Integrating knowledge-based and drawing systems for steel construction

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Intégration d'une base de connaissance et du projet assisté par ordinateur en construction métallique

Integration von Expertensystemen und CAD im Stahlbau

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SUMMARY
A computer-based tool, SteelTeam, is under development that integrates knowledge-based systems with a computer-aided design and drafting environment. SteelTeam is a communications tool that provides a medium for the electronic transfer of data in the steel industry. Through the use of knowledge-based systems, SteelTeam acts as an intelligent assistant to aid in the decision-making process, helping engineers understand the effects that early decisions have on the final product in order to avoid downstream conflicts.

RÉSUMÉ
Un outil informatique est en phase de développement: il combine un système basé sur la connaissance avec un environnement de projet et de dessin assistés par ordinateur. Cet outil de communication fournit un véhicule pour le transfert électronique de l'information dans l'industrie de l'acier. Il assiste intelligemment dans le processus de la prise de décision. Cela permet à l'ingénieur de comprendre les effets que les premières décisions ont sur le produit final et aide à éviter les conflits potentiels.

ZUSAMMENFASSUNG
Ein auf Computerbasis arbeitendes Hilfsmittel ist in Entwicklung, das intelligente Systeme mit rechnergestütztem Entwerfen verbindet. Es ist auch ein Kommunikationsmittel, das eine elektronische Datenübermittlung in der Stahlindustrie unterstützt. Durch die Anwendung intelligenter Systeme funktioniert es wie ein Assistent, der bei dem Entscheidungsfindungsprozess hilft. Die Anwendung gibt dem Ingenieur zu verstehen, welche Auswirkungen Entscheidungen in der Entwurfsphase auf das Endprodukt haben.

1. INTRODUCTION

In the design and construction industry, insufficient communication and coordination can lead to project failures and other problems. Because of the high degree of interdependency among the activities involved in collaborative design, the ability to communicate and coordinate the various members of the design team is crucial to the production of the best product and to the success of the project. This is especially true in the domain of steel building design, where each phase in the design, detailing, fabrication, and erection of steel buildings is normally carried out with little interaction between the participating parties. Much attention has been paid to this phenomenon occurring in the manufacturing sector, and has been informally characterized as engineering tossing completed designs "over the wall" to manufacturing.

A computer-based tool, SteelTeam, is under development that integrates knowledge-based expert systems (KBES) with a computer-aided design and drafting (CADD) environment. SteelTeam helps bridge communication gaps in the steel building industry by providing a communication tool for use by the various members of the collaborative design team. SteelTeam is used to electronically transfer data between the design engineer, detailer, fabricator, and erector. This improves the accuracy, efficiency, and completeness of the information used by each member of the design team. The inclusion of KBES makes expert advice available for informed decision making among all parties in the steel building industry. Thus the quality of the engineered product improves by making design, detailing, fabrication, and erection knowledge available to each member of the design team.

Several computer-based tools exist that integrate KBES and CADD. An early example of such a system is the LSC Advisor [1] that uses a KBES to assist an architect in making certain that floorplans are consistent with major fire safety code regulations. The KBES in the LSC Advisor operates on top of a geometrical database contained in a CADD system. Several systems have been developed that combine graphics and expert systems [2]. Both BERT and Evaluator use rule-based shells and CAD packages [2]. Many systems in existence have characteristics similar to the SteelTeam system. The PMAPM [3] system uses an object-oriented information model to facilitate information sharing in the design, construction, and management of a facility. The intelCAD system [4] integrates an object-oriented inference engine with AutoCAD [5]. Finally, the Interdisciplinary Communication Medium, ICM, [6] uses KBES and graphic modelling techniques to facilitate communication in collaborative conceptual design. SteelTeam combines these characteristics to create a computer-based tool to facilitate communication in the steel building project.

2. PROGRAM DESCRIPTION

Collaborative engineering requires that the knowledge of various team members be brought into the design process at the necessary times. In the steel industry this communication is not always possible because of the separation between the design, detailing, fabrication, and erection phases. Often the design is completed without input from the fabricator or the erector. This input, though desirable, is not always available because many times the fabrication and erection firms are not hired until the design is completed. The most exact and innovative design cannot overcome shortcomings that make the structure difficult to fabricate or erect. Therefore, close dialogue between the design-detail side and the fabrication-erection side of the steel building project is necessary to obtain an economical building design where all costs of producing the finished structure are considered. The quality of the communication and cooperation among the design team members directly affects the quality and value of the finished product. A problem exists when different parties in the design process are not aware of what suits other parties as the best solution to the problem being considered [7, 8]. Therefore, it is important to communicate design intent along with the design artifact.

SteelTeam runs under AutoCAD [5] on a PC-compatible platform. AutoCAD is chosen because of its widespread use in the engineering industry and because of the availability of AutoLISP as a built-in programming language. SteelTeam incorporates knowledge bases that represent the expertise of the various parties involved in the steel building design, detailing, fabrication, and erection. The KBES advise the user regarding fabrication issues, constructibility issues, design issues, section availability, and completeness of the design document. The presence of this knowledge allows SteelTeam to act as a decision support tool. SteelTeam helps the engineer understand the effects of early decisions, and through this understanding, aids the engineer in avoiding downstream conflicts. SteelTeam provides the knowledge needed to investigate design alternatives by presenting varying views where there are often conflicting goals.

