Development of a New CIS/2 (CIMsteel Integration Standards) Model Viewer

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Abstract: The purpose of developing a CIS/2 data viewer is not only to facilitate software developers to visualise exported CIS/2 files and to validate geometric correctness, but also to provide non-3D-model-based CIS/2 applications with an interface for geometric visualisation and complex 3D-spatial computation. The GT CIS/2 Model viewer enhances the functionality of existing data viewers and proposes a new visualisation method for a CIS/2 model.

1 INTRODUCTION

The paper reports the current development progress of the GT CIS/2 model viewer, which is a divisional project of the CIS/2 SQL Database project (C. Eastman et al. in prep.) and the EDI (Electronic Data Interchange) project of AISC (American Institute of Steel Construction). The initial goals of this project are: to assist the CIS/2 translator developers to validate the geometric correctness of exported objects, to interface the GT CIS/2 SQL DBMS (Database management System) with 3D graphical visualisation and also to support the visual query system. The last goal is to propose a novel visualisation approach, comparing to existing visualisation tools, to exploring a 3D model in a hierarchically decomposed visual mechanism.

The first section of the paper provides the overall background and a brief introduction to the CIS/2 data model. The second section illustrates problems of the existing visualisation tools and defines the scope of developing an enhanced model viewer. The third section describes implementation strategies and methods.

1.1 Introduction of the CIS/2 Data Model

The CIS project was an extended effort of the CIMsteel (Computer Integrated Manufacturing of Steel fabrication) project started at the late 80’s (C. Eastman 1999). The CIS1 (CIMsteel Integration Standard version 1) was developed under the
lead by Dr. Alastair Watson at the University of Leeds, UK and expended into the CIS/2 Logic Product Model (LPM) (A. Crowley and A. Watson 1997) in the late 90’s. The general concept for having the CIS/2 data model is similar to the IFC (Industry Foundation Classes) directed by the IAI (Industry Alliances of Interoperability). Instead of embodying the entire design and construction information within a single data model, the CIS/2 focuses especially on the structural steel domain knowledge, which incorporates the entire lifecycle of the structural steel construction. The CIS/2 LPM schema is defined in the EXPRESS data model language (ISO-STEP 10303 Part 11 the EXPRESS language reference manual) and uses the ISO-STEP 10303 Part 21, the Clear-text Encoding Exchange Standard, to standardize instance-level expressions. The CIS/2 LPM500 also includes the partial Part 41 (ISO-STEP 10303 Part 41 Fundamentals of Product Description and Specification) and the entire Part 42 (ISO-STEP 10303 Part 42 Geometry and Topology Representation) to describe generic data specification and geometric representation.

1.2 The AISC Electronic Data Interchange (EDI) Effort

The American Institute of Steel Construction (AISC) has adopted the CIS/2 standard as a main EDI (Electronic Data Interchange) effort since 1999. Currently, over nine leading international CAD/CAM software developers have joined this AISC EDI effort to implement CIS/2 translators on top of their applications for exchanging data using the CIS/2. Most developers had implemented and commercialised their CIS/2 translators with both an importing and an exporting capability. These CIS/2 translators are implemented based on their own professional specialties and associated with one of the CIS/2 domain models, the analytical model, the design model or the manufacturing model.

Most developers incrementally expend their translators to manage more CIS/2 entities along the time. In order to export objects with more accurate geometries, it is demanded to obtain a sophisticate visualisation tool to assist developers validating their translators during a development phase.

1.3 The CIS/2 SQL Database Project at Georgia Tech

The CIS/2 SQL Database project is an ongoing research project at the College of Architecture, Georgia Institute of Technology led by Professor Charles Eastman. The initial scope is to integrate the current data-exchanging convention from a file-base exchange into a database exchange, and is expected to be used as an interoperable data repository for assisting the CIS/2 community. Currently, the system is able to convert any EXPRESS defined schema into a relational database and populates instances from imported CIS/2 P21 files.

The development of the model viewer enables the DBMS (Database Management System) to process visual queries and other database operations within a graphical environment.
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1.4 Existing STEP and CIS/2 visualisation tools

There are several existing data viewers for visualizing a STEP model for instance the STEP Viewer (STEP Tools Inc.) visualises data with full geometric representation only. The viewer displays entity instances that are defined within the ISO-STEP Part 42 or other relevant STEP standards such as the AP203 (Configuration-controlled Design) only.

