TECHNIQUES FOR KNOWLEDGE ACQUISITION FROM TEXT

ROBERT T. PLANT
University of Miami
Coral Gables, Florida 33124

INTRODUCTION

The development of expert or knowledge-based systems can be undertaken through the adherence to one of several life-cycle models that have been reported in the literature (19, 23, 32). These models may vary in terms of the rigor imposed, the knowledge, representational forms advocated or the degree to which iteration and prototyping are proposed; however, central to all models and all knowledge-based systems is the presence of the knowledge-acquisition phase in the development life-cycle.

Knowledge acquisition has been defined as:

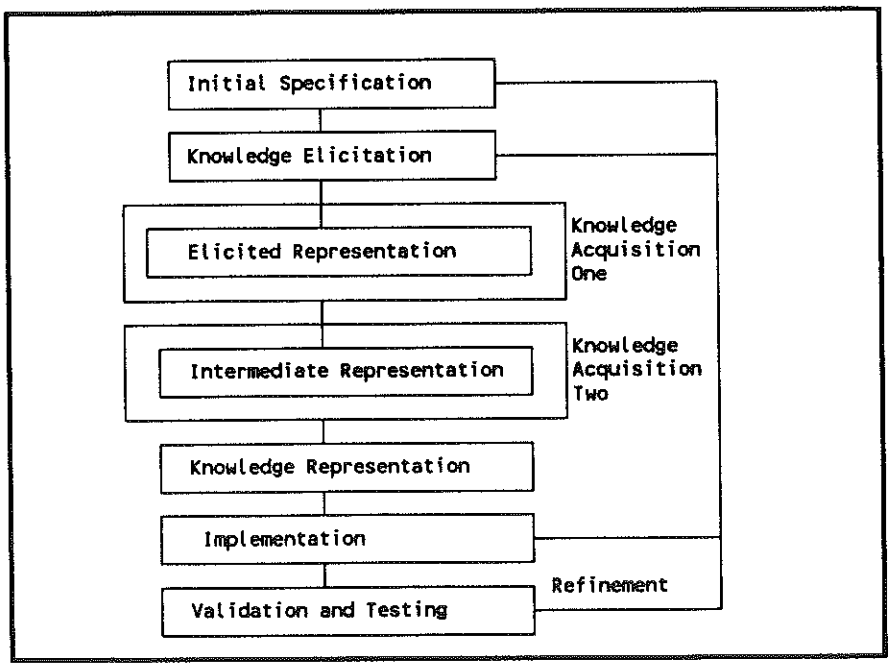
> An investigative experimental process involving interviews, protocol analysis, and reformulation of written materials in order to design computational, qualitative models of the expert system (8).

Knowledge acquisition therefore can be seen as a fundamental process in the lifecycle. We will in this paper consider the process, and the focused techniques which assist in the analysis of textual information such as conversational coherence and conceptual analysis.

AN OVERVIEW OF KNOWLEDGE ACQUISITION IN THE ESDLC

The primary phases in the expert system development life-cycle (ESDLC) can be considered as follows:

FIGURE 1
Basic ESDLC Model



The basic ESDLC model (23) commences with the initial specification and requirements phase. This allows the knowledge engineer to have a baseline document from which to create a system. This specification is used in order to formulate a knowledge elicitation strategy -- the second phase. It is in this phase that the knowledge is obtained from the expert source, and this can then be held in the elicited representation formalism. It is this formalization that is then

analyzed during the knowledge acquisition process in order to characterize the information, the relationships in that information and classify the knowledge within it. The results of this analysis may be held in some intermediate representation such as a conceptual graph or a decision table. These in turn are analyzed to provide the basis of the knowledge representation used within the implemented system (e.g., frames, rules...).

Thus it can be seen that the knowledge elicitation, acquisition and representation processes are closely associated. We will discuss these phases and their interrelationships further in the remainder of the paper.

KNOWLEDGE ELICITATION

Knowledge elicitation can be defined as: "The extraction, gathering and articulation of knowledge and information from an expert source in an area of interest" (22). This provides us with a variety of techniques from which we can draw:

TABLE 1
Knowledge Elicitation Techniques

- Critical Incident/Critical Decision Method
- Multidimensional Scaling and Network Analysis
- Psychometric Scaling Techniques
- Personal Construct Theory/Repertory Grid
- Knowledge Acquisition Grid
- Heuristic Meta Cognitive Bases
- Grounded Theory/Literature
- Baysean Elicitation Procedures
- Interview/Reporting/Teachback
- Categories/Sequencing
- Brainstorming
- Checklist/Observation
- Goal Decomposition/Distinguishing Evidence

Table 1 lists a set of elicitation techniques (7, 23, 33), each of which can produce as an output a textual representational form, either as a transcribed interview, a section of text or as an annotated diagram. These textual representations are what we have termed the *elicited representation* in Figure 1.

KNOWLEDGE ACQUISITION ON TEXTUAL ELICITED REPRESENTATIONS

In this section of our paper we are going to consider the process of knowledge acquisition upon transcribed interviews and other textual elicited representations. We will commence our examination of knowledge acquisition techniques by examining a basic but pragmatic approach to breaking down transcripts and developing a more structured *intermediate representation* from them. We will then consider ways of enhancing this information via techniques such as conceptual analysis, erotetic logic and task analysis.

