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Development of Maintenance Support System for Oil Storage Tanks using Prolog †

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Abstract

The maintenance of structures has now been accepted as the problem of rapidly growing importance, because structures are being operated for a much longer period of time than ever before and their operating conditions are becoming more and more severe. Although maintenance work might be formalized in their fundamental procedures, most of the work involved are difficult to put into proper form or perspective. Therefore, to perform good maintenance work, wide variety of knowledge and experience is called for and what is just as much important as deep knowledge and experience is the adequate decision making as to what kinds of knowledge or experience should be applied. As the problem of maintenance is thus too much complex, an interactive decision support system for the application to an oil storage tank has been developed. What differentiates our system from others is that our system is programmed mainly using Prolog to cope with the non-deterministic and ill-formed nature of the problem. The effectiveness of introducing logical programming technique has been verified through development of the system and TSS sessions.

KEY WORDS: (Maintenance Support, Oil Storage Tank, Expert System, Prolog)

1. Indroduction

Recently in addition to the increasing severity of operating conditions, the structures have come to be operated for a much longer time than ever before. Therefore, the problem of their maintenance has become increasingly important.

Now, even if their fundamental procedures might be formalized, most of the maintenance work do not have a definite form, and in order to carry out maintenance work well, it is necessary to apply appropriate knowledge and/or experience to the problem involved. Although the knowledge or experience thus applied would be better if they are deeper, what is just as much important is the judgement as to what kinds of knowledge should be applied, i.e., the adequate decision making as to what kinds of knowledge and/or experience should be applied to the problem and as to in what sequence.

But the knowledge of maintenance has such characteristics as

(1) There are many difficult to quantify factors.
(2) Factors involved are too many and too diversified. And in addition, their relations are intermingled and too much complex.
(3) Structures, expecially large ones, are produced to order. Therefore, the amount of production is quite small, usually two or three, and knowledge and experience are individual.

Thus, it is quite difficult to make an appropriate decision.

This work is an attempt to construct an interactive decision support system for the maintenance of a structure by introducing logical programming technique with the aim of releasing maintenance engineers from these burdens. In this report, we selected oil storage tanks as a sample of structures because they are constructed using small number of members and their maintenance is known to be one of the very complex and troublesome work. And as most of the failures of oil storage tanks are due to corrosion, we take up the problem of corrosion here.

Thus, although oil storage tanks are selected as a sample, the fundamental methodology developed here is expected to be applicable to other kinds of structures.

Although we have still more points to be examined and improved for actual application to a real oil storage tank, the fundamental framework has been developed and the effectiveness of the present approach has been verified through TSS sessions, so that we will report the outline of our system here.

2. Why corrosion?

The reason why we chose corrosion as a sample of maintenance work is because, in addition to the reason that most of the failures of tanks are directly or indirectly related to corrosion,

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(1) As too many and too diversified factors are involved in corrosion, the methodology or approach has not been systematized and therefore, there are various descriptions to the same phenomenon, so that the amount of trouble in retrieving relevent information is too much, and sometimes there are good chances of overlooking important information.
(2) As corrosion is triggered by uncontrollable environmental conditions, the appearances of the phenomena are too diversified and consequently their reproductions are most difficult in laboratories. Therefore, it is of utmost importance to extract a case close to the present one as much as possible. In other words, the full utilization of the experience of actual oil storage tanks and the knowledge of laboratory tests close to the present problem as much as possible is most important.
(3) The types of inspection, on stream or shut down, or fixed point measurement or sample point measurement, full or sample, etc. is determined by the manner of appearance of corrosion.

Therefore, it is considered as one of the most typical example of the case where appropriate decision making is called for to make exact diagnosis, but is difficult to be programmed by the conventional method.

3. Advantages of Introducing Logical Programming Technique

In this work, we used Prolog as a programming language. The advantages of using Prolog are

(1) In the conventional programming, the data are processed by the procedures pre-determined by the program. Therefore, it is quite difficult to correspond to such an ill-defined or ill-formed problem as maintenance. Even if the program can be made, the program itself becomes too much large and most of its content are the descriptions of procedures for data processing, so that it becomes increasingly difficult to understand. Logical programming, on the other hand, processes the data based on the results of pattern-matching so that it can easily correspond to such an ill-formed problem.
(2) In order to make an appropriate decision, it is necessary to retrieve pertinent information from the large amount of information pattern which are described using various forms. As Prolog is provided with a very strong pattern-matching function, these tasks are relatively easy to carry out.
(3) As knowledge and experience are described using too many and too diversified forms, it is most difficult to put them into a systematic form. But as Prolog permits such diversified description when loading the knowledge and experience, the users can retrieve information without much worrying about the description format.
(4) As Prolog is fundamentally developed for symbolic manipulation, the difficult to quantify factors can be processed with much ease.

