Web-enabled model-based CAD for design

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Abstract

Increasingly innovative ways of exploiting the Internet is giving rise to potentially new ways of designing and managing constructed facilities. The ability to source design components from different locations on the web and incorporate them in developing a design solution is an evolving technology that would have major implications for the way design and construction are carried out. Many CAD applications have developed user interfaces and connectivity supports that enable the incorporation of online information and web applications in a convenient manner. Building information modeling is another promising technology that facilitates knowledge management and collaboration among stakeholders throughout the design, construction, and maintenance operations. In a building information model, each component has its properties, information, and semantics. Application programming interfaces (APIs) in CAD software can be used to facilitate the management and exchange of building information. Therefore, a CAD application can become a service hub for acquiring and capturing design and project information.

This paper describes an effort in applying web-enabled technologies using both software Autodesk Architectural Desktop (ADT) and Google Sketchup. Three scenarios will be illustrated to show the potential of web-enabled model-based CAD in the design and construction processes. The first scenario demonstrates the usage of CAD programs to perform configuration design by directly interacting with the web and online information through web browsers and a CAD software plug-in namely SpecifiCAD. The second scenario illustrates the evaluation of design alternatives according to energy and carbon emission simulation and analysis results, provided by using a Sketchup plug-in that links to the Integrated Environmental Solutions (IES) software. The third scenario shows the utilization of the entity information from CAD models to facilitate project planning and control with suppliers.

Keywords: CAD, Web-enabled, Design, Construction, BIM.

1 Introduction

Computer-aided design (CAD) applications have been widely used in the construction industry as a tool to aid architectural design, to visualize the physical appearance of a building, and to specify design details for construction processes. Many of them have application programming interfaces (APIs) to enable extension of application functionalities. For example, users can execute programming scripts through APIs to automate the drawing and conformance checking of building components.

Current CAD programs are mostly standalone. With the emerging Internet infrastructures and technologies, buildings can be designed and constructed in a more co-operative manner. The growing trend of CAD drawings supported by building information models also provides much potential for integrated design and construction among scattered stakeholders. In this paper, we describe a few examples to demonstrate the potential applications of web-enabled model-based CAD for design, procurement, and project management.

2 Web-enabled model-based CAD

2.1 Integrating online information and web applications

The Internet has been leveraged to build an environment that connects distributed CAD software clients to a centralized product data server for collaborative design (Fuh and Li, 2005; Han et al., 1999; Zhuang and Chen, 2000). In this paper, we demonstrate the use of the Internet technologies to explore and retrieve information available on the web, and to integrate distributed applications as web-based services within CAD programs. Figure 1 shows a conceptual representation of web-enabled model-based CAD applications. The ability to source design components from different locations on the web and incorporate them in developing a design solution could greatly impact the way design is developed and create many business opportunities. There have been growing interests in integrating and interaction with online information among CAD vendors. For example, the i-drop technology developed by Autodesk and the drag-and-drop capability of Google Sketchup user interface enable a designer to 'pull' an object (e.g. door, window, chair, etc.) over the web and directly drop them into a CAD design. These technologies not only allow designers to create and change a design easily and quickly, but also enhance the communication among the designers, manufacturers and suppliers within the construction industry.

2.2 Model-based framework for information repository and management

Traditionally, a design is drawn using a combination of geometric entities such as lines, planes, and volumes. This geometry-based approach is now evolving to an object-oriented model-based approach, in which each design object component (e.g. door, wall, and slab) has its properties, information and semantics (Eastman et al., 2008). The sets of properties and semantics affect the operations on the object in a model-based CAD software application. The object properties and information can also be manipulated by other software applications and can further be utilized throughout the project life cycle. The component information such as product data, supplier information, and schedule information is stored and managed at the back end, in a database or inside the CAD drawings. This information can facilitate decision making, production of construction documents, prediction of building performance, cost estimating, and construction planning. Therefore, a CAD application can become a service hub for acquiring, capturing and managing design and project information.

