

Theme:

Title: **Multi-stakeholder collaboration: The CIFE iRoom**

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Abstract: *The CIFE iRoom is a collection of linked software and hardware that allows users to readily structure, display and manipulate the various information used to design and implement a large construction project. The objectives of this research are to define and evaluate new ways for project teams to interact with and visualize project information to facilitate fast and effective decision-making. This paper summarizes the CIFE iRoom infrastructure and gives examples of its use. It shows the importance of separating a model from its view and from its control and of visualizing relationships across different views to conveniently view and compare alternative states of a project model simultaneously.*

Keywords: *Interactive Workspaces, Decision Making, Meeting Support, Human Computer Interaction, Collaboration*

Introduction

Facility engineering and construction management involves integrating data from a wide variety of different sources. Typically, this ends up on paper, which is pinned to walls and spread out on tables for comparison, as shown in Fig. 1. Information includes project schedules, CAD models, spreadsheets, work orders, contractual documents, PERT charts, parts lists, and more. These documents are tightly related, representing different views of the same project. Effective decision making requires analyzing critical relationships among these documents, but paper provides no support for even something as simple as finding the same date or part number across documents.



Fig. 1. Typical construction trailer with project information displayed in paper form.

What if these documents were “live” viewed on “electronic walls?” Then, it would be possible to create active views that included tools for highlighting and comparing common items across applications. Data could be dynamically collected and reformatted across applications, making it easier to construct and compare different design and production scenarios. Novel views and visualizations could be designed specifically for comparing scenarios, enabling “what if” discussions far beyond what is currently possible. It would be easier to be sure that information shared at meetings was up-to-date, and to capture the results



of decision-making processes by immediately applying the specified changes. This could eliminate delays and ensure that everyone in the meeting understands the context and impact of decisions made.

To support such an interactive view of facilities engineering, the CIFE iRoom has been designed in collaboration between the Stanford Center for Integrated Facility Engineering (CIFE) and the Interactive Workspaces Project (iWork) from the Stanford Computer Science Department. The iWork Project is exploring new ways for people to work together in technology-rich spaces with computing and interaction devices on many different scales (Fox et al. 2000). An iRoom is a room-sized interactive workspace, supported by the iRoom software infrastructure. Most iRooms include large-format displays as electronic walls to facilitate shared views of applications and information. The iRoom infrastructure implements linking and coordination among applications running in the iRoom in a way that supports legacy applications as well as custom-built tools and viewers.

The CIFE iRoom project uses the iRoom infrastructure to allow active views of data and documents such as those used by multi-disciplinary project teams to support group tasks, such as project review, project planning, and decision-making (Liston et al. 2001)¹. Its implementation is based on the following key concepts:

- separate a model from its view and from its control,
- visualize relationships across different views of a single model, and
- conveniently view and compare alternative states of a model simultaneously.²

Overview of the CIFE iRoom

Fig. 2 shows the CIFE iRoom, with its three large SMART boards. Each board acts as a large Windows desktop that can be easily viewed by a group of people. The SMART boards are simply projection surfaces; the projectors are in the center of the room. While front projection inevitably causes shadows, this configuration is more flexible and less expensive than rear-projected SMART boards. Each SMART board has a touch panel, which substitutes for a mouse. Touch input allows a user, or a group of users, to stand at the screen and interact directly with it. To more conveniently treat the three displays as a continuous workspace, there is a wireless mouse and keyboard that can operate on any of the three desktops. This facility is provided by an iRoom software application called PointRight.



Fig. 2: The CIFE iRoom. There are three, front-projected SMART Boards with touch panels, plus a wireless keyboard and mouse.

Users can run applications such as Microsoft Project, Excel, or Common Point Technologies' (CPT) 4D Modeler³ to display and manipulate project data, just as they would on a personal desktop. This makes it easier to view the most up-to-date and relevant information, to view a variety of information

¹ The (Liston et al. 2001) reference describes the motivation for environments like iRooms and related literature in detail.

