White paper on AEC Practice and Research Issues for the Future

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Vision of Future Practice

Horizontal Integration of multiple disciplines

My vision of future practice in civil and environmental engineering involves an increasing degree of integration of disciplines that will be needed to address the environmental, cost and engineering issues involved in most infrastructure and facility problems. These disciplines will use software and communication tools that support design and analysis in a collaborative manner using Internet technology. The use of stand-alone computer applications for specialized analysis will be replaced by modeling tools that support collaborative efforts over a broad-band network that links the project model(s) to the various project participants and to an electronic commerce environment. Visualization will become an increasingly important capability that can be used to help all project participants understand the implications of a design and quickly resolve design and site changes. Thus, the ability to share a 3D and 4D model in a collaborative mode will become a standard approach to supporting a project team. Web-based services will be able to use these models for many functions (engineering and commerce).

Vertical integration of multiple stages in life cycle

An important aspect of integration will be to provide data that can be used over the life of a facility. Currently, most data that is generated for a project needs to be reentered in a different format when used for the next stage in the life cycle, e.g., design data is reentered for facility management. The life cycle of data will be of increasing importance to facility owners to allow improved management of their assets. This need for the reuse of data will provide an impetus to use database rather than document oriented approaches to capturing and storing data.

Longitudinal integration over time

Another aspect of integration is the capture of knowledge that allows improved performance or better decisions in the future. This includes the capture of design intent that allows better knowledge of why design decisions were made so that these can be reflected when modifications are needed in the future. It also includes the capture of case studies of both problems and their solutions that allow improved performance in the future. However, knowledge capture and reuse has a somewhat unsuccessful history of research and implementation. They are difficult problems that apply to all areas of engineering design.

Implications for business model

The business model needed to support this vision will need some relatively minor changes from that used for today's practice. The major issue will be to allow various disciplines to work together in a collaborative framework that protects their legal and commercial interests without sacrificing those of the client. Because of the need to accommodate changes in requirements and conditions that always are present in real projects, there will be an increasing need for both the business model and software and communication environment to support the use of shared information with minimum conflict and maximum consistency. Electronic commerce vendors selling products and services will need to adopt their services to support computer to computer communication and product modeling requirements. The current use of html web sites will be supplemented by XML and modeling standards that allow web-based commerce.

Research Issues

To support the above vision of AEC practice, there are some important R&D issues that must be addressed. These are summarized below.

Integration Technology

Objects for defining and exchanging design, construction and facility data

There is need for multiple parties to use and exchange data in a collaborative environment. This information is currently defined in a various types of documents that do not allow a computer to understand the content of the documents. There are current efforts to define objects for the AEC industry (STEP, IAI) that are beginning to see use (particularly for other industries that are using STEP for graphic exchange functions). There are also efforts to use XML for e-commerce in some industries. Each approach provides a solution for a vertical market, e.g., computer manufacture and assembly. CAD companies are releasing software with proprietary objects that are used only within the CAD and tailored applications. Thus, a new cacophony of data formats is replacing the computer documents currently in use. Research is needed to find some approach that will provide a robust base for sharing data in the AEC industry and its vendors and suppliers. It is unlikely that any one approach can support all requirements, but perhaps some form of public translation service can provide the needed interoperability and updating as features and objects change.

Visualization tools for manipulating 3D objects on the Internet

Use of large 3D models on the web is currently difficult because of slow model generation and poor resolution. Better tools for working with 3D models are needed before the web can become a practical collaborative design and construction environment. Of course, this is a requirement for many applications, but it of particular importance for the AEC industry.

AEC Applications

Integrating design and construction

Current CAD tools makes it difficult to integrate design and construction processes because of inadequate support for the information needs during the construction phase. Typical CAD systems can generate 3D models that are useful for visualization of the design, but are difficult to use for cost estimates, construction planning and procurement. These needs are typically extracted from detail and working drawings, which require a separate manual effort after the schematic design drawings are completed. This adds cost and time to the process, which can be reduced by allowing the early design model to be used as the starting point for a fully detailed model needed for construction use. The research issue involves identifying how objects can be defined and used that will support both design and construction requirements.

Visualization and analysis of construction (4D CAD)

The current products available for construction visualization are slow and expensive to use and do not permit computer analysis of a plan for feasibility, spatial requirements, safety, cost and critical path analysis. Considerable work is needed to refine 4D CAD tools so that they are easier and faster to use and generate plans that can be analyzed quickly by the computer (with suitable GUI for human interaction with the generated plan).

Organizational analysis of project plans

There is a natural link between 4D CAD and organizational analysis of construction plans. The people and systems supporting a design and/or construction project are an integral part of the plan and need to be analyzed to gain insight into anticipated bottlenecks which are not revealed by traditional CPM analysis. Research is needed to find convenient and powerful modeling tools that can be used to gain insight into the organizational and process issues associated with projects. The problems caused by these aspects of project performance can be more difficult to identify and solve than those associated with traditional CPM analysis (task durations, relationships and resource constraints).

Visualization and analysis of facility use and maintenance

It should be possible to analyze a design for maintenance and use requirements such as life cycle cost for maintenance under given site and usage conditions. For industrial plants, it is also necessary to analyze whether sufficient space exists for access to equipment for maintenance, storage of materials and supplies, etc. After a facility has been constructed, the "as constructed" data should be usable for CAFM systems. Research is needed to evaluate how these needs can be modeled and supported in computer applications.

Project execution using lean construction techniques

While the use of better design and planning tools can greatly reduce the cost and time required for construction, because of the continual changes that are a normal part of the construction process, there is a need for better job site planning tools. These tools will help to respond to changes in the project design and implementation by ensuring that information about the changes is rapidly communicated to all who need to know, that approvals are expeditiously handled, that work is not planned until the necessary resources are available, etc. This lean approach to construction will reduce wasted effort and time in the field. Research is needed to identify useful approaches to these issues and how these can best be implemented in the field (human issues, communications, hardware, software, GUI, etc.).