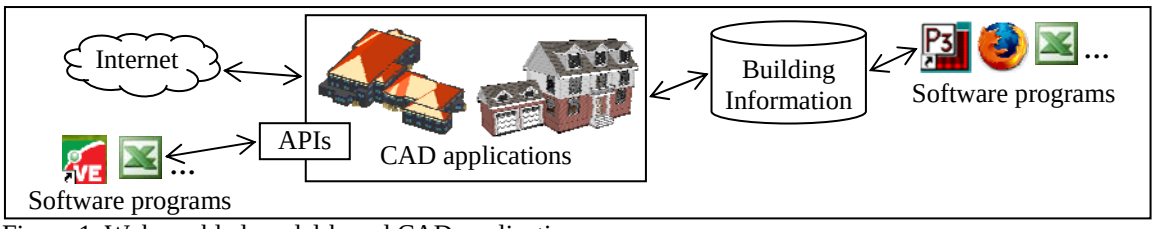


Figure 1. Web-enabled model-based CAD applications.

3 Example scenarios

3.1 Example 1: configuration design and procurement

Although buildings have different shapes and designs, many of them share similar building components. In configuration design, parts are selected and connected to meet customer specifications and engineering and physical constraints (Darr et al., 1998). The i-drop technology developed by Autodesk and the graphical user interface in Google Sketchup allow users to drag-and-drop contents from the web to a CAD drawing. As shown in Figure 2, architects can choose a specific product item from online catalogs and drag-and-drop the product model as well as the associated information to CAD software programs, using Autodesk i-drop technology. The catalogs can be either publicly accessible or password protected. In password protected catalogs, suppliers can show different choices of items with customized price information. The HTML web page is modified and enhanced as an XML file, which includes the location of the product and the information, such as product code and supplier information, about the product. The product information in the CAD drawing can then be extracted to Microsoft Excel through API to create an item list for final checking before procurement.

Dynamic catalogs can also be created. In this example, we leverage SpecifiCAD developed by CADalytic, Inc. to provide connectivity and interaction between CAD object components and the web within Autodesk ADT and Google Sketchup. As illustrated in Figure 3, when a designer clicks a window in Sketchup and selects the "catalog" option in SpecifiCAD, a list of window alternatives is shown. In fact, since the component name contains the word "window," the program searches within the extranet all the windows from partnering suppliers and obtains the product and contact information through the suppliers' web services. The architect can drag-and-drop from the dynamic catalog and insert a new object in the CAD drawing. The architect can also click the hyperlink "Our replace tool" to show an interface that allows all the window components to be replaced in the CAD programs with the alternative from the catalog. The component properties, information, and display are updated automatically.

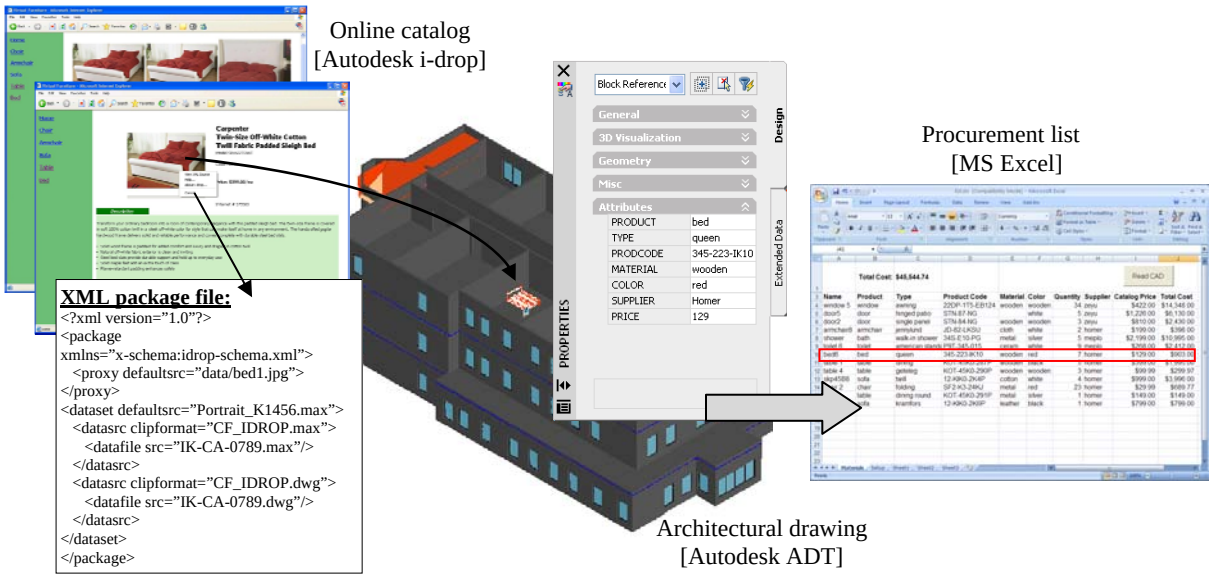


Figure 2. Drag-and-drop web contents to CAD drawings using Autodesk i-drop technology for design and procurement.