² Much of the research in construction IT in the last 15 years has focused on defining ways to integrate project information at the data level through information standards, translators, shared databases and project models, etc. This information modelling research has somewhat neglected how to interact with the resulting large integrated data sets. Clearly, a mouse, a keyboard, and a desktop do not enable an individual user, let alone a group of users, to interact effectively with the project model and to leverage the project model for (group) decision-making. This paper focuses on how to present the multiple views of a project model necessary to understand the perspectives of the multiple disciplines that contribute to and that are affected by a decision. This user focus highlights functionality that needs to be provided by environments that support the interaction of groups with project models.

³ See (Fischer et al. 2001) for a description of the functionality of this 4D modelling software.

simultaneously, and to easily make changes during a meeting. Construction teams can create this basic iRoom configuration with commercial hardware and software today. However, use of this basic iRoom would quickly show the need for additional functionality to manage the views and synchronize data.

The CIFE iRoom project primarily focuses on software enhancements that would make a multi-display or multi-view environment functional and productive for decision-making. The three major areas of focus in this project are:

- highlighting related sets of data within and across views and applications,
- managing views of project models and comparative states of a project model, and
- exchanging and synchronizing sets of project model information to support visualization.

This functionality is implemented with three core software components:

- **CIFE iRoom Scenario Database.** There is no centralized database that represents the entire project model in the CIFE iRoom; the project model is represented by a collection of data that is stored in many different forms. There is, however, a database of *scenarios*, each of which is represented as an XML file in a commercial XML database. iRoom users generate these scenarios from the native formats of a variety of programs, allowing users to make modifications in whatever program is most natural. Different scenarios can reside in the database simultaneously, making it possible to compare alternate states of the project model.
- **Information Viewers.** The CIFE iRoom includes a variety of viewers and applications for displaying and manipulating the information stored in the scenario. These include applications such as MS Project and Excel, which are commonly used today as part of the construction management process, as well as CPT's 4D Modeler. The CIFE iRoom also includes custom-made Data Viewers that provide simplified views of the scenario data and act as controllers for simultaneous highlighting. Users can click on an activity or part to highlight the same or related parts in all the applications and viewers. Similarly, a universal TimeController can be used to synchronize the views provided by all applications to the same date.
- **Room Controller.** A special tool called the Room Controller provides a graphical interface for managing applications and data in the CIFE iRoom. This tool is a Java applet, built on the web-based controls provided in all iRooms for managing applications and events. As a result, its functionality can also be presented as customized web pages.

This rest of this paper summarizes first the CIFE iRoom architecture to identify the different components in the iRoom. Then, we describe the use of the CIFE iRoom and give examples of different visualizations supported by the room. Implementation details and a guide on how to create an iRoom can be found on the CIFE iRoom project website at <http://cife.stanford.edu/iRoom/>.

CIFE iRoom Architecture

The CIFE iRoom is built on top of the iRoom software/hardware infrastructure, which in turn, is built on a standard, networked collection of PC systems. Table 1 shows a layered view of the CIFE iRoom architecture.

CIFE Applications, Viewers, Controllers 4D Modeler, Data Viewers, MS Project Listener, TimeController
CIFE Database and Services XML schema on eXcelon server, Import-Export Utility, Room Controller
iRoom Software Infrastructure (from iWork group in Computer Science) EventHeap, Multibrowsing, PointRight
Special iRoom Hardware SMART boards, touch panels, wireless mouse and keyboard
iRoom Computing Infrastructure Desktop PCs, Windows 2000, Java, Network support

Table 1. The different layers of the CIFE iRoom; the top two are implemented by CIFE.

