A CAD-based decision support system for the design stage of a construction project

G. Cooper[1], Y. Rezqui[1] and M. Jackson[1], B. Lawson[2],
C. Peng[2], C. Cerulli[2]

[1]Information Systems Institute

University of Salford

Manchester, UK.

[2]School of Architecture

University of Sheffield

Sheffield, UK.

ABSTRACT

Decisions made during the design process are multi-dimensional, combining together factors which range from the highly subjective to the perfectly objective. These decisions are made by many, often non co-located, actors belonging to different disciplines. Moreover, there is a high risk for misunderstandings, inappropriate changes, and decisions, which are not notified to all interested parties. The ADS project (Advanced Decision Support for Construction Design) builds on the results of the earlier COMMIT project to provide an information management system, which addresses these problems. It defines mechanisms to handle the proactive management of information to support decision-making in collaborative projects. Different aspects of the COMMIT system have already been widely published, and the team is now applying the results in the context of construction design. These are referenced in the present paper, which gives an overview of the results of the COMMIT project and discusses some of the issue involved in applying them to the design process in conjunction with an advanced CAD tool.

1 INTRODUCTION

In order to support collaborative engineering, it is important not only to share information, but also to manage that information in a manner that actively promotes integration. The motivation behind the ADS project is concerned with defining mechanisms to handle the proactive management of information to support decision-making in collaborative projects.

Integration has been addressed by several research projects, including COMBINE (Dubois 1995), ATLAS (Architecture, methodology and Tools for computer integrated LArge Scale engineering) (Bohms et al 1994), ICON (Integration of Information for CONstruction), or previous work in standardizing for the exchange of product data such as STEP (ISO 1994), and more recently the IAI (International Alliance for Interoperability). However, little attention was given by these projects to information management (which were not primarily concerned with this topic). Other research tackled various aspects that fall within the scope of information management (Choi and Ibbs, 1995), including change notification and propagation (Khedro 1996), and versioning support (Katz 1990), (Law and Krishnamurthy 1996), (Talens et al. 1993). All these aspects, however, are interdependent, making it difficult to tackle them individually. Therefore, the COMMIT project proceeded on the premise that they should be described and modelled all together in a more general context of information management. Building on the previous EPSRC funded "ICON" project, COMMIT dealt specifically with the management of information in a distributed, object-oriented IT environment.

The ADS Project (Advanced Decision Support for Construction Design) is a collaboration between two research groups: the Sheffield group led by Prof. Bryan Lawson at the School of Architecture, University of Sheffield, and the Salford group led by Prof. Grahame Cooper at the Information Systems Institute, University of Salford. It focusses strongly on the application of the COMMIT results in a real-life design context. The work of each of the two groups emphasizes different aspects: the Salford group being concerned more with the generic concepts and software aspects, whilst the Sheffield group emphasize the design process and application issues (Lawson et al. 2000). However, the groups are working extremely closely together and there is a very strong overlap in interests.

2 OVERVIEW OF THE COMMIT PROJECT AND SYSTEM

From a construction perspective, the overall aim of the COMMIT project is to improve the long-term effectiveness of the UK construction industry by the provision of intelligent integration of information to support decision making for the effective management of all the stages of design and construction. From an IT perspective, the aim of the COMMIT project was to draw together and develop the theoretical and practical foundations necessary and sufficient to address the above construction aim. The IT and construction aims translate into the following objectives:

- to show how communication and decision-making in the construction industry can be improved by means of intelligent, pro-active knowledge-bases;
- to show how first and second-generation knowledge-based systems and construction industry software application packages can be intelligently integrated to bring benefits to decision-makers in the construction industry;
- to build upon existing contributions to international standardization activities in the area of information modelling for the construction industry;
- to ensure that the results relating to the construction industry can be transferred to other domains of application;

- to create and demonstrate the construction of a pro-active kernel knowledge-base that actively promotes integration across design, construction management and procurement;
- to contribute to emerging standards of analysis and design, and Computer Aided Systems Engineering (CASE) tools, for developing integrated, intelligent, object-oriented knowledge-base systems;
- to show how knowledge-based systems and CASE tools can be integrated to develop intelligent information systems for use in different industries.

