RETURN

USING PHOTO-MODELS AS A BASIS FOR AN INTERACTIVE THREE-DIMENSIONAL INFORMATION SYSTEM

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ABSTRACT

For a lot of tasks concerning architecturally valuable buildings photogrammetric methods have shown to be best suited to obtain the geometrical basis. Using photogrammetry, a three-dimensional photo-realistical model ("Photo-Model") can be produced based on digital images taken from a building.

A photo-model is a three-dimensional surface-model of a real object with texture information taken from photographs. It can be used - among other things - to present structural projects to the public as well as to decision-makers. The geometrical modeling of the photo-model is supported by assumptions on the object shape. These assumptions are introduced as fictitious feature observations into the process of hybrid bundle block adjustment. The resulting geometrical model is then filled with texture by projecting the original photographs onto it.

A suitable data format for such purposes is VRML (Virtual Reality Modeling Language) thus enabling access to the three-dimensional photo-model via internet. With methods coming from field of virtual reality additional information can be linked to the photo-model in the form of texts, sound sequences or movies. Even external data-base systems can be connected to the VRML scene. In this way, the photo-model becomes the kernel of an interactive spatial information system.

This paper describes the generation process of photo-models and the setup of a building information system with the help of a practical example realized in Neunkirchen near Vienna.

KURZFASSUNG

Für viele Fragestellungen in bezug auf architektonisch wertvolle Gebäude haben sich photogrammetrische Verfahren zur Beschaffung der geometrischen Grundlage bewährt. Durch photogrammetrische Auswertung von digitalen Gebäudeaufnahmen kann ein dreidimensionales photorealistisches Modell („Photomodell“) erzeugt werden.

Die Bezeichnung "Photomodell" steht für ein photorealistisches dreidimensionales Oberflächenmodell eines realen Objektes. Formal besteht das Photomodell demnach aus Bild- ("Photo") und Geometrieinformationen ("Modell"), die gemeinsam abgespeichert werden. Das geometrische Modell wird durch hybride Bündelblockausgleichung unter Verwendung von Gestaltinformationen erzeugt. Auf dieses wird schließlich durch Transformation die Textur aus den Aufnahmen projiziert.

Auf dieses Photomodell können verschiedene Sachinformationen des Gebäudes bezogen werden. Um mit so einem System eine breite Öffentlichkeit zu erreichen, werden Standardwerkzeuge aus dem Bereich der Computernetzwerke und der Technologien der virtuellen Welten eingesetzt. Das dreidimensionale Photomodell läßt sich im Format VRML (Virtual Reality Modeling Language) ablegen. Die Sachinformationen – in Form von HTML (Hypertext Markup Language) Dokumenten, Video- oder Audiosequenzen – werden räumlich im Photomodell verankert und sind so für den Benutzer interaktiv zugänglich. Auch der Zugriff auf externe Datenbanken aus der VRML Welt heraus ist mit Hilfe spezieller VRML Methoden möglich.

Der Beitrag beschreibt die Erzeugung von Photomodellen und den Aufbau eines Gebäudeinformationssystems anhand eines realisierten Projektes in Neunkirchen, südlich von Wien.

1. INTRODUCTION

The expression "photo-model" is used for a photo-realistic three-dimensional surface model of an existing object. It consists of image information ("photo") and geometrical information ("model"), which are stored together. The generation of photo-models is done using methods coming from digital photogrammetry. It includes the process of modeling and the projection of the photographs on to the object model.

For representation of photo-models all objects are suited which are well textured and may be composed of a reasonable number of plane surface patches. In our projects we mainly concentrate on buildings. So it is rather simple to generate a rough three-dimensional object shape. The abundance of details of the facades and roofs is shown only by the projected texture. This principle of replacing time consuming geometrical modeling by texture information results in a considerable reduction of work.

The areas of application for photo-models are varied. They are situated in the technical area, as for example to serve as a basis for architectural planning (*Kofler et. al, 1992)*. In public relations work photo-models can be used to present structural projects to the public as well as to decision-makers. A virtual sight-seeing tour in a city or a museum is an example for the use in advertising. Last but not least the area of education should be mentioned, where it is sometimes important to have realistic surroundings within a computer simulation.