The bottom layer is a standard computing infrastructure consisting of four desktop PC systems running Windows 2000 and the Java runtime. A TCP/IP network, either wired or wireless, must connect these

PCs. The special iRoom hardware consists of the three SMART boards with their touch panels, plus a wireless mouse and keyboard. Three of the PCs drive the SMART boards; the fourth is connected to the wireless mouse and keyboard and acts as the iRoom server machine. There can be more or fewer SMART boards as needed—three is simply the number that fit well in this installation.

The iRoom Software Infrastructure was created by the iWork project in the Computer Science department, and is available for OpenSource distribution from the iWork website (iwork.stanford.edu). The main components of the iRoom Software Infrastructure are:

- **The EventHeap.** The general coordination mechanism for an iRoom is called the EventHeap, or eHeap. Messages called “Events” can be posted and retrieved by programs running in the iRoom. The EventHeap itself runs on the iRoom server, and EventHeap clients run on all machines that send or receive events.
- **Multibrowsing.** Included with the basic iRoom software is support for Multibrowsing events. These events are normally used to request that a specified URL be displayed in a machine’s browser. However, they also provide a general mechanism for passing Windows commands between machines. The Multibrowsing client runs on all the machines in the iRoom.
- **PointRight.** A program that enables all of the machines in the iRoom to be controlled with a common mouse and keyboard. PointRight runs as a server on the iRoom server, and as a client on all of the other machines.

The top two layers are the suite of programs that define the CIFE iRoom.

The Database and Services Layer includes those components that manage the project scenarios. It also includes the server-based Room Controller used for managing applications and data in the iRoom. The primary components are:

- **XML Database.** Commercial database supplied by eXcelon (www.excelon.com), which includes a web-based set of tools for managing it.
- **Import-Export Utility.** Program for translating between the database and native file formats for the construction of scenarios.
- **Room Controller.** A Java applet that provides a graphical view of the iRoom layout. Users can drag and drop applications and data around the room using the Room Controller.

CIFE Applications, Viewers and Controllers allow users to display, highlight and manipulate information about a scenario. Communication between these components involves sending and receiving eHeap events such as “set date” or “highlight activity.” The key components are:

- **Applications.** These include a customized version of CPT’s 4D Modeler, Microsoft Project, and Excel. These have been augmented to make them send and receive eHeap events.
- **Viewers.** The CIFE iRoom includes three custom-made Data Viewers for concisely displaying table, tree and document views of information in the database.
- **Controllers.** Controllers send events. The TimeController is a custom controller used to link all applications to a common date. The Data Viewers are also controllers. Clicking on a piece of information in one of these viewers sends an event that highlights the same information, or in some cases, related information, in all other views.

Using the CIFE iRoom

This section shows several examples of using the CIFE iRoom for exploring and comparing scenarios. Using the CIFE iRoom begins with the Room Controller, a Java applet that is used to direct applications to the different screens in the room. It is also used to manage machines and to select content from the database via Query Frames. The Room Controller is launched from a web page. Fig. 3 shows the Room Controller, which has four separate frames. Frame 1 is a schematic of the iRoom machines; the three SMART board machines in a horizontal row, plus the server machine (cife-32). Frame 2 provides a way to add other machines to the iRoom configuration, such as laptops brought by meeting attendees. The figure shows a dialog box generated by a request to add a machine. The user must provide a name and ID for the iRoom infrastructure. Frame 3 provides a list of applications and data. These can be dragged onto one of the gray boxes representing the machines to display them. For example, dragging a URL will launch a web browser to display it. Frame 4 is a Query Frame showing a list of scenario files that are stored in the scenario database. The applications listed below them can read them. First, the user selects

an application using the radio buttons and then selects an XML data file corresponding to the desired scenario. Clicking “Done Selection” creates a text string (shown at the bottom of the frame) that can be dragged onto one of the gray boxes (machines) in Frame 1. This launches a Tree View of the selected data. If necessary, a dialog box is provided for the user to select which aspects of the data should be included in the view. Multiple scenarios can be viewed simultaneously, as will be shown below.