Although the overall aims and objectives of the project have remained consistent with the original proposal, it was found throughout the course of the project that the detailed requirements of the work were changing quite fast due to: rapid technological developments; changes in construction industry perceptions of IT; and developments in construction IT standardization. The response of the project to such changes was strongly informed by feedback from the project steering group, particularly in relation to construction industry requirements. The project has been significantly affected by rapid developments in the base software and distributed object technologies, particularly: CORBA (Common Object Request Broker Architecture), and the release during the project of the Java programming language. It has also been important to take account of developments in the standardization of object-oriented modeling languages and tools, particularly the emergence of the Unified Modeling Language (UML 1997) as a de-facto international standard along with associated tools. These developments were successfully anticipated and used to advantage within the project, and indeed helped to confirm the appropriateness of many of the project's underlying assumptions regarding developments in software technology. Care was also taken to accommodate the emerging Industry Foundation Classes (IFC) standards of the International Alliance for Interoperability (IAI), though it was considered important that these developments should not be allowed restrict the applicability of the COMMIT results.

It has always been a difficult balancing act to produce prototypes that are sufficiently technologically advanced in relation to the research context of this kind of work, whilst at the same time providing demonstrations that are meaningful to industry practitioners in relation to the tools and interfaces that they are used to working with. This was eventually tackled by producing two prototypes: one with limited functionality, but sufficient familiarity for industry partners to appreciate, and another, more recent one, to address the technical feasibility of some of the more advanced ideas behind COMMIT.

3 STRATEGIC FRAMEWORK AND KEY ISSUES

Analysis was carried out in collaboration with steering group members of the problems faced by construction project participants in relation to information management. This was done in the context of existing and new developments in information technology including Java and CORBA, and standardization in the areas of information representation for construction, including STEP (Standard for the Exchange of Product Models) and the IAI (International Alliance for Interoperability).

Discussions with steering group members, and literature review revealed that most of the limitations are due to the following problems:

- A great deal of project information is stored on paper-based media (drawing, written document, etc.). This information is frequently not structured and difficult to use, and also easy to lose or damage.
- The intent behind decisions leading to information is not recorded or documented. It is also very complex to keep track and trace the route of the thousands of ad hoc messages, phone calls, memos, and conversations that lead to information.
- People responsible for collecting and archiving project data may not necessarily understand the specific needs of actors who will use it, such as the actors involved in the maintenance of the building(s).
- The data is usually not managed while it is created but instead it is captured and archived at the end of the construction stage. People who have knowledge about the project are likely to have left for another project by this time - their input is not captured.
- Lessons learned are not organized well and are buried in details. It is difficult to compile and disseminate useful knowledge to other projects.
- Many companies maintain historical reports of their projects. Since people always move from one company to another, it is difficult to reach the original report authors who understand the hidden meaning of historical project data. This historical data should include a rich representation of data context, so that it can be used with minimum (or no) consultation.

In the light of these conclusions, it was agreed with the project steering group that the COMMIT technical work should address six "key issues", which are closely related and are central to information management:

- ownership, rights and responsibilities: each actor is assigned a specific role (or roles) in the project through which he or she interacts with the project information base;
- versioning of information: a mechanism used to keep track of all the states in which an object has existed, including its current state;
- schema evolution: allowing the underlying conceptual model used by the project actors to be altered, and to evolve over time, without affecting the overall consistency of the project information base;
- recording of intent behind decisions leading to information: provides support for recording the factors that influence decisions that leads to information being produced or changed;
- tracking of dependencies between pieces of information;
- notification and propagation of changes: ensuring that objects and actors are kept informed of relevant changes introduced to the project information base

4 SYSTEM ARCHITECTURE AND OBJECT MODELS

The system architecture for COMMIT was designed to support information management in a distributed object environment. In defining the architecture and models, great importance was attached to adherence to object-oriented methods in order to support industry and process oriented concepts rather than simply data processing concepts. Much of the modelling effort itself was expended on the need to understand the interplay between these different issues. In order to ensure that the technical results are transferable across different industries, emphasis was also placed on separating the information management concepts from construction industry specific concepts and distinguishing information management from project management.

