ENGINEERING SIMULATIONS WITH WEB-BASED SERVICES

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ABSTRACT

The web services model is becoming a popular approach for integrating software applications to improve the flexibility and extend the functionalities of a software application by making it interoperable with other application services. With the continuing rapid growth of online information sources, the integration of such services can further include many up-to-date information for engineering simulations. Three example applications are presented to demonstrate that the web service approach can potentially have significant impacts in facility design and engineering.

KEY WORDS

web services, engineering simulation, project management, design, procurement

INTRODUCTION

As computer programs become ever more complex, the trend of software development has shifted from focusing on programming towards focusing on integration, as illustrated in Figure 1 (Beringer et al. 1998). This trend is of no exception in the A/E/C industry. As stand-alone engineering applications (such as structural analysis, CAD, project management, etc..) of the 1960s and 1970s began to mature, the industry has been pushing for shared or integrated platforms, extending domain-specific tools and capabilities beyond an individual application to support project-wide activities (planning, design, construction, business transactions and other functions). In parallel to this trend, as communication technologies advance, there is a shift from stand-alone desktop applications toward distributed (e.g. Web-based or Web-enabled) services. Many new developments and business models will take advantage of advanced communication technologies and will be based more and more on the composition and integration of existing application components.

With the rapid development of the Internet and networking technologies, the computing environment is evolving toward an interconnected web of autonomous services, both inside and outside of enterprise boundaries. A "web service" can be described as a specific function

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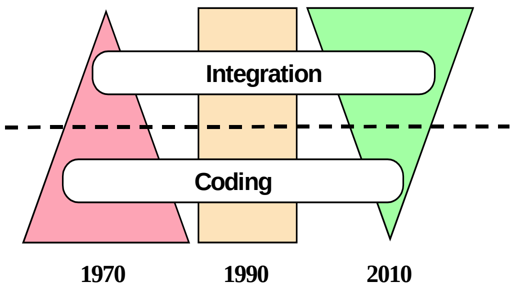


Figure 1: Trend of Software

that is delivered over the Internet to provide a service or information to users. Users of information systems now have tremendous sources of services on the Web: they can manage a bank account, purchase books, arrange travel reservations, and track shipping packages. Web service integration is important for the automation of application-to-application or organization-to-organization cooperation using the Internet infrastructure. However, it is not easy for a user to perform a complex task which composes of many sub-tasks and requires access to many web services.

The web services model has become a favorite approach for integrating software applications in that the model can improve the flexibility and extend the functionalities of an application by making it interoperable with other software services. An engineering simulation may now involve a number of geographically distributed software applications. Additionally, online information can be dynamically integrated with the applications. The simplicity of the web services model makes it possible to build a complex software system incrementally. In this paper, we describe a few examples to illustrate the potential applications of web services, ranging from project management to design and procurement services.

A FRAMEWORK FOR INTEGRATION OF WEB SERVICES

With the emergence of Web-based software applications, many languages have been proposed to facilitate the reuse of Web services or software components. Examples include Web Services Flow Language (WSFL) (Leymann 2001), Business Process Execution Language for Web Services (BPEL4WS) (Andrews et al. 2003), and Web Service Ontology based on DARPA Agent Markup Language (DAML-S) (Ankolekar et al. 2001). These service description languages, however, are mainly targeted for business oriented applications and are not designed for managing and reusing information to support engineering applications. In the engineering and construction domain, many stand-alone applications (e.g., Microsoft Project, Microsoft Excel, Primavera Project Planner, and AutoCAD) are widely used. These tools are designed for specific application and generate large volumes of information that are not easily shared among the applications. Even with many existing online Web services, such as weather forecasting, product catalogues, finance reports, etc., these services are not readily integrated with traditional standalone applications.

For web service applications, software components exist as autonomous services managed under multiple administrative domains and controlled by different service providers. The loosely coupled, distributed web services model allows new services to be added as needed during runtime. Our prototype web service simulation framework builds upon a software composition infrastructure based on data and control flows (Liu et al. 2002) and software wrappers. The Flow-based Infrastructure for Composing Autonomous Services (FICAS) (Liu 2003) is utilized to invoke distributed services and to direct data flow among different services. While there are other solutions available for distributed service invocation, including Remote Procedure Call (RPC), Common Object Request Broker (CORBA), and Simple Object Access Protocol (SOAP), FICAS is designed to handle applications that involve high volume of data typically found in engineering applications. Specifically, FICAS takes advantage of distributed data flows to efficiently route the data to designated applications. Wrappers are developed with information exchange protocols based on Extensible Markup Language (XML) and the Process Specification Language (PSL) (Cheng et al. 2003).