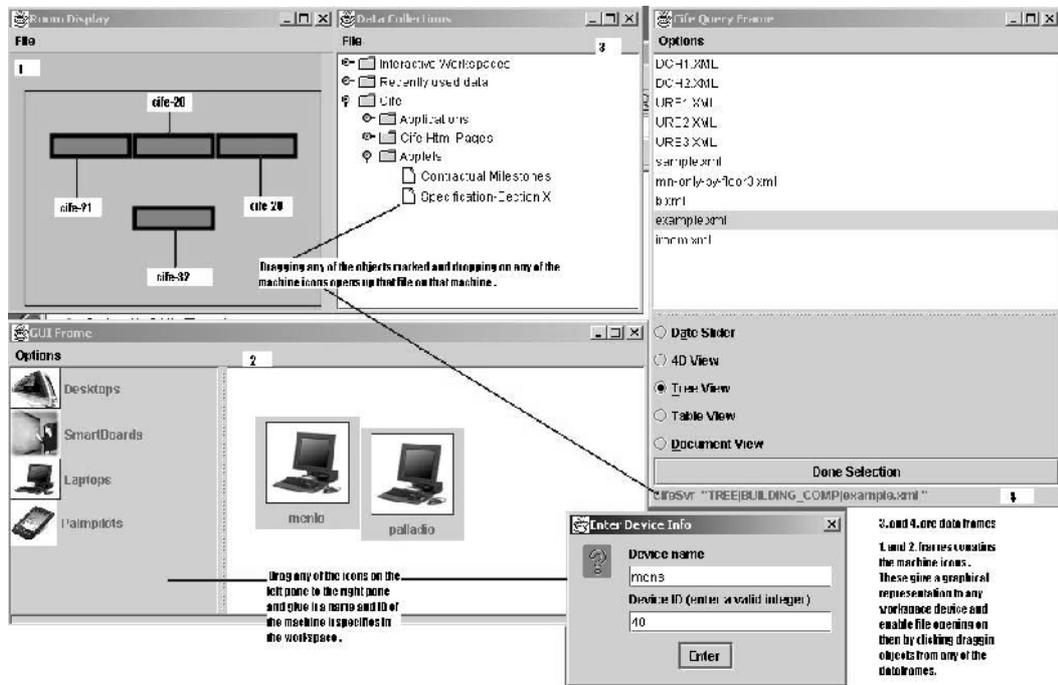


Fig. 3. The CIFE Room Controller is used to manage and arrange data and applications.

To visualize a scenario, one or more viewers and applications are launched and displayed on the large displays. Fig. 4 shows a snapshot of the three iRoom screens. The 4D Modeler is running on the left board, MS Project is running on the center board, and the Room Controller is running on the right board. Using multiple screens provides more space for showing multiple views. But even with three screens, it is still a challenge to present the complexity of construction management tasks.

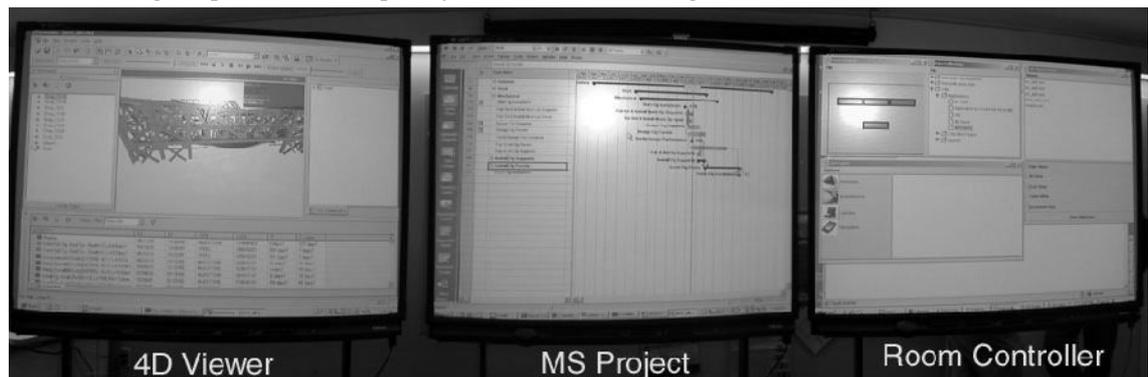


Fig. 4. Panoramic view of the three CIFE SMART boards.