In the course of the continuous development of computer networks and of technologies dealing with virtual reality the photo-model may reach an importance that goes far beyond the field of photogrammetry. Today, using standardized tools, photo-models can be distributed, visualized and experienced by nearly everybody. Because of the possibilities of linking additional information in the form of text, sound sequences or movies to photo-models multimedia worlds can be generated. In this way, the photo-model becomes the kernel of an interactive spatial information system.

Our approach deals with man made objects, in particular with buildings. The shape of a house for instance can approximately be described by segments of primitive surfaces like planes or cylinders. Moreover, we may assume that some of these segments are vertical or horizontal and that some are parallel or orthogonal onto each other respectively.

Realizing this concept we have to be aware that observations are substituted by assumptions, which seems to be inconsistent with the conventional photogrammetric principle of gaining redundancy by observations. Nevertheless our approach is justified by the specific goal of visualization.

When generating a photo-model clearness is in general more important than highest precision. In addition there is still some sort of final check after generating the model. In case of gross errors in the geometrical model, they might become obvious as soon as texture is projected onto the object.

2. GENERATION PROCESS

The generation of photo-models is done on the basis of digital images, in which terrestrial and aerial photographs can be combined. These may be either digitized photographs or images taken with a digital camera. For terrestrial photographs we use a KODAK DCS 460c.

Using these images the geometry of the surface-model is determined. Apart from spatial coordinates of object points the geometry also contains topological information about line connections enabling the description of surface patches, which are joined together in order to build the modeled object-surface. Finally texture information taken from the original photographs is transformed onto these patches. The transformation parameters necessary result from the orientation of the photographs with regard to the position of the geometrical model. The determination of image orientation and object shape is done simultaneously by hybrid block adjustment.

2.1. Image measurement and feature information

In this step the image coordinates of homologous points have to be measured. The individual object points must appear in at least two photographs and the rays must not intersect at narrow angles. Due to great distortions in corresponding image parts, as a result of the highly convergent camera axes in close range work (Figure 1), the process of tie point measurement cannot be automated reliably and has to be done interactively in a rather time consuming way.

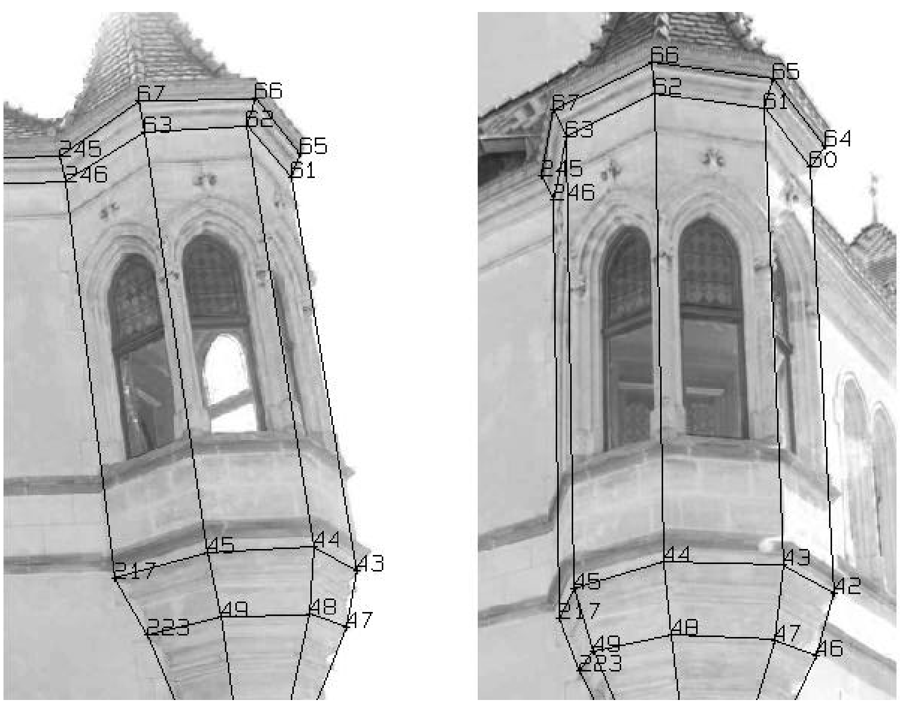

Figure 1: Two images showing the same oriel. At such great convergent photographs fully automatic matching algorithms do not work reliably.