The design information that is passed by SteelTeam is in the form of an object-based project model. The representation of the building's elements follows the object-oriented convention of encapsulating data structures along with the procedures needed to manipulate that data within objects. For example, the object representing a simple shear connection contains data slots for values of the reactions due to unfactored dead, live, and other loadings as well as a data slot for the value of the reaction due to the governing factored load combination, which may be generated automatically by the attached procedure. The SteelTeam project model must carry all the information used by the design team members to perform the tasks of design, detailing, fabrication, and erection of the steel building. The information includes all data that traditionally is passed between the design team members in the form of hardcopy drawings and specifications. This data is represented in SteelTeam by the electronic AutoCAD drawings with the augmented object-based model. In addition, information on issues of fabrication, constructibility, availability, drawing completeness, and other design areas are contained in the knowledge bases. For example, the fabrication knowledge base contains data on material and labor costs along with procedures to determine relative cost of such tradeoff options as using column stiffeners versus increasing column web thickness. These knowledge bases allow tailoring of their contents for regional and fabricator specific assumptions and preferences.

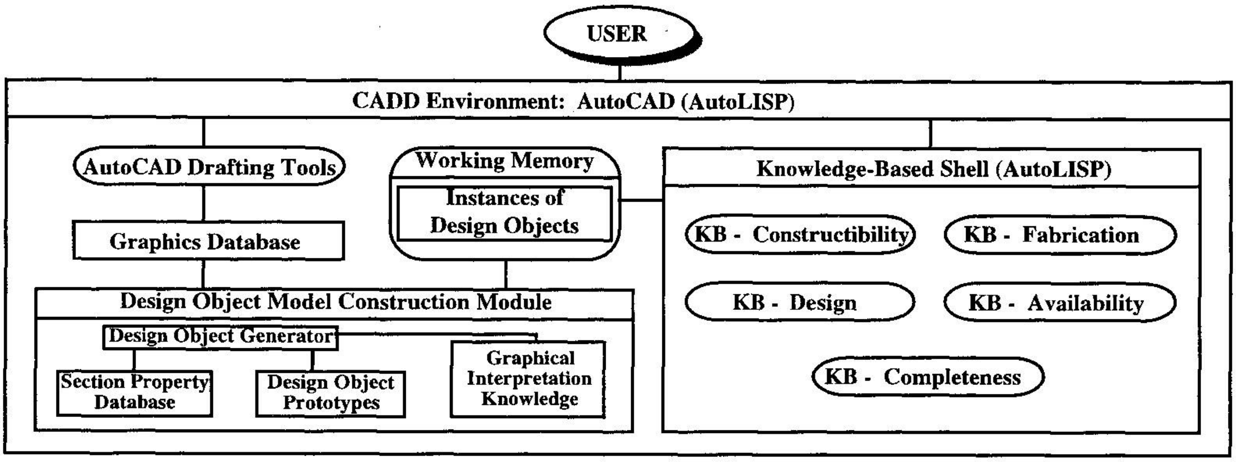

Fig. 1 SteelTeam system architecture

Figure 1 shows the architecture of the SteelTeam system. From within the AutoCAD drafting environment, the user may choose to either enter the design object model construction module or query the knowledge-based system shell. When first generating the design documents, the user enters the design object model construction module where the drawing entities and their associated attribute data are defined. This module contains the design object generator that assigns instances to the attributes that describe an object. The objects and their instances that make up the building model are stored in the working memory of the system. The building model consists of the collection of design instances that describe the beams, columns, connections, and other information needed to describe the structural configuration of the building. The second module that the user accesses is the knowledge-based system shell. This shell is a typical rule-based expert system shell implemented in AutoLISP. Only the component knowledge bases are illustrated in Figure 1. The knowledge bases cover constructibility issues (e.g. placement of column splices to avoid excessive erection costs), fabrication issues (e.g. notifying the user when a heavier section may be more economical than attaching stiffeners to a lighter section), design issues (e.g. bay layout of beams and girders for maximum economy), section availability (e.g. flagging sizes only available in large tonnage lots), and completeness (e.g. if highly skewed intersection on plan, then highly skewed connection detail should be addressed). The knowledge-based system shell accesses the working memory of the system to obtain information about the design being considered. The KBES is being enhanced to operate in a cooperative distributed problem solving (CDPS) architecture, allowing each knowledge base to function independently [9].

Current status of the knowledge-based shell only allows single or sequential operations of each knowledge base. In this single knowledge-base mode, the integration of CADD and the KBES has been explored for purposes of drawing checking, red-flagging possible problem areas. Details of the operation on a sample building may be found in [9]. The drawing of the building is checked for fabrication issues such as required coping and simple connection clearance issues. Currently, the fabrication KBES is being expanded and the other KBES are under construction. In the near future, the interactions between the different KBES will be explored using the CDPS architecture.

3. PRELIMINARY RESULTS

The benefits from the SteelTeam system include:

- The data exchange mechanism that allows transmittal of a more complete set of information. This increased access to better information allows more informed decisions to be made by all of the parties involved in the steel building design.
- The SteelTeam system performs a valuable completeness check on the documents that are being transmitted between parties.
- The expert knowledge that is available to the user in the form of the KBES provides the engineer with the ability to look ahead in the design process and avoid downstream problems and conflicts.
- SteelTeam allows the members of the design team to check the performance of alternative designs under the scrutiny of other experts.
- SteelTeam provides a two-way communication network for the members of the steel design team, allowing early and continued exchange of expert knowledge between the designer, detailer, fabricator, and erector.

ACKNOWLEDGEMENTS

This research is supported by the National Science Foundation under NSF Grant MSS-9221977 and the Center for Excellence in Computer-Aided Systems Engineering at the University of Kansas.

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