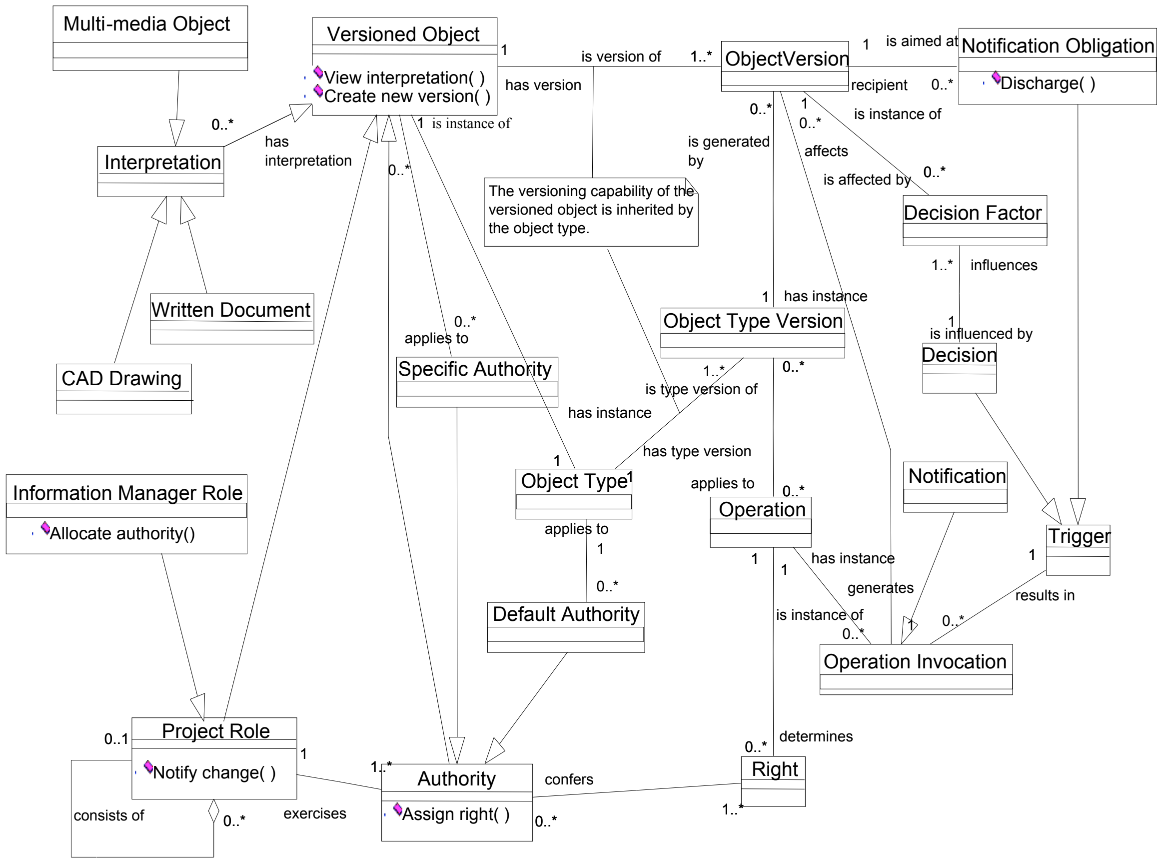

Figure 1: **Simplified view of the CIMM classes using UML**

The final models from COMMIT have been transferred almost unchanged to the ADS project, and are represented in the Unified Modelling Language (UML 1997), using the “Rational Rose” CASE tool. The UML language is rapidly being established as a de facto standard for object-oriented modelling and has been adopted as an international standard within the OMG (Object Management Group) that develops the Common Object Request Broker Architecture (Orfali et al 1996). These version 2 models (a simplified version of which is presented in figure 1) were defined relative to a four level architecture which helped the team to manage the scope of the model itself (Rezgui et al. 1996). The models were subsequently refined and extended to cover the six primary issues identified above, and were revised to address issues raised by steering group members evaluating the first prototype. The latest version of the CIMM is available in (Rezgui et al. 1998).

5 THE ADS PROJECT DEMONSTRATOR SYSTEM

The majority of the prototypes in COMMIT were created using the C++ language in conjunction with the ObjectStore database. These prototypes were restricted in certain areas of functionality such as: schema evolution, and access to class definitions from within the object browser. However, these prototypes have been particularly useful due to the ability to integrate them with integrated databases developed previously in the EPSRC funded ICON project and the DoE funded OSCON project. The advantage of this approach was that it allowed the COMMIT functionality to be demonstrated in the context of industry standard tools such as AutoCAD, improving the ability of the project to communicate with practitioners and to gain valuable feedback which helped the research team to refine and extend the COMMIT Information Management Model. A comprehensive description of the COMMIT prototype V1 can be found in (Rezgui et al. 1998).

