Virtual building lifecycle -

Giving architects access to the future of buildings by visualizing lifecycle data

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Abstract

Today's software for architects and civil engineers is lacking support for the evaluation and improvement of building lifecycles. Facility Management Systems and 4D-CAD try to integrate lifecycle data and make them better accessible, but miss the investigation of the development of the structure itself.

Much money is inappropriately spent when materials with different life expectancies are combined in the wrong way and building parts are repaired or replaced too early or too late. With the methods of scientific visualization and real-time 3D-graphics these deficiencies can be eliminated.

The project "Virtual Building Lifecycle" (short VBLC, [W-VBLC]) connects 3D geometrical information to research data such as life expectancy and emissions and to standard database information like prices. The automated visualization of critical points of the structure in the past, presence and future is a huge advantage and helps engineers to improve the duration of the lifecycle and reduce the costs.

Key words

Visualization, lifecycle, virtual building, realtime 3D graphics, architectural database, 4D-CAD, Facility Management

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1. Introduction

The end of the 20th century is marked by an immense growth of information which is continually increasing in its availability and speed of delivery (e.g. through databases on CD-ROM and the internet). This has also markedly increased the difficulty in finding and evaluating the information that is sought. It is also increasingly important to have the required information as soon as it is available or, at the latest, when it is required.

This problem plays a large role in the building industry and it is particularly critical through the singular nature of the projects and their attendant information structures. A large quantity of material and energy flows are involved within the lifetime of a building. A building could be considered as a temporary storage where each installed „sin“ will eventually be removed: at the demolition at the latest. In viewing a building with this method, it becomes apparent that evaluating the life cycle of various building parts over an average lifetime of 80 years is more important than ever. Not only new construction, but also the optimization of use, reuse and conservation of existing buildings requires planning tools that use innovative CAx Technologies.

2. Related work

The project unifies the characteristics of scientific visualization, 4D-CAD and Facility Management systems. The Center for Integrated Facility Management at Stanford University, CA, USA, namely Prof. John Kunz, Prof. Martin Fischer and their colleagues, is conducting several research projects about the integration of time into 3D-CAD-Systems (CIFE, [W-4DHome]).

The Institute for Industrial Building Production (ifib, [W-ifib]) at the University of Karlsruhe, Germany with Prof. Niklas Kohler is conducting research in the area of architectural lifecycle data.

The presented prototype has some features in common with commercial 4D-CAD-Software as for example Bentley´s Dynamic Animator and Schedule Simulator. Furthermore it is related to commercial Facility Management software as for example Nemetschek´s ALLFA.

3. Hardware and software environment

The prototype implementation of the VBLC concept is done in form of an extension to our 3D modeling system ARCADE (Advanced Realism CAD Environment). ARCADE is designed in an object-oriented way (see section 5.1), which eases extensions towards new requirements such as integration the fourth dimension: time.

The aim of ARCADE is to explore VR hardware technology such as 3D input and output devices for the modeling process and support the user by appropriate direct 3D interaction techniques. Real-time stereoscopic rendering and visual hints aid the perception of spatial relationships of static anf dynamic scenes. By pluging

VBLC into ARCADE the interaction, visualization and navigation techniques are fully accessible to VBLC. It is possible - for instance - to walk through a building while it ages.

The commercial architectural database “sirAdos” [sirAdos98] provides the semantic data, e.g. life expectancy , unit prices, to be visualized.

The standard hardware configuration for a desktop workplace consists of a SpaceMouse as 3D input device and a monitor with stereoscopic output in combination with stereo-glasses.

4. Approach

The idea of the "Virtual Building Lifecycle" (short VBLC, [W-VBLC]) is to visualize data from an architectural database on a 3D-CAD model of a building. The user should be enabled to get access to values like “unit price” and “life expectancy” while navigating around and through the virtual model. She then can retrieve information by picking objects of interest or get an impression of the lifecycle of the structure by activating different visualization modes.

