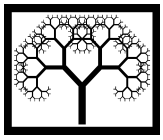
Paper 63



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Fundamental Research concerning a Three-Dimensional CAD Engine

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Abstract

It is important for the construction industry in Japan to build an environment where 3D CAD data are used for CALS/EC and IT-based construction to improve productivity. The current use of 3D CAD data in the industry is infrequent because a quality yet affordable 3D CAD engine does not exist. Such an engine must be designed and developed in order to enable low-cost use and quick implementation, leading to its deployment in various stages of the life cycle of construction projects.

Here, we propose the design of a suitable 3D CAD engine by investigating the following: situations where 3D CAD is used, seeds accompanying 3D CAD packages, standardization trends, existing products, and IT technologies. Based on the results of the investigation, functional requirements for a 3D CAD engine for the construction field are concluded, and specifications regarding the 3D CAD engine design are provided. Based on these functional requirements and specifications, a design plan for a 3D CAD engine is proposed.

Keywords: three-dimensional computer aided design, three-dimensional data, ISO 10303 (STEP).

1 Introduction

The infrastructure of Japan supports many bases of the economy, including an industrial base (e.g., roads, ports, airports, electricity services, and gas services), a life services base (e.g., hospitals, welfare facilities, parks, and water services), and a land conservation base (e.g., afforestation, river improvement, disaster recovery, pollution prevention). It argued that tools for IT-based maintenance and construction within the industry need to be developed and utilized [1]. The nation's infrastructure, established during Japan's high-growth era, is due for an upgrade. However, such a task is complicated by reductions in public investment and a lack of expertise. The Japanese construction industry is faced with the difficult task of

maintaining the current level of a public service and keeping up with growing maintenance demands, while coping with a limited budget. The challenge is compounded by frequent natural disasters, a lack of clarity regarding public works, and stringent quality requirements. Productivity improvements, gained through the application of IT technology, are necessary in order to solve these problems.

Two-dimensional CAD software is typically used in the construction industry. One example of this is Scadec data eXchange Format (SXF) [2,3], which is a CAD data exchange standard format used for electronic commerce in public works, and it is incorporated into numerous products. The CALS/EC action program 2008 [4] of the Ministry of Land, Infrastructure and Transport set a goal of "utilizing electronic data which can be used in surveys, plans, designs, construction, and maintenance" (3). The use of 3D data results in improvement in quality, reduction in cost, and an increase in productivity for construction production systems. As a result, three implementation topics are proposed:

- Decision of a standard for 3D data exchange.
- Implementation of model design and construction for 3D data
- Imaging of maintenance information for 3D data

To use 3D data in these situations requires the data to be generated. Therefore, a 3D CAD engine must be developed. The spread and promotion of IT-based construction for improving the quality of construction should be set as a goal (4). This goal will target computer-based construction utilizing 3D data. As a result, a specialized 3D CAD engine for the construction industry should be used.

Use in the industry is less than desirable because a quality yet affordable 3D CAD engine does not yet exist. A 3D CAD engine must be designed and developed in order to enable low-cost use and quick implementation, leading to its deployment in various stages of the life cycle of construction projects. Here, we propose the design of a suitable 3D CAD engine by investigating the following: situations where 3D CAD is used, seeds accompanying 3D CAD packages, standardization trends, existing products, and IT technologies. Based on the results of the investigation, the functional requirements for a 3D CAD engine for the construction field were determined, and notes regarding the 3D CAD engine design are included. Based on the functional requirements and notes, a design plan for a 3D CAD engine is proposed.

2 Investigation for the design of a 3D CAD engine

In this chapter, we propose an investigation for the situations in which 3D CAD is used, seeds accompanying 3D CAD packages, trends in standardization, and existing products. We then propose IT technologies to be used in the development of the 3D CAD engine. Based on the results of the investigation, we conclude the functional requirements for a 3D CAD engine for the construction industry, and include notes regarding the design of the 3D CAD package.

