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Andrea Schneider (conferences@tu-ilmenau.de)

Faculty of Computer Science and Automation
(Phone: +49 3677 69-2860)
Univ.-Prof. Dr.-Ing. habil. Jens Haueisen

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TECHNOLOGY OF 3D DATA TRANSFORMATION FOR INTERACTIVE VIRTUAL BUILDING INFRASTRUCTURE MODELS

Hermin Kantardshieffa

University of Applied Sciences Dresden

ABSTRACT

The complete development and implementation of an interactive virtual building model including its entire infrastructure such as the facility inventory and the components of the technical building equipment in a three-dimensional shape requires the employment of an efficient software technology. This technology represents a multi-level pipeline-like data manipulation, whereby the processing of the three-dimensional data is implemented in a certain processing sequence of the individual procedures. The main focus of the proposed method lies on three key processes – providing, transforming and optimizing, which form the essential core of the technology. During the implementation of the processing pipeline different kinds of systems are used. Interfaces enable an efficient exchange of the 3D data between the various systems. The results of the technology are user friendly final applications with a practical use and a high usability.

Index Terms - Technology, data transformation, building infrastructure

1. INTRODUCTION

Regarding various software-technological aspects the development of an interactive virtual building infrastructure model in a three-dimensional shape requires the efficient implementation of certain sub-processes of a whole complex data processing flow. The campus of a university is suitable particularly well with its versatile substantive complexity of the existing building structures as a close-to-reality application for the proposed technology [1]. Due to the obvious fact that the three-dimensional data used for the structure of this model is developed by different personalities and at different times in several CAD systems, the employment of a multi-level data transformation represents the essential prerequisite for an effective completing of a coherent total result.

2. PROCESSING FLOW OF 3D DATA

The operation management of the required processes during the development of the interactive model of a three-dimensional building infrastructure is enabled and supported by the employment of a multi-level technology. The main focus of the technology represented by a sequence of processing (fig. 1) lies on the optimum transformation of three-dimensional data with objective of the implementation of efficient final applications depending on the specific requirements of the users.

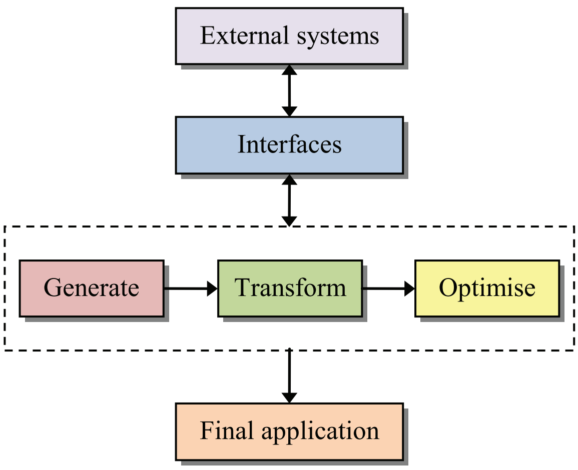

Figure 1 Technology pipeline of 3D data transformation

The starting point of the data processing is the availability of various 2D CAD drawings and additional files in textual or tabular form in Word or Excel format. These raw data from the external systems are the essential basis for the manually providing or the partially automated generating of the particular models of the building infrastructure in a three-dimensional form. The core of the technology consists of three successive running phases - providing, transforming and optimizing of 3D data. Thereby the resulting data of a single procedure are used according to the pipeline principle for the input data in the next stage. The required data exchange between the different phases of the technology is implemented using interfaces. Depending on the final application's type a concrete processing sequence of the three-dimensional data is specified on the basis of the basic pipeline. In each phase different systems can be used as well as single stages can be skipped completely.

3. DATA PROVIDING

During the first key phase of the transformation pipeline the generation of the required components for the comprehensive three-dimensional model is proceeded. This process is based on the given two-dimensional graphical and textual raw data. A building infrastructure model as part of a virtual campus is composed of the carcass, the technical building equipment such as heating, plumbing or electrical installations and the spatial interior including the furnishings and the scientific laboratory equipment such as machinery, devices and experimental rigs (fig. 2). Due to the complexity of the entire building infrastructure model is practically impossible to develop it from the beginning on in one single software system. For this purpose a number of different programs and appropriate interfaces for the data exchange are required.

