Leveraging Information Technologies Applications in the Canadian AEC/FM Industry

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LEVERAGING INFORMATION TECHNOLOGIES APPLICATIONS IN THE CANADIAN AEC/FM INDUSTRY

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ABSTRACT: The architecture, engineering, construction, and facility management (AEC/FM) industry in Canada has been facing an unprecedented level of competition. To stay competitive in today's marketplace, the Canadian AEC/FM industry must develop and deploy IT solutions for planning, designing, constructing, and managing facilities, and to perform these tasks in the most effective and productive way. Identifying the role that information technologies can play and developing solutions that implement these technologies is a major challenge the industry is facing in order to achieve this goal. This paper presents an overview of an ongoing research effort, called "Information Technologies for AEC/FM in Canada" (ITAC), that aims to leverage the current use of IT in the AEC/FM industry through the development of a computational infrastructure and a component-based framework to enable the integration of AEC/FM projects information.

1. INTRODUCTION

The AEC/FM industry is characterized by large-scale, one-of-a-kind construction projects carried out by many small organizations brought together for short durations under high economic and technical risks and low profit margins. This has led to an industry known for its fragmentation and stagnant productivity growth. Engineering works and buildings are maintained and repaired for decades, and eventually renewed or rehabilitated scores of years later, in many cases by a single owner. In fact, there is little inter-relationship between the constructors and maintainers, adding to the apparent fragmentation.

The construction industry has a reputation for being "ultra-conservative", and is traditionally a "late adopter" of technology. A recent report by the Canadian Construction Research Board confirmed that "The Canadian construction industry is highly fragmented; most are small, independent, widely dispersed regional and local companies, totaling some 20 000 general contractors and 107 500 trade contractors, with 80 percent having revenues less than $250 000. Individually they lack the resources to undertake research and innovation projects and depend heavily on off-the-shelf technology, building codes and standards" (Van Vliet 1999). The same report also confirmed that "considering the commitment of our national investment in the construction industry, Canada's research and innovation efforts in this industry must improve significantly to become more effective and profitable in an increasingly competitive global market."

AEC/FM industries demand better use of information resources: to improve work efficiency and collaboration through improved access to information. The potential for improvement within the industry has largely been linked to its ability to better coordinate work, to more efficiently communicate project information, and to more effectively use information resources to support asset management decision-making. Emerging information technologies are poised to produce the most dramatic changes currently facing Canadian AEC/FM industries. The Canadian AEC/FM

industry's ability to develop and adopt new IT tools and techniques that can be used to analyze, design, construct, manage, and communicate, has the potential to strengthen and revitalize the industry in its domestic and international markets, and to enable the industry to stay competitive in today's increasingly sophisticated and competitive international marketplace.

A recent survey of the use of IT in the Canadian AEC/FM industry has found that "the introduction of information technologies is considered to have raised productivity in most areas" in particular general administration, design and project management (Rivard 2000). The same survey has also identified the most important areas of IT research for the industry to be "the implementation of computer-integrated design and construction, which integrates data and communication among firms as well as the development of new design tools that would let several designers participate and work together on a project and that would assist them in the conceptual stages of design."

ITAC (Information Technologies for AEC/FM in Canada) is a consortium of Canadian researchers and practitioners that aims at developing new ways to implement efficient IT solutions in the AEC/FM industry. ITAC has been formed in order to realize a broad set of objectives to facilitate the implementation and deployment of IT tools to support facilities planning, design, construction, and management, and to enable these tools to interoperate and share information throughout projects life cycle.

This paper is intended to provide a general overview of the ITAC project. Specific ITAC sub-projects are presented in more detail in other papers in these proceedings.

2. RESEARCH OBJECTIVES

The main goal of ITAC is to develop a computational infrastructure and a framework to facilitate the implementation of new generations of software tools to support the integrated planning, design, construction, and management of large-scale constructed facilities. The primary objectives of ITAC can be summarized as follows:

- Addressing a range of issues involved in the business practices associated with the development and deployment of new IT solutions.
- Development and integration of data models to represent the design information, the construction process, and the facility management data. The developed models will contribute to the ongoing effort by the International Alliance for Interoperability (IAI) to develop international standards for AEC/FM data modeling and exchange.
- Development of IT tools based on the data modeling standards and methodologies developed by ITAC team. The tools will include generic tool sets that can be used across various facility development domains as well as function-specific tool sets to support various AEC/FM activities.
- Implementation of a prototype software environment on top of the developed framework with emphasis on tools interoperability, enabling project team collaboration, and information and process management.
- Transfer of AEC/FM information technologies to the Canadian Industry and providing a roadmap for implementing and deploying the solutions developed in ITAC.

3. RESEARCH METHODOLOGY AND APPROACH

ITAC research is carried out as a set of inter-related sub-projects or work packages. These sub-projects can be grouped into two main threads. The first thread focuses on the design, construction, and project management phases of a project while the second thread focuses on the facility management phase with emphasis on modeling performance requirements and current conditions of building components, modeling life cycle cost and risk attributes of building components, and modeling maintenance management information. The following sections summarize the main components of each thread.