In order to describe the usage of web services, a simple, easy-to-use simulation access language, SimAL, is designed and implemented to coordinate application tools and to simulate scenarios in assisting decision making (Cheng 2004). In general, three key factors are involved in decision-making: alternatives, information, and preferences. Alternatives imply that more than one option should be available. Information refers to the knowledge available to users about different options. Preferences specify the aspects that users want to optimize. To support these functions, operational statements for Invocation, Operation, Control, and Decision-Support are provided in SimAL (Cheng 2004).

The objective of our research in web services is to develop methodologies that can effectively wrap legacy applications and make them accessible over the network. Different applications would require different models for integration and coordination. Detailed discussion of the simulation framework and the integration architecture is beyond the scope of this paper. Interested readers are referred to the works by Liu (2003) and Cheng (2004) for details. Instead, a number of demonstrative examples are employed here to illustrate the methodologies and potential applications of engineering web services.

APPLICATION EXAMPLES

To illustrate the web-based service integration framework, commercial software applications, such as Microsoft Project, Microsoft Excel, Primavera Project Planner, Vite SimVision, Autodesk Architectural Desktop (ADT) and 4D Viewer are wrapped as web services that export their functionalities (see Figure 2). Applications run on heterogeneous platforms can be accessed homogeneously through standard web services interfaces. Functionalities from various software applications can be brought together to complete a specific engineering task. The prototype also incorporates a variety of devices ranging from PDA, web browsers, desktop computers, and server computers to support ubiquitous access to the information and simulation applications. Additionally, online services, such as weather forecasting and product information, are also

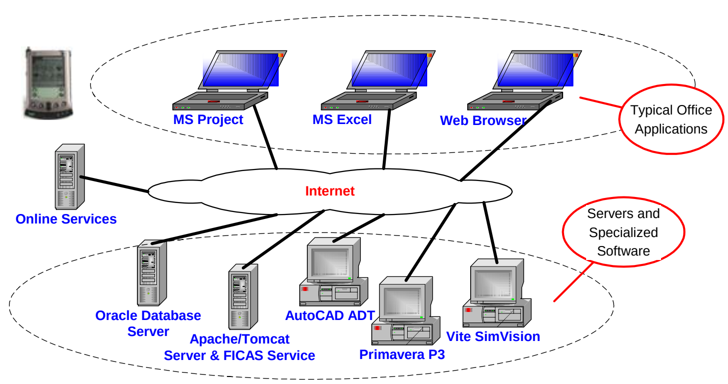


Figure 2: Demonstration Infrastructure for Web Services

included. In short, by using the web services model to develop the integration framework, engineering applications can interoperate regardless of locations and platforms.

EXAMPLE 1: INTEGRATION OF CAD AND SCHEDULING TOOLS

CAD and scheduling tools are among the most important software applications in design and construction. This example illustrates how to integrate CAD and scheduling tools using the simulation framework. To build the link between a CAD model and a schedule, the 3D model needs to be object based. In addition, objects in CAD models should be grouped and associated with corresponding tasks in the project schedule. Once the association is established, the program can display the 3D model according to a specified schedule. For each object (or a set of objects) in ADT, the program first retrieves the corresponding scheduling task from the association table. It then compares the targeted display date against the start and finish dates of the task to determine whether the object should be displayed, partially displayed, or not displayed at all. The appropriate CAD models are created to show the construction progress on the targeted date. Using a Web browser, users can view the CAD model of the project at various dates without the need of having ADT installed on their computers. This functionality can be very useful to field personnel who may not always have access to computers that host complex CAD tools; on the other hand, it is not unusual for them to have PDA or laptop computers, as well as Internet connections. It should be pointed out that the CAD models are dynamically generated by ADT and Primavera P3 according to the latest model and scheduling information. This approach is different from Web-based project repositories, which do not offer real-time analysis tools to process project information. Once the connection between the CAD model and the schedule, users can adjust task schedules, update CAD models and view the results using a Web browser. This process is depicted as shown in Figure 3 and can be implemented as a program written in the SimAL language.

