A Semantic Network for Construction Knowledge Base

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Abstract

No expert system would be practically useful without implementation of a competent knowledge base. Although many expert systems have been studied and developed, there has not been much exploration of the structure of knowledge bases in the expert systems for construction planning and scheduling. This paper discusses the merits of semantic network methodology as applied to knowledge bases, then describes the manner of encapsulating the ill-structured construction knowledge into a semantic network. The author concludes the semantic network would play a competent role in developing knowledge bases for the domain of construction.

1. Introduction

The knowledge base is becoming more essential for implementing expert systems for construction planning and scheduling. Competent systems require more extensive and sophisticated knowledge in formulating construction plans.

Many construction models have been developed with graph notation, which is a primitive form of semantic network. The earliest one is PERT/CPM diagram, but Precedence Network would be a more appropriate model using the presentation rules of a semantic network. In addition to these diagrams, various models for simulation of construction operations have been developed: for instance, Cyclone by D. Halpin[1] and Process Graph by the author.[2]

Although those models are capable of visualizing the information on precedences among activities, resource and other requirements in a graph notation, the capability of structuring construction knowledge is not enough to implement the domain knowledge into an expert system for construction planning and scheduling.

This paper describes the methodology of using a semantic network to represent construction knowledge, and the methodology of representing the real knowledge with a semantic network in order to formulate a knowledge base in an expert system for construction planning and scheduling.

2. Modeling Construction Process

2.1 Semantic Network

In representing construction operations and processes in a semantic network, the node is used to describe an object which exists in construction, and an arrow or a link is used to depict the relationship between two objects. These principles have been discussed in detail in several author's papers.[3)4)]

In the semantic network, the following elements of construction should be considered as objects.

1) Activity
2) Substance
3) Event
4) Space
5) Time

In addition to these objects, the relationships between objects should also be considered as objects in order to expand the capability of encapsulate knowledge of construction. Therefore, the semantic network defined in this paper has two kind of objects: elements and relationships, with which construction knowledge might be presented generally as shown in Figure 1.

2.2 Knowledge Unit

Knowledge is composed into a unit having a specific aspect, which is characterized by the content of the information that is referenced, and the purpose of implementing the knowledge. The knowledge unit can not represent the whole aspect of the content at the same time, but only explain some specific aspect and implement it in defining the relationships among other knowledge units which formulate the whole aspect of the knowledge.

For instance, the construction process might be explained by the PERT/CPM diagram expressing the aspect of the precedences among activities. Simultaneously, we might need to have the work package of each activity express the resource requirements and the various alternative methods of activities if necessary.

As mention above, it might be appropriate to develop the knowledge base so that the knowledge is broken down and encapsulated into knowledge units with respect to the context of the knowledge. In this paper, a knowledge unit is defined as a unit of knowledge which comprises all the knowledge concerned. It works as a cell of the knowledge, and is stored in a sheet. It is obvious that in using the knowledge unit, the whole aspect of knowledge is represented as a set of units as shown in Figure 2.

In the semantic network, each sheet should be considered as an object which integrates the pieces of various objects.

3. Domains of Construction Knowledge

3.1. Classification of Knowledge Unit

Knowledge units stored in sheets are categorized into the following nine classes.

1) Unconditional Knowledge: Ex. Crane "A" has a coverage of 20 meters in diameter.
2) Conditional Knowledge: Ex. If wind exceeds 10 m/sec, crane should be stopped.
3) Past Knowledge: Ex. Reinforcement on 2nd floor finished on June 20, 1990.
4) Current Knowledge: Ex. Wind speed at site is no more than 5m/sec.
5) Future Knowledge: Ex. For this week, the possibility of having no rain is 0.4.
6) Plan Knowledge: Ex. Reinforcement on 10th floor is to start on Oct 10, 1990.
7) Hypothetical Knowledge: Ex. Reinforcement on 10th floor will need 10 days.
8) Inferred Knowledge: Total construction period has been calculated as 450 days.
9) Method Knowledge: Functions, rules, procedures and external packages

Unconditional knowledge is knowledge which is definitely true in any case, while conditional knowledge is knowledge which may turn out to be true or not depending upon external conditions.

Past, current and future knowledge correspond to knowledge which occurs on a time horizon. Plan knowledge means knowledge which has been authorized as a plan, while hypothetical knowledge is knowledge which has been hypothesized in a certain period for developing the plan. Inferred knowledge results from calculations using method knowledge or the slot value acquisition algorithm described later. Method knowledge consists of functions, rules, procedures, and external packages.

3.2. Format of Knowledge Unit

Each sheet is designed to store a specific knowledge unit in order to formulate an appropriate cell of knowledge. In manipulating the knowledge unit in the sheet, the treatment of each knowledge unit varies by category of knowledge. Therefore, the knowledge unit should accompany specific appropriate methods in accordance with the context of the knowledge unit in a sheet.

To implement these methods for knowledge units, each sheet is categorized so as to define the context of knowledge and to install specific methods according to the category. The following categories of sheet define various aspects frequently used as domain knowledge in construction.