Because of technical restrictions in these tools, it was not possible in the first prototype to demonstrate some of the more advanced aspects of the CIMM, such as schema evolution, nor to achieve the level of proactive information management proposed. In the later part of the COMMIT project, therefore, a new implementation of the prototype was created using the Java language in order to demonstrate some of these more advanced aspects. Java provides much greater flexibility in relation to schema evolution, the ability to analyse classes at run-time, and the ability to add and instantiate new object classes in the system dynamically at run-time. In Java, classes are represented as objects in their own right allowing the versioning of classes and the full implementation of schema evolution to be achieved as defined in the CIMM. This also provides the possibility for new classes to be downloaded into systems from libraries and brought into applications under the control of the COMMIT system at run-time. The object/class browser in the Java prototype provides the ability to load and instantiate classes, manipulate objects, and manage the rights and notification obligations of classes and instances.

An opportunity was recognized with the release of the Microstation/J CAD package by Bentley Systems, which uses a Java-like (and Java compatible) language (JMDL) Java to provide application development facilities and an Application Programming Interface (API). Whilst the current version of Microstation/J, and therefore the ADS demonstrator, is based primarily on drawing objects such as lines, shapes, and cells, the API does provide excellent access to the event handing mechanisms of the CAD tool, therefore permitting a fairly intimate relationship between the ADS components and the CAD elements during the interaction with the user. Much of the software development work in the ADS project has been concerned with the integration of the COMMIT functionality with the Microstation/J system from Bentley Systems, and with the creation and implementation of suitable user interface components for use within the design process and the CAD environment. It is in the latter area that the work of the Salford and Sheffield groups is most tightly integrated.

6 EXAMPLE USER INTERFACE ELEMENTS IN ADS PROTOTYPE V0.5

The second release of the experimental ADS user interface is designated version 0.5, and this section illustrates some of the basic ideas included in this version of the software within the Microstation/J environment.

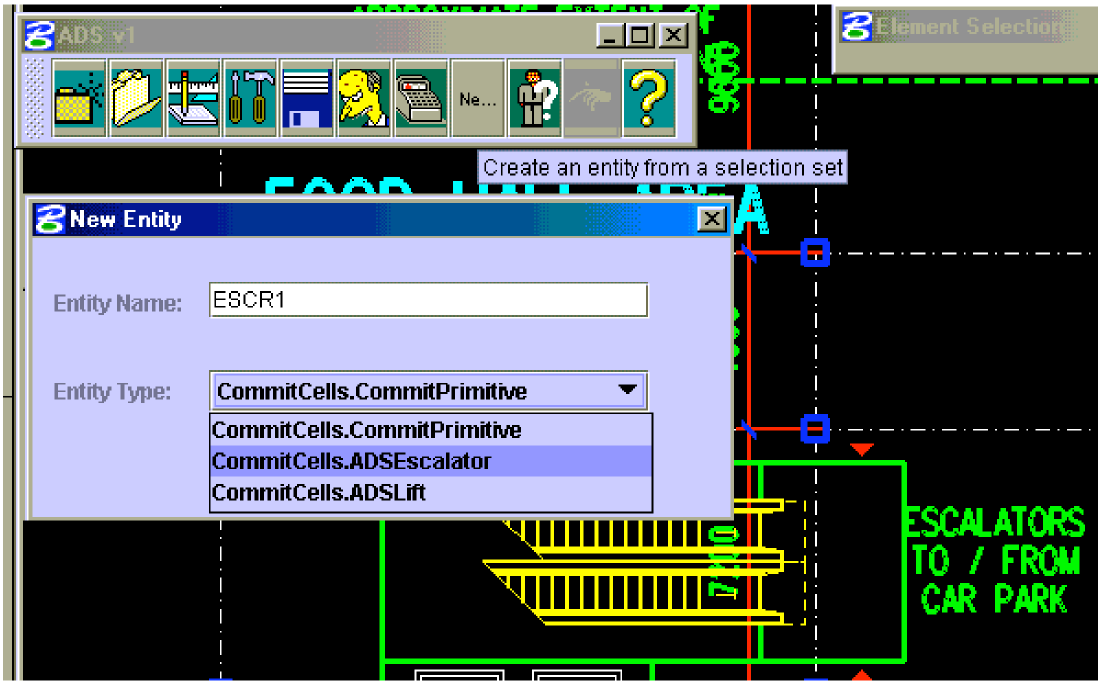

Figure 2: **Aggregation of drawing elements**

To improve the semantic level of the model, a facility has been incorporated into the ADS prototype to aggregate a number of drawing primitives into a cell, which is then represented by a single fully managed ADS object, to represent a higher level design concept such as an escalator or a lift. (See
Figure 2.) When a number of changes have been made as the result of a design decision, they may be committed as a single transaction, with a brief explanation of the reason for the changes (see

Figure 3). This is similar to filling in a change box in a paper drawing, but it can encompass a change that would be represented on more than one drawing, and there is much greater freedom of choice regarding the granularity at which this information is recorded. At this point, the COMMIT system checks to see which previous decisions may have been affected by the change (by inspecting the changed elements), and provides the opportunity to explore those previous decisions in terms of information such as the recorded rationales, and which objects were affected.