To illustrate, as shown in Figure 4, suppose that the user modifies the duration of task *ID5* ("Grading/Excavation") from 55 to 85 days and update the schedule on a Web browser. Once the simulation program receives the change, it notifies Primavera to reschedule the

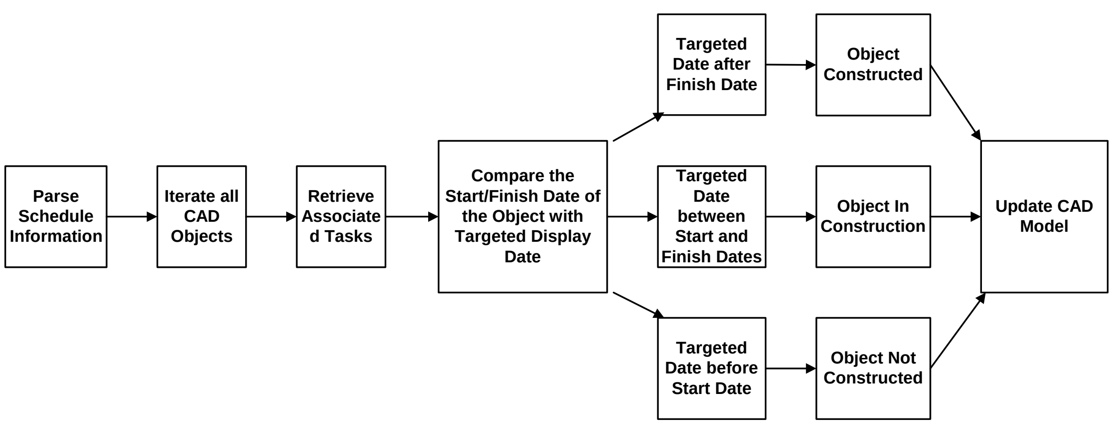


Figure 3: Process for Integrating Project Schedule and CAD Model Display

project (see Figure 5). When rescheduling is completed, the simulation program proceeds to instruct ADT to incorporate updated scheduling information and to display the CAD models corresponding to the updated schedule, as shown in Figure 6. The changes in the construction progress can also be viewed on a Web browser, as shown in Figure 7.