The amount of point measurements for modeling the object can be reduced by specific assumptions on the object shape. In our approach we use the adjustment program ORIENT *(Kager, 1984)*, because this program system allows to work simultaneously with image observations and assumptions. These assumptions, called feature information, are introduced into the process of hybrid bundle adjustment as fictitious observations. They are, in fact, not really observed but are defined by the human interpretation and knowledge. In principle such observations define that particular object points should lie on one surface patch or on one line, as an intersection of two surfaces. Whether such assumptions about features fit the final model more or less well, also depends on the real observations, mainly on the measured image coordinates.

Note that the use of feature information not only reduces the amount of point measurement, but in some situations (for instance hidden points) provides the only way of correct object modeling. *(Dorffner et al., 1998)*

In the course of point measurement and feature definition the connections between points for the definition of lines and surfaces of the photo-model are also fixed (Figure 1). This topological information must be stored in the data set together with the point identifiers and coordinates.

2.2. Bundle block adjustment and photo-texture

After image measurement the orientation of the photographs are computed. In ORIENT, all feature information and image measurements available are used to obtain the 3D object shape and the image orientations simultaneously.

This hybrid adjustment process usually starts with the orientation of the photographs using some well defined tie points. Then, absolute orientation of the model is carried out using measured distances, control features, like vertical and horizontal planes and lines, and control points if available. Next, all object points and feature information are adjusted in one step thus modeling the object in detail.

Finally, after blunder detection by applying robust estimation, fine tuning can be carried out. During this hybrid adjustment process all image observations and fictitious observations are adjusted simultaneously. As result of this hybrid block adjustment the spatial position of all modeled surface patches as well as the orientations of the photographs, with regard to the object model, are known within a local or global coordinate system.

In a final step the photo-texture of each surface patch has to be found. For transforming the texture information of the original photographs onto the object model a local coordinate system is defined for each surface patch (Figure 2).

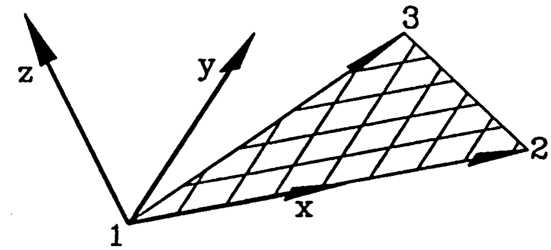

Figure 2: Local coordinate system with xy-plane in the plane of a triangle to be filled with texels.

In the xy-plane of the local coordinate system a very dense two-dimensional square raster of **te**xture-**el**ements (=texel) is defined. *(Kraus, 1997)* This raster is then transformed into the original image and the gray values for the photo-texture are obtained by bilinear interpolation of the original gray values. Besides other parameters the texel-size defines the resolution of the photo-model and in addition the physical memory necessary to store the photo-model.

To reduce file sizes, the texture images are stored JPEG compressed. The resulting loss of information is acceptable, as the images are used for visualization and animation purposes and not any more for geometric or radiometric measurement.

3. INFORMATION SYSTEM BASED ON VRML

The three-dimensional photo-model is stored in VRML format. VRML is an acronym for "Virtual Reality Modeling Language". It is the international Standard (ISO/IEC 14772) file format for describing interactive 3D worlds and objects on the Internet *(Carey., 1997)* It is in fact the 3D analogy to HTML. This means that VRML serves as a simple, multiplatform language for publishing 3D Web pages.

For visualizing a VRML file a VRML-Viewer (CosmoPlayer™ *(Platinum)*, WorldView ™ *(Intervista)*, ...) is necessary. This viewer can either be a standalone program or it can be integrated as plug-in into a HTML-Browser (Netscape ™ *(Netscape)*, Internet Explorer ™ *(Microsoft)*, ...). There are a lot of such viewers on the market for every current operating system (Windows, Unix, MacOs, ...), most of them as freeware. Therefore, no additional cost may arise for the final user.