1) Work Package Sheet: Conditions and effects of activities
2) Precedence Sheet: Precedence relationship among activities
3) Substance Flow Sheet: Flow of substance at the site
4) Causality Sheet: Causality of events
5) Space Structure Sheet: Spatial relationships among elements and locations
6) Time Horizon Sheet: Time definition
7) Breakdown Sheet: Breakdown structure of the elements
8) Alternatives Sheet: Exclusive-OR structure for the elements

Each sheet stores specific methods of handling the knowledge unit in it; for instance, to present the context of knowledge, to transform the knowledge to another pattern of structure, and to utilize the knowledge itself. Figure 3 shows an example of a method in a work package sheet; it is a method of visual presentation of the context in the work package for super_structure work.

3.3 Unification of Knowledge Units

Since a knowledge unit is represented as a fundamental cell of knowledge, in utilizing knowledge units, they should be grouped to some extent according to the purpose for which the knowledge is used. This unification of knowledge units might occur, if the user of the knowledge base needs to summarize a set of knowledge units and to acquire a much broader aspect of knowledge. The unification takes place by developing a new sheet which contains a set of knowledge units.

4. Frame of an Object

4.1 Slot in a Frame

Semantic networks break down knowledge of construction processes into objects: that is, elements and relationships. However, since all knowledge can not be represented by semantic network notation, the knowledge which is not depicted by it is stored in slots of each object.

Each slot has an attribute which characterizes its value as shown in Table 1.

4.2. Acquisition of a Slot value

In order to use knowledge in various cases, the knowledge should be assembled in general. Common knowledge which can be applied to construction planning should have a flexible knowledge structure, where slot values of objects should be subject to given conditions, rather than have fixed values. For instance, in the case of a work package, the slots should be capable of estimating the resource requirements according to the quantity of task to be specified.

Although it could be inferred by the method defined in the sheet mentioned above, the slot itself has to have its own slot value acquisition algorithm, which leads to the reduction of knowledge and to the speed-up of acquisition.

4.3. Acquisition Algorithm

If the slot of objects is a value dependent on the values of other slots, this slot value might be formulated with the slot values of the same object and other objects which influence it.

To acquire the slot value based on other slot values by using a formula, the following acquisition algorithm is defined.[5] This formula is placed in the slot as if-needed facet. To trace the other slot values, the trace scripts are implemented as follows.

```
(@trace (thisunit >output * :number_of_floor))
```

The above script depicts the trace procedure: to trace through relationship "output" from this unit, and to find the slot "number_of_floor" at the head of the arrow (relationship).

With this trace script, Formula 1 below would be used to estimate the duration of superstructure work.

```
(@plot (thisunit 20 60 100 250 600)
     ((@trace (thisunit >output * :number_of_floor))
            1  4 10 30)
                                  --------------------(1)
```

Formula 1 shows that the duration value will be acquired by using a slot "number_of_floor" in a component and a given plot function. If the number_of_floor is five, it implies a duration of 125 days according to the correlation between duration and number_of_floor.

5. Conclusion

The knowledge base by semantic network notation is an effective structure for representing construction knowledge in detail and in a sophisticated manner. The author has incorporated this prototype of knowledge base into several expert systems for construction planning and scheduling. As a result of experiments, it has been concluded that the semantic network notation is essential for representing the sophisticated structure of construction knowledge and that the concept of the knowledge unit will play a major role in supplementing semantic network methodology.

