

THE IMPLEMENTATION OF INTEGRATED ENVIRONMENTS USING THE INDUSTRY FOUNDATION CLASSES STANDARDS AND WEB TECHNOLOGIES

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ABSTRACT

Integrated Computer Environments have been the subject for research for many years. Among others, the issue of exchanging and sharing data between project participants has been their major concern. International initiatives have been set up for this purpose, mainly STEP and the IAI/IFCs. The latter aims to produce standard data models for the building industry to facilitate the exchange of data between all partners involved along the project life cycle. On the other hand, the large increase in the Web usage has made the large software vendors such as Microsoft, IBM, SUN, etc, produce standards for data communication for client-server applications. These attempts have resulted in the production of the CORBA-ORB (Object Request Broker Architecture - Object Request Broker) which has been recommended by the Object Management Group (OMG) and the Microsoft ActiveX. These standards have facilitated the development of distributed objects environments where users can exchange data from and to different servers without knowing where the objects are stored. This is an important concept if the implementation of integrated construction environment is to be successful.

The aim of this paper is to report on the findings of a large research project which is being carried out, by the AIC (Automation and Integration in Construction) research group, at the University of Salford based on the Salford's previous experience in the development of integrated environments, such as SPACE and OSCON. This project is adopting international standards in data models and communication protocols. The IFCs have been used as the core data model and has been implemented in a three-tier architecture using CORBA-ORB as its communication standards.

The proposed environment adopts open standards and focuses on using existing Internet technology. The project aims to:

- *Test the state of the art technologies and recently emerging standards such as CORBA and IFC,*
- *Define and select the necessary software components for the integrated environment*
- *Develop an architecture of this environment which will be implemented with the selected software components,*
- *Develop a number of use-cases and scenarios to gain an insight on how such an environment can be used by the Construction Industry professionals.*

Keywords: STEP, IAI, IFC, integration, Internet, data exchange.



INTRODUCTION

The issue of exchanging and sharing data between project participants have resulted in the establishment of international initiatives such as STEP and more recently IAI. The International Alliance for Interoperability (IAI) aims mainly to produce standard data models; the Industry Foundation Classes (IFCs). It has successfully rallied the industry behind its activities. Through co-ordinated committees, industrialists have participated in defining the general requirements for data exchange throughout the project life-cycle. A number of IFCs data models have been released, the most recent of which is version 1.5, and a large number of software vendors have started to adopt these standards in their products.

On the other hand, the large increase in Web usage has made the large software vendors such as Microsoft, IBM, SUN, etc. produce standards for data communication for client-server applications. These attempts have resulted in the production of the CORBA-ORB (Object Request Broker Architecture - Object Request Broker) which has been recommended by the Object Management Group (OMG) and the Microsoft ActiveX. These standards have facilitated the development of distributed object environments where users can exchange data to and from different servers without knowing where the objects are stored. This is an important concept if the implementation of integrated construction environments is to be successful.

This paper focuses on the implementation issues of the IFC as the core data model for an environment. This environment allows geometric and non-geometric data to be exchanged between the different partners of a construction project through standard Web pages. In addition, this paper describes the framework developed by the research team which facilitates the implementation of the aforementioned technologies and standards. Screen snaps taken from the developed prototype will be shown to illustrate how information can be exchanged between designers, planners, estimators and clients using the IFC standards in a very managed distributed environment.

PREVIOUS RESEARCH

There had been extensive studies in the area of computer integrated construction. Projects such as ATLAS, COMBINE, RATAS, ICON, COMBI, OSCON, OPIS and SPACE are few examples of good work in this area (Aouad et al 1997, Alshawi 1997, AIC 1996). The work presented here builds on these previous projects and proposes an improved architecture for computer integrated construction using IFC, Web and CORBA standards. The CORBA standard has been specified by projects such as COMMIT (Brown et al 1996) and work at CSTB (Zarli & Amar, 1997). IFC are being developed by the IAI (<http://iaiweb.lbl.gov/>, Wix 1997). The web as an environment for collaborative working has been recommended by (Danier and Turk 1994)

OVERVIEW

This section presents an overview of exchange standards, internet standards, dynamic web content, object oriented and data exchange.