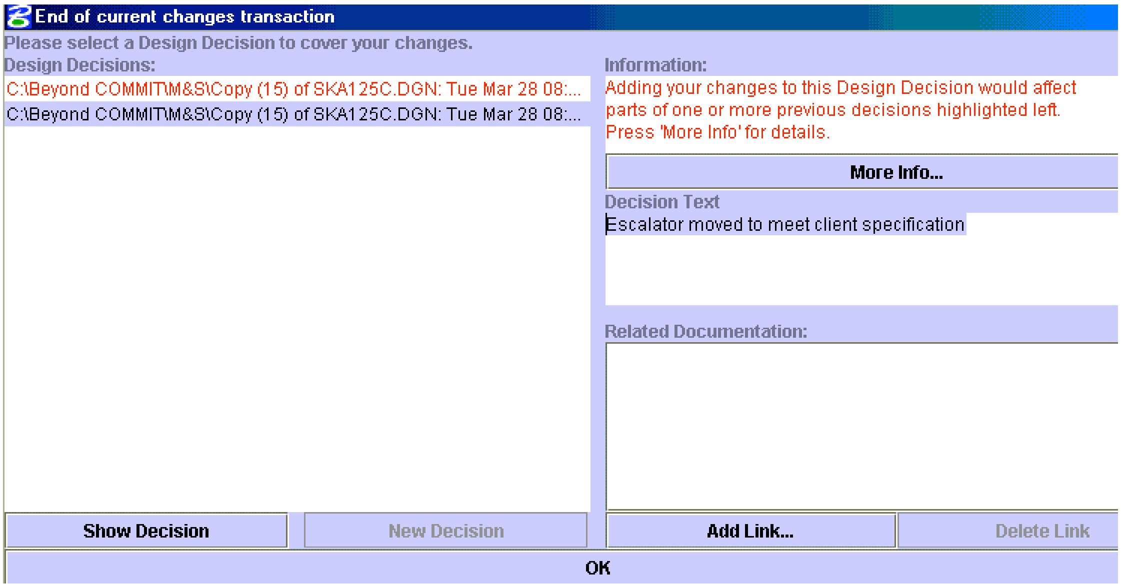

Figure 3**: Commiting a design transaction (decision) which affects previous decisions**

In order to allow the user to explore consequences oin a more rich manner, a decision browser has been constructed showing the past decisions that have been affected by the changes in the current transaction andf the objects that were affected by those earlier decisions (Figure 4). For objects that are able to be represented graphically in the CAD tool, this facility also allows the user (by means of the “show me” button) to view the different versions of an object graphically in context within a window of the CAD tool. Figure 5 shows the position of the escalator that created in
Figure 2, before (green) and after (red) a change of position has been made.

7 CONCLUSION

This paper has described the initial prototype developments made in the ADS project project, and the manner in which they build on the original concepts of the COMMIT project.