2.1 Situations where 3D CAD is used

Approximately 50 scenarios where 3D CAD and 3D data are used were investigated based on reports Ministry of Land, Infrastructure and Transport reports, Japan Society of Civil Engineers treatises, Japan Construction Information Center (JACIC) reports, web pages, and other sources. Hearings were carried out with researchers, such as those at the National Institute for Land and Infrastructure Management, and the Ministry of Land, Infrastructure and Transport. The investigations were classified into the following topics: surveys, plans, designs, construction, and maintenance of highways and bridges; river management; and town planning and landscaping. Currently, 3D data is used in the design and IT-based construction of highways and bridges. In general, situations where 3D CAD and 3D data are used are limited. The use of 3D CAD is expected to grow in the fields of highway and bridge construction. 3D data can also be used for town planning and landscaping to reach a consensus among stakeholders or explain plans to citizens.

2.2 Seeds accompanying 3D CAD packages

The seeds accompanying 3D CAD packages were investigated. Seeds are needed for the design and develop of the 3D CAD engine. The investigated seeds include information about the coordinate system, data structure, expressive style and modeling technique of the 3D model, surface generation techniques, transformations, operation and manipulation of 3D geometric elements, data quality and display technology. A method of generating a surface that represents the ground is especially important for a 3D CAD engine for this industry. An algorithm for 3D TIN generation using Voronoi regions and the Delaunay split was investigated. The algorithm and additional details were investigated, and components required in the design of a 3D CAD engine with both excellent functionality and processing speeds were specified.

2.3 Standardization trends in 3D CAD

When designing the 3D CAD engine, it is important to ensure that the 3D CAD data is based on international standards and can be exchanged between different CAD software packages. The Standard for the Exchange of Product Model Data (STEP; ISO10303 Part 42, Part 59, Part 108, Part 109, AP202, AP203) specifications for the design of a 3D model or a 3D CAD engine was investigated. To express the geometric features of a 3D CAD model, the following standards must be applied: Part 42 [5], AP202 [6], and AP203 [7]. In addition, Part 59 [8] can be used in order to specify the quality of the topological data of the 3D model. In order to exchange data regarding parametric modeling, Part 108 [9] should be followed. Similarly, for the exchange of assembly modeling data, design should adhere to Part 109 [10].

2.4 Existing 3D CAD products

Functions and features in existing 3D CAD packages were investigated. About 50 products were reviewed from every field, including construction, electrical design, and mechanical design. The investigation enabled us to grasp the required functionality for the design of the 3D CAD engine, including 3D modeling techniques, coordinate systems, and curve modeling techniques. Furthermore, functionality and details necessary for 3D CAD use in the construction industry were also understood.

2.5 IT technology necessary for the development of the 3D CAD engine

Investigation into requirements for graphic libraries, databases, OS's, programming languages, and graphics boards was conducted. The investigation resulted in the adoption of OpenGL as the graphic library. It follows that the OS and programming language must be selected to allow smooth development of the engine using OpenGL. An investigation into graphics boards confirmed it is possible to develop an engine using OpenGL with existing IT technology.

2.6 Notes about the design of the 3D CAD engine

Based on the results of the investigation, functional requirements for a 3D CAD engine for the construction industry were concluded, and notes about the design of the 3D CAD engine were written. First, the required 3D CAD engine functionality was specified. Functions that must be designed include the coordinate system, 3D model display, selection and display techniques for features, 3D modeling, assembly modeling, parametric modeling, attribute information, input and output of files, a viewer for 3D CAD, quality of data preservation, and functions depending on domains. Notes regarding the design of the 3D CAD engine were summarized as follows:

- The 3D CAD engine requires modeling records (operation records) to create 3D models and topological data to display 3D models with the graphics library.

- 3D data is exchanged based on AP203 from ISO10303 Standards (STEP). Parametric modeling is based on standards in Part 108 and assembly modeling is based on standards in Part 109.

- Surface models with topology are adopted as 3D models.

- The 3D CAD engine requires fundamental functions for creation, editing and modeling of the 3D model.

3 Design plan for the 3D CAD engine

3.1 Assumption for the design plan

Based on the results of the investigation and the notes for the 3D CAD engine, our assumptions for the design are explained below.

The construction industry mainly uses 2D CAD for drawings. In Japan, SXF was developed for and is used as the exchange format for 2D CAD data. There are a few examples of 3D CAD software being developed and introduced. However, it is assumed that only a fixed topology is applied, and the packages are in reality only an extension of 2D CAD. In this case, as only a fixed topology is represented, it is difficult to modify when design changes occur.