This visualization is realized by a protoype-plugin to a research based 3D-CAD system. The 3D geometry can be imported via different standard interfaces (ACIS, STEP, OpenInventor, VRML) with or without supplemental data. VBLC allows to add arbitrary data to the model. The semantic information from a database that belong to a certain 3D objects in the scene can then be accessed and an visualized.

The commercial architectural database provides information about construction materials and elements in a certain order. The information connected to single objects of the 3D model follow this structure.

The program provides intuitive and rapid access to numerical and graphical information from a database. Like any type of scientific visualization it is meant to help to find and compare requested data faster and more efficient than if a search was performed on tables and texts. It is not meant to be a photo-realistic visualization (or animation) of a building.

Professions that benefit from the VBLC approach are architects and engineers in their functions as designers, facility managers, researchers and teachers.

5. Technical details

5.1. System architecture

The development of ARCADE is partly done within the project CAD Reference Model [W-CAD-RM]. ARCADE's system architecture is object-oriented and conformant with the one proposed by the Reference Model project.

Figure 1 shows the relevant parts of the system architecture of ARCADE. The graphical input and output of ARCADE is based on OpenInventor [W-OpenIn], whereas the modeling functionality uses the ACIS kernel [W-Spat]. The Graph-

IO-Manager on the one hand and the Modeller on the other hand encapsulate these two representations of the same geometrical object. The Object-Manager takes care of the consistency between the different representations of each object. The user interface is generated using X/Motif and UIL [W-XMotif].

The VBLC-General-Manager (short VG-Manager) is the central control of VBLC. It handles all general manipulations such as reading from and writing to.

The VBLC-Info-Manager (short VI-Manager) is responsible for the attachment of the correct numerical data to the geometrical objects, and it has to provide the access to these data afterwards.

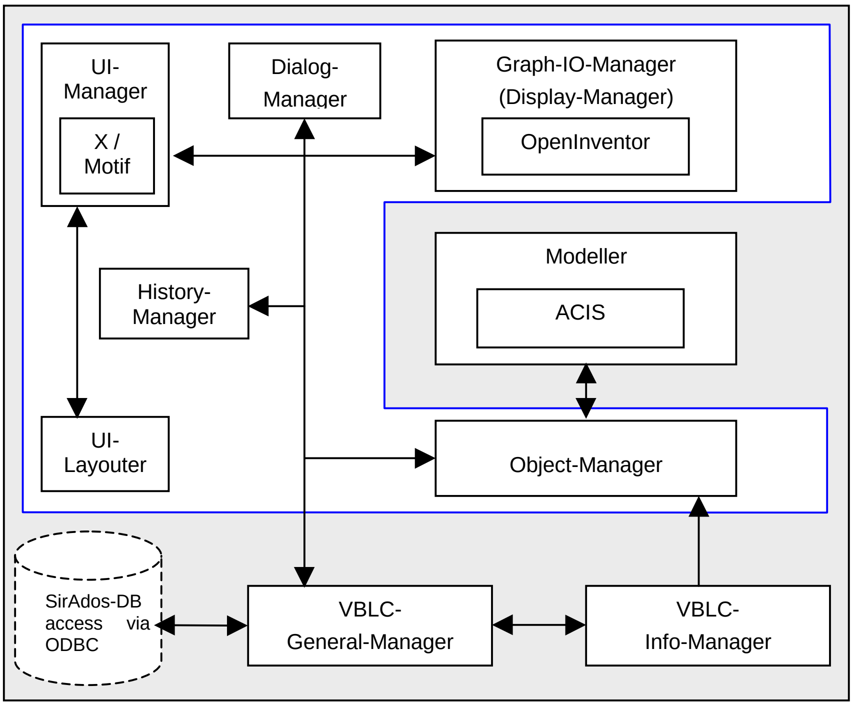

Figure 1: System architecture of ARCADE with VBLC.

