A METHODOLOGY TO DESIGN AN EXPERT SYSTEM FOR REMOTE SENSING TECHNOLOGY MANAGEMENT.

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Abstract:

This paper examines an alternative approach to the analysis of the complex problems associated with the management of remote sensing technology. Soft Systems Methodology is introduced as an effective and efficient way of undertaking a systems analysis of interdependent technological and human processes.

A systems model based on an Australian study is presented for remote sensing technology transfer. It is demonstrated that this model provides a practical framework upon which to develop a rules-based expert system.

The paper draws attention to a new range of problem solving skills that are appropriate to the domains of expert systems and remote sensing. An evaluation is made of the success of this methodology.

Key words: Expert System, Knowledge Base, Remote Sensing, System Design.

INTRODUCTION

This paper discusses an analysis of the complex problems associated with the management of remote sensing technology. It presents an alternative approach to knowledge elicitation in domains where there is complexity arising from human activity.

Soft Systems Methodology is introduced as an effective and efficient way of undertaking a systems analysis of interdependent technological and human processes. It is argued that the use of this methodology will help an analyst avoid the pitfalls associated with developing an expert system by the conventional method of prototyping.

BACKGROUND TO PROBLEM

An Australian study (Bureau of Industry Economics, 1990) indicates that successful commercialisation of new technologies is dependent upon the linkages that exist between the public sector research organisations and industry. Similarly, studies of the technology transfer process for remote sensing have been undertaken by Ferns and Hieronimus (1989), Forster (1990), and Specter (1989). Of particular relevance are reports by the Australian Space Office (1989, 1992) which identify weaknesses in the commercialisation of remote sensing in Australia. Common problem areas identified by these studies include:

- How can linkages be developed and maintained between industry and public sector research organisations?
- How can industry effectively identify and specify research needs?
- How can industry be involved at an early stage of research?
- Are public sector research organisations prepared to support industry in the commercialisation process?
- How to erase preconceptions that build barriers to successful technology transfer?

A study has been undertaken by Finegan and Ellis (1991, 1992) that has developed a systems model for the management of remote sensing technology transfer. It is proposed that this model is able to provide a practical framework upon which to design a rules-based expert system for remote sensing technology management.

METHODOLOGICAL CONSIDERATIONS

The traditional systems approach to problem solving is based on the technique of reductionism, which solves a problem by fragmentation, one stage at a time. This technique is appropriate in complex and highly structured situations that are able to be well defined, particularly in terms of inputs and outputs. In information systems this is formalised in the system development life cycle (SDLC) and the alternative method of prototyping.

The builders of expert systems have generally adopted prototyping as the preferred method for system development. However, there is strong evidence that prototyping is of limited success, particularly where human factors and poorly defined complexity exist. There is the danger that prototyping can be "technology-driven", which can lead to the situation described by Stowell and West (1989):

> By allowing the expert to work directly with the expert system being developed, the technology places a strict framework on the way in which the expert is allowed to think about his expertise. It is argued that such a framework may be detrimental to the elicitation of expert knowledge (p. 331).

Similarly, the pitfalls of expert system development as described by Curtis (1989: 536-537) include such human factors as "the system does not match the working practices of the final users", "there is no willing expert(s) prepared to part with the knowledge essential for the expert system", and "management commitment is lacking or unrealistic".

Studies in knowledge elicitation by Gaines and Shaw (1984, 1985), Shaw and Gaines (1986), and Shaw (1985) have focussed upon the need to use systemic and psychological foundations to develop models of human knowledge representation, acquisition and processing. It is argued that the standard formal logic of the accepted reductionist or mathematical systems theory may be inappropriate for knowledge elicitation.

A systemic approach to problem solving is provided in a methodology developed by Peter Checkland, Professor of Systems at Lancaster University. This is variously known as the Checkland Method, Lancaster Methodology, or the Soft Systems Methodology (SSM). The concepts were developed through practical application and experience in a wide variety of complex managerial systems.

The problems associated with technology management and technology transfer are complex, unstructured and poorly defined. Therefore Soft Systems Methodology has been used to provide the theoretical framework for a study of the processes of remote sensing technology transfer in Australia (Finegan and Ellis, 1991, 1992). The design of an expert system for remote sensing technology management, based on the model developed by this study, is being developed as a practical outcome.