Parametric modeling has been introduced into 3D CAD packages for automobile and mechanical design fields, and this was followed by the introduction of 3D CAD to the field. ISO10303 (STEP) defines the international standard for representing 3D topology. The design of the 3D CAD engine developed by this research is carried out as discussed below.

3.2 Design plan

The 3D CAD engine creates 3D models through a method of parametric modeling. Parametric modeling is expressed for the last 3D geometric topology and the restraining conditions (topological restraints), and operation records. In this research, the designer's modeling sequence is recorded as an operation record, and the adopted method incorporates the regeneration of the topology modeling once more. Moreover, a topology can be redefined by changing a parameter and rerunning the operation. The data architecture of the 3D CAD engine is shown in Figure 1.

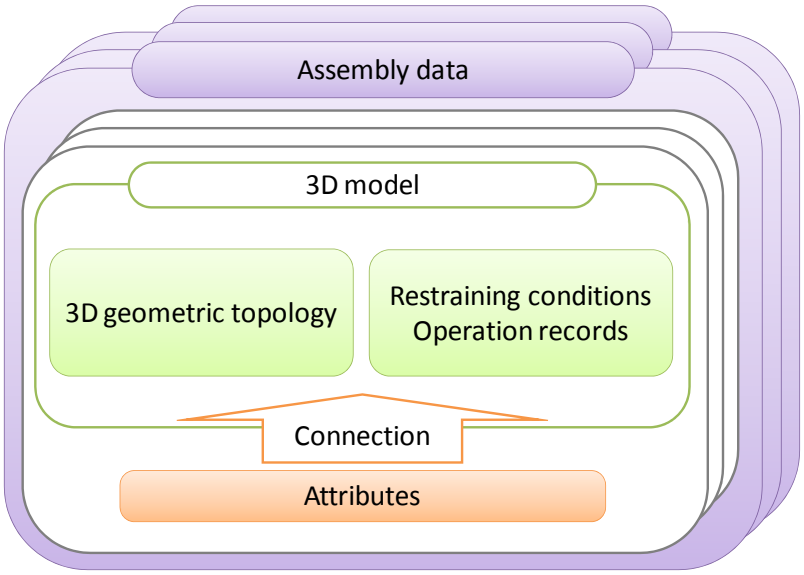

Figure 1: Data architecture of the 3D CAD engine.

4 Application of the 3D CAD engine

4.1 Application in various software packages

This research not only enables the design of a prototype of a 3D CAD engine, but also serves as basic documentation for multi-system application, application to a 4D CAD engine, and the utilization of domain 3D CAD. Thus, this research can lead to the implementation of 3D CAD, 4D CAD, and domain 3D CAD. The rapid growth in the number of software packages incorporating a 3D CAD engine is shown in Figure 2. It is expected that a CAD/CG/GIS vendor in Japan can develop a specialized 3D CAD package for the construction industry soon. Examples of potential packages include highway CAD, bridge CAD, river CAD and dam CAD. 4D CAD, which includes the dimension of time, can be developed from the 3D CAD engine for IT-based construction, expanding its possible application within the construction industry. Furthermore, we anticipate the development of software for not only CG of VR but also 3D GIS and 4D GIS, as well as infrastructure represented by the next generation ITS.