Fig. 5 shows a screen snapshot of the three CIFE Data Viewers. The Table View on the left lists construction activities. Building components are shown in the hierarchical Tree View in the bottom right. The activity, “R/I Ductwork-S1/3 Lvi 7,” was selected in the Table View and highlighted. This also caused the related Building Components to highlight in the Tree view. The window in the top right is the Document View, used to show Specification Items. If there had been a Specification Item that related to the selected activity, it would also be highlighted. This cross-highlighting is a key component of the CIFE iRoom necessary to establish focus among meeting attendees.

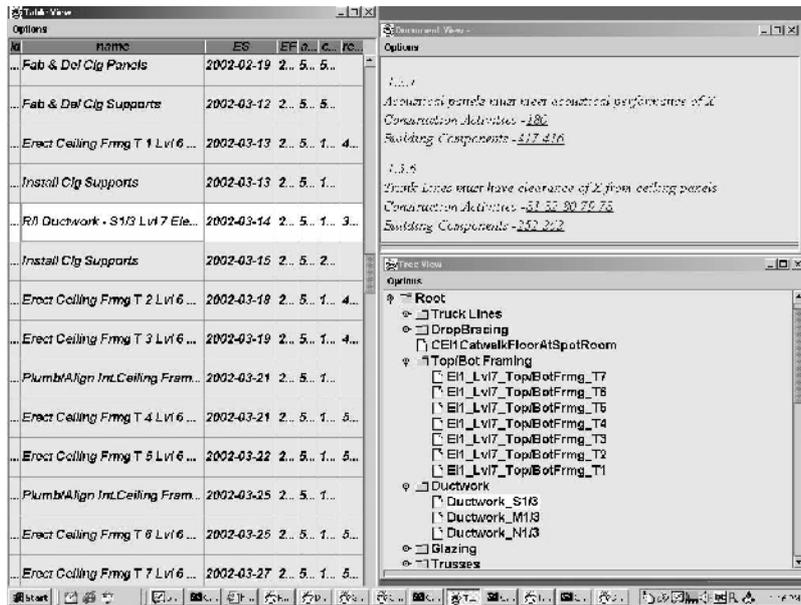


Fig. 5. The CIFE Data Viewers. The Table View is on the left, the hierarchical tree view is on the lower right, and the Document View is on the top right.

Fig. 6 shows the 4D Modeler plus the CIFE TimeController. Moving the slider sends date events, which are received by the 4D Modeler and any other program listening for date events. In this way, the iRoom presents views that are synchronized automatically according to a common date.