APPLICATION OF THE METHODOLOGY TO EXPERT SYSTEMS DESIGN

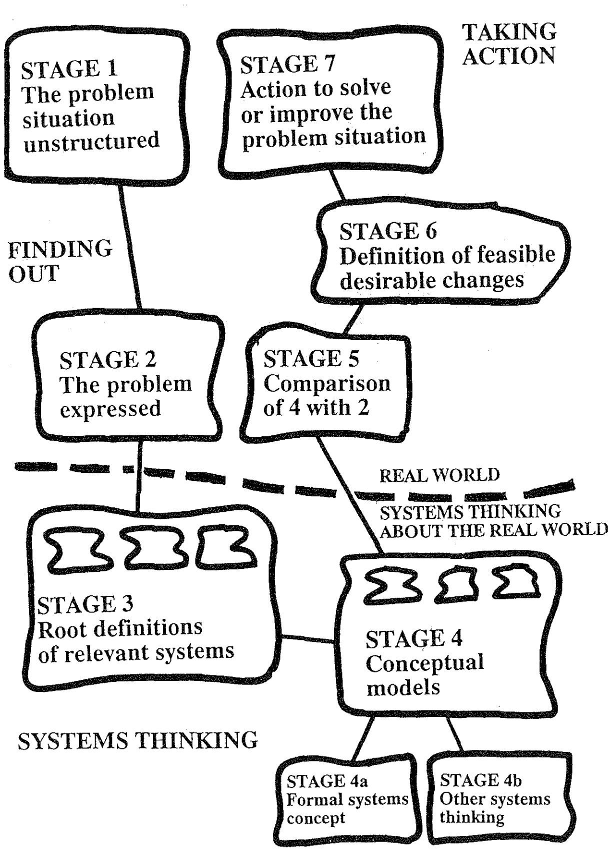

Figure 1: The Soft Systems Methodology (Checkland, 1981: p.163)

The Soft Systems Methodology is described by Wilson (1984) as "a seven stage process of analysis which uses the concept of a human activity as a means of getting from finding out about the situation to taking action to improve the situation" (p.64). These seven stages are illustrated in Figure 1. This figure represents the pattern of activities in the methodology, it does not necessarily impose a sequence in which it should be applied. As Wilson says: "The analyst may start with any activity, progress in any direction, and use significant iteration at any stage" (p.64). The dotted line between the real world and the systems thinking is significant in that it defines the boundary between the use of everyday language (real world) and the systems language.

The Rich Picture

The first two stages of Soft Systems Methodology involve the examination of the background of the problem. This is expressed the form of the "Rich Picture" (Figure 2) which aims to show the elements of slow-to-change **structure** and elements of constantly-changing **process** within the situation being investigated.

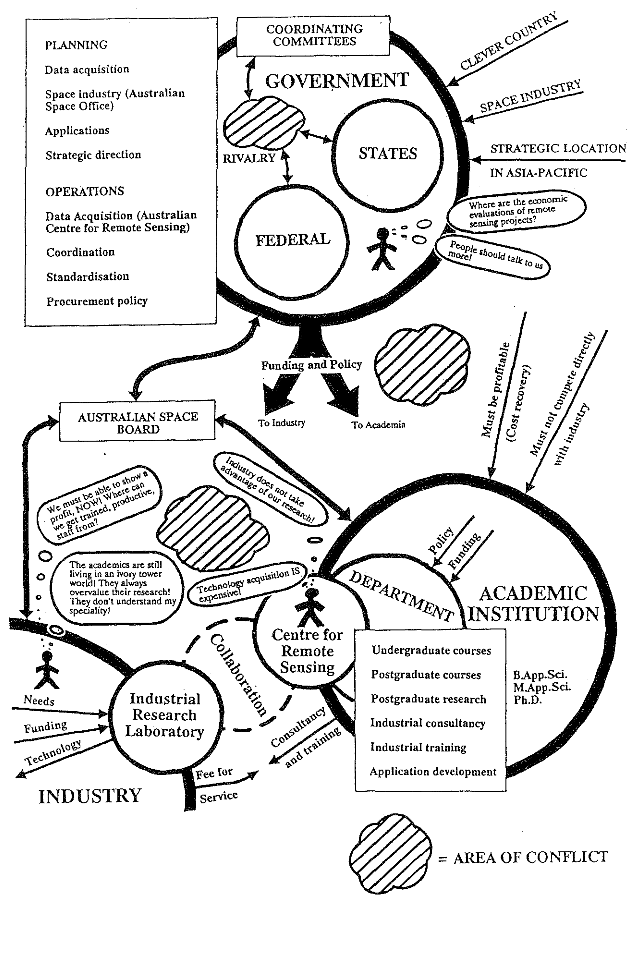

Figure 2: "Rich Picture" of the technology transfer of remote sensing in Australia.

The Rich Picture can be applied to the initial stages of the knowledge elicitation process to help develop a representation of relevant domains, and an understanding of the views of people within each domain. Stowell and West (1989, 333) suggest that the Rich Picture is very useful as a summary of the knowledge elicitated from the expert. The analyst can use it as a prompt for discussions with experts, as an aid for assimilating knowledge elicited, and as a means of identifying the areas in which knowledge is limited.

Root Definition and CATWOE

In this stage a choice is made of relevant systems that the analyst believes will produce insight into the problem situation. The chosen systems are expressed in statements as the Root Definitions, which incorporate the points of view that make the activities and performance of the systems meaningful. The initial Root Definition for this study of technology transfer has been formulated as follows:

> An industry driven system operating within research centres with the objective of transferring untransferred technology by: knowing about untransferred technology, knowing about targeted industries, selecting technology to be transferred, selecting means of transferring technology, applying those means to an industry, stimulating the ongoing transfer, and monitoring the success of such transfers; in order to benefit all involved parties, in an environment of research, industrial competitiveness, and national and international economic development.