5.2. Data input

For the implementation of VBLC the problem of accessing the data was solved with a simplification in two steps. The three levels of access, starting with the highest, are:

1. Direct access to the database from the application via ODBC with SQL,
2. The application reads the necessary data from a specific collection of text-files that represent the database,
3. The data necessary for a special demo model is hard-coded.

The first level is the most elegant and flexible one. The sirAdos database is based on the Paradox format [W-Para]. The standard of the ODBC knows this format and, therefore, the database can be accessed from all applications that are able to use ODBC. With the Select Query Language (SQL) this way the necessary values can be read out from sirAdos.

At the second level the database is represented by a specific system of text-files. Therefore, all relevant data was exported from the standard database front-end and some data added from the research data source. These database files are stored in the format with comma separated values, specified by the extension '*.csv'. This format was chosen because the export of 'csv'-data is supported by the sirAdos-database.

For the first implementation of VBLC the data access was more simplified. To get a visual result and an impression of the visualization fast, an example 3D. It is a model of a small house with only 40 graphical objects. For these objects a sample data set was created from the database and then hard-coded in the application.

The VBLC-InfoManager reads and manager these data. Internally the VBLC-InfoManager is prepared for ODBC access.

For the import of the geometry standard interfaces of ARCADE (ACIS, OpenInventor) were used.

6. Session examples

The system shows the state of a building at any time with two main modes. The first mode visualizes only the dates (times) of the building lifecycle. It uses the construction and destruction date and the life expectancy. The option "Normal decay" demonstrates how a building without maintenance would probably decay. The user gets a different impression when the option "Life expectancy" is selected. Now the construction parts fade out according to the life expectancy value (Figure 2).

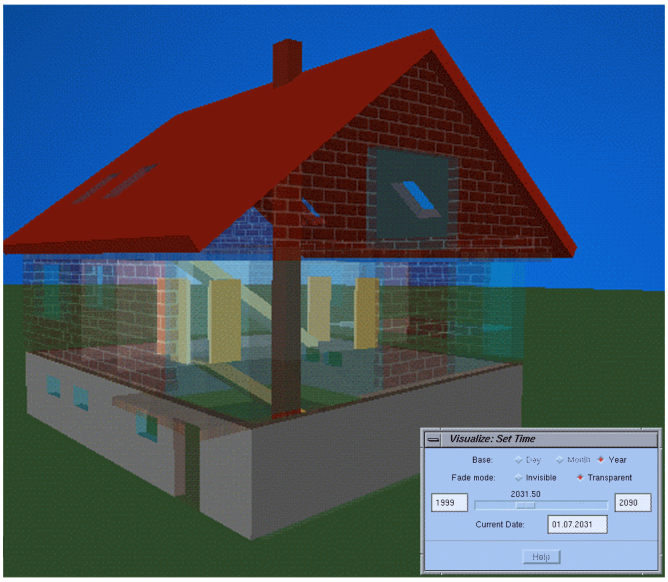

Figure 2: Visualization of a house with VBLC. It shows the situation at a certain time in future. Objects which have reached the end of their life expectancy are displayed transparent.

In a second mode the values are mapped to a basic color ranging from light to dark. Values that depend on a visualization time, as the age of a building part or the remaining life time, change, when the user moves a slider specifying the "current visualization time" (Figure 3).