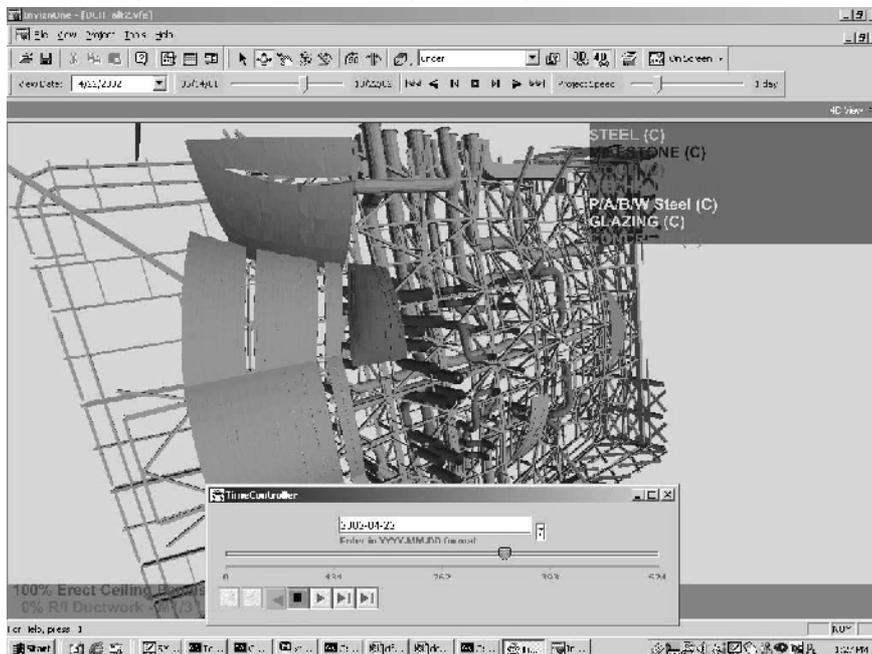


Fig. 6. 4D Modeler and TimeController. Both views display the same date, 2002-04-22.

Fig. 7 shows a portion of a MS Project screen showing a Gantt chart view of the project. The date line indicates the date under consideration. This line moves in response to Date Events, and the Activities highlight in response to a highlight activity event, as do the Data Viewers. MS Project and Excel listen for events using extensions written as Visual Basic macros.

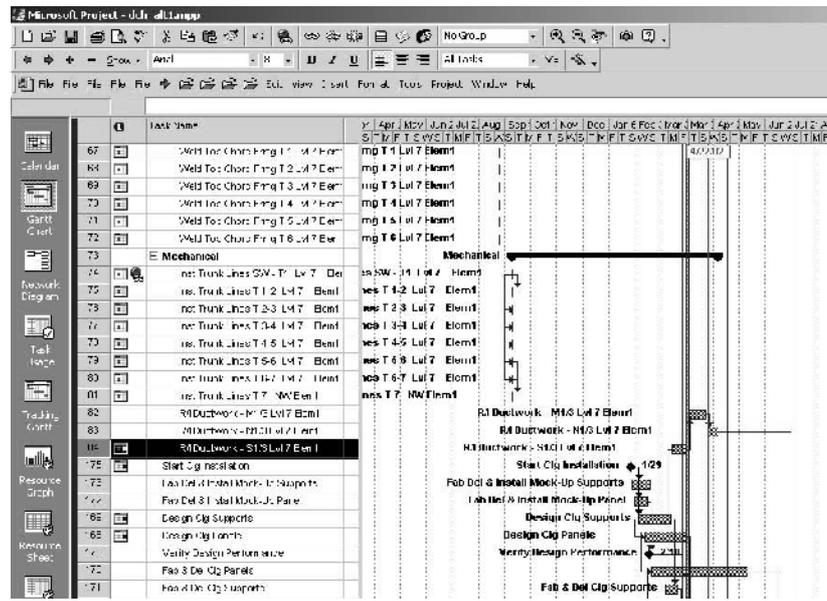


Fig. 7. Microsoft Project, showing a highlighted activity. The date line moves in response to date events sent, for example, by the TimeController.

Multiple copies of each viewer or application can be run to compare scenarios. Color-coding can be included in the scenario database to consistently color backgrounds and other markers for each scenario on the displayed windows. This makes it easier to identify and compare scenarios. Fig. 8 shows two scenarios being compared. The frames on the left have a different background color from the frames on the right. Also note that clicking on a view (upper right frame in Fig. 8) will change the virtual camera position, providing a different view of the 3D model. All active 4D Modelers respond to such an event.

