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Automated Construction Schedule Analysis and Evaluation

Analyse et évaluation de programmes de construction automatisés

Berechnung und Ueberwachung von computergestütztén Bauprogrammen

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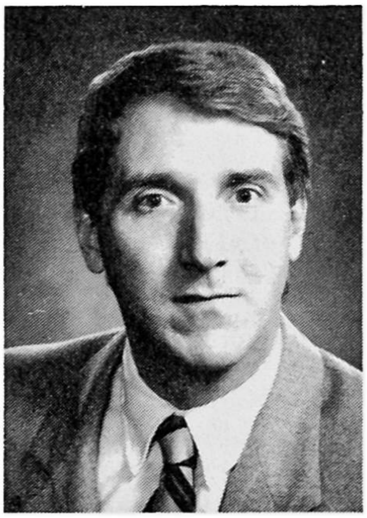

Professor Ibbs leads an active research group dedicated to applying advanced computer technologies to construction project control.

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SUMMARY
This paper explains in some detail a knowledge-based computer system for the analysis and updating of construction schedules. Special attention is devoted to discussing the various representation forms and the relationships used to link the system's knowledge concepts. The project will be used in managing large-scale civil works construction.

RÉSUMÉ
Cet article présente en détail un système expert pour l'analyse et la mise à jour de programmes de construction. Il porte un intérêt particulier aux diverses formes de représentation ainsi qu'aux relations entre les différents concepts du système expert. Le projet sera utilisé pour la gestion de grands travaux de construction.

ZUSAMMENFASSUNG
Dieser Beitrag beschreibt ein System zur Berechnung und Nachführung von Bauprogrammen. Spezielles Gewicht wird auf die verschiedenen Darstellungsformen und die Verbindungen zur Information des Computerprogrammes gelegt. Das Projekt wird für das Management grosser Bauaufgaben angewandt.

Introduction

Construction scheduling, along with estimating, cost control and quality assurance, is a vital ingredient to effective project control, particularly on renovation and rehabilitation work. Knowledge-based expert system (KBES) technology offers the promise of significant advance to all elements of project control, and in this article we outline the progress we have made in developing an intelligent scheduling system. Our approach has been to view scheduling from the owner's perspective and to examine both original submittals and updates.

The system being developed, CONSAES (CONstruction Scheduling Analysis Expert System), relies upon existing project control system software as its fundamental source of project data. The hardware, software, and communication linkage schemes we chose have also been documented in previous articles and interested readers are accordingly directed there (1, 2, 3).

KNOWLEDGE ORGANIZATION

As the "paper" knowledge base became larger, it began to exhibit some regularity in the sense that expressions of similar form frequently reappeared. Once these regularities were identified, they were captured by building an English-like knowledge acquisition grammar. This grammar allows us to express the facts, rules, and concepts of the construction schedule analysis domain. For example, the syntax for the rule and condition categories is:

```
(rule)        :: = IF (conditions) THEN (conclusions)
(condition)   :: = (frame) HAS (parameter) OF (value)
(condition)   :: = (frame) IS IN CLASS (frame)
```

As a specific example, RULE-111 within the Look-Ahead rule group can be represented by the following English and English-like grammars:

"Paper" knowledge base format:

> Make projections based on what has happened versus what was planned.

Knowledge Acquisition format:

```
IF   ((?some-activity IS IN CLASS activities) AND
      (?some-activity IS IN CLASS concrete) AND
      (?some-activity HAS status OF finished   in-progress) AND
      (?some-activity HAS assessment OF slow-progress) AND
      (concrete HAS lagged OF ( > 5 )))

THEN ((?activities IS IN CLASS activities) AND
      (?activities IS IN CLASS concrete) AND
      (?activities HAS status OF unfinished) AND
      (set (?activities HAS new-duration OF (* old delay))))
```

Here, previous job experience with a particular class of work activities is scrutinized for a deterministic delay factor. If found, that modifier is then applied to all subsequent unfinished activities in that class to develop a new projected schedule duration. This update is advisory only in nature allowing the system user to see clearly and in real time the changes recommended.

Use of this English-like knowledge acquisition grammar reduces the effort expended on acquiring additional rules. In addition, the knowledge represented in this generic syntax can be easily adapted to a variety of inference engine designs.

KNOWLEDGE REPRESENTATION

The Automated Reasoning Tool (ART)™ programming environment has been selected and acquired as the inference engine to process the knowledge base. ART is a set of specialized tools that facilitates the rapid prototype of expert systems. ART's knowledge representation language supports the expression of a wide variety of different types of problem-solving knowledge. These include: if-then rules, facts expressed in a logical-relational notation, frames that describe general classes of objects in the application domain, and procedural strategies used to represent algorithmic knowledge not easily expressed in the classic AI if-then rule framework. A large part of construction schedule analysis involves considering and evaluating different possible actions or evaluating a situation that is changing over time. Towards the end, ART provides "hypothetical worlds" as its most fundamental technique for generating, representing, and evaluating either static or dynamic alternatives.

The power of CONSAES is derived largely from the knowledge captured within it. Object-oriented programming provides the facilities, e.g. objects, to structure information which describes a physical item, a concept, or an activity. Each object is represented as a frame, containing declarative, procedural, and structural information associated with the object. That is, a frame is a collection of facts that represent an object or class of objects that share certain properties. Object-oriented programming is an extremely advantageous feature of ART, which allows information of common nature to be stored declaratively in the frames, where it is easily accessible and modifiable.

Since CONSAES deals with a highly complex domain, it is necessary to impose a structure on the domain. For example, some of the data elements can be organized into related groups. This makes them easier to analyze, describe and manipulate than hundreds or thousands of unstructured facts.