Using the possibilities of distributing VRML world over the internet the product "Photo-Model" can be made available to a great public. Each person who has access to the internet can be seen as potential customer. By distributing the models on CD or DVD this number can even be increased.

With the help of photo-models complex spatial objects can be visualized in a really impressive way. Besides this pure visualization, for setting up an information system it is necessary to have possibilities to react on user inputs. These inputs can be mouse-clicks within or without the VRML world or just the movement of the virtual user walking through the VRML scene. By using special objects - called nodes - VRML provides different methods to react on user commands. In connection with an information system the most important nodes are "Anchor", "Inline", "Sensor", "Script" and the external interface EAI *(External Authoring Interface)*.

3.1. Anchor

Similar to HTML VRML also allows access to other files using an Anchor-node which serves as hyperlink. Each object of a VRML scene can be used as Anchor. By clicking on such an object the scene is replaced by the selected Web address (HTML file, other VRML world, ...). In a 3D information system a mouse-click on an entrance of a store, for instance, may change to a photo-model of the interior of the shop. The hyperlink may concurrently also open a HTML page showing additional information about opening hours, phone-number, merchandises and so on.

3.2. Inline

The Inline-node allows the inclusion of another VRML file stored anywhere on the Web into the current VRML scene. So very large and complex photo-models can be split into smaller parts leading to a higher performance during visualization and simplifying the problems of updating the model. Besides, photo-models generated at different time-stamps can be visualized simultaneously for comparing variable states of an object.

3.3. Sensor

Sensors are special VRML-nodes which generate events when the user interacts with them. This can happen by a mouse-click or by moving the cursor over an object of the VRML scene. This event is then passed to other nodes (for instance Scripts) which then launch some action (starting of an animation, playing of some audio- or video-clips). Events can also be generated just by the movements of the virtual user within the scene. In reaction on such movements different levels of object resolutions can be loaded, depending on the distance and visibility of parts of the model with respect to the current position of the virtual user (Figure 3).

3.4. Script

Script nodes allow the world creator to define arbitrary behaviors, defined in any supported scripting language. The VRML 2.0 specification defines Script node bindings for the Java and JavaScript language *(Carey et al., 1997).*

Scripts are used in animations where position and orientation of the camera have to be interpolated depending on predefined time-stamps. When measuring coordinates or distances on the photo-model Scripts are used to perform the type conversions that become necessary to display the measured values on the screen (Figure 4).

Figure 3: Two different resolutions of the same shop window, depending on the user's distance.