Exchange standards

The development in CAD and other computer aided applications systems led to these systems being used in defining the geometrical and non-geometrical data associated with a project. The upsurge in use of CAD and construction applications necessitated the need for project data to be exchanged between different systems. The need for data exchange can be attributed to many reasons, for instance different CAD/Construction systems exist within a company, transferring data from a CAD system for analysis by another system, or a company may need to transfer project data to a third party for analysis due to the limited analysis facilities within that company.

The major international standards for data exchange are the STEP and the IAI/IFCs. STEP is a pan industry approach whilst the IAI is concerned only with building construction at this stage i.e. AEC/FM industry. Both efforts, however, seek to arrive at an industry consensus. For building construction, there has always been a problem getting industry interest fired up for STEP whereas that has become a strength of the IAI. STEP has been fundamental in making available technologies to support Computer Integrated Construction (CIC). This is recognised within the IAI by their adoption of STEP standards to assist the development of the IFCs. A number of Chapters are formed in a number of countries e.g. UK, Japan, Germany to promote the development of IFC's. The objective is to promote the development and use of applications for the exchange and sharing of information to improve the efficiency and quality of building design, construction and maintenance

It can be argued that neither STEP nor IFC development represents leading edge technology and this is certainly true. However, they are well in advance of where industry is at present and probably represent stages through which industry must pass. In this sense, they may be regarded as typical of standards generally (Wix 1997)

Internet Standards

The Internet with its open standards and accessibility is fast evolving into a powerful environment for supporting distributed group work. This work recognises this reality and takes advantage of open Internet standards wherever possible.

The proposed system will use the concept of a 'project web site' as a first point of access for all shared project information. Each new project will have its own web site (multiple projects may share the same physical machine). This will allow project information to be accessed through an internal network (Intranet) or through the wider global Internet. This enables us to leverage existing security mechanisms (password protection, certificates, IP address filtering etc). All users will be able to access pages concerning, for example, contact information (email addresses etc) but only certain users will have full access to pages containing design information. All web servers now have easy to manage security facilities, usually also accessible remotely over the web.

Adopting an open web based approach to establishing an integrated construction project database gives greater flexibility to the project process manager. Once a project web site has been established the manager can incrementally introduce other Internet technologies to facilitate smooth communication between project participants. An example of this would be use of an NNTP (Network News Transfer Protocol) server containing a set of project specific

newsgroups. These would allow multi-user discussion of any problems that may occur, bringing problems to light at the earliest opportunity. The archived news messages could also be useful in resolving disputes, as they would provide a record of problems found and decisions taken.

Another technology which can complement an integrated project database is the use of HTML based email for managing workflow. By using this form of content rich email it is possible to distribute mail messages containing forms or links to appropriate news messages or project web pages. For instance a message requesting acceptance of a piece of work can hold a pointer to the web page containing the work together with a form that allows the user to accept the work or request further changes.

Dynamic Web Content

Originally the web was a static client server environment with most people being consumers of information produced by a relatively few people with specialist knowledge. However, as the web is being transformed from a publishing technology to a collaborative environment it is becoming easier for end users to produce their own content. This is achieved in two main ways:

- 1) Web page production through personal productivity tools such a word processors, spreadsheets or wysiwyg (what you see is what you get) editors in web browsers.
- 2) Dynamic creation of web contents from information held in data stores e.g. Object Oriented Databases.

In order to support the 'universal client' approach of being able to use a web browser to access all project information the Salford team have concentrated on the second of the above approaches. By providing the ability to dynamically generate web content from an IFC database we will be able to provide a seamless link between the object-oriented database holding the project model and the World Wide Web. This way we can extend the universal client concept to the IFCs. We are currently using Netscape's Web Application Interface (WAI) to generate dynamic content from ObjectStore databases.

Object Oriented Databases

The ObjectStore object-oriented database management system is being used as the main project database. The latest version 5.0 of ObjectStore provides support for both Java and C++. By using an OODBMS we avoid the problem of having to translate the instances of the IFC classes into fields suitable for storage in a conventional relational database system. Object databases are also particularly good at storing the relationships between objects in the model classes.