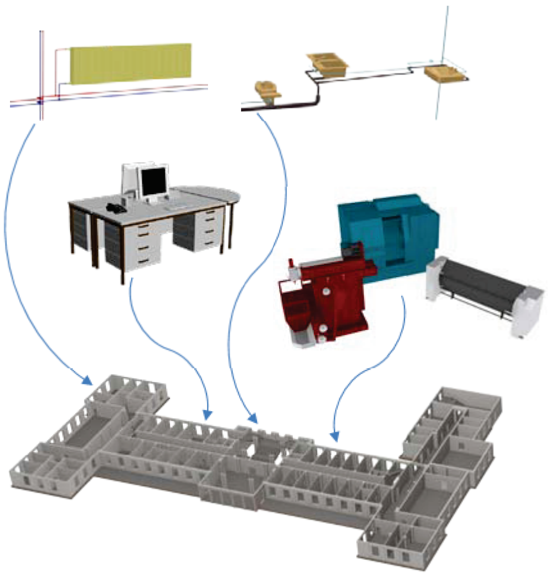

Figure 2 Building carcass und infrastructure elements

Providing a virtual building can be done in two ways. In the first method, the object is completely manually modeled using the predefined routines in the appropriate application (e.g. Allplan). Furthermore, there is another possibility to simplify the processing of the 2D line drawings by developing of functions directly in AutoCAD using the built-in programming language AutoLISP. In that way a semi-automated 3D generation of the basic structure of the building carcass model is achieved, whereby the result has to be refined afterwards manually and completed by the corresponding extension elements.

The software program Allplan is suitable from the civil engineer-technical point of view particularly well for creating three-dimensional building models [2]. The definition of an internal building structure offers a helpful support with the subsequent modeling. In this structure, the individual stories and their carcass and extension elements (floor, walls, columns, stairs, windows, doors) of a building are regarded in a hierarchical manner to the entire building model and are therefore separately editable. It is also possible to export the created building floor by floor. As a result, there are enormous advantages for the subsequent processing in the next phase of the pipeline. However, the created building model is static and is suited especially well for presentation purposes. Mobile elements such as doors, windows, elevators, and switches cannot be animated in Allplan and thus be used for an interaction with the user. The components of the technical building equipment and the interior decoration are provided with the graphical applications AutoCAD MEP and AutoCAD Inventor. Standard modeling software such as 3ds Max enables the modeling of three-dimensional objects by manually modifying the surface geometry (vertices, edges, faces) of basic geometric shapes or meshes. Compared with it, specialized systems such as Inventor or MEP offer the simplified and rapid generation of components of a certain technical area, e.g. mechanical engineering or heating, since these objects are usually predefined in the program libraries and have to be only exactly parameterized for the appropriate purpose.

4. TRANSFORMATION PROCESSES

At the transformation phase of the processing pipeline certain functionality to the already provided components of the building infrastructure model is added. The input data for this operation are purely geometrical objects in a three-dimensional shape. These components are merely suitable for the computer-aided viewing of their detailed modeled surfaces from different points of view. However, they cannot be operated interactively and are therefore static in the way they are used. The essential requirement for demanding final applications is the implementation of functions to the existing geometry in order to obtain a real-time interaction with the user. An interaction occurs by the time the virtual elements of the model trigger predefined functionality on the part of the user's actions. Such functions usually represent changes in the position and orientation states of the individual components of the building infrastructure and are implemented by animation sequences in the software program 3ds Max. Thus, specific object parameters are visually determined directly in the 3D model. As examples the opening and closing of doors or windows in order to determine their opening direction and angle or the activation of control switches of virtual machine tools are cited.

5. DATA OPTIMIZATION

Due to the use of heterogeneous systems in the already described providing and transforming phases result 3D data with a certain inhomogeneity regarding to their dimension units, geometry resolutions and file sizes. In order to minimize as far as possible the mentioned inconsistencies optimization processes in the last phase of the technology pipeline are performed before producing the final applications. These processes are proceeded by applying of various functions on the data in the programs 3ds Max and Chisel. The processing and data exchange of three-dimensional models with 6 - or 7-digit polygon count is inflexible, inefficient, and demands enormous computer resources such as processor and graphics card. That often leads to unexpected program crashes and even further to the inability to perform simple operations on these objects. For this reason it is essential to optimize the complexity of the object geometry to increase the flexibility of the real-time presentation of these models. Other important aspects of the optimization are the reducing of the file size by deleting non-relevant for the further processing information and the subsequent encryption of the 3D data files to thus obtain more rapid transmission and protection against unauthorized access.

