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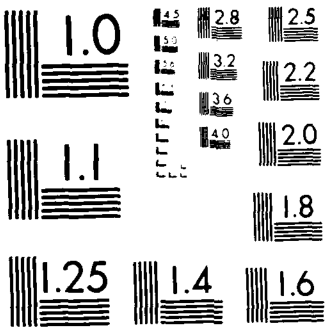

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THIRD INTERIM REPORT

(Covering the period 1 April to 31 August 1986)

1. Introduction

Since the last report the development of CRANES has proceeded satisfactorily. Section 2 describes this work and no further comment is offered here.

Regarding the BID/NO BID domain we have made good progress with the other contractor mentioned in our last report namely IDC Ltd of Stratford on Avon. We are dealing with Mr Ivor Davies, the Deputy Chairman, and his reactions have been favourable.

We have concluded that, on account of the paucity of information on real world cases we should try a different approach in the general exploration of knowledge acquisition methods. In particular we shall attempt to produce a system to advise project managers on items such as the scheduling technique, the level of sophistication and detail and on methods of training and communication. We plan to use this as a vehicle to explore alternative methods.

We have continued our work on rule induction but, as previously reported, we are giving this work a low priority. We have had interesting discussions with Rense Lange of CERL and had some correspondence with him regarding his program STAT. However the details he has sent us are at present incomplete. We have written to Frank Kearney to suggest that Rense Lange should visit us to try out his program on data we can supply. No decision on this is yet available but we remain convinced that a short visit, say of 2 or 3 weeks, would be beneficial for the project.

The remainder of this report is presented under the following headings:

Section 2	CRANES
Section 3	BID/NO BID
Section 4	Alternative knowledge aquisition methods
Section 5	Rule induction
Section 6	Future work

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SECTION 2 CRANES

Work on the *cranage domain* has continued with a total of 7 knowledge elicitation meetings completed and a prototype system coded for the SAVOIR shell now in operation.

The knowledge elicitation sessions have brought to light a number of interesting findings including the following:

- In the early stages the experts' description of their method of working when choosing cranes appeared to change markedly between one meeting and the next.
- Each expert has his own approach to the important hook time calculation (an estimate of the number of cranes required to perform the necessary duties). Experts tended to talk in general terms about this calculation but were reluctant to reveal the actual figures they themselves assumed. This may in part have been due to a reluctance to be "shown up" in front of colleagues.
- The two most senior experts appear most sympathetic to the objectives of the work and hence have provided the most useful knowledge.
- When the first prototype system was demonstrated to the most senior expert it became clear that his expectation had been of an automatic system capable of undertstanding a co-ordinated model of a building rather than an advice system. This was suprising in view of earlier discussions we had had about the purpose of the graphic displays we are developing.
- Experts tend to dismiss complex areas of knowledge as too difficult to formalize and it is often difficult to elicit knowledge about such areas.

The prototype system is being developed as a series of modules to enable the user some freedom in the order of approach to his particular problem. Modules in operation so far are as follows:

1. Preliminary strategy module. This is aimed at the novice user to advise whether to consider the superstructure or basement first and to indicate which type of crane (i.e. tower, crawler, mobile) he should consider first.

2. Hook time calculation. An essential calculation to determine the minimum of crane hooks required to complete the structure within the contract period. The module will be required several times - for the superstructure, for the basement, and later to check that each individual crane can do what is asked of it. Considerable knowledge acquisition effort has been focussed on this topic and the resulting system module embodies much specialist expertise.

3. Graphics module. Besides having sufficient hooks to perform the required crane duties within the construction period the planning engineer must also position cranes suitably to cover the whole structure. The graphics module enables

him to define and adjust the coverage of tower cranes on a graphic display. The system then checks that cranes capable of lifting the necessary loads at the required radii are available using a data base. Development of software to enable graphics routines to be called from the SAVOIR shell has taken considerable effort. However our discussions with the domain experts led us to conclude that this facility was essential to any real world system.