Data Exchange

There are a number of ways to integrate existing applications into a web integrated environment:

- 1) Provide a means for exchanging files between the project database and the applications using file interchange. This involves writing import/export applications that can run of the

server side and provide information in the appropriate application format. One example of this approach would be to write a server application, which could dynamically convert part of the project database into an IFC flat file format for import into a CAD system. Another would be to generate CSV (Comma Separated Values) text files containing equipment schedules for import into a spreadsheet.

2) Use the existing information sharing capabilities of the existing applications. At the moment there are two main competing standards for distributed object computing, OMG CORBA and Microsoft Active X technologies. It is generally agreed that CORBA is the better technology when it comes to true Internet wide scalable object-oriented client server systems, whereas Active X technology has a firm hold over the Windows desktop. In order to provide links between these two competing standards some companies have produced bridging software (e.g. IONA Inc) which allows CORBA to see OLE Automation objects and vice-versa. This technology is in the early stages but may provide a route for more dynamic integration between the project database and Windows applications.

3) Provide 'wrapper' objects to encapsulate the functionality of the existing software and make it available to clients on the web. Because CORBA IDL only specifies what a server should do and not how it should be implemented. It is possible to specify server functionality in IDL and then use existing software to implement that functionality. For example, consider an existing structural analysis package. Using this the user may be able to enter information from architect's plans and then perform structural calculations. By wrapping this package in a CORBA jacket this functionality could be made available to other parts of the system.

The Salford team has adopted method (1) above as a way of providing universal web based access to a project database. This functionality is being implemented using Netscape Enterprise Server's Web Application Interface (WAI). This involves implementing CORBA servers running in parallel with the project web server. These servers handle URL style requests for access to the project database.

THE ARCHITECTURE

The architecture of distributed environment would require client/server infrastructure. Mainly, there are two types of client/server architecture, two- and three-tier architecture. The two-tiered architecture contains two computers, a client and a server. The three components of an application, the user interface (client), data processing (application server) and data storage are divided among two software entities or tiers: the client application code and database server. User interface is handled exclusively by the client, processing is split between client and server, and data is stored on and accessed through the server. The client handles most data processing with respect to functionality logic. The disadvantage with this approach is, data processing and user interface are tied together, and any type of modification involves major changes of application. Figure 1 shows the components of a three tier architecture.

Three tier separates data processing from interface and data storage. User interface (client), data processing (application server) and data storage. User interface (Client), data processing (application or Web servers) and data storage (database server) are the three layers in this architecture (Campbell 1997).

Java applications can be built using three tier architecture depending on the complexity of the applications or the environment that needs to be developed. Internet clients view applet or applications as interfacing with application servers, which actually communicates with the database server.

The research team at Salford uses Web browser as the main user interface and each construction application is built as a WAI application. WAI is a CORBA-based programming interface that defines object interfaces to the HTTP request/response data and server information. Using WAI, the user can write a web applications that accepts an HTTP request from a client, processes it, and return a response to the client (Netscape 1997). The IFC schema and its instances are stored in ObjectStore database (see Figure 1). The end user would not need to know where the data reside or which server is processing it (Faraj et al 1998).