The ART schema system is a language for classifying data logically as well as for reasoning about data that has been structured. In addition to providing a way to structure all or part of a complex database, the schema system offers a convenient language for indicating that some data items share properties. Schema definitions can be organized into hierarchies in which knowledge about an object can be automatically deduced or inherited based on the class or classes to which it belongs.

KNOWLEDGE IMPLEMENTATION

The specific manner in which CONSAES works is as follows. During the construction planning phase, a work breakdown structure is routinely defined based on project phases, goals and organization. Milestone descriptions are derived from the work breakdown structure as tasks suitable for scheduling and monitoring. Traditionally, milestone descriptions are defined in such a way that they convey both a building and a construction process, e.g. "cast in place 2nd floor slab." The hierarchical relationship as well as the inheritance path of such a milestone are shown in Figure 1. A relation connects a schema to one or more other schemata. The inclusion of one or more relations in a schema serves to establish it as a node in a hierarchy. In other words, relations are the links that establish a schema hierarchy and permit inheritance of attributes. Note that the arrows shown in the diagram have significance in that they originate with the object being defined. They point to each schema that is listed as the value of the relation.

UTILITY AND RELEVANCE OF THE RESEARCH

This research is leading to fundamental advances in the knowledge base of project control thought in four distinct ways.

First, the development of the prototype is demonstrating that this new approach is satisfactory for accelerating and, indeed, improving upon many of the brute-force analyses and calculations typical of routine scheduling.

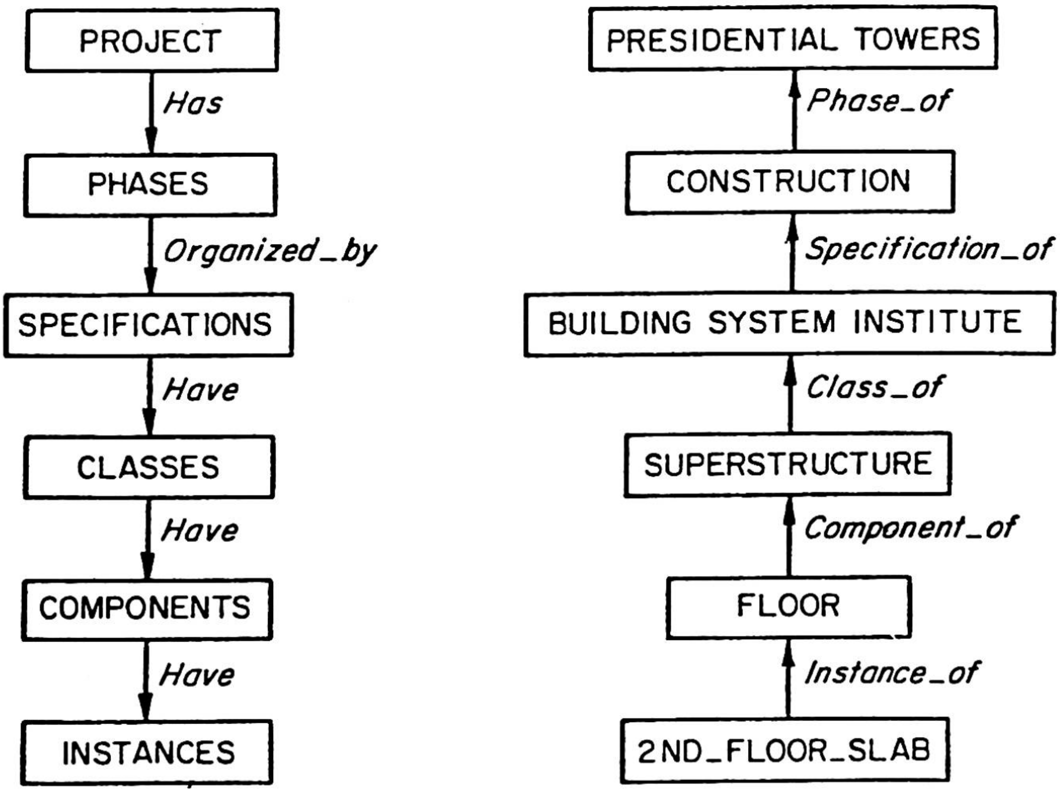

FIGURE 1 Knowledge Base Taxonomy

Second, this investigation identifies and organizes the knowledge (analytic and heuristic) that successful construction engineers use to schedule and time management projects. This work can be though of as a natural extension of important research conducted by a previous generation of investigators like Fondahl, Crandall and Halpin. They carried scheduling theory and practices to the refined science that it is today. Now that the analytical methods and mathematical theory are so mature, it seems quite proper, even critical, that researchers turn their attention to the project and practice-oriented features; e.g., developing or at least formalizing methods of re-estimating activity durations.

The third important advance represented by this research is of an applications nature. For a field as practice-driven as construction, expert systems concepts seem ideal. Especially so for a body of knowledge like scheduling which is part quantitative and part subjective.

Finally, the development of an expert system in construction schedule analysis could lead to the identification of new theory, or develop deep knowledge in the field, by formalizing the existing state of knowledge. In particular, the object-oriented representational approach may provide new and better ways to integrate cost quality and schedule information that to date has been so elusive. In this way, expert systems technology can provide heuristic answers to today's problems while suggesting research to develop and use new heuristics as well as new algorithmic solutions in the future.

Many other researchers are working quite hard to develop KBES tools for project management. Some of the more prominent and accessible work is documented in references 4, 5, 6 and 7.

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