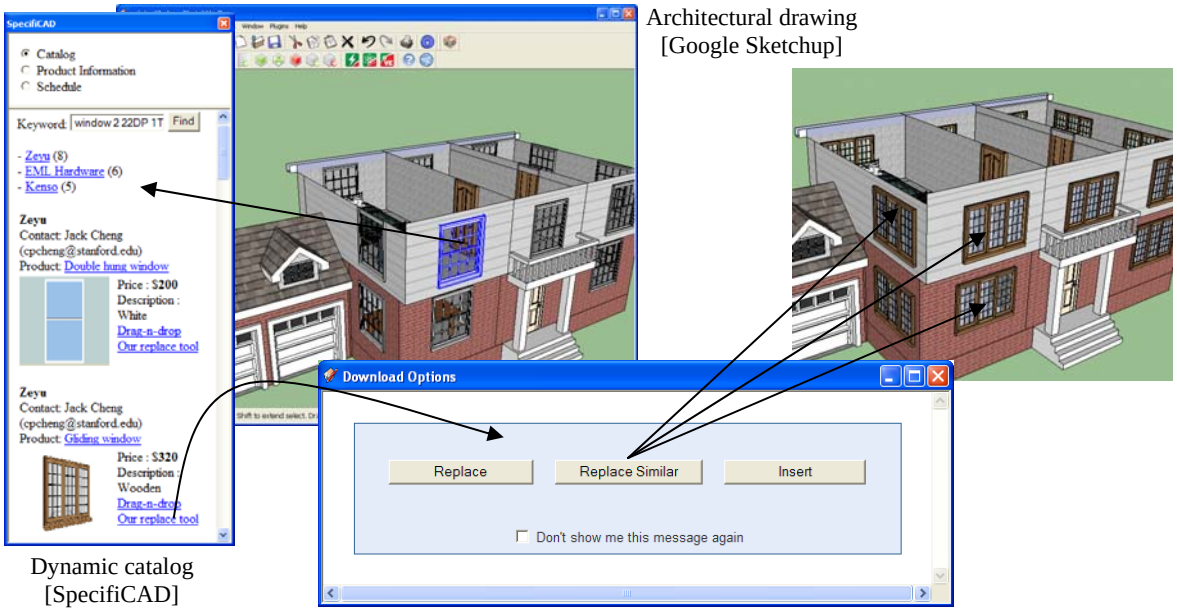
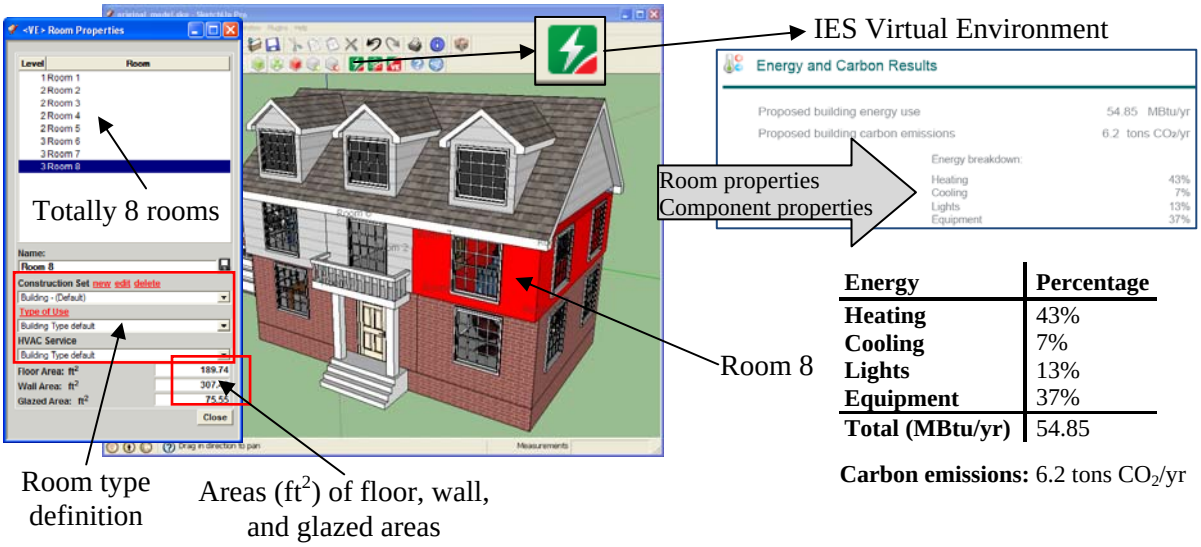


Figure 3. Interaction between CAD object components and dynamic online information.