3.1. Design, Construction, and Project Management Thread

This thread addresses four main areas that we consider as a prerequisite to any successful and practical implementation of integrated AEC/FM systems. These areas include: modeling of project information; designing a distributed, integrated, and component-based framework; developing a set of model-based tools to aid in performing various project activities; and implementing integrated systems that support the interoperation of function-specific software tools and enable project team members to collaborate and share information throughout various phases of a project.

3.1.1. Project Data Modeling

A major requirement to implement integrated AEC/FM systems is to develop industry-wide standards to represent and exchange project information. The International Alliance for Interoperability (IAI) was formed to develop international data modeling standards, based on ISO 10303 STEP standards, to enable interoperability among all AEC/FM processes throughout the life cycle of a project. The IAI has been developing a standard data model, called the Industry Foundation Classes (IFCs) (IAI 2001) to enable data sharing and exchange throughout the project lifecycle.

The main objectives of the data modeling effort in ITAC are: (i) Extension of the models into a number of important complimentary areas such as specifications, project documents (e.g. design documents, contracts, change orders, etc.), construction work methods, and references to external libraries of construction information (e.g. pricing databases, equipment catalogs, etc); (ii) Validation of the models and their extensions, and developing a library of "use cases" to illustrate the use of IFC models in typical practices; and (iii) Technology transfer of the IFC models.

3.1.2. Development of a Framework for Total Project Systems

Total project systems are inherently complex and involve a large number of interacting and interdependent components that need to be organized and coordinated. For such systems, a high level architectural design to define the functionality of each component and the method of interaction and communication among these components is very crucial.

This research activity focuses on developing a component-based framework that embodies a set of methods and technologies to address the specific characteristics and requirements of the AEC/FM domain. The purpose of the framework is to serve as a generic or a Reference Architecture for AEC/FM applications and to provide the specifications and the architecture to facilitate the implementation process by providing a set of generic and reusable tools and services that are useful in the context of the AEC/FM domain. In particular, the framework needs to support information sharing and exchange among different function-specific software tools, and to develop efficient integration mechanisms.

3.1.3. Implementation of Model-Based Tools

AEC/FM projects involve a large number of activities including: preliminary design, analysis, detailed design, cost estimating, construction process planning and scheduling, etc. Most of the existing tools define and use their own internal data models that are generally inaccessible or unusable to other tools. In ITAC, we will be developing new tools and extending the functionality of existing tools to support model-based representation of the facility design and construction data using IFCs.

The ITAC framework is intended to be tool-independent, where tools can be integrated into the system without requiring changes to the framework (i.e. plug-and-play). Hence, the framework can be extended to support different AEC/FM projects by replacing or extending the tool set.

3.1.4. Implementation of Total Project Systems

This research activity involves the implementation of an integrated system based on the developed framework. The focus areas will include: establishing central project repositories; implementing data sharing and exchange through the use of model-based standard IFC and XML schemas between system components; developing new design, construction, and project management tools based on the shared data model; and extending existing tools to enable them to interface with other system components. The developed tools will emphasize the modeling and management of large shared data sets, and effective visualization of project information.

3.2. Facility Management Thread

The research activities in the FM area are mainly extensions to the Building Envelope Life Cycle Asset Management (BELCAM) research project (Lounis et al. 1999) that has been underway at the Institute for Research in Construction at NRCC. BELCAM has resulted in an extensive data set and knowledge base, and has contributed several new software tools and techniques for building performance modeling and simulation. BELCAM uses Markov Chain stochastic modeling to predict the service life of building components.

FM research activities in ITAC will include data collection related to long-term performance of roofing systems, and developing an expert system to assist roof inspectors to classify roof defects. The research will also develop new data models that extend IFCs in the asset management domain. The primary IFCs

extension areas include: data modeling of roof systems, modeling the performance requirements of building components, modeling current conditions of building components, modeling life cycle cost and risk attributes of building components, and modeling maintenance management information.

An integrated FM system will be developed to incorporate the knowledge gained in the BELCAM work, the new data models, and the integrated system approach developed in the design, construction, and project management work of ITAC. FM components will also include tools for capturing existing facility as-built data, specifying, measuring, and managing building component performance, conducting life cycle cost and risk analysis, and maintenance management.

4. A COMPONENT-BASED FRAMEWORK FOR AEC/FM APPLICATIONS

This section presents a brief overview of the architecture and the main components of the ITAC framework and discusses the technological requirements and approach to develop these components. The framework defines a flexible and extensible component-based architecture to serve as a generic computational model to implement integrated project systems. The modularity of component-based architecture would lead to more efficient implementation and maintenance of the framework. A component typically represents a subsystem that can interact with other components and is used to support a particular functionality of the framework.