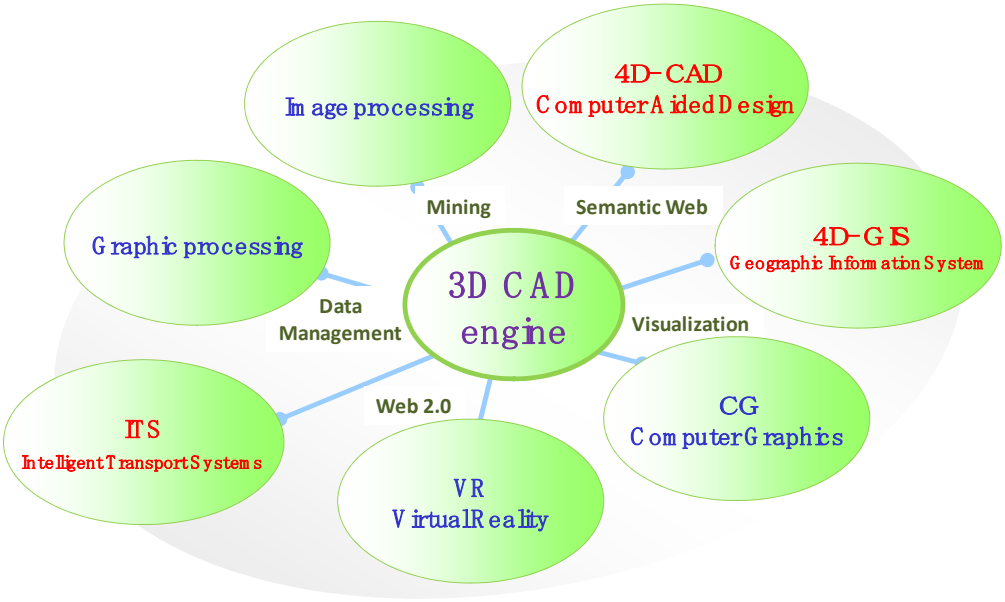

Figure 2: Application to various software packages.

4.2 Application-to-application system

Various application systems (Figure 3) that contribute to public services can cooperate through 3D models with the development of a 3D CAD engine. This will enable smooth exchange, cooperation, sharing, and reuse of infrastructure information. A 3D CAD engine could also be used to design an application system for 3D design, temporary structure design, and IT-based construction.

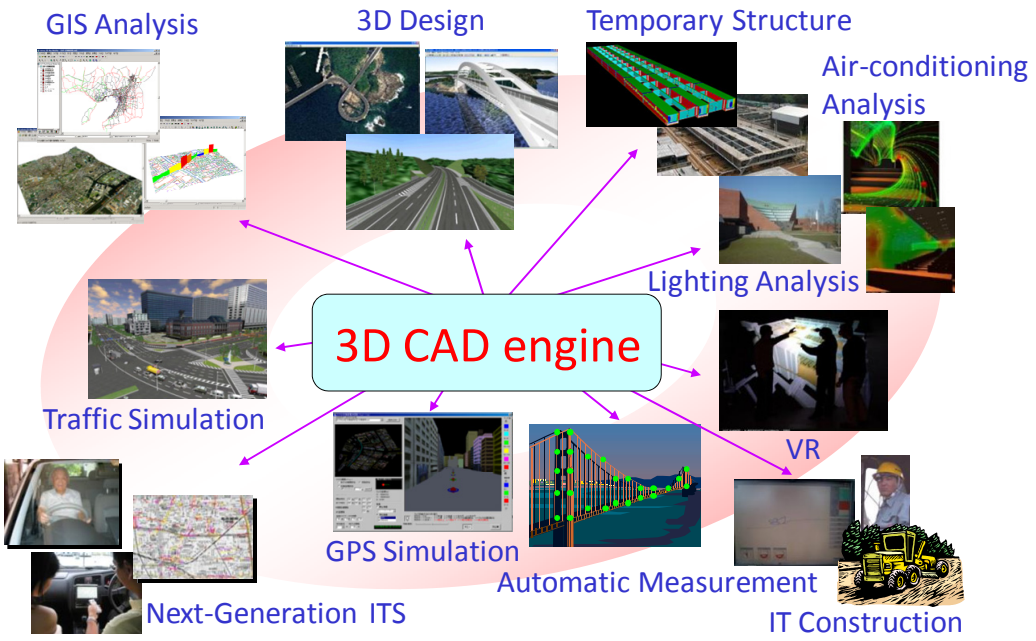

Figure 3: Application-to-application system.

5 Conclusion

In this research, investigation into the design of a 3D CAD engine is proposed to facilitate quick and affordable proliferation of 3D CAD in the construction industry in Japan. The objects of investigation include situations where 3D CAD is used, seeds accompanying 3D CAD packages, trends in standardization, existing products, and IT technologies.

This investigation demonstrated the need for development in accordance with international standards ISO/STEP, in order to strengthen international competitiveness. By clarifying the positioning of each related ISO/STEP standard, the data model of the 3D CAD engine was investigated. Based on the results of the investigation and notes regarding the 3D CAD engine, a design plan is summarized. In the future, a 3D CAD engine will be developed in accordance with this design plan.

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