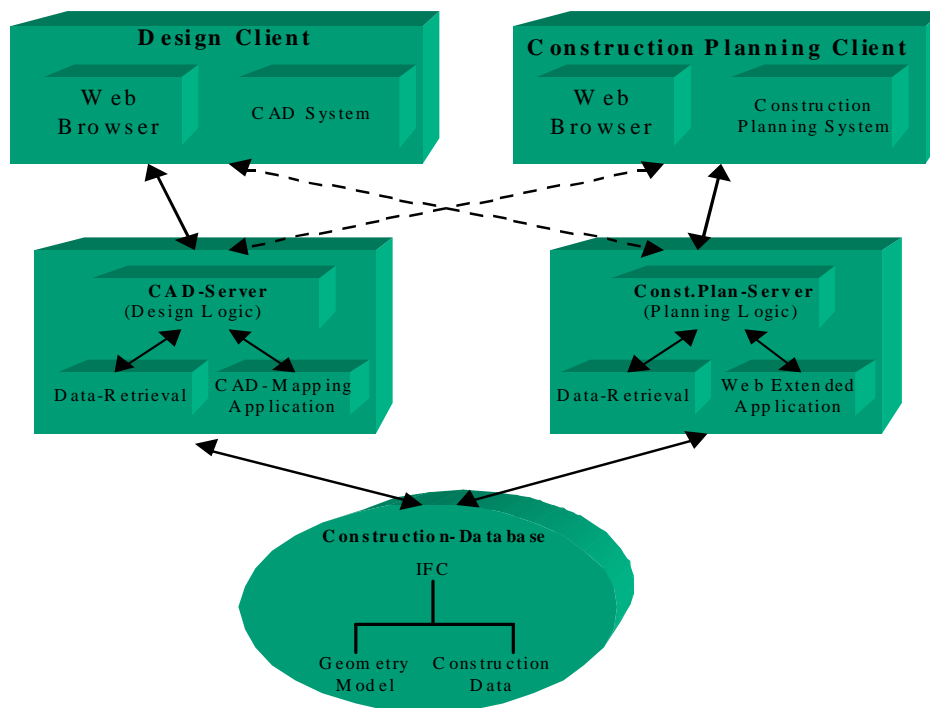


Figure 1: Overview of the Implemented Environment

IMPLEMENTATION OF THE ENVIRONMENT

Use cases have been adopted at the implementation stage. A number of use cases have been identified, these are: establishing a new project database, populating a database with design information, generating cost estimates, browsing data through a VRML viewer, generating construction planning information, and accessing data sheets. Only the design and VRML applications are reviewed here.

The User Interface

A set of generic web pages is created to act as an interface to the overall integrated environment. These pages are used as a template for the creation of project web sites. They contain further web pages for accessing the various project applications and other project information such as actors and contact addresses.

Generating the IFC Schema in ObjectStore Database

The IFC v1.5 published its project model using a EXPRESS (ISO10303-11). To map this schema to ObjectStore, ST-Developer was used to convert the IFC schema from EXPRESS to a set of programming language classes in this case pure Java classes. ObjectStore utilities are then used to read the Java classes to create the database schema. This schema can then be used and instantiated by the various construction applications.

The CAD Application

Due to the lack of availability of commercial IFC compatible CAD systems, the research team implemented its own CAD system that uses AutoCAD-14 geometry engine. This application is capable of supporting both newly created and existing project. The application is written in C++, as AutoCAD does not support Java.

Newly Created Projects

The purpose of this application is to enable the user to create new building design and to share information with other construction applications. The design information can also be exchanged with other CAD commercial CAD systems. AutoCAD 14 supports both 2D drafting and solid modelling geometry. The data in our application is saved as a solid model of which the 2D wireframe can be derived. The format in which the data is saved is STEP Part 21 file. This would enable us to exchange our design models with different CAD systems that support STEP/IFC.

Existing Projects

The user interacts with this application through a Web page. The application populates the database from STEP Part 21 file and is implemented as a Netscape Web Application Interface (WAI) web server extension. The WAI application creates and registers CORBA objects with the web server associated with project database.

Browsing a Design Using VRML

This application is implemented as a WAI server extension application which is written in Java. Before the user can interact with the application the design needs to be uploaded to the ObjectStore database and VR application server invoked so that it can process requests sent to it by the client application. The user issues the request for generating VRML representation of the design. The VR application responds by accessing the geometric data of the IFC project model and generates the corresponding VRML representation. The user interacts with the application from the client through a Web page and the VRML representation is displayed on the web browser using COSMO Player 2.0 plugin.

OVERVIEW OF THE WORKING ENVIRONMENT

The system consists of a project process manager which would enable the project manager to create the project web site and database for each project and issue request and authorisation to the project participants to access and use the project data. Users can login to the site through standard access control mechanisms, i.e. password protection, certificates etc. Controlled access to appropriate subsets of the site can be given. For example, all users are able to access pages concerning contact information (e-mail addresses etc.), but only certain users have full access to the design information.

The implemented interface enables individual users if authorised to login to the project web site to request or submit data. Data access (query or submission) is handled through menus on the web pages. Each menu item issues a command to a web server. The web server then delegate the responsibility to a dedicated WAI application to act on the requested by accessing the project database and displaying the results on a web browser, planning applications, spreadsheets, etc.

