The Building Performance Perspective for Interoperability

Requirements for a Future Analysis Network

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Abstract: *There is an increasing demand for building performance assessment among architects mostly due to a rising awareness for issues related to environmental sustainability. However, after thirty years of research, interoperability of performance analysis tools with CAAD environments is still far from being seamless. Yet, all commercial CAAD vendors have recently started offering an array of building analysis tools. It is fair to expect a new surge of efforts in integrating prediction and evaluation capabilities within CAAD systems over the next few years. Building on lessons learned, this paper argues the need for a unification infrastructure for building performance and outlines the requirements for building an analysis network.*

Keywords: *Building performance analysis; interoperability; BIM.*

Background

Interest in Building performance analysis is rising in the building industry. This is partly due to an increased sensitivity towards environmental sustainability and partly due to advances in available tools. Yet, a satisfactory integration scheme between analysis tools and architectural design tools still eludes us. Consequently, analysis applications are not utilized as design support tools that provide rapid evaluation of multiple design alternatives. They are utilized more for design verification after most decisions are finalized.

Integration of prediction and evaluation capabilities with computer aided design environments has been a topic of research for well over thirty years. Augenbroe provides a good summary for all the various approaches that have been investigated. (Augenbroe, 2002). Unfortunately, the quest for the integrated design system has failed to produce a working solution. Yet the need for integration of evaluation capabilities with design environments is becoming more apparent. Malkawi points out, "the building industry, including architects, is aware of the need for better integration of these [simulation] tools into the lifecycle of the building." (Malkawi, 2004)

While efforts for an integration scheme failed to make their mark commercially, product modeling research has been very successful in influencing the evolution of CAAD systems. After the late 90's, with the aid of object oriented technologies, concepts such as solid modeling, parametric objects, smart components and virtual buildings were successfully implemented. A detailed history is given

by Eastman (1999). Large scale standardization efforts such as International Standards Organization's STEP (ISO 10303), COMBINE (Augenbroe, 1995) and International Alliance for Interoperability's (IAI) Industry Foundation Classes (IFC) [1] have all focused on product models in order to lay a foundation for interoperability.

Current tools

The current generation of commercial CAAD software are based on Building Information Modeling (BIM). BIM encapsulates the semantics of design components as well as the geometric form in order to increase the reusability of design information across various domains of specialization throughout the lifecycle of buildings (Eastman et al., 2008). Although these commercial CAAD packages do not come with built-in prediction and evaluation capabilities geared towards use by designers, they are offered together with commercial analysis tools for use by domain experts as part of a "BIM Suite". The reuse of the semantically rich representation necessitates the adoption of a common format by every tool in the BIM suite that will participate in data exchange. IFC is currently the most widely accepted data exchange format among BIM applications. All BIM tools today are IFC compliant. However, interoperability based on IFC has still not matured after more than ten years of development and many building performance researchers are critical of IFC due to its top-down approach to modeling as well as its complexity (Behrman, 2002). The alternative bottom-up approach was carried out by IAI's aecXML effort. Green Building Studio's gbXML schema had been developed for aecXML and currently, many energy analysis tools prefer to use the gbXML format. A recent comparison of IFC and gbXML where gbXML was chosen for development is reported by (Dong et al., 2007). To add to this confusion, other formats such as DXF or 3DS that carry no semantic information are still utilized as workarounds. By adopting BIM, the building industry has fully committed to the use of product models, but how to best leverage the information collected in these models is still an issue to be addressed.

Over the last five years, the trend shifted from integration of analysis and design tools in a single environment to ensuring interoperability among design and engineering tools as predicted (Augenbroe, 2002). IFC has been at the center of most research efforts related to interoperability. However current trends tend to steer away from solutions based on this and other open industry standards. Support for IFC continues but CAD companies are acquiring analysis tools for various disciplines to be integrated into their BIM suites and priority is given to developing custom, proprietary links for them. Naturally this results in a tighter, smoother integration as long as architects and engineers choose software from a single vendor. Although this trend seems to offer a quick solution for the long standing problem of interoperability, and provide access to analysis for architects, it is inadequate especially from a building performance perspective. There is usually no need to question the validity of architectural visualizations that are produced in CAAD systems, but the performance predictions and simulation results of analysis tools are always under scrutiny. Building simulation tools all utilize different methodologies with their unique algorithms, assumptions and constraints. Especially domain experts will naturally prefer to utilize more than one tool for comparison of verification purposes. Software offered as part of a single BIM suite will never be enough to quench the need for second opinions. Interoperability requires industry wide adoption and development of open standards instead of proprietary solutions.