For the immediate future it is our intention to concentrate on tower cranes and to attempt to expand the system into the following areas:

- choice of jib type
- choice of foundation for the crane
- methods of crane erection and dismantling
- advice on when cranage requirements might be reduced by, say, pumping or working overtime
- when to bring in a large mobile crane for heavy lifts

SECTION 3 BID/NO BID

3.1 Introduction

The bid/no bid system has been developed in conjunction with IDC Consultants, a firm of design/construct contractors.The system is designed to advise the user in deciding whether or not to bid in response to a new enquiry. Intially, the system was intended to be developed using SAVOIR. However, after consultations with the Deputy Chairman and his colleagues, the prototype system has been developed as a forward-chaining interpreter. The knowledge base is, however, separate from the inference mechanism, enabling it to be used by other companies.

3.2 System description

BID/NO BID operates with a knowledge base containing some 120"checklist" items and an interpreter which calculates the bid "scores" from the values assigned by the user to each checklist item. The checklist items are weighted according to the significance ascribed to them by IDC's "experts". The system also contains a built-in editor which can be used to delete items; add items; change the wording of items; resequence the order of presentation of the checklist, or change the weights or type of each item. Item "type" refers to the way in which the item is scored (-5 to +5; Yes or No; 0 to 100). The checklist is structured into a series of modules as follows:

- preliminary questions: this module contains factors identified by IDC as factors which, may, depending on the answers, unequivocally mean a straight-forward decision to bid or not to bid. The remaining modules, serve to clarify a situation. where the position is uncertain
- client-factors: this module contains factors which evaluate client charactersitics such as financial soundness
- project factors: this module evaluates details of the proposed project
- bid factors: this module evaluates the bidding situation in terms of factors like number of competitors involved
- resource factors: this module evaluates IDC's capacity to "cope" with the project's resource requirements.

3.3 Knowledge acquisition

The knowledge base was developed using two main techniques: interviews and documentation analysis. Initial knowledge elicitation sessions were carried out in the form of "unstructured" interviews. A subsequent session was carried out using a structured inteview approach. The data obtained from the intial interviews was analysed and classified into categories. In particular, contradictions in the data - were identified and resolved.

This "resolution of contradiction" approach proved to be a particularly fruitful means of expanding the knowledge base.

The base was subsequently expanded by incorporating a number of factors drawn from a previous project carried out by IDC for training purposes on bid strategies.

3.4 Further development

IDC are currently using the prototype system as a training aid. A procedure has been agreed whereby one of the experts involved in the elicitation sessions will monitor the use of the system and record responses to it. In this sense, the current phase of the project constitutes both verification and elecitation, since it is envisaged that additional data will be generated in the ensuing monitoring phase. Decisions on further developments will be based on the findings.

SECTION 4 EXTRACTING SIGNIFICANT INFORMATION ON KNOWLEDGE ACQUISITION

4.1 Introduction

We set out initially to investigate the area of knowledge acquisition because it was generally accepted in "expert system" circles that knowledge acquisition was difficult, badly co-ordinated, sparsely-researched- and of crucial importance to the development of careful and efficient intelligent knowledge-based systems.

Our experiences, after almost a year of that investigation, has largely confirmed this view. Indeed, the history of the investigation, and the direction in which it has been led, has been shaped to a large extent by the difficulties the project team has experienced in firstly obtaining information on knowledge acquisition, and, secondly, in imposing a coherent structure on the information obtained.

In the early stages, it was envisaged that our existing awareness of expert system projects in construction-related fields, or in applications within our sphere of contacts, would generate sufficient diversity of case material to enable us to develop typologics of knowledge acquisition and to produce definitive recommendations to support the development of a useful, practical methodology.