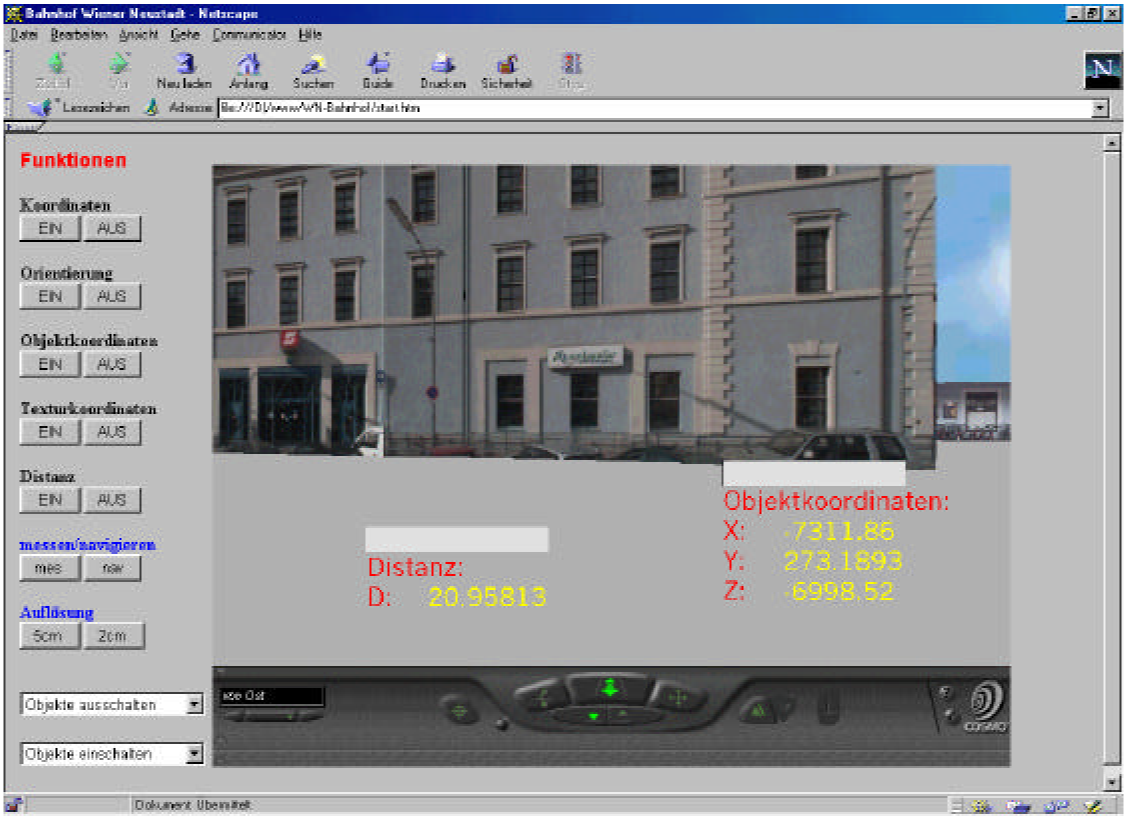

Figure 4: Coordinate and distance measurement using the EAI.

3.5. EAI

Up to now all mentioned possibilities are limited to interactions within a VRML scene. Concerning information systems it is also necessary to be able to control the scene from outside. This can be done using the EAI (External Authoring Interface). This interface allows programmers to establish a connection between a web page and an embedded VRML browser window, thus providing a possibility to manipulate the VRML scene depending on user requests on the web page. Questions like "Where can I find ...?" or "How do I come to ...?" are forwarded to external data-base systems and the results are used to generate new objects within the VRML scene, as for example a flashing point, or to launch an animation *(Zeisler, 1999)*

4. EXAMPLE

The goal of this project was the generation of an information system for the stores located at the main square of the city of Neunkirchen near Vienna. The project was carried out in close cooperation with the civil engineer group Polly - Pazourek - Burtscher. In this project 40 terrestrial and 2 aerial photographs had to be combined. First the roof scenery was modeled by digital aerial stereorestitution. Then, using the measured eaves as constraint the terrestrial photographs were used to model the facades.

Altogether 130 surface patches were determined for the roof scenery and 181 patches for the facades and details, covering an area of 2602 m² and 2552 m², respectively. To improve visualization the model has been put on an elevation grid of the main square using an orthophoto as texture source.

After loading the model the user stands on the main square of Neunkirchen looking towards the town hall (Figure 5). Now the user can start his/her virtual window-shopping expedition.

All entrances of shops are configured as Anchor-nodes. By clicking on an entrance a new HTML window is opened providing information about the shop and his products. This information is stored in separate files so that each owner can change and update the contents itself without needing access to the whole information system. In the same way there are, in the shop window, links to firms of the displayed products (Figure 6).

To get a more realistic surrounding the plague-column has also been modeled. The background has been provided with clouds and the trees have been placed into the scene.

Using the left side of the main HTML page (Figure 5) the user can also get information about the shops or the town hall. If a name is selected from the list an animation starts leading the virtual user in a guided tour to this building.