The framework defines a flexible and extensible component-based multi-tier distributed architecture to serve as a generic computational model to build integrated IT solutions for the AEC/FM industry. The framework adopts and extends the standard IAI Industry Foundation Classes (IFCs) and develops a set of model-based software tools to support the integration of information models, process models, and computational tools. Integration of information models will allow the mapping of project information from one view (or discipline) to another and hence allow the exchange of project information between project team members representing various disciplines within the project. Integration of process models will allow the development of computational tools to support the coordination and management of the facility design and management activities. Finally, integration of function-specific computational tools will allow these tools to interoperate and share a centralized representation of the project information throughout the design, construction, and management processes.

4.1 Data Management and Interoperability Components

The main function of the data management components is to support data sharing and interoperability between other framework components as well as among the project participants. The framework adopts the IFC 2X schema as the basis for modeling project information. However, the IFC model still lacks support for several vital aspects of project information. One of the main objectives of ITAC is to identify these areas and to develop information models to support these areas.

Data components are used by different applications components (Section 4.4) to interface with the integrated project schema. Two main methods of data sharing are supported in the framework: document exchange and centralized model-based project repository. First, the document exchange method involves exporting and importing project data between applications using the standard data model schema and a neutral file format. Documents can be formatted either as STEP Part21 physical files or as XML files. Second, sharing a centralized model-based project repository is supported via the use of a client-server database management system. The centralized project repository is essential to support sharing and exchange of up-to-date project information and to maintain the integrity and consistency of the data. The database schema is automatically generated by mapping the IFC schema to the database schema. The schema translator component will significantly simplify the database design process.

4.2. Process Management Component

In typical AEC/FM projects, project participants work with various inter-dependent components of the facility. Such interdependencies necessitate defining rules and procedures to manage and coordinate the information flow and the workflow within the project. The process management component implements methods to support modeling and implementation of these rules in the framework.

The process management component emphasizes two main aspects. The first aspect involves defining a standard for AEC/FM transactions to formalize the context and requirements for specific technical and business data exchange transactions. The second aspect involves developing web-based tools to support the collaboration and coordination of geographically

distributed project participants. Collaboration tools will enable project team members to evaluate and review the project documents and to resolve inconsistencies and conflicts through synchronized access to the project data model.

4.3. Document Management Component

Project information is usually represented and exchanged as documents. Documents include design drawings, analysis calculations, bill of materials, schedules, contracts, etc. Managing and tracking project documents is a crucial task in any AEC/FM project. The document management component implements the functionality to link project documents to the product model, thus enabling context-based accessing and managing of these documents. The component will also enable project team members to access and manage the project documents using a web browser. The web-based document management component will display design models with their links to relevant project documents.

4.4. Domain-Specific Applications Components

The applications components represent a set of function-specific software tools to perform various project activities such as CAD, analysis, construction scheduling, and cost estimating. A distinguishing characteristic of the framework is that it employs a model-based approach to support various project activities. This approach involves basing the project data representation on a standard and detailed model of project "objects" that can capture and represent the information pertinent to various project activities. Model-based applications will use the standard IFCs as its underlying data model and will be able to share and exchange project information using STEP Part21 physical files or XML files. In the course of this research, a set of new applications will be developed based on that approach. Also, a number of commercially available applications will be integrated into the framework. However, the majority of the existing tools use non-standard and proprietary data models. Adapters to map the internal data models to and from the standard models need to be developed as well. Adapters serve to enable application components to exchange data in a standardized format. A number of existing applications, however, possess the capability to import and export their data sets using standard IFC data models.

A new model-based CAD application is under development to be used for geometric design and layout of 3D AEC objects. AEC objects implement the structural, functional, and behavioral characteristics of standard domain objects represented in the IFC model and support the representation of various aspects of project information pertinent to these objects. The objects also implement design rules to maintain the consistency of the design within each object and with regard to the interdependencies among various objects. The application also provides a facility model browser to allow users to navigate through the facility objects. The application can exchange the AEC objects using XML and Part21 files.

Other applications will be able to access the project information embedded in the AEC objects. For example, cost estimating application will perform quantities takeoff and produce a cost estimate based on the design data. Also, structural design and analysis applications will also be able to access these objects to obtain relevant information necessary for their operations.

A model-based construction process planning application will also be developed to allow planners to access design and estimating information. The planning tool will interface with a scheduling application to generate schedules. Using the design information and the schedule information, a visual simulation of the construction progress will also be generated.

An important application that will be developed in this research is the Specifications Modeling and Processing Component. This component will be used to create and manage construction specification documents and to link these documents with the product model.

5. Conclusion

This paper presented an overview of ITAC, a research initiative that aims at leveraging the use of IT applications in the Canadian AEC/FM industry and to disseminate information in this area throughout the industry and academia. It described an outline of the ITAC research program and the implementation of technologies that will benefit the Canadian AEC/FM industry.

ITAC is a newly formed consortium of Canadian researchers and practitioners that requires the participation of many industrial partners. The consortium is taking an active role in a large international effort to establish industry-wide data modeling standards and to promote IT applications in the AEC/FM industry. ITAC will be forming an Industry Advisory Board to help in transferring knowledge and technology between our research group and the

industry. Canadian and international organizations that are interested in ITAC are welcome to join the consortium.

6. Acknowledgment

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