EXPERT SYSTEM TO PRODUCE A WELDING PROCEDURE SPECIFICATION

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1. Introduction

This paper describes the outline of the expert system for producing a welding procedure specification for a pressure vessel which has been developed in the 5 year project of Nagasaki Prefecture financially supported by MITI (Ministry of International Trade and Industry). The aim of this project is to reduce the burden of welding engineers because requirements are getting more and more severe and products are getting more and more complicated and diversified.

2. Knowledge Representation

What is important in developing an expert system is how we represent our knowledge. Welding is related to many engineering fields so that many factors of different nature are involved. This is why it becomes a burden for a welding engineer to make appropriate decisions when the conditions change to a large extent and/or frequently. Thus, unless we represent our knowledge appropriately, the system developed based on it would not serve for the purpose.

As one of the authors, Shuichi Fukuda, chaired the similar project called the Welysis Project in which 11 major Japanese companies participated and the logical network for producing a WPS shown in Fig. 1 was obtained after a very long and lively discussion and after checking by developing a prototype system using Knowledgecraft on Micro Vax II, the same logical network is adopted here because although there are some points which could preferably be modified, the knowledge representation as a whole seems to be appropriate. Of course, the network varies from application to application if we discuss rigorously. But this network may as well be accepted to represent the general framework of producing a WPS.
Fig. 1 Logical network

Inputs are divided into two kinds. One is called Primary Inputs which provide the initial conditions and are in most cases designated by designers and are rarely changed by welding engineers unless they cannot find a proper solution within the designated search space. Thus, these inputs constitutes the hard (not to be changed easily) constraints.

In the Welsys Project, other inputs are treated as soft or negotiable constraints. These values change with how the dialogue proceeds and what should be stressed is that how to impose and relax these soft constraints differ from welding engineer to welding engineer. Unless we provide the appropriate lines of reasoning to suit to each welding engineer, he is very much frustrated. This is the most important lessons we learned from the Welsys Project.

In this Nagasaki Project, the inference mechanism is improved further, because there are other hard constraints, too. They are, for example, the availability of welding machines, etc. If we can use only one type of a welding machine, then we have to reason so that a WPS be produced under the condition that a welder uses this type of welding machine.

But to satisfy such hard constraints which lie ahead in the lines of reasoning in addition to the initial conditions is very difficult and still remains an open question in the AI field what inference mechanism should be the best. In our system, we realize the same function by introducing the inference mechanism fundamentally
similar to the case based reasoning. The similar cases are stored as files and the
nodes which are negotiable in these files remain to be determined by the user.

Further, the system in the Nagasaki Project elaborated on introducing a hierachy
into the inference mechanism. The hard constraints such as codes and rules can
be put at the top of the hierachy. Thus the degree of constraints can be taken into
account by considering the hierachy.

3. Hardware and software

The Mitsubishi Electric PSI is used for an inference machine and a Sun
compatible workstation is used for the user interface. Thus, the inference is carried
out on a Prolog based PSI machine and the results are displayed using an X
window on a Unix machine. The PSI machine was originally developed as the
result of the 5th generation project. Why we decided to use Prolog and Unix
machine together is because if we write the inference engine using Prolog, it
would be more transparent and easy to understand the logic of the reasoning and
the graphics and data base are more easily handled in C.

4. Features of the system

In our system there are such features as follows;

(1) As we have already discussed in chapter 2, we can consider the hard
constraints not only at the beginning of the reasoning process but also in the
middle of it. The inference mechanism similar to CBR permits such processing. In
most of the other expert systems related to welding, constraints are propagated
only to subsequent nodes through the logical network and the reasoning in other
direction is not possible.

(2) In our system we can find only one solution or if we are not satisfied, we can
let the system search every possible solution. This is done by utilizing the Prolog
functions.

(3) The direct correspondence between the spreadsheet and the graphic is
realized. We can designate the section in the spreadsheet and the corresponding
part is shown in the graphics or vice versa. Thus, we can search for a solution
considering how a range of parameter affects the solution.

(4) The inference mechanism is hierarchized. So that the codes and standards
can be placed at the top level and inference can proceed with this designated
boundary. And if we wish we can consider the user's level just in the same
manner.

(5) There is a trace mechanism to trace the lines of reasoning to find out where
the inappropriate solution comes up.
(6) It is possible to refer to a file similar to the present case.
(7) Knowledge editor is provided making the most of the Prolog functions.

5. Sample screen image

Fig. 2 and 3 shows the samples of screen images. The screen image of Fig.2 comes up when a user is making inputs and searching for solutions. The corresponding menu comes up prompting the user to make inputs. And the final result of WPS is also shown using this screen image. The retrieval of similar results from a file is also carried out using this screen image.

What we should like to stress here is that even the dialogue proceeds the way a welding engineer reasons, it is not enough. No matter how flexible the reasoning process is and how well it reasons fitted to each engineer's lines of reasoning, he still feels uneasy unless he cannot see the reasoning in a broad perspective or he cannot see the whole picture. The screen image of Fig. 2 is the simplest solution to
Fig. 3 Sample screen image

this. The terms corresponding to the node just inferred are shown by different color from the previously inferred ones. Thus, the user knows how the inference goes and the whole perspective at the same time.

The screen image of Fig.3 is for choosing the range in the graphics or in the spreadsheet or for checking where the data lie in the graphics or what are the data in the spreadsheet. We can easily turn to the screen image of Fig.2 from here. Thus, we can come and go from Fig.2 to Fig.3 and Fig.3 to Fig.2 without any difficulty.

6. Summary

This paper describes the outline of the Nagasaki Project for developing an expert system for producing a WPS for a pressure vessel.

What we have learned from the Project is that to really reduce the burden of a welding engineer, several special cares such as follows must be taken into account in addition to the usual procedures of developing an expert system.
(1) The inference must be processed in accordance with the lines of reasoning of a welding engineer. It must be remembered that these lines differ from engineer to engineer. Thus, a very flexible inference mechanism is called for.

(2) The constraints are propagated in any direction. The mechanism to deal with this kind of constraint propagation is called for.

(3) The user wishes not only to follow the lines of reasoning but also to get the whole perspective during the reasoning process.

(4) The search space must be made visible to the user. Thus, the range must be clearly shown in the spreadsheet and in the graphics. And their correspondence must be established.

(5) Hierarchical inference mechanism is preferred.

Reference