4. The Outline of Our System

Language: Prolog/KR[1] (This Prolog is constructed on Utilisp[2] and permits floating point operation)
Computer: HITAC M280H (Computer Center of University of Tokyo)
Number of Assertions: approximately 1000 (approximately 900 are for describing knowledge and experience, and the rest is related with data processing)
Content: Provides advices on where to inspect and with what to inspect for corrosion based on the prediction of the appearance type using the inputs as to the content of a tank, the operating years, operating environment, etc. Also predicts remaining life or time to leakage by referring to the similar cases and by using the measured data and by referring to the similar cases. Life prediction is made using the worst data to be on the safe side.

Program is described mainly by Prolog, and although relatively simple numerical munipulations are processed by it, the complex numerical manipulations such as fracture mechanics analysis, analysis of buckling due to thinning of the shell plate thickness, and service load simulation are processed by Fortran which is subroutine-called within the Prolog program. The transfer of data between Prolog and Fortran is carried out using files.

5. Sample of a TSS Session

: (START)
"CORROSION CHECK"
"SHELL PLATE CORROSION CHECK FIRST? Y/N"
–: Y
"CORROSION CHECK OF SHELL PLATE"
"CORROSION CHECK OF SHELL PLATE INSIDE FIRST? Y/N"
–: N
"CORROSION CHECK OF SHELL PLATE OUTSIDE FIRST THEN"
"CORROSION CHECK OF OUTSIDE SHELL PLATE"

"INSPECT WHERE THE PAINT IF SPALLED OFF OR CRACKED OR SWELLED AND IS COVERED WITH BROWN SCALE OR RUST"

⋮

"CHECK NEAR-BOTTOM OF THE BOTTOM SHELL PLATE"
"REASON: RAIN POOL DUE TO OVERALL SINKING OR WETTING DUE TO SAND OR GRASS, OR SPALLING OF PAINT DUE TO FLYING PARTICLES"
"EFFECT: LOCAL CORROSION"

⋮

"THE CORROSION OF INSIDE SHELL PLATE"
"THE CORROSION OF GAS PHASE PART – INSIDE TOP"
"WHAT ROOF TYPE? FLOATING OR CONE"
–: FLOATING
"ROOFTYPE FLOATING"
"CORROSION IS SIMILAR TO THAT OF OUTSIDE SHELL PLATE WITHOUT BEING AFFECTED BY THE VAPOR OF STORED LIQUID"
"THEREFORE, CORROSION IS GREATLY INFLUENCED BY THE QUALITY OF PAINT"
"INPUT PRESENT QUALITY USING SCALE 1 – 10"
–: 3
"EFFECT: TOTAL CORROSION WITH THIN RUST"
"WHAT CONTENT? CRUDE-OIL, HEAVY-OIL, NAPHTHA, GASOLINE, KEROSENE, LIGHT-OIL"
–: CRUDE-OIL
"LOCAL CORROSION HAS BEEN OBSERVED AT DEFECTIVE ROOF SEAL WHEN SULPHUR IS HIGH"

⋮

"IN CASE OF PITTING, RATE INTO DEPTH DIRECTION SHOULD BE STUDIED"
"IN CASE OF REPETITIVE CORROSIVE ENVIRONMENT SUCH AS INFILTRATION OF RAIN, MOST CASES ARE LOCAL CORROSION AND PROGRESS IS NOT SO FAST"
"IF THE FACTORS ARE NOT SO AGGRESIVE, THEN CORROSION PROGRESSES INTO TOTAL CORROSION, SO THAT CORROSION RATE IS SLOW"

⋮

"CONTENT CRUDE-OIL? Y/N"
–: Y
"ESTIMATION OF INTERNAL BASE PLATE THICKNESS BY MEASURING EXTERNAL THICKNESS FOR CRUDE-OIL"
"INPUT EXTERNAL THICKNESS MEASURED"
–: 18.0
INTERNAL-THICKNESS-ESTIMATED+0.1650000E+02-MM
"IF ABNORMAL REDUCTION OF THICKNESS IS DETECTED BY FIXED POINT MEASUREMENT, THEN DETAILED MEASUREMENT SHOULD BE CARRIED OUT. SAMPLING CUT IS QUITE RECOMMENDABLE"
"INPUT DESIGN THICKNESS"
–: 20.0
"INPUT MAXIMUM PITTING DEPTH"
–: 2.0
"INPUT PAST OPERATING YEARS"
–: 8
"CAUTION: PITTING FASTER THAN EXPECTED"
PREDICTED-YEARS-PITTING-9

⋮

6. Summary

In this work, as the maintenance of structures calls for quite a wide variety of knowledge and experience, and interactive decision support system is developed with the aim of releasing engineers from the troublesome burden.

What is to be stressed in this paper is that we introduced logical programming technique by noting the ill-defined or ill-formed nature of the problem. We take up here the problem of corrosion in oil storage tanks as one of the typical sample problems of most troublesome maintenance, and we developed a system using Prolog and confirmed the usefulness of the present approach through TSS sessions.

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