FLOW OF INFORMATION

Figure 2 shows the implementation of three-tier integrated distributed construction environment and the flow of data within the environment. At the heart of the environment is the IFC project model defined by the IAI. Designs can be created using a CAD system. The CAD system is capable of writing to and reading data from Part 21 files that conform to IFC v1.5 schema. Once the design is created its Part 21 file can then be loaded to the database through the user interface. The user interface can be used to pass and retrieve processed data associated with the project. Different construction experts use different tools to view or process the data, the environment supports a number of these tools.

The interface uses HTTP protocol to communicate with the web server. The web server delegates the responsibility for processing the HTTP requests to the CORBA objects which can then invoke the relevant application e.g. CAD, VRML Generation to process the data and return the result to the user in a format that can be viewed and understood by the construction expert. For example, costing will be displayed on Excel spreadsheet or planning data is returned to be viewed on Msproject.

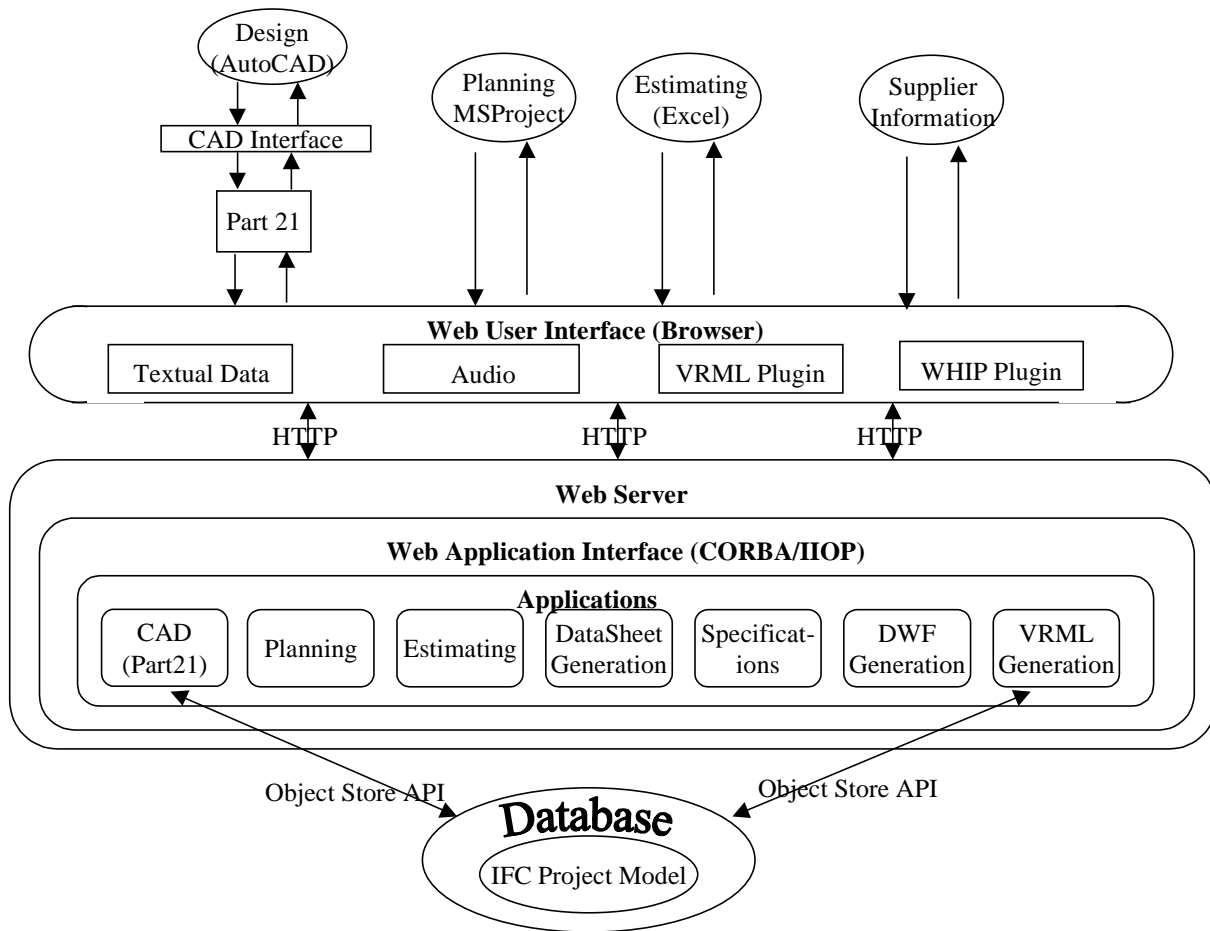


Figure 2 A schematic representation of the integrated system.