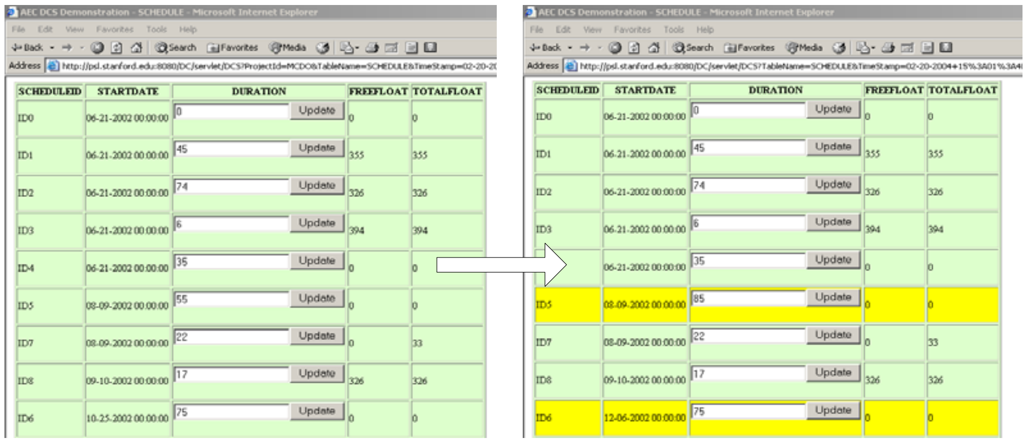


Figure 4: Modifying Schedule on a Web Browser

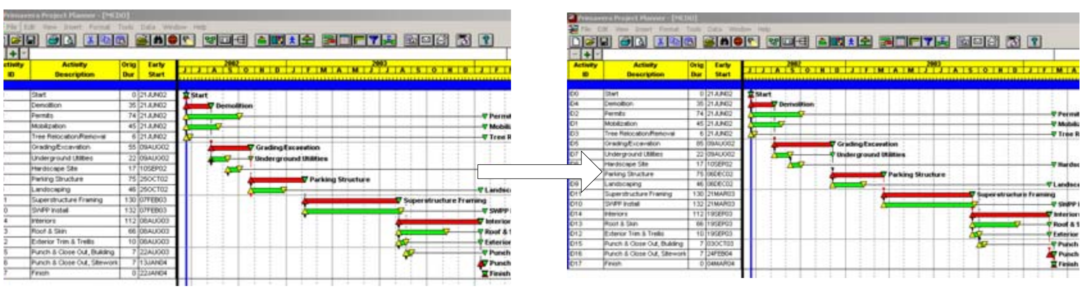


Figure 5: Re-scheduling Project Activities using Primavera P3

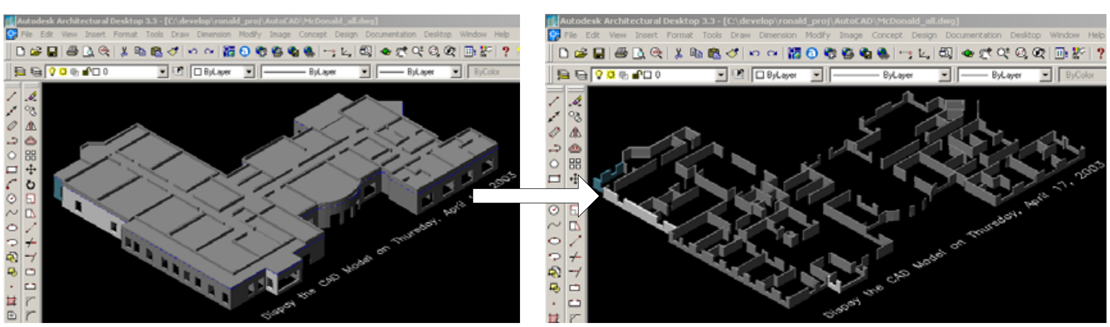


Figure 6: Displaying 3-D Models According to Schedule Changes on AutoCAD ADT

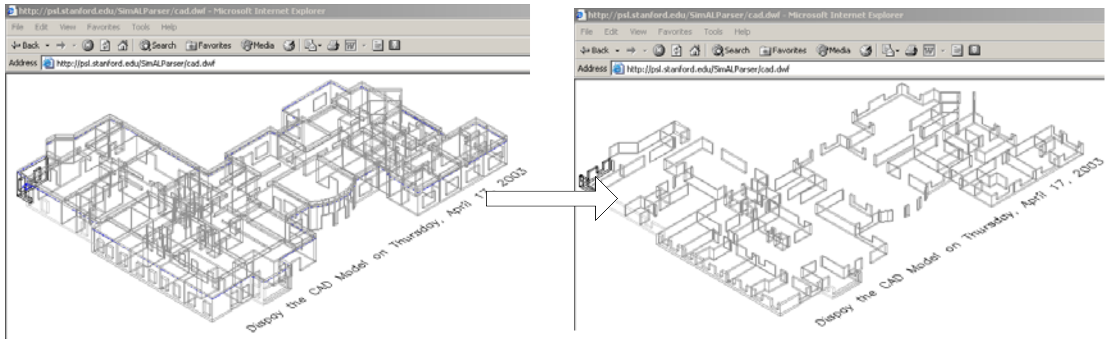


Figure 7: Visualizing Model Change on a Web Browser

EXAMPLE 2: INCORPORATING ONLINE WEATHER INFORMATION FOR SIMULATION

The purpose of this scenario example is to illustrate bringing on-line services to engineering simulation. Figure 8 shows an example workflow to include weather conditions in project management. A parser is developed to convert the weather forecast service information into XML format as shown in Figure 9. In addition, as depicted in Figure 10, a simulation program written using SimAL is embedded in Microsoft Excel to specify the workflow. Figures 11 and 12 illustrate the impacts of the weather conditions to the schedules displayed in Primavera P3 and the results of task and resource backlogs generated by Vite SimVision and displayed as charts using Microsoft Excel.