Building performance perspective

Interoperability research has always defined the problem focusing on the CAD environment. Research efforts focusing on integration schemes as well as efforts on product models for the building industry mostly adopted a top-down approach with

a wide perspective. The search was for a universal solution. Building performance community in the meanwhile has focused on individual domain problems in isolation. The lack of collaboration among researchers can be seen in the stand alone nature of most tools as well as their idiosyncratic data input schemes. The middle ground where only the integration between a limited number of analysis tools takes place is mostly left unexplored. There is a need to provide a common infrastructure for analysis tools focusing primarily on building performance requirements. Instead of integrating analysis tools individually with design environments, integrating analysis tools with each other should be seen as the necessary first step. There is much to be gained from investigating an analysis platform tailored for evaluating building performance isolated from issues associated with design manipulation, and construction management. Treated as a sub-task in solving the overall problem of interoperability, the development of a multi-domain analysis platform will be a valuable source of input for future research.

One past effort that investigated exactly such a partial solution was the S2 system (Lam et al., 2002). S2 was a continuation of the SEMPER project (Mahdavi, 1996) and demonstrated with its prototype that independent analysis tools from multiple domains can work seamlessly over a distributed computing environment. S2's analysis modules covered the following seven domains: Energy, air flow, HVAC, thermal comfort, acoustics, lighting, and life-cycle analysis. All analysis modules employed first-principles based simulation methods. S2 was able to deal with complicated geometries as well as design resolutions available at early stages of design.

Based on the lessons learned, next section will outline some expectations from future efforts in interoperability research.

Future outlook

The vision for the near future should include developing a loosely coupled federation of analysis tools based on component architectures that support independent development. This *analysis network* should be independent of CAAD tools but accessible from within them. Analysis will become services that can be accessed over the network. The platform should provide the necessary communication and storage mechanisms for seamless access to design data and evaluation results. This seamless operation should happen through databases rather than flat files. Specialized user interfaces should exist for use by domain experts in carrying out domain specific tasks. Project databases should incorporate versioning schemes for design data that allows parametric studies. Once this building performance network is in place, it should act as a gateway for building performance to CAAD systems. Users should be able to call an analysis control window, activate one or more analysis tools from one or more domains, adjust their simulation parameters, set-up parametric studies, select the desired outputs, schedule the simulations, and review results when they become available. Legacy applications should be linked to this network through straightforward automated wrappers that create necessary input files, control the simulation and collect the results.

Requirements

The success of the envisioned analysis network rests on meeting certain requirements. While some of these requirements are design principles that need to be adhered to, others are functionalities that need to be implemented. These will be discussed under three headings: Integration approach, system design, and developer framework.

Integration approach

Building performance perspective calls for utilization of a bottom-up approach much like the ones adopted by the S2 project and aecXML. The bottom-up approach provides formalization of common requirements across disciplines by first compiling individual domain requirements. This performance perspective

can later be incorporated into more comprehensive top-down interoperability efforts such as the IFC.

The bottom-up process especially impacts the building representation to be utilized throughout the network. All tools that will connect to the network should be allowed to utilize the representation that is most appropriate to them. However, a domain neutral representation for the network is useful especially in communicating with external design environments. This representation should naturally include all the information about the building design related to all participating domains. However, this representation should define a clear separation between data that is common to all domains and data that is required by only a sub-set. This separation when implemented with a modular structure will simplify mappings into various representations. Mappings into open standards like IFC should be explored. Especially the mismatches with such top-down models will undoubtedly provide valuable input for further development and adoption of these standards. A bottom-up approach that organizes negotiations among participating domains is necessary to recognize the differences in representations.