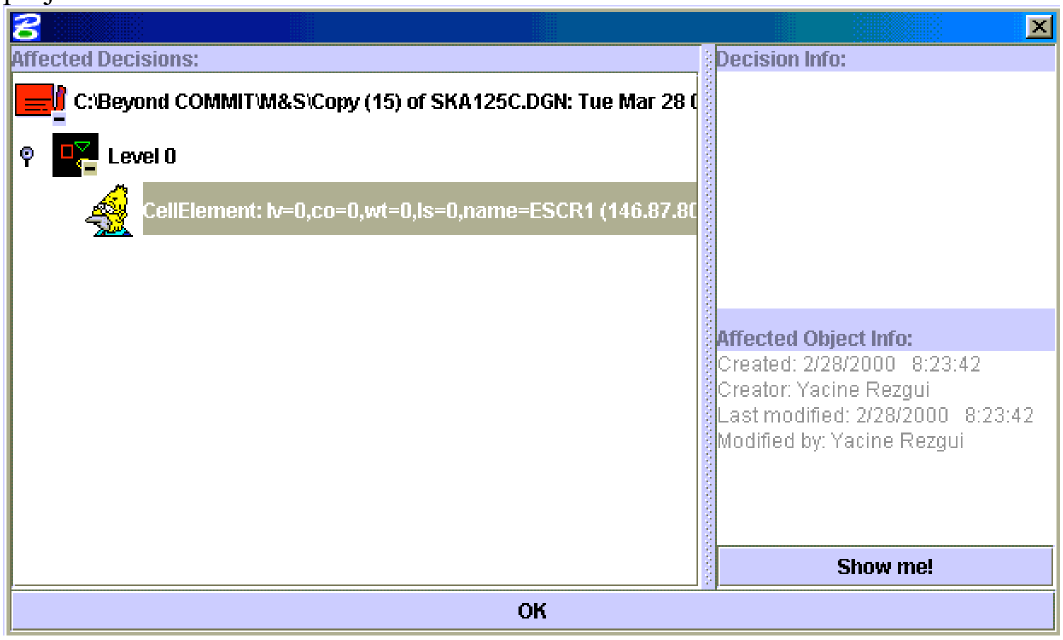

Figure 4: **A prototype decision explorer**

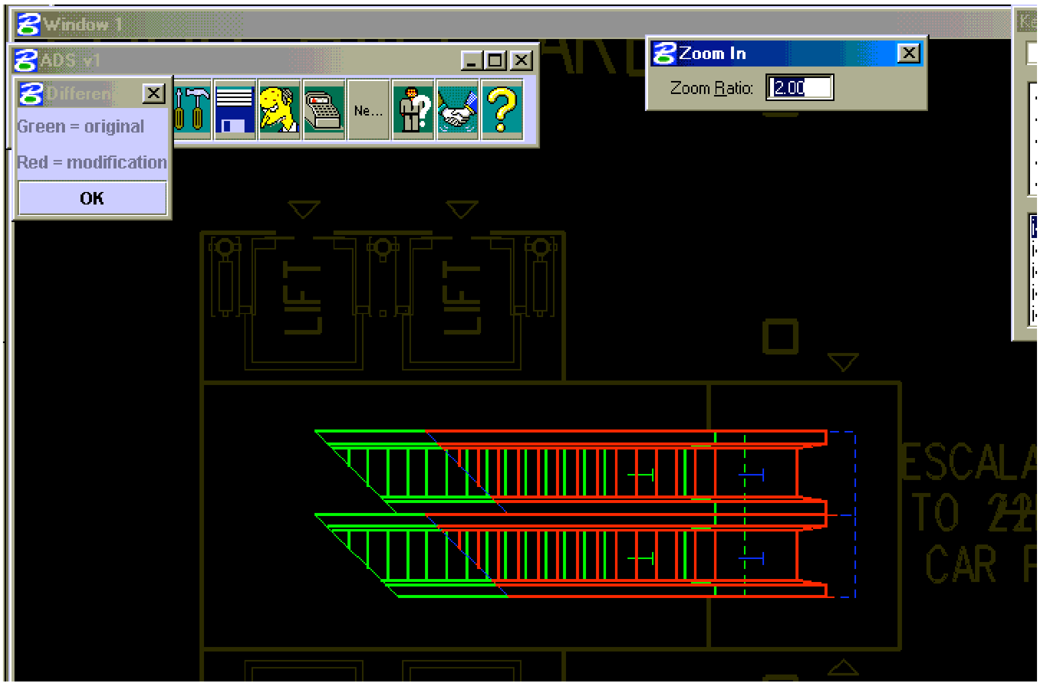

Figure 5: **Graphical exploration of a change history**

Both projects are concerned with the management of object-based information, and are being carried out in a construction project context. The ADS project has shifted the emphasis from developing the basic concepts and underlying software support towards exploring their use in a challenging application: the management of design information to support decision-making in the construction design process. In order to achieve this, the ADS prototype system has been created by integrating the COMMIT system with a CAD tool (Microstation/J) and developing, through an incremental prototyping approach, user interface components to facilitate the capture of decision related information and exploration of the resulting decision/change network. The user interface aspects are still in the early stages, and represent the core of the collaboration between the two research teams. To improve the richness of the information being managed, the team is also investigation the use of more recent technologies, including Bentley's ProjectBank and Engineering Component Modelling, to raise the level of representation to a more abstract design level.

8 ACKNOWLEDGMENTS

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