Although the CIS/2 schema encloses the entire ISO-STEP Part 42 for geometry and topological representation, none of the existing or commercialised CIS/2 translator supports exporting models within full geometric representation. A STEP model with full geometric representation includes the enormous amount of geometric instances and enlarges the physical file size. Among the P21 files collected by the “Georgia Tech CIS/2 Test File Repository”, an online service for CIS/2 translator developers to store exported CIS/2 models and to request a performance test of them, the largest model is a manufacturing and detailing model of a four stories high factory building with a 100 by 100 square feet footprint. This factory building semantically expresses a regular size building. The CIS/2 model of this building contains over 36,000 instances and the total file size exceeds 39MB. Nevertheless it is not expressed with full geometric representation. The total number of instances in a model will exponentially grow as the size of building grows and more accurate and detailed geometric representation of a building is required in the future. Hence, it is crucial to have a visualisation tool that can display large CIS/2 models.

The only visualisation tool specifically designed for CIS/2 is the NIST (National Institute of Standards and Technology) VRML CIS/2 Viewer developed by Robert Lipman. The NIST VRML CIS/2 Viewer reads in CIS/2 model files through the Internet and displays a model in the VRML (Virtual Reality Modelling Language) environment. The viewer is incrementally implemented to handle more CIS/2 entities. The system provides selectable visualisation options for displaying controls and displays imported model in a single window frame.

2 DEVELOPMENT SCOPES

2.1 Criteria and Goals of Developing a CIS/2 Data Viewer

Most commercialised VRML viewers display models in a single window interface. To explore a detail of a model usually requires a series of zooming or panning operations. The other disadvantage among existing VRML viewers are the single view window and their visual options are not expendable. Due to the limitations and unsatisfactory capabilities founded in existing visualisation tools, an enhanced CIS/2 data viewer is developed. The scope of developing a new CIS/2 model viewer is as follows:

1) Proposing a hierarchical visual mechanism for semantic representation and
Digital Design

applying abstract geometry representation

2) Extendibility to incorporate with other systems

3) Interoperability and remote visualisation for collaborative work

2.1.1 Proposing a Hierarchical Visual Mechanism for Semantic Representation and Applying Abstractive Geometry Representation

The CIS/2 entity structure can be categorized into three domain models, the analytical model, the design model and the manufacturing model. These three models were separated at the early CIS1 model but were merged together in the new CIS/2 LPM500 product model (A. Crowley 1997). The CIS/2 defines several methods to map objects between domain models.

The analytical model and the design model are defined as more abstract models compared to the manufacturing model, which has more detailed information and geometric expressions to represent a construction project. A significant difference between the complexity in a manufacturing model and in the analytical or the design model is the geometric representation. Analysis applications, which are implemented for processing structural analysis or finite element analysis, represent structural members as linear lines and nodes as points. These abstract representations reduce the total number of instances. Similar to the analytical model, the design model also has a certain degree of abstraction of geometric representation. In the CIS/2 design domain model, features and joints are defined at a very abstract level. For instance in a manufacturing model, a “double clip angles with plate” joint usually requires twenty to thirty instances to be completely expressed, but it needs only one instance, the design_joint_system entity instance, in a design model. Since the manufacturing model represents a real construction project in 3D with most fabrication details, the complexity and the file size of the project model grow in proportion to the level of detail.

The abstracted and simplified geometry representation is not available at the CIS/2 manufacturing domain model. Feature entities are used only in the manufacturing model and include all volumetric subtractions of a steel member such as a cope, a hole or a notch. At a more detailed level, CIS/2 feature entities define whether a partcorner is filleted, sloped or chamfered. These feature entities are commonly used in data interchange between fabrication and detailing applications.

Comparing to main structural steel members, e.g., a beam or a column, detailed features are relatively small in terms of scale. In order to see detailed features in with a single window viewer such as the Cosmo Player, users need rapidly to zoom in until they can see the detailed features. Since detailed features are defined to associate with a main part in the CIS/2 schema. Thus, a new strategy of how to display detailed features and their corresponding main parts is proposed in the GT CIS/2 viewer.

The proposed strategy is to support multiple windows for displaying objects in a hierarchical structure that logically matches the decomposed structure of the original
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CIS/2 schema definition.

In each display window, displayed content is visualised differently in scale. Features are categorized into two levels the primary and secondary level features. The primary-level features are cut features, which can be obtained by the subtractive Boolean operation from their host parts such as beams and columns. These primary features include holes, notches, copes and etc. They are displayed in a decomposed part window frame. The secondary level features are blending features. The secondary-level feature includes detail geometry like an edge fillet or a chamfer, which can be generated by a special blending function without any complex Boolean operations. These features can be optionally displayed depending on a user’s selection.