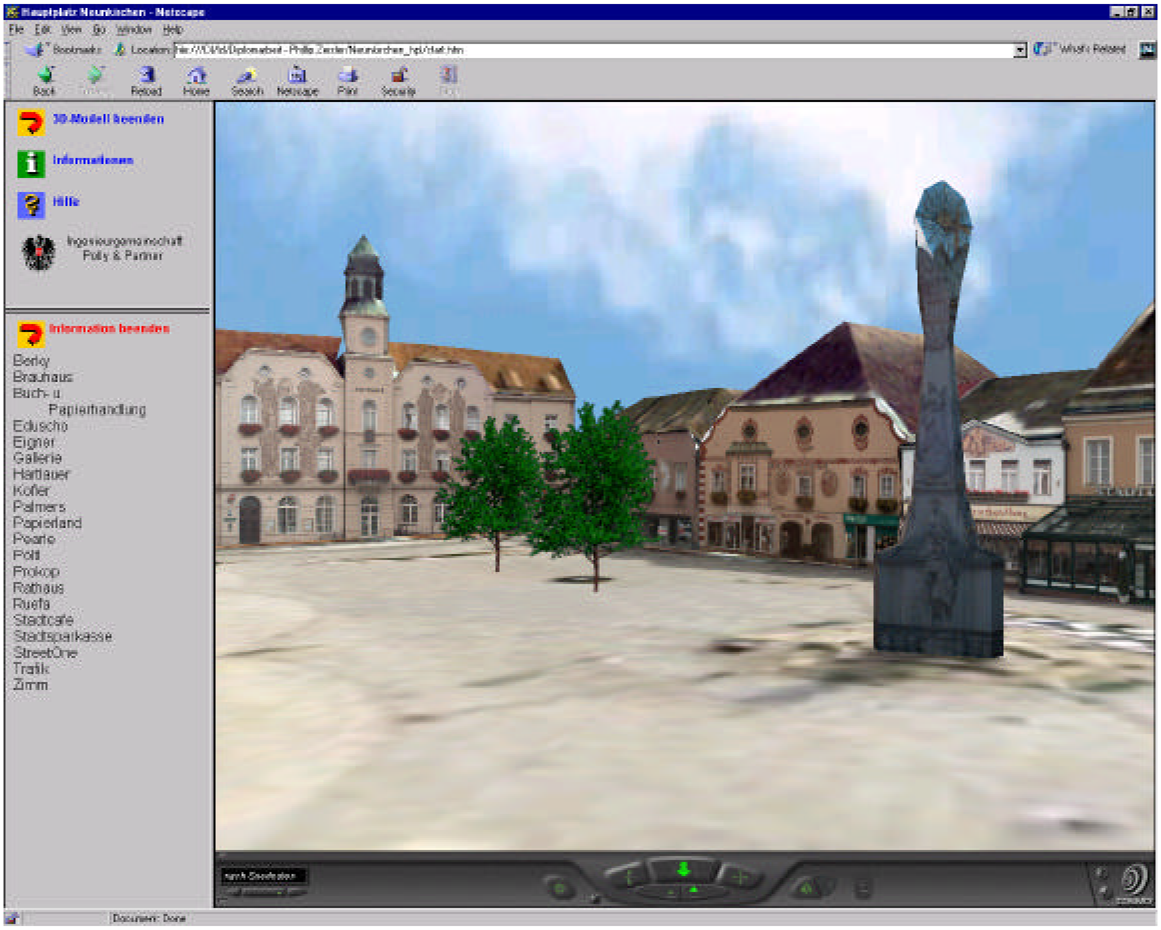

Figure 5: Main HTML page with the entry VRML scene of the main square in Neunkirchen.