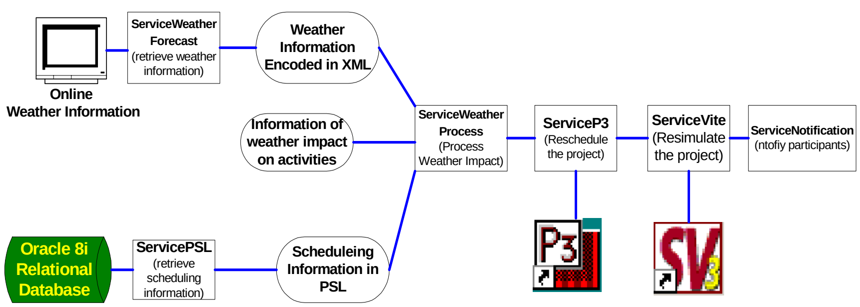
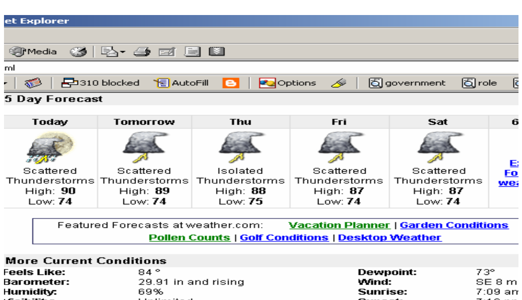
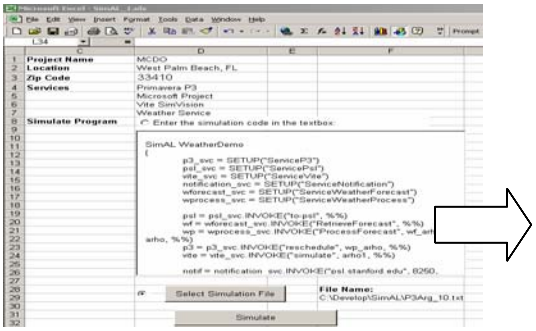


Figure 8: The Workflow in the Weather Demonstration



<?xml version="1.0"?>
<WeatherReport>
<weather date="2003-9-23">
<location>
<zipcode value="33410" />
</location>
<conditions value=" Isolated thunderstorms early, mainly cloudy overnight with a few showers" />
<temperature>
<templow c="23.3" f="74.0" />
<temphigh c="32.2" f="90.0" />
</temperature>
……
</weather>

Figure 9: Expressing Weather Information in XML



```
SimAL WeatherDemo
{ /* Establish Connections */
  p3_svc = SETUP("ServiceP3")
  psl_svc = SETUP("ServicePsl")
  vite_svc = SETUP("ServiceVite")
  notification_svc =   SETUP("ServiceNotification")
  wforecast_svc = SETUP("ServiceWeatherForecast")
  wprocess_svc = SETUP("ServiceWeatherProcess")
  /* Invoke Services */
  psl = psl_svc.INVOKE("to-psl", %%)
  wf = wforecast_svc.INVOKE("RetrieveForecast", %%)
  wp = wprocess_svc.INVOKE("ProcessForecast", wf_arho, arho, %%)
  p3 = p3_svc.INVOKE("reschedule", wp_arho, %%)
  vite = vite_svc.INVOKE("simulate", arho1, %%)
  notif = notification_svc.INVOKE("psl.stanford.edu", 8250, status)}
```