A higher level window frame, called the assembly window frame, displays a user-selected assembly that includes assemblies of parts, joints, and the primary-level features.

It is legal to structure assemblies in a nested hierarchy based on the CIS/2 data definition. An assembly in a nested hierarchy is an assembly of other assemblies. Therefore, it is possible for a high-level assembly that contains a large number of associated instances. This “assembly window frame” allows a user to select a specific assembly to display.

The highest-level window frame displays the entire project in another window frame and displays parts and assemblies but no features. This window frame assumed to be used only to display relationship between assemblies in the whole structure. Hence, parts in an assembly are simplified into a solid object that has zero thickness to accelerate the rendering speed. Essentially, this window visualises the entire project model globally and acts as a navigation widow for selecting decomposed assemblies.

2.1.2 Extendibility to Incorporate with Other System

Another important requirement for a new CIS/2 model viewer is that it should be able to incorporate with other CIS/2 systems or applications. The GT viewer is designed to incorporate with the GT CIS/2 SQL Database internally and to the FabTrol MIS (Management Information System) Database system externally. The following paragraph describes how the system is able to interface other systems.

2.1.2.1 Interfacing the DBMS CIS/2 SQL Database

The viewer is integrated with the DBMS of the CIS/2 SQL Database to provide interactive 3D visualisation functionalities that allows a user to select 3D objects from the model view and to process a visual query on user-selected objects. The visual query can allow users to visually manage or to inquire stored objects from the CIS/2 Database and display result into a 3D model.
2.1.2.2 Interfacing the FabTrol MIS Data Item

FabTrol system (FabTrol Inc.) is a commercialised construction steel information management system that manages the project information, erection management, delivery schedules, and fabrication information. The FabTrol is an ERP (Enterprise Resource Planning) application which is internally built upon a relational database. The FabTrol system has a standard MIS (Management Information System) interface to standardized meta-data that are used natively in its internal database. The standard mapping mechanism between the CIS/2 and the FabTrol’s MIS are proposed to the AISC CIS/2 committee for approval. In order to exchange data between the FabTrol MIS database with the GT CIS/2 SQL Database, the GT CIS/2 SQL Database includes a series of SQL (Standard Query Language) view tables, which are generated based on the proposed mapping and enable the FabTrol MIS database system to extract mapped MIS records directly out from the CIS/2 SQL Database. Although the direct communication between the two database systems are possible, a few MIS data items are still not directly retrievable from the CIS/2 database because of the absence of an internal 3D-modelling capability in the FabTrol MIS system. Without an embodied 3D modelling kernel, the system cannot perform any complex spatial computation. For instance, one MIS data requires overall measurements of an assembly, which is prerequisite information for delivery and shipping, to check whether the assembly is able to fit in a single truckload. In a 3D-model-based application, the task is easy to accomplish by computing the overall dimensions by returning the boundary-box measurements through the 3D modelling kernel. But the computation of geometric models is difficult for a pure relational database application without 3D geometric computational capability to do so.

Therefore, for all the MIS items which are needed to be derived from a geometric computation are able to be pre-processed inside the GT CIS/2 viewer and retrieved explicitly by the MIS system.

2.1.3 Interoperability and Remote Visualisation for Collaborative Work

The most magnificent feature of the NIST CIS/2 VRML Viewer is the online interactive observation capability which allows an end user directly to upload a CIS/2 model and to explore the model through internet.

One advantage of the remote visualisation is it allowed collaborative users to work remotely and to check the visualised model through the internet.

The disadvantages of using the NIST CIS/2 VRML Viewer are that its browser requires a third-party VRML plug-in application installed on user’s web browser. Most VRML viewers provide fundamental operations such as basic zooming operations or selective projection views for exploring a model, but they do not provide dedicated or customized visual-operations for user. The basic operations may not be applicable to the content of displaying. The inflexibility and primitive functionality to incorporate a third party, non-opened source application, into system implementation limits the integrative possibility and extendibility for the system’s future development.
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From an interoperable perspective, a sophisticated CIS/2 model viewer must also be able to export a geometric model in diverse file formats, for example, the system should be able to export geometry into a DXF (Drawing Interchange File Format) file or an IGES (Initial Graphics Exchanges Specification) file, and thus, geometries are exchangeable and viewed among various CAD applications.

In order to achieve the scope of interoperability and remote visualisation, the system adopts an advanced open-source API named HOOPS developed by the TSA (Tech Soft America) to handle the interactive online model browsing and the diverse file format exporting capabilities, the detailed architecture is described in the development strategy section.