The formulation of "good" root definitions is decisive to the creation of the conceptual model in Stage 4. Therefore, the Root Definition is tested against a group of elements known by the mnemonic CATWOE, that defines a check-list for Customer, Actors, Transformation process, Weltanschauung (worldview), Owner, and Environment. Invoking the CATWOE for this study results in:

- **C** Industry which can benefit from Technology Transfer.
- **A** Researcher who wishes to promote a technology.
- **T** Untransferred technology becomes transferred technology.
- **W** Transfer of technology is desirable.
- **O** Industry (that has the power to accept or reject a transferred technology).
- **E** Research / Industrial Competitiveness / National and International Economies.

The elements of CATWOE emphasizes the need for constructive alternativism (Shaw, 1985: 491), that it is important to examine the problem from a number of viewpoints. The root definition and CATWOE provide the analyst with a framework for ensuring that all points of view and interest are considered in the knowledge elicitation process.

Conceptual Model

This stage is where a logical expansion of the Root Definition is made into the minimum necessary set of activities to define what the system actually does at a particular resolution level. The qualitative modelling process uses pictures and diagrams to define and communicate structure, logic, ideas and relationships. The Conceptual Model should be expressed by verbs.

The logical expansion of the Root Definition for technology transfer results in a Conceptual Model of three sub-systems, "knowledge", "criteria" and "application" while the activity "monitor and control" remains at the first level of resolution (Figure 3).

This detailed model represents a human activity system that can now be used to create a well structured evaluation of the state of the real world. This is achieved by comparing the model with perceptions of "what is the present mechanism". It provides a means of enquiring into areas of expertise which seem difficult to understand or that have been poorly defined by the expert (Stowell and West, 1989).

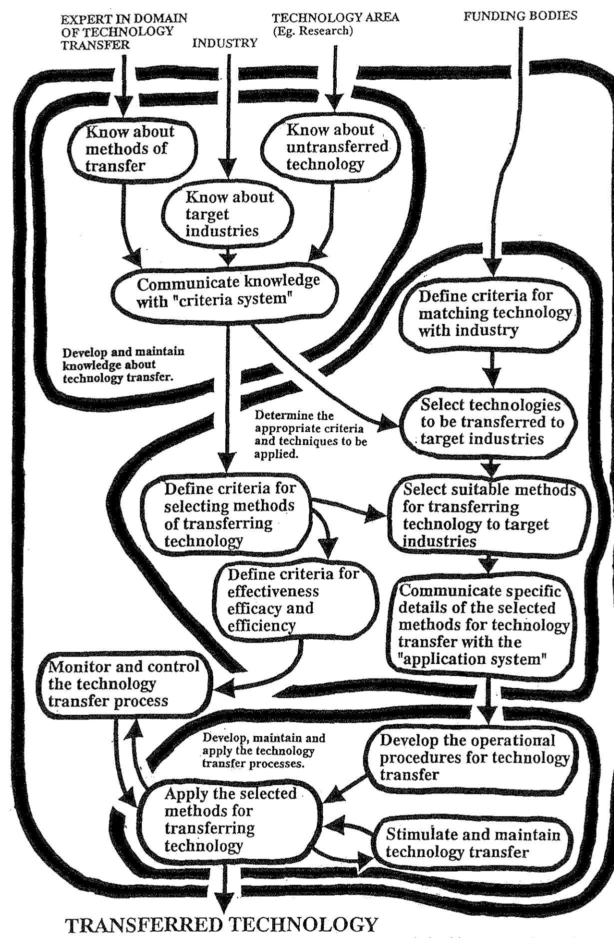

Figure 3: Conceptual Model

Stage 5 : Comparison

Comparison of the Conceptual Model with the real world is undertaken by comparing each of the second resolution activities within the model with the real world problem situation. This was achieved in this study by the rigorous interviewing of project managers in agencies and companies that use remotely sensed data. In the interview the following questions were asked for each activity:

1. Do you undertake the described activity?
2. If so, please briefly describe how this is accomplished.
3. If so, please define the measure of performance for undertaking this activity.
4. If so, please describe any improvements that could be made to the way you currently undertake this activity. If not, are you likely to undertake this activity in the future? How would you do it?
5. Do you think that this is an important activity?

The study is now at this stage of the analysis.

EVALUATION OF THE METHODOLOGY

The participative nature and strong focus upon human activity systems of this methodology has facilitated the development and testing of a systems model of a "messy", poorly defined and complex problem area.

The use of the model as a knowledge elicitation tool has been successful, both in the quality of the information gathered, and in the response of the participants interviewed. It is pertinent to note that the majority of individuals claimed that their participation in the analysis has lead to useful insights into problems they are having with remote sensing technology management. Many have volunteered to take part in further studies.

CONCLUSION

This paper has discussed some of the difficulties associated with knowledge elicitation, and introduces Soft Systems Methodology as a theoretical framework for examining complex and poorly defined problems.

The case study illustrates the application of Soft Systems Methodology to the problem of remote sensing technology management, and suggests that this approach is a suitable method for knowledge elicitation in expert system development.

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