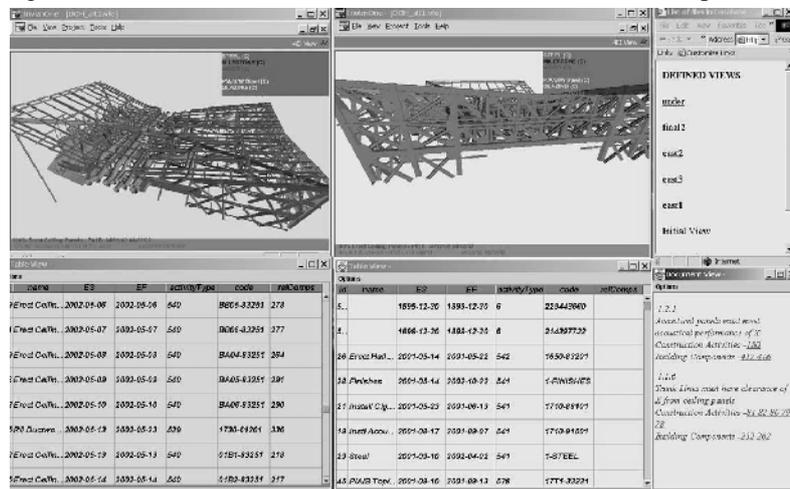


Fig. 8. Multiple views of two different scenarios. Colored backgrounds group which views go with each scenario. All viewers listen for events, and respond accordingly.

Discussion and Conclusions

The CIFE iRoom demonstrates the power of using the iRoom infrastructure with custom programming to create a cross-linked visualization suite. Scenarios are defined and stored in an XML database. This structure is used to construct visualizations for comparing scenarios. Applications, viewers and controllers communicate through the iRoom EventHeap to cross-highlight common components, select a common date, or a common view.

The work presented here has drawn our attention to a number of research issues:

Separation of control from data and application: The separation of data from applications is well underway. Data in applications used for the design and construction of capital facilities is far more accessible, open, and useful to other applications than even five years ago. Certainly, significant progress still needs to be made to achieve the dream that each item of data is entered once and then flows seamlessly through the facility supply chains and life cycle. However, in addition to separating the data from the applications, the control over the data needs to be separated, to some extent, from the applications as well. Today, each software application has its own interface with its own interaction functionality. Hence, even if all the applications used for design and construction were interoperable today, users who wanted to get various views of the underlying project model would need to learn the interfaces of the applications whose views they want to produce and manipulate. This is prohibitive, of course, and not conducive to leveraging the investments in information assets for decision-making, especially in group settings. We argue that research needs to be conducted to define, implement, and test simple, intuitive interaction functionality to manipulate the increasingly available integrated project models. Such interaction functionality should include functionality to synchronize views (like the TimeController presented here), to establish and highlight relationships between data in various views, to store and display scenario-specific information (e.g., different colored backgrounds), and to compare different project scenarios. A challenge is to establish the relationships between datasets in legacy applications, a problem that may not disappear as quickly as we wish since today's new, integrated software tools will become tomorrow's legacy applications.

Focus on simple integration approaches and on group interaction with project models: The construction IT community has made significant progress in defining and testing concepts, mostly data modelling concepts, that enable project teams to model and share project information more effectively and efficiently than possible today. However, the results of this work have found a somewhat slow uptake by software vendors and practitioners. Our experience with the iRoom has shown that data integration through data modeling is not sufficient to bring about integrated information access and decision-making. We believe that complementing the data modelling approaches with simple, message-based integration approaches and with interaction functionality focused on groups of users could speed up the adoption of information integration in the construction industry. Our anecdotal experience with the CIFE iRoom has shown that practitioners who were unaware that data interoperability might help them in their work became quickly aware of the shortcomings of simply running three different, unconnected applications (showing the same project) on the three computers connected to the SMART boards. Invariably they wanted to click on an activity in one view and see related information in another view. Or they wanted to make a change and see the change propagate. This experience sensitized them to the shortcomings of existing software applications to support dynamic data sharing and intuitive multi-user control.

Our next steps in the iRoom research include testing in industrial settings and measuring the effectiveness of the iRoom and its current infrastructure and implementation to support group decision-making.

Acknowledgments

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