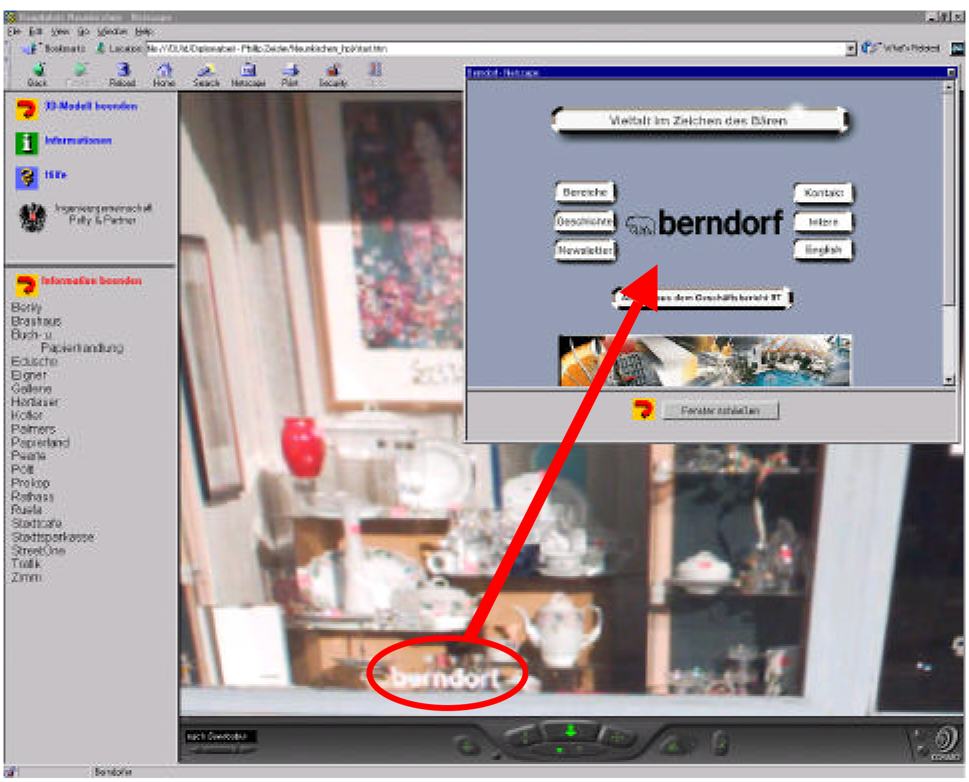

Figure 6: HTML window showing information about a exhibited product of the shop window.

5. CONCLUSIONS

Three-dimensional photo-models are best suited to give a clear and detailed impression of existing and planned situations. For the generation digital images are needed. To obtain the geometrical model a hybrid block adjustment serves as valuable tool.

The geometrical model itself is composed of surface patches. Because of the different arrangements in close-range photogrammetry, often resulting in severe distortions in corresponding image parts, the definition of the patches enforces interactive work to a high degree. In order to minimize the amount of point measurements and - as a consequence – to reduce time and cost for generating a three-dimensional photo-model, additional feature observations describing the object shape can be employed successfully. The texture applied to the three-dimensional object model is taken from photographs and need be generated artificially only in areas not covered by existing images.

By using VRML for interactive visualization additional information apart from geometry and texture can be linked to the three-dimensional photo-model. Complex spatial and thematic situations can be shown in a really vivid way through animation. The use of EAI enables a close connection between web-sites and VRML scenes. So external data-base systems can be made available to the user from within the VRML scene.

Experience proves the dramatically growing importance of interactive virtual worlds in future. Hence, the three-dimensional photo-model in connection with VRML bears the potential for providing new attractive products in the area of planning and documentation.

REFERENCES

References from Journals:

Dorffner L., Forkert G., "Generation and visualization of 3D photo-models using hybrid block adjustment with assumptions on the object shape", in ISPRS Journal of Photogrammetry and Remote Sensing, Vol. 53 No. 6, Dec. 1998.

Kager H., "ORIENT: A Universal Photogrammetric Adjustment System", Optical 3D Measurement Techniques, Wichmann Verlag, Karlsruhe, 1989, S. 447-455.

Kofler M., Rehatschek H., Gruber M., “A Database for a 3D GIS for Urban Environments Supporting Photo-Realistic Visualization”, International Archives of Photogrammetry and Remote Sensing, Vol. 31 part B2, Vienna 1996, pp 198-202.

References from Books:

Carey R., Bell G., "The Annotated VRML 2.0 Reference Manual", Addison Wesley Developers Press, 1997 – online version: "The Annotated VRML97 Reference Manual", http://www.wasabisoft.com/Book/.

Kraus K., with contributions by J. Jansa and H. Kager, “Photogrammetry, Volume 2”, 4. Ed., Dümmler Verlag, Bonn, Germany, 1997.

References from Other Literature:

External Authoring Interface Working Group, http://www.vrml.org/WorkingGroups/vrml-eai/.

Intervista Software, Inc., http://www.intervista.com/download/index.html.

Microsoft Corporation, http://www.microsoft.com/windows/ie/default.htm .

Netscape Communications Corporation, http://home.netscape.com/browsers/index.html.

Platinum Technology, Inc., http://www.cosmosoftware.com/download/

Zeisler P., “Nutzung von VRML für Informationssysteme basierend auf 3D-Photomodellen”, diploma thesis at the Vienna University of Technology, Vienna, 1999.