Figure 10: A Demonstration SimAL Program Embedded in Excel

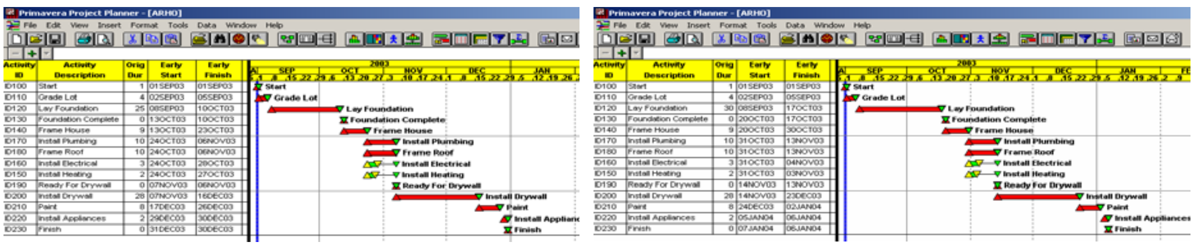


Figure 11: The Impact of Weather on the Schedule Displayed in Primavera P3

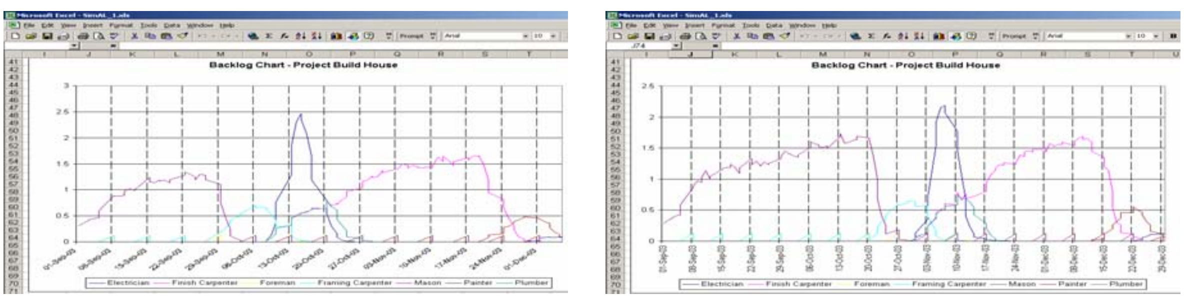


Figure 12: The Impact of Weather on Task Backlog Displayed as Charts in Excel

EXAMPLE 3: INCORPORATING ONLINE CATALOGUE INFORMATION FOR DESIGN

With the rapid increase of online catalogs, the interactions and the information flow between product descriptions and design activities can be valuable. Manufacturers can publish their product information and professional designers can acquire design data online. One example is Autodesk's i-drop technology (see http://www.autodesk.com/idrop) which enables a web developer to add drag-and-drop capabilities to a web site, which then acts as an open gateway between the web content and the web user. As shown in Figure 13, the content of a product is expressed in HTML and the product information can be structured in an XML file, which can also includes other files (such as drawing or image) to be transferred. Designers can easily incorporate manufacturing products into their design. Product information such as model code, manufacturer, supplier, price quote, etc. can be attached as object attributes. Furthermore, once the object is dragged-and-dropped into the design drawing the designers can update the information to produce a procurement list during the design phase.

Take a floor plan of a residential building shown in Figure 14 as an example. The designer can drag items found on different web catalogues into the design drawing. The inherited information about the items are also included. Once the items are added into the design, the designer can copy and paste the downloaded objects as desired. The designer can also change the values of the attributes. Figure 14 shows the floor plan with furniture and utilities imported into the design. Figure 15 shows a spreadsheet tabulating the items and their descriptions. The data can be outputted in XML format and forwarded to other applications.

A “virtual” supply chain is a vital element of today’s business environment. Companies around the world are trying to take advantage of the Internet and information technologies to create virtual supply chains where customers, suppliers, and business partners collaborate with each other. Our current research is to utilize FICAS and SimAL to create a demonstration prototype modeling a procurement supply chain as shown in Figure 16. An organization holds information about corresponding entities and keeps monitoring key data, such as inventory level, order and delivery status. Project participants can gather information with schedule data so that they can forecast potential problems. If problem arises, others across the chain can quickly be informed so that new services and strategies can be deployed to resolve issues at hand.

