heritage related information. It can also turn out to be of interest to many other fields of study due to its simplicity and effectiveness.

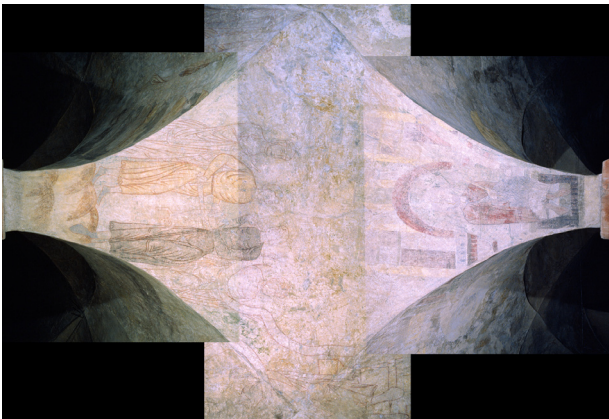


Fig. 6. The crypt of the Cathedral of St. Servatius, Quedlinburg – orthophoto image.

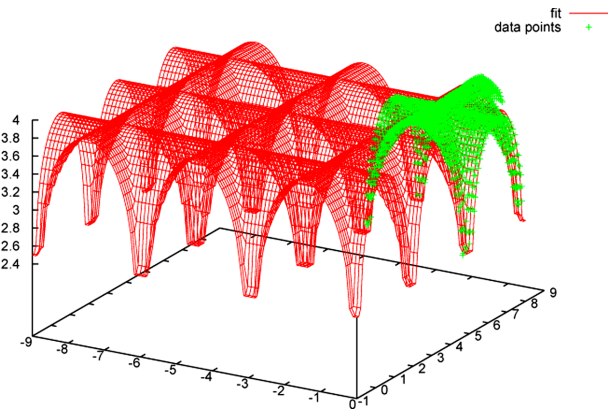
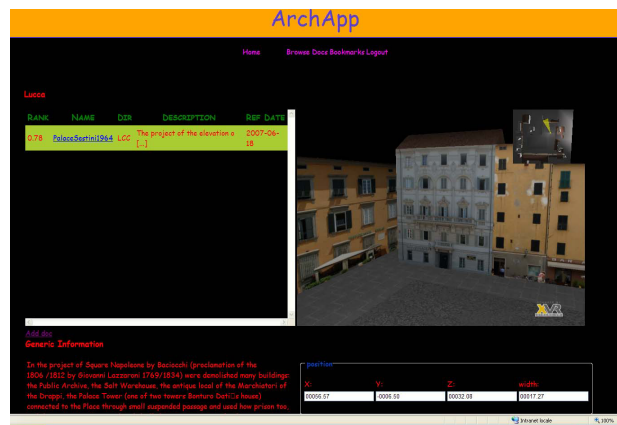


Fig. 7. The parametric surface.



Figs. 8–9. Two screenshots of ArchApp.



Fig. 10. The application of the ISEE.



Fig. 11. A photo of the 3D interface of ArchApp during the application of the ISEE.

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