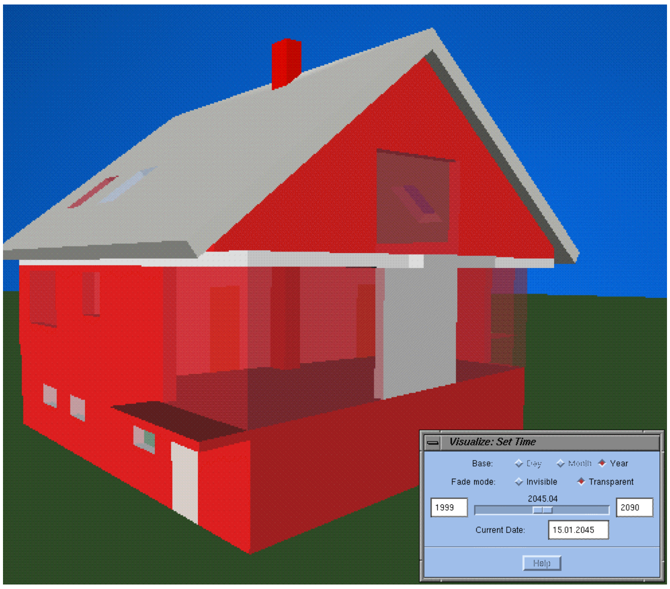

Figure 3: The color visualization for the data type "Age". The "Set Time" window used to manipulate the current time. Light objects are "younger", because they were maintained somehow recently.

7. Conclusions

In general, the whole process of accessing data by a walk-through and selecting geometry objects is satisfying and motivating. Important extreme values can be rapidly recognized in a very intuitive way. The localization of necessary actions is easier than by studying tables or lists of numbers and the visual way to analyze data seems to be much more comfortable and less fatiguing.

These statements appear trivial according to the model used for this project. But it is easy to imagine that the advantages of such a visualization become crucial when the methods are applied to 3D models and Virtual Environments ten or hundred times bigger than a small two floor building.

The project addresses in conjunction challenges of scientific color visualization, 4D-CAD and Facility Management (FM) systems. The new feature is the combination of the visualization of the construction phase and the addition of user data to a 3D model of a building. Both parts are integrated in the prototype and appear under the same layout. The data can be accessed and modified at any time and position in the model. The difference to common FM-systems is that the focus always lays on the lifecycle of the construction itself. Facilities or technical aggregates are not treated in any special way.

The connection of the prototype with a specific database is a logical step and common in most of today´s FM systems. The visualization of data from an architectural database using a color mapping is a new approach to access these data. The advantage of the sirAdos database is the provision of a system for structuring buildings in several levels of elements, which completely describe the construction.

8. Further work

There are many further development possibilities for this project. The first point concerns the import- and export-possibilities of data and the integration to other, especially commercial 3D-CAD software. The following remarks consider the data base access, the navigation and the visualization itself.

The development on the market shows that most of the leading 3D-CAD systems as well as 3D-animation software are quite successful with a semi-open architecture. They provide several import- and export file formats for the models and their attributes, and they are open for plug-ins. These plug-ins are mostly developed by independent software companies and form a wide market themselves.

For VBLC in ARCADE an import via ACIS, already supplied with database values, would be an interesting feature. As stated previously, this functionality is supported by ACIS, and a corresponding implementation in ARCADE can easily be performed.

Thus, 3D-geometry already enriched with sirAdos data is necessary. As far as the researchers at ifib are aware of, up until now nobody is using such a combination. But increasingly architects and engineers add data to their 3D-models already in the design phase, and one can expect, that the commercial 3D-CAD-systems will support this stronger in the future, and eventually include architectural databases or force the production of plug-ins thereof.

Consequently, also the data analysis functionality of VBLC could be implemented as a visualizing plug-in for the leading 3D-CAD-software. A similar project was successfully completed at Fraunhofer IGD in Darmstadt. It is named MiroWalk and provides a design review with an interactive walk-through as a plug-in for the 3D-CAD-software Bentley Microstation [W-MiroW].

Another challenging feature for VBLC is the support of a cooperative analysis inside of ARCADE or as an independent lean tool like the Shared-Viewer [W-Shared], which was developed by the Fraunhofer IGD in cooperation with industry.

An important aspect to discuss for further development is the access to the database. A direct request in SQL via ODBC would follow standardization trends and should be implemented, and other leading architectural databases might be considered as well.

A research-oriented development could include the investigation and visualization of the influence of the construction location, like geographic location, orientation (north- or south-front), climatic zone and weather, plants around and on the building. And there are many other factors that influence the lifecycle of a construction and could be visualized.

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