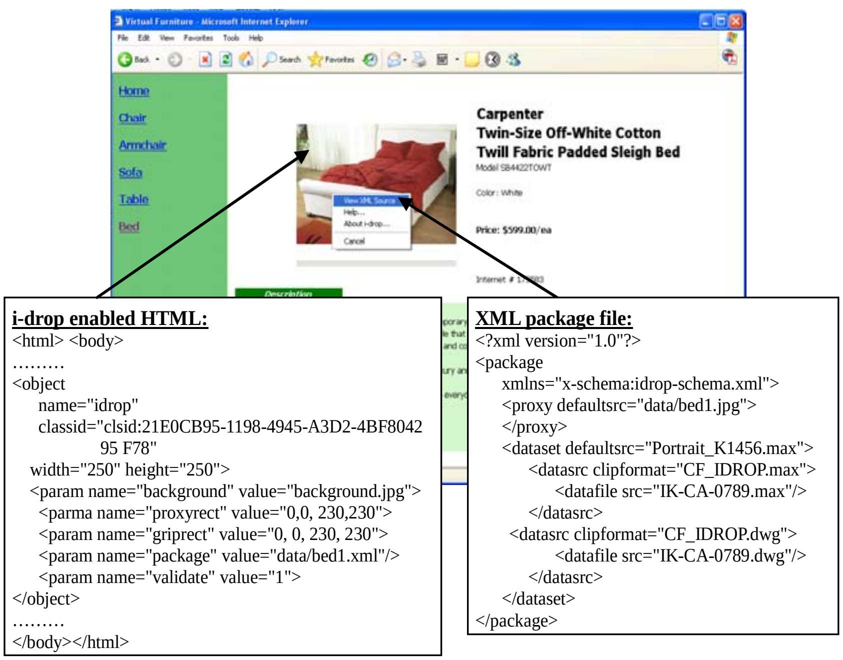


Figure 13: Integrating Online Catalog and Associated HTML and XML files

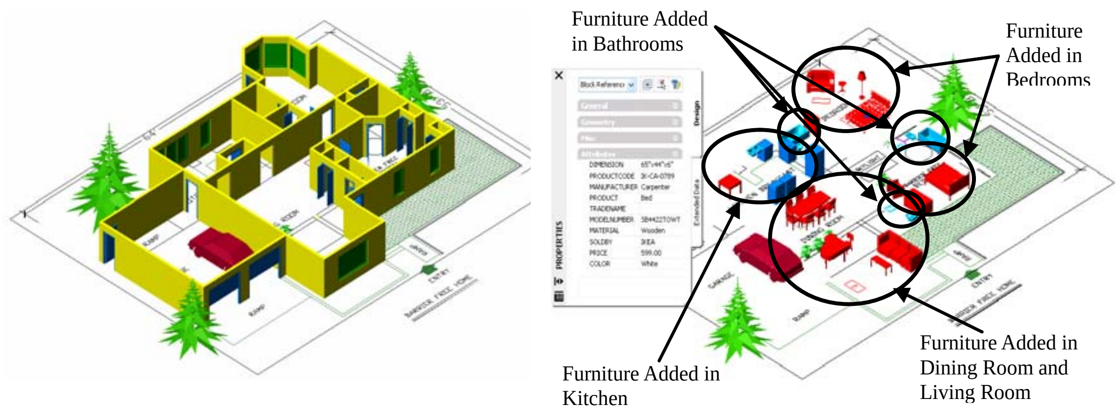
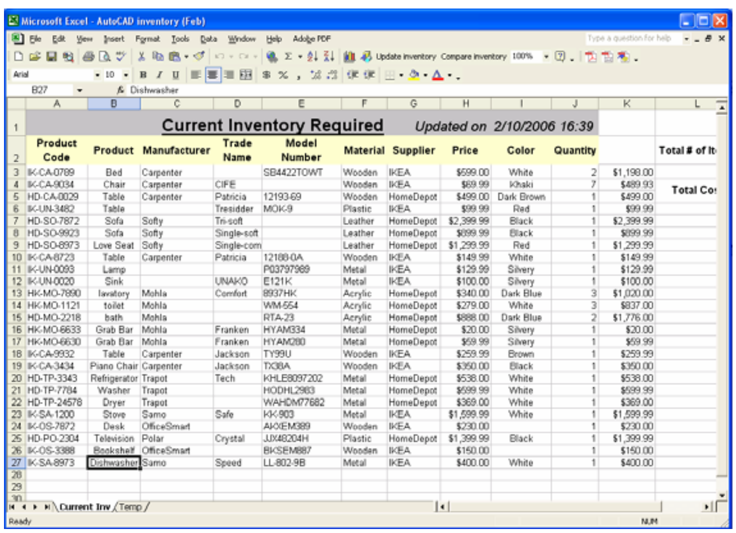


Figure 14: Drag-and-Drop Online Product to a Design Drawing



Microsoft Excel - AutoCAD inventory (Feb)