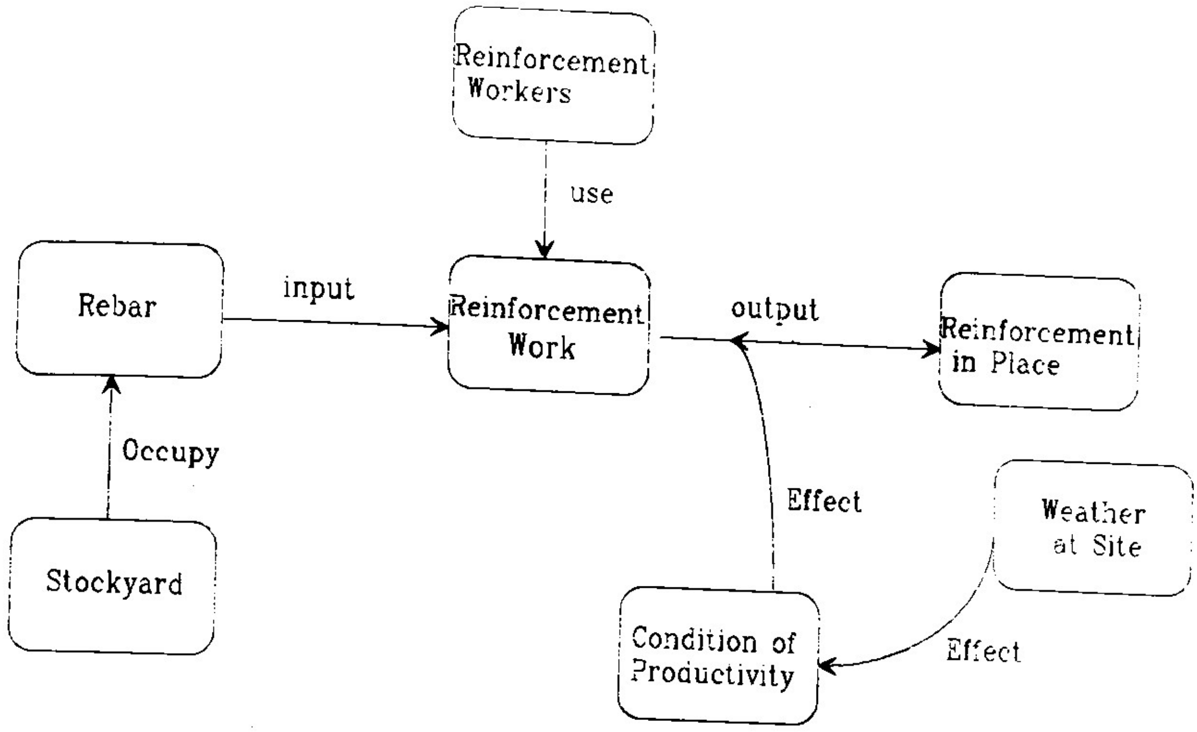

Figure 1 A Semantic Network for Construction Knowledge

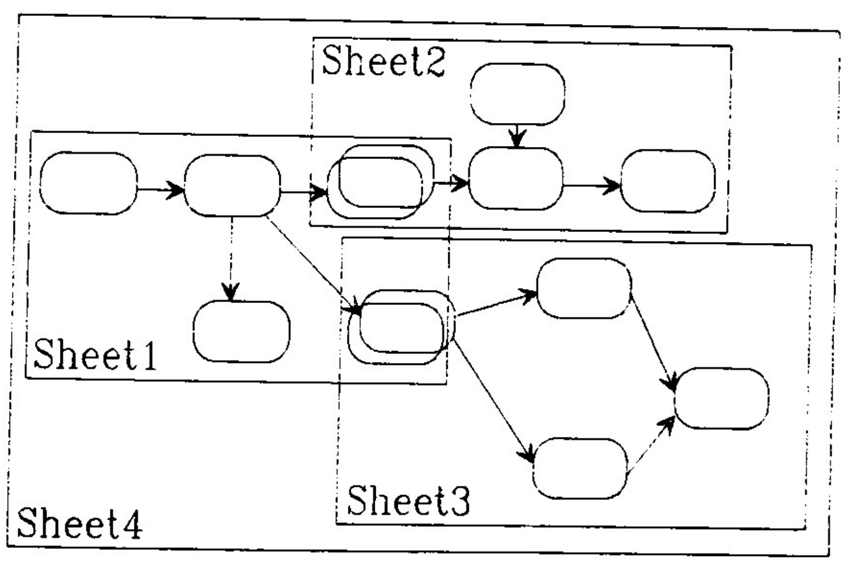

Figure 2 Knowledge Unit in a Sheet

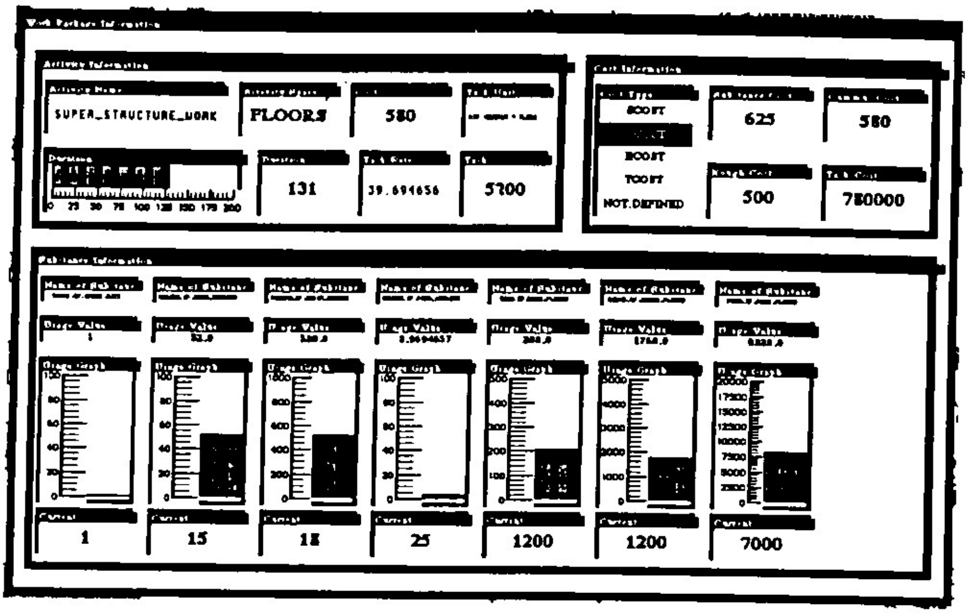

Figure 3 Output from the Work Package Sheet Presentation Method

Table 1 Slot Attribute in a Frame

Attribute	Function
Truth	Value of truth
Past	Value of past time
Hypothesis	Value hypothetically set
Inferred	Value inferred from method
Plan	Value authorized as plan
Defined	Value defined by user

References

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