6. INTERFACES

The software interfaces DXF, IFC and VRML are important key elements of the technology. They are used for the efficient exchange of 3D data between the systems in the various stages of the whole transformation process and enable therefore the required data communication consisting of data import/export operations. The essential criterion of using interfaces is the possibility of a direct manipulation of the files. Compared to a binary format and due to the fact that the IFC, DXF, and VRML files are in ASCII form, the data structures can be easily modified using standard word processing tools. By applying of filter methods (fig. 3) developed in CLisp certain 3D elements are filtered from the entire building infrastructure model.

```
(defun rem()
 (setq *vslist*
  (remove-if #'(lambda(s)
   (search "groundColor" s))
    *vslist*)) nil)
```

Figure 3 CLisp function for filtering of 3D objects

In that way the virtual representation of these objects in the resulting 3D applications is omitted. The filtered information is also added as textual data records in a relational database such as MySQL.

7. FINAL APPLICATIONS

The results of the multi-level processing and transformation of a large variety of three-dimensional data of a building infrastructure are sophisticated and user friendly applications mostly used by technical areas of an institution for various planning, presentation and management purposes. For the efficient generation of such applications a detailed processing sequence including the specific systems and interfaces is defined based on the developed technology. Due to the exact work procedures being specified in advance, an unnecessary waste of valuable time resources during the accomplishment of the tasks is avoided (fig. 4).

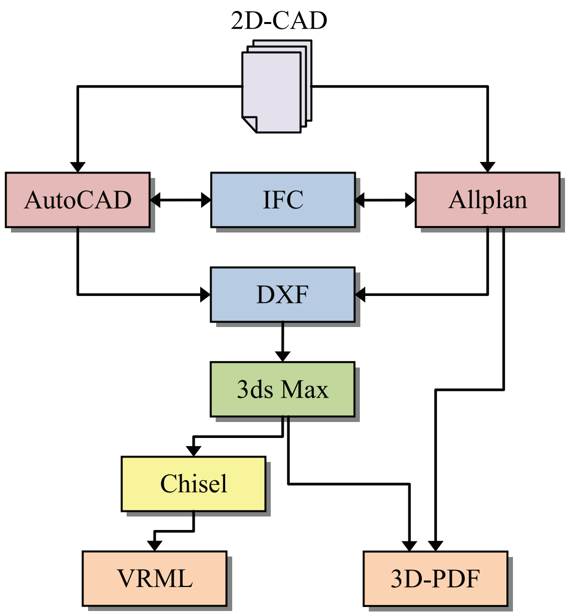

Figure 4 Precise technology pipelines of the used systems and interfaces

The final applications are in principle divided into two categories depending on the level of their interaction degree. The first type of them are static 3D PDF applications suitable for the pure viewing of the 3D model by shifting, rotating, zooming in and out of the perspective view. An applying of functions integrated in the used software program in order to define sectional views and projections, to change the global illumination and to temporarily fade in and out the building components is also possible. The 3D PDF applications are mainly used by users to receive a quick overview of the three-dimensional structures. Compared to them, dynamic VRML applications (Fig. 5) offer various possibilities of a fully interactive handling of the virtual model by committing and exploring of the three dimensional world similarly as in the reality. Due to the resulting interaction between the user and the function triggering components of the virtual representation a much better understanding of the real existing situation is reached [3].

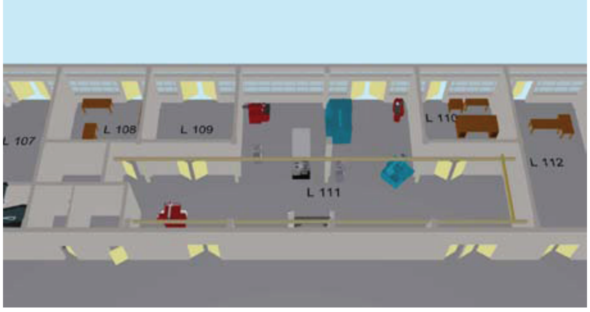

Figure 5 Interactive VRML application

8. CONCLUSION AND OUTLOOK

In this paper, the implementation and the use of a pipeline-like multi-process technology for the efficient processing of three-dimensional data with the objective of attaining of demanding final applications for various technical, administrative and presentation purposes is described. The proposed method requires further improvement of the existing processes by adding of semi- or fully-automated routines. Therefore, an essential, time-saving accomplishment of the various stages of the technology pipeline is achieved.

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