3.2 *Example 2: building performance analysis*

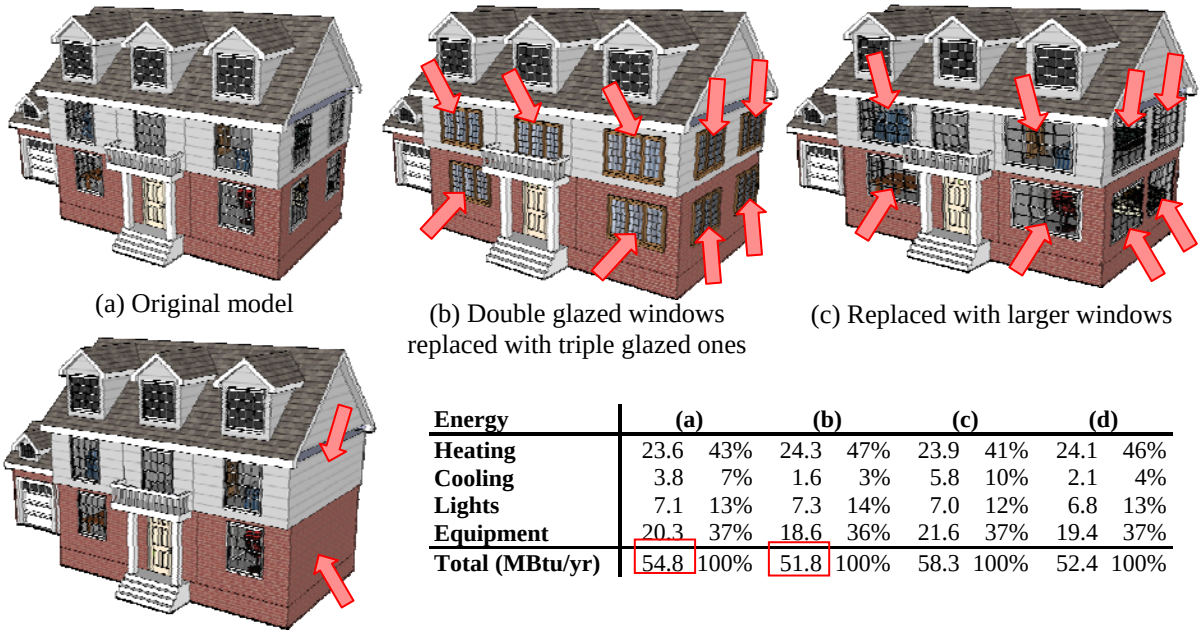
Besides geometry, model-based CAD drawings also contain building component information which can be utilized for simulation and analysis of building performance. In this example, Integrated Environmental Solutions (IES) Virtual Environment is used to simulate and evaluate the energy consumption and carbon emissions of a building within Google Sketchup. Before simulation, IES Virtual Environment extracts the information from the Sketchup drawing and identifies individual rooms (Figure 4). Room types such as "dining area" and "bedroom" can be defined using the interface provided by the IES plug-in. The size and property definitions of the rooms and of the components such as windows and doors are then transferred to IES Virtual Environment. With reference to local climate data, the program estimates the annual carbon emissions and energy use.



Energy	Percentage
Heating	43%
Cooling	7%
Lights	13%
Equipment	37%
Total (MBtu/yr)	54.85

Carbon emissions: 6.2 tons CO_2/yr

Figure 4. Energy and carbon emissions analysis of a building.