System design

While an efficient representation is necessary, it is not sufficient for realizing the envisioned analysis network. The processes in which this representation is to be utilized are just as important. While designing the system architecture for the analysis network, the following should be adopted as guiding principles:

- CAAD independence. The network should treat CAAD tools as a pluggable resource. Plug-ins can be developed as user interfaces that can control analysis settings, schedule simulation activities, and collate results. The plug-ins should prefer to handle data based on open standards such as IFC or aecXML rather than the underlying proprietary BIM.
- Modularity. The network should provide a high level modularity that allows independent development for individual tools. The development of new tools should be allowed. Domain specific representational objects should be treated as pluggable resources that augment the common representation without hindering the execution of existing tools. Similarly user interface controls can be developed as plug-ins that are activated as needed.
- Distributed software architecture. The system that is being outlined requires the utilization of a distributed computing principles, allowing independent development for individual components. This should be seen as an essential feature and not as an enhancement that can be introduced later. The size and complexity of the problem necessitates a component based architecture that allows independent development cycles. Data exchange between components should be through live network connections or project databases. File based data exchange should be implemented as a secondary option.
- Smart databases. The system should be able to connect to multiple databases for design data as well as information on materials and costs. Project databases should have built-in version management to support automated generation of alternatives for parametric design explorations. While project databases can be managed by individual firms, material properties and detailed construction information should reside on central databases that update their data regularly through live links to manufacturers.

Developer framework

The absence of a satisfactory integration adversely impacts not only the building delivery processes but also research and development as well. New analysis methods and tools are constantly being developed. The Energy Software Tools Directory maintained by the U.S. Department of Energy currently lists 344 different tools [2]. Unfortunately, most of them are quickly abandoned and forgotten. The proper interoperability scheme should not only enable seamless data exchange for users but should also form a

platform that provides a framework for developers, encouraging collaboration and allowing researchers to build on previous work. Developers should not need to implement input/output routines for the elements in the common representation. The main analysis control window implemented as a plug-in to the CAAD systems should handle the input/output for the elements in the common representation. Developers should only provide user interface elements for domain specific settings and results as an add-on to this common CAAD plug-in. Furthermore, this network should include facilities for benchmarking. It should allow multiple tools to evaluate the same design enabling comparisons between them and their underlying simulation models.

Benefits

Once an analysis network that meets the above requirements is realized, the following major benefits can be expected:

- Simulation as services. Analysis applications will turn into components that are activated on demand. Simulations will become 'services' offered by these components. Available services will be dynamically discovered and utilized by the rest of the system (as well as users) improving the flexibility and scalability of the system. Services will be accessible over the internet, controlled within an intranet or installed on the local computer. Simulations will be executed simultaneously by different tools and their results will be collected and compared. Validation and benchmarking of tools will be simplified.

- A Central Repository for design exploration. Design information as well as material libraries will be kept centrally in a shared storage area. With an appropriate versioning scheme this will guarantee up-to-date design information for all users and analysis applications. This will provide support for collaboration and eliminate the need for file management. Also it will provide access to various states of the design as well as alternatives that are to be explored as part of parametric studies.

- A Framework for developers. The network will unify input/output mechanisms. The component based architecture will support independent development of analysis applications. Developers will be able to focus on domain algorithms rather than interfacing and data exchange. Tool validation and benchmarking will be possible.

In conclusion

Today, while BIM technology is treated as the Holy Grail of interoperability, bottom-up approaches such as S2 or aecXML are especially valuable in demonstrating that BIM is necessary, but far from being sufficient. In order to advance the analysis capabilities in design environments, a common infrastructure for analysis needs to be investigated with a distinct building performance perspective. Without a clear map for future integration, commercial concerns behind today's BIM suites have the risk of casting a shadow over the benefits of building performance analysis. Performance predictions for the same design might naturally vary to a high degree from one BIM suite to another, depending on the assumptions and methods employed. For designers, this lack of reproducibility in results will be a source of serious confusion and possibly cause designers to lose interest in analysis and encourage them to go back to decision making based on simple rules of thumb. A common platform that offers simultaneous access to multiple analysis tools is necessary not only to increase the usefulness of building performance tools but also to simplify tool development.

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