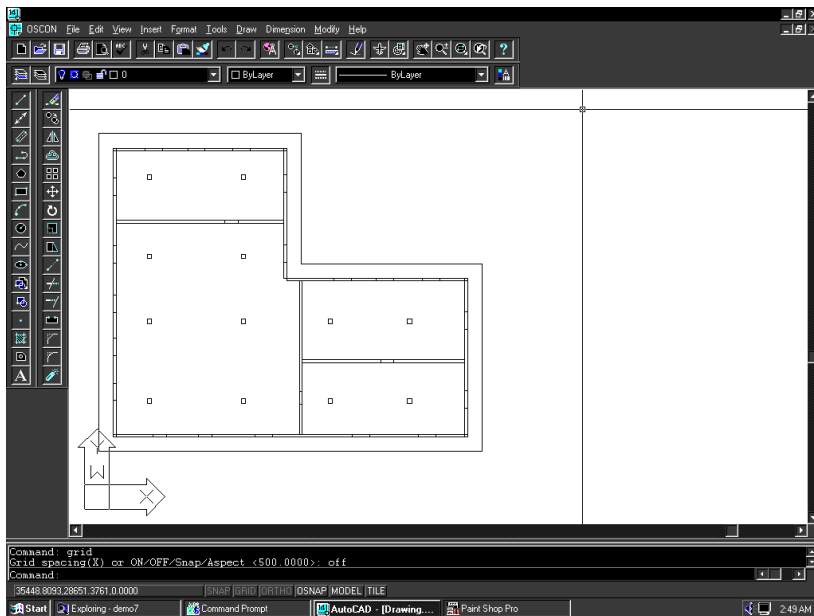


Figure 3 2D plan produced in AutoCAD

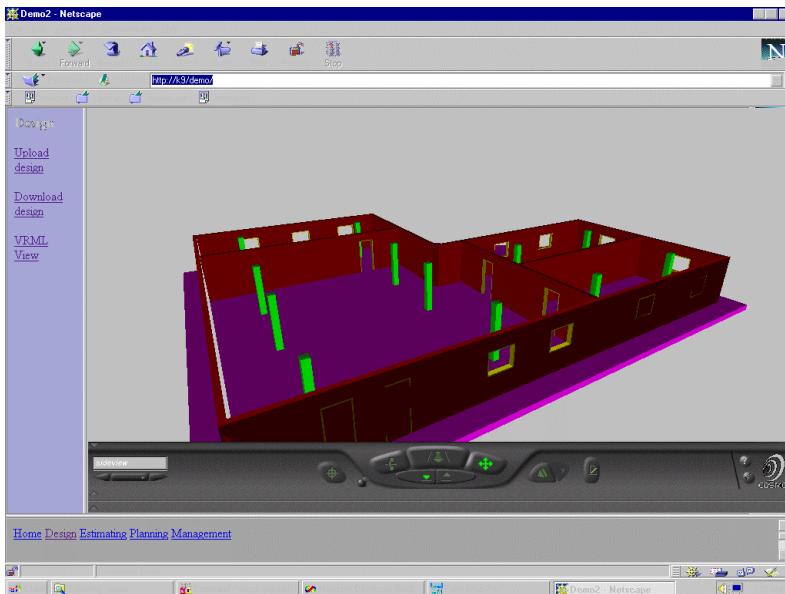


Figure 5 A VRML representation of the design.

CONCLUSIONS

This paper presented an integrated construction environment based on IFC standards and implemented within a distributed environment using object oriented, web and CORBA technologies. The results obtained so far are encouraging and the developed prototype demonstrated that the technology is progressively maturing in this domain. IFC standards are providing the mechanisms for defining models which are exchangeable. The World Wide Web and CORBA will ultimately facilitate the communication of information between construction professions operating in distributed geographical locations. It is concluded that the coupling of previously mentioned standards and technologies will offer many benefits to all industries, particularly to the fragmented construction industry.

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