Current Inventory Required *Updated on 2/10/2006 16:39*

Product Code	Product	Manufacturer	Trade Name	Model Number	Material	Supplier	Price	Color	Quantity		
IK-CA-0789	Bed	Carpenter		SB4422TOWT	Wooden	IKEA	$599.00	White	2	$1,198.00	Total # of It
IK-CA-9034	Chair	Carpenter	CIFE		Wooden	IKEA	$69.99	Khaki	7	$489.93	Total Co
HD-CA-0029	Table	Carpenter	Patricia	12193-69	Wooden	HomeDepot	$499.00	Dark Brown	1	$499.00	
IK-UN-3482	Table		Tresidder	MOK-9	Plastic	IKEA	$99.99	Red	1	$99.99	
HD-SO-7872	Sofa	Softy	Tri-soft		Leather	HomeDepot	$2,399.99	Black	1	$2,399.99	
HD-SO-9923	Sofa	Softy	Single-soft		Leather	HomeDepot	$899.99	Black	1	$899.99	
HD-SO-8973	Love Seat	Softy	Single-com		Leather	HomeDepot	$1,299.99	Red	1	$1,299.99	
IK-CA-8723	Table	Carpenter	Patricia	12188-0A	Wooden	IKEA	$149.99	White	1	$149.99	
IK-UN-0093	Lamp			P03797989	Metal	IKEA	$129.99	Silvery	1	$129.99	
IK-UN-0020	Sink		UNAKO	E121K	Metal	IKEA	$100.00	Silvery	1	$100.00	
HK-MO-7890	lavatory	Mohla	Comfort	8937HK	Acrylic	HomeDepot	$340.00	Dark Blue	3	$1,020.00	
HK-MO-1121	toilet	Mohla		WM-554	Acrylic	HomeDepot	$279.00	White	3	$837.00	
HD-MO-2218	bath	Mohla		RTA-23	Acrylic	HomeDepot	$888.00	Dark Blue	2	$1,776.00	
HK-MO-6633	Grab Bar	Mohla	Franken	HYAM334	Metal	HomeDepot	$20.00	Silvery	1	$20.00	
HK-MO-6630	Grab Bar	Mohla	Franken	HYAM280	Metal	HomeDepot	$59.99	Silvery	1	$59.99	
IK-CA-9932	Table	Carpenter	Jackson	TY99U	Wooden	IKEA	$259.99	Brown	1	$259.99	
IK-CA-3434	Piano Chair	Carpenter	Jackson	TX38A	Wooden	IKEA	$350.00	Black	1	$350.00	
HD-TP-3343	Refrigerator	Trapot	Tech	KHLE8097202	Metal	HomeDepot	$538.00	White	1	$538.00	
HD-TP-7784	Washer	Trapot		HODHL2983	Metal	HomeDepot	$599.99	White	1	$599.99	
HD-TP-24578	Dryer	Trapot		WAHDM77682	Metal	HomeDepot	$369.00	White	1	$369.00	
IK-SA-1200	Stove	Samo	Safe	KK-903	Metal	IKEA	$1,599.99	White	1	$1,599.99	
IK-OS-7872	Desk	OfficeSmart		AKXEM389	Wooden	IKEA	$230.00		1	$230.00	
HD-PO-2304	Television	Polar	Crystal	JJX48204H	Plastic	HomeDepot	$1,399.99	Black	1	$1,399.99	
IK-OS-3388	Bookshelf	OfficeSmart		BKSEM887	Wooden	IKEA	$150.00		1	$150.00	
IK-SA-8973	Dishwasher	Samo	Speed	LL-802-9B	Metal	IKEA	$400.00	White	1	$400.00	

Figure 15: A Spreadsheet Enlisting Items Inserted in the Design

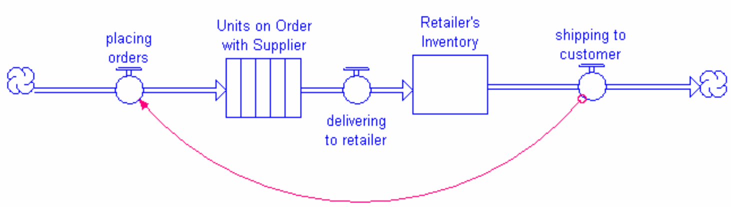


Figure 16: An Illustration of Procurement Supply Chain

SUMMARY AND DISCUSSION

This paper has presented three example applications that demonstrate the potential applicabilility and flexibility of the web services technology. Integrating distributed engineering applications as web services provides an effective mechanism to extend the functionalities of legacy applications and make them more accessible to a broader group of users. With the flexibility and scalibility of the web services technology, the impact could have significant impact in project life cycle design, operations and management.

Web service is still an emerging technology, and many improvements need to be made. Many general-purpose features, such as security, reliable message delivery, and transactional semantics, are needed to facilitate the development of web services. Specifications for the web services need to be standardized for handling heterogeneous data formats and software platforms. To promote scalability in the integration of web services, programming models need to shift from procedural call style services toward specification-centric services. As these new developments progress, the web services technology will be applied more widely for developing engineering software applications.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Chuck Han for his assistance on the i-drop technology. Mr. Xiaoshan Pan provided the original floor plan shown in Figure 14. The authors would also like to acknowledge the software support from Autodesk Inc..

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