A number of factors made the undertakings difficult; not least the growing evidence that many expert system applications were based on knowledge acquisition processes which had proceeded ad hoc without the support of a pre-determined, systematic methodology. Other problems - notably the lack of detailed and up-to-date information on knowledge acquisition aspects of expert systems (typified by the d'Agapeyeff and OVUM reports); and the tendency for developers of expert systems to play their cards close to the chest - has forced the research team to adopt a diversified approach to the investigation of knowledge acquisition. This approach is focussed on three main themes:

- i) Practical experience in the development of working expert systems
- ii) Detailed analysis of case study material
- iii) Evaluation, under experimental conditions, of comparative knowledge acquisition methods

4.2 Development of expert systems

As noted above we are already working on CRANES and BID/NO BID. We are just starting on the development of PROJECT MANAGEMENT which will form the vehicle for the comparative study described in section 4.4 below.

4.3 Case studies

To augment our access to case study material we are conducting a survey of industrial companies. The questionnaire which forms the basis of this survey is designed to elicit data on

- past, present and future expert system applications.
- knowledge acquisition techniques employed and problems encountered.

4.4 Comparative knowledge acquisition methods

We have started to explore the following methods of knowledge acquisition and plan to apply each to one module within the general domain of PROJECT MANAGEMENT.

- Use of questionnaire survey
- Fast prototyping
- Machine induction
- Evolutionary development

Each is now amplified

Survey Questionnaires have been despatched to a structured sample of project managers and planners obtained partly by negotiation with the Association of Project Managers and partly from the Association of Consulting Engineers.

Fast prototyping This is an expression that is being used in KBS circles. It refers to the process by which a start is made with a relatively limited system which is then augumented by knowledge acquired from domain experts. The principle is that, the existence of a meaningful system prompts the experts to contribute from their experience.

Machine induction This needs little amplification. Section 5 reports on our experience to date.

Evolutionary development The evolutionary method involves developing the expert system from "original" data extracts using a number of different interview techniques. These techniques include:

"unstructured" interviews, or "brainstorming" sessions

"focussed" interviews based on pre-determined questions

structured attitude-testing inventories including multi-dimensioned scaling and repertory grids

"introspection" involving simulating problems with the expert

The research design adopted in the "slow prototyping" approach is based on the "Latin Squares" method. This involves 4 experts using each interview type consecutively (i.e. Expert 1 starts with type A; Expert 2 with type B and so on) in order to reduce the effect of "personality" and "learning curve" factors on the outcomes. During the interview sessions, responses are monitored and evaluated by the knowledge engineer on the basis of factors such as volume of data extracted; problems encountered; elapsed time and "depth" of knowledge elicited.

By modules within project management we mean the sets of goals which reflect the expertize. For example one set may represent alternative techniques, another set the choice of computer program. Several more modules would be necessary to represent the whole domain and it is perhaps worth noting that we are in liaison with the PARC community club set up by the Department of Trade and Industry.

SECTION 5 RULE INDUCTION

5.1 Background

As described in an earlier Interim Report (Interim Report 2 March 1986) our evaluation of Expert-Ease by developing a sub-section of the BREDAMP expert system raw data by machine induction has been largely negative. Our main conclusions were as follows:

Expert-Ease works best on hierachical, deterministic knowledge-trees in which outcomes are arrived at by "single" rather than multiple, paths. Expert-Ease imposes its own algorithmic logic on a rule base, which in many instances is inconsistent with the real world logic perceived by the expert.

Expert-Ease cannot adequately handle uncertainty.

The program "edits" the knowledge base input according to its own induction process, and there is very little user control available over this process.

However, despite these disappointing findings we had received good reports on Expert-Ease from an international oil company. In their case the experts themselves use the program. We therefore decided to undertake a further evaluation using the BREDAMP domain expert.

5.2 Procedure adopted

The procedure adopted was as follows:

i) the ceiling-under-floor segment of BREDAMP was selected for the evaluation.

ii) the Expert and a "knowledge Engineer" familiar with Expert-Ease worked together to build a rule base for the Ceiling-under-floor segment directly into the computer.

iii) there was no initial "paper model" constructed. The sequence of operations worked as follows:

Expert decides on the attributes to be input.

Knowledge Engineer keys in the attributes directly into Expert-Ease.

Expert identifies suitable examples of causes of Pipe Leakage in a ceiling under floor.