3 DEVELOPMENT STRATEGY AND PROCESS

3.1 System Structure

The system can be roughly divided into three parts, which are the input module, the 3D modelling module and the graphic module based on the implementation.

The input module is the system backend that controls where and how source data is imported. The input module can read in data either from the GT CIS/2 SQL Database by calling several database-accessing subroutines or from the ROSE data repository, provided by the ST-developer from STEP Tools, Inc., whose instances are imported from CIS/2 P21 files.

The 3D modelling module is a component that regenerates 3D objects in the model space. In order to represent objects in a full solid-modelling context and handle complex geometric operations, the model module adopts the Spatial-ACIS API (Application Programming Interface) as its 3D modelling kernel to reduce the complexity of implementation.

The graphic module is the core of how to display a model onto the hardware. It adopts an alternative graphic core code called HOOPS developed by the Tech Soft America. The HOOPS actually integrates OpenGL codes into a higher-level coding interface and releases an API for system implementers.

The other component is a data indexing structure, which provides internal mapping capabilities while passing objects through different modules. The primary mechanism of the indexing structure is described at the next paragraph.

3.1.1 Data Structure and Internal Data Indexing

The 3D modelling module builds 3D objects correspondingly to originate STEP objects. An index between a 3D object and the originated STEP object is stored into the indexing data structure. The reason to keep a reference between a 3D object and a STEP object is because it provides a bi-directional mapping relationship between
the 3D object and the STEP object. If the viewer is only implemented for displaying geometries, this indexing mechanism may not be applicable. But it is important if the system provides interactive capability which means a user can directly manipulate the model through the system. In the visual query, the graphical module returns selected topological elements, vertexes, edges, faces, bodies and etc., and the 3D modelling module determines the ownership of those selected topological elements. Once the ownership is identified, the system is able to trace originated STEP objects through the indexed data. Therefore, a user can manipulate, modify or highlight an object from a user interface and the system can propagate changes to the 3D objects, then to the originated STEP objects or stored entries on the CIS/2 database.

3.1.2 User Interface and The Graphic Module

To support online interactive visualisation for a CIS/2 model, the system is able to export a model to a HSF (HOOPS Stream File) file. This HSF file is defined in an open standard file format, called OpenHSF that is interactively observable on any web browser. The HOOPS API is interoperable with many 3D modelling kernels such as the ACIS, the Parasolid and the Granite One. In the system implementation, there are internal and external ways of how the 3D modelling module, the ACIS API, can be integrated with the graphic module, the HOOPS API. Internally, objects are passed through a rendering pipeline that bridges the 3D modelling module with the graphic module. Externally, the HOOPS API includes a default translator to input a Standard ACIS Text formatted file (SAT file).

Another advantage to deploy the HOOPS API for implementation is that it offers a sophisticated and friendly graphical user interface (GUI) development environment. A default user interface allows implementers to customize system commands using the Microsoft Foundation Classes (MFC).

3.1.3 Data Input Module

The input module supports both file-based input and database-based input. Many EXPRESS/STEP applications such as the ST-Developer (STEP Tools, Inc.) or the EDM (EPM Technology) provide a standard interface to access the in-memory data repository.

In the GT viewer implementation, the input module uses the ST-Developer ROSE interface and data repository to handle importing physical CIS/2 P21 files and uses a late binding approach to retrieve objects from the data repository. Most EXPRESS/STEP applications support the SDAI (ISO-STEP 10303 PART 22: Standard Data Accessing Interface) for accessing the data repository and support other early-binding interfaces in different programming languages such as the C++ or JAVA.

While inputting data from the CIS/2 SQL Database, in order to extract data from the CIS/2 SQL Database more efficiently, many lower-level geometry entity tables are
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pre-joined together as one pre-existent SQL view table to shorten the retrieving duration for a query. The pre-existent SQL view tables are not applicable to any normalization processing (E. Codd 1972a), but are to optimise the query performance without eliminating replicated data entries.

The following figure (Figure 1) illustrates the essential system architecture and a snapshot from the system interface:

![Figure 1 (left) System modules; (right) User interface](image)

4 **FUTURE WORK**

The system will entirely be incorporated into the CIS/2 SQL DB-DBMS implementation that shares the front-end code of receiving data through the data repository. From the visualisation perspective, more decent and sophisticated visualisation methods are to be studied for processing a semantic query that can allow users to extract semantically aggregate parts and features: e.g., a visual query for all “staircases” where the staircase is not a predefined entity in the data model but only semantic expression of aggregated objects.

It is necessary to optimise data retrieving from the database and the rendering strategy of the application to confirm the performance of the system before further implementation is proceeded.

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