(a) Original model

(b) Double glazed windows replaced with triple glazed ones

(c) Replaced with larger windows

(d) Windows on the sides and at the back are removed

Energy	(a)		(b)		(c)		(d)	
Heating	23.6	43%	24.3	47%	23.9	41%	24.1	46%
Cooling	3.8	7%	1.6	3%	5.8	10%	2.1	4%
Lights	7.1	13%	7.3	14%	7.0	12%	6.8	13%
Equipment	20.3	37%	18.6	36%	21.6	37%	19.4	37%
Total (MBtu/yr)	54.8	100%	51.8	100%	58.3	100%	52.4	100%

Figure 5. Comparison of different architectural designs in terms of energy use.

Web-enabled configuration design described in Section 3.1 can be used to facilitate the generation of various architectural designs. Designers can conveniently modify a design and evaluate its building performance before procurement. For illustration, Figure 5 shows the comparison of energy use among four architectural design alternatives, and thus provides valuable information regarding the cost to replace double-glazed windows with triple glazed ones.

3.3 Example 3: project planning and control

While CAD applications are often used for architectural design, they can also be used for project planning and management. With model-based CAD that include back-end building information such as schedule information, the project manager can submit a query and view the building components involved in the activities within a specified period, as illustrated in Figure 6. The project manager can utilize this information for planning and management purposes.

We leverage the SpecifiCAD interface to show the back-end building information model and to interact with web applications within Autodesk ADT. For example, when the user clicks a window in ADT and selects the “schedule” option in SpecifiCAD, the schedule information of the window component is shown. In addition, the user can initiate material delivery by clicking the “Shipping Request” button, which invokes the web services deployed in the supplier’s management system. This allows a “pull” strategy for just-in-time delivery. As a result, the delivery schedule becomes adaptable to the exact site situation and minimizes on site inventory.

4 Summary and discussion

This paper has presented three example scenarios that demonstrate the potential of web-enabled model-based CAD for architectural design and project planning. The ability to integrate CAD model with web contents, the building information models, and API supports make CAD applications more

extensible, flexible, and accessible. CAD systems can serve as an interactive tool for information management, communication and collaboration, and construction planning, operations and maintenance. Further research is needed to address the issues such as information concurrency and consistency, security, and data semantics to enhance the usability of web-enabled model-based applications.

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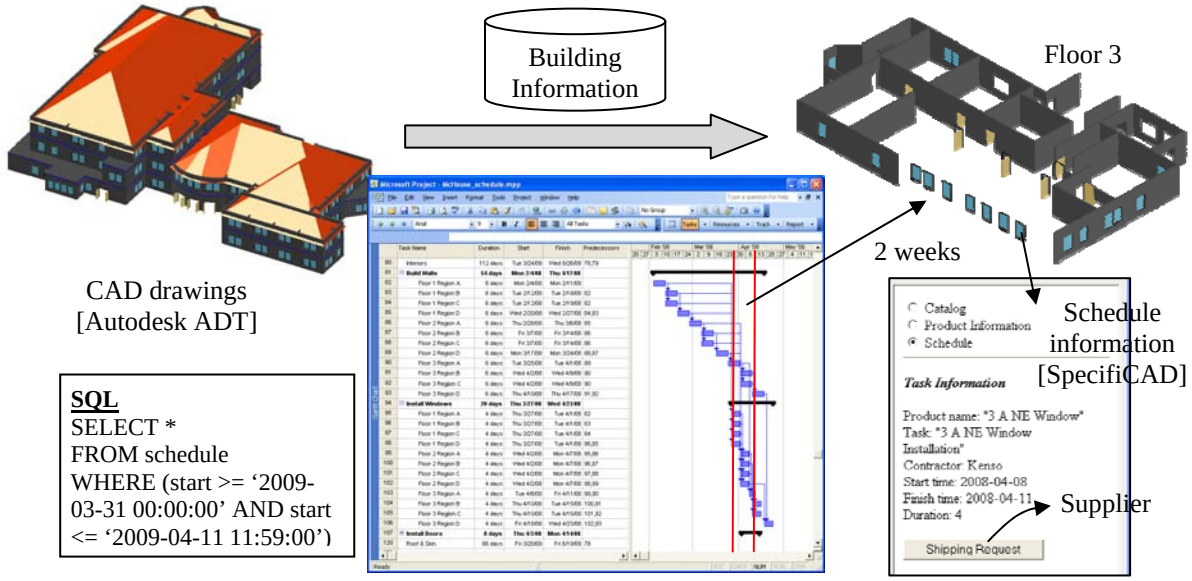

Figure 6. Model-based CAD model in Autodesk ADT for project planning and control.