Knowledge Engineer inputs examples directly into Expert-Ease.

Expert-Ease induces a rule consistent with Expert-defined attributes and examples.

5.3 Characteristics of rule base developed

The attributes input by the expert showed some variation from those used in BREDAMP, although the variations were largely a matter of emphasis rather than "new" variables. As the initial evaluation of Expert-Ease demonstrated, the program needs to generate a fairly strictly defined hierarchical tree. Thus, it finds it difficult to handle situations within BREDAMP which contain mutually exclusive conditions - such as the presence of a drain v. a rising main. The expert attempted to overcome these problems by introducing sub-bases within the overall knowledge tree in Expert-Ease.

The procedure adopted produced the following set of steps:

Establish whether there is a stain
If stain present, identify if water is dripping
If yes, establish whether the floor above is wet
If wet continue
If not wet, chain to sub-tree
Establish if pipe present
If No chain to sub-tree
If yes, establish if pipe is visible
If not visible, chain to sub-tree
If visible, establish type of pipe
If drain, chain to sub-tree
If not drain, establish if pipe is wet
If sometimes wet, chain to sub-tree
If wet continuously, establish type of wetness
Then probability of pipe leak is established

The development of the knowledge base in this type of modular form for pipe leakage was aimed at eliminating the problems encountered in the initial evaluation of Expert-Ease, where the unitary model initially developed produced inconsistent results.

In this exercise the expert developed 28 examples in order to comply with the operation of Expert Ease. This is considerably more than the number developed originally by interview techniques and suggests that machine induction may have the effect of expanding the knowledge base.

However, the rule base generated using the attributes and examples identified by the expert was inconsistent with the expert's cognitive model. As in the initial evaluation using coding from BREDAMP, the rule base generated was illogical, mis-sequenced and omitted a number of critical attributes.

5.4 Observations

Employing the expert to input data directly into the program elicited a number of significant departures in the type of knowledge elicited compared with the data elicited in the original BREDAMP development using interviews with subsequent coding for SAVOIR. These are now listed.

- The expert found that the hierarchical structure of the program forced him to consider hypothetical "cases" of pipe leakage which he might not otherwise have communicated during a "conventional" knowledge elicitation process.
- These cases were derived from the expert's interpretation of possible permutations suggested by the attributes and values he had intially input into the program, and from "prompts" (i.e. nulls and clashes) displayed by Expert-Ease after rules derived from the data had been produced.
- The expert considered the program to be a useful elicitation tool as a prompt to induce knowledge not immediately contained within the expert's day-to-day "portfolio" of expertise. He also perceived it as a method of verifying existing knowledge and a means of forcing him to outline "deep knowledge" representations of cases normally expressed through "shallow" representations.
- The expert considered the rules induced by Expert-Ease to be very remote from what could be considered to be a realistic knowledge tree for the investigation of causes of damp penetration through pipe leakage. Thus, the expert considered the prescriptive element of the program (its capacity to act as an interrogative expert system) to be of little value.

5.5 Conclusions

The evaluation exercise with the expert confirmed initial impressions that Expert-Ease is of little value as a tool to develop working knowledge-based systems capable of interrogation and consultation. However, the results of the evaluation suggested that machine induction could play a positive role in "second stage" elicitation. Thus, initial domain parameters might be established through conventional means (via interviews, content analysis, observation, task analysis etc) and Expert-Ease used to fine-tune these initial parameters, to identify "gaps" in the knowledge base, to verify the existing knowledge and to generate hypothetical case material as a basis for further exploration and elicitation.

6. Future work

The foregoing sections on CRANES, BID/NO BID, and knowledge acquisition methods each include statements of our future plans. We shall continue to give low priority to rule-induction but hope that it may eventually make a contribution to our comparative study of available methods.

We have deliberately set out in this report the several initiatives we are taking. The research team is meeting at regular intervals to exchange information and to monitor progress and thus to maintain a cohesive line of thought about the project as a whole. We are giving careful consideration to the way in which our eventual findings can be encapsulated in a structured framework.

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