PROTOCOL ANALYSIS

An elicited representation of a transcribed interview between a Knowledge Engineer and a Welfare Benefits Officer has the following form.

TABLE 2
Transcribed Interview

KE: A person calls into the office and asks if he is eligible for sick pay benefits. What questions do you automatically ask yourself to determine if the employee is eligible for SPB?

DE: First of all, you must say to them are they in receipt of a salary above a lower limit, which at the moment is 56 Pounds per week. Obviously, if anyone is far above that wage you can discount them immediately...

KE: And that is averaged out over the eight preceding weeks?

DE: Yes, you might get someone who comes along and because they are off sick and they hear about the SPB thing they go along to their doctor and get a SPB note from him as well if you employ an employee at the wage of 55 per week you don't have to go any further as there is no liability at all. I know shop keepers who deliberately keep themselves below that limit so there is no benefit to pay...

It can be seen that a transcription may be coarse in nature, lacking continuity or flow and that in its natural language form the ability to judge its contents for completeness, consistency or correctness is severely limited. This in conjunction with the potential for large amounts of text and the volume of materials involved implies that without a set of guidelines for transcription decomposition, the knowledge engineers ability to extract the pertinent information from the text will be severely limited. We therefore outline a set of guidelines to assist the knowledge engineer structure the text. These guidelines are intended to be for a primary analysis of the text to be later complimented by more exacting techniques such as conversational coherence.

Guideline 1:Partition the transcript into blocks that are logically connected.

This is achieved by reading through the transcript and noting where one theme finishes and another starts. This will then form a logically connected block.

Guideline 2: Partition the blocks into a series of knowledge engineer/domain expert question and answer interactions, each of which we will refer to as an adjacency pair.

The transcript is broken down into a series of adjacency pairs that are numbered and marked off from each other. The numbering and the dialogue can be seen as a series of points where a question and an adjoining answer combine to make a conceptual point. Having numbered the adjacency pairs, observations can be made regarding the referential flow within a domain through examining its information points. For example:

i) Points can only reference other points which temporarily precede them.

ii) Items usually refer to items at a similar or higher

level before referencing a lower level item. For example, someone might say:

DE1: "...This method needs an arbitration procedure.

DE1: "...as in conflict resolution:

DE2: "... yes"

Here the knowledge engineer tries to clarify a point made by the domain expert in DE1 by asking if the point is similar to the concept of conflict resolution (which we will assume was discussed as an earlier concept) to which the domain expert gives an affirmative response DE2. The knowledge engineer is more inclined to do this than to ask about an individual conflict resolution strategy which is at a lower level of granularity.

Guideline 3: Create an information flow diagram of the elicited text.

The natural language used in the elicited representation does not, as we have stated, assist in the identification of completeness, consistency or correctness of the domain knowledge. A powerful vehicle for achieving this is to use a diagrammatic form. This can be at many levels: High level in the form of a flow chart, or at a lower level in the form of a conceptual graph. We will commence our discussion of these visual forms through consideration of a series of guidelines for the creation of flow diagrams from text.

Transformation Technique One

Elicited Representation Sources: i) Concurrent Vocalization Transcript, ii) Text from literary source

Intermediate Representation: Flow Diagram

1. Decide upon the criteria that may be needed for the removal of noise
2. Remove the noise.
3. Take a small segment of text whose pairs are logically connected.
4. Break the segment down into the data types of the flow chart:

   -Decisions, Conditions, Actions, Rules, Procedures, Functions
5. Construct separate flow diagrams for each set of logically connected points.
6. Unify the separate flow diagrams into one large diagram
7. Examine the structures for repetitions and redundancies.
8. Examine the structure for deficiencies, i.e., undefined paths, incomplete actions.
9. Refine the flow diagram

Transformation Technique Two:

Elicited Representation sources i) Concurrent Vocalization Transcript, ii) Text from Literary Source

Intermediate Representation: Decision Table

1. Decide upon the criteria that may be needed for the removal of noise.
2. Remove the noise.
3. Take the text and define its constituent parts and assign the types.
4. Take the conditions and associated actions and place them into a decision table structure.
5. Rationalize structure. This can be done through utilization of "don't care" condition, "don't perform" actions and the "else" structures where appropriate.
6. Consider the use of an extended entry format for the conditions and actions. This involves using an abridged natural language for the entries and has the benefit of heightening readability.

These basic guidelines for the creation of two commonly utilized intermediate representations are only intended to act as a basis for a coarse transformation and need to be tailored to a given problem. However, these intermediate forms are extremely valuable to the knowledge engineer, as they provide a much stronger basis for examination of the structure of the information elicited. The use of a decision table for example will easily reveal any lack of completeness of the knowledge as well as the consistency and correctness of that information, to an extent not allowed through textual sources.

Having outlined these basic analytical techniques of transcript analysis, we will now consider more sophisticated analytical techniques by which we can identify more subtle aspects of the elicited text with added sensitivity.

CONVERSATIONAL COHERENCE

In order to obtain a clearer insight into the dialogue between the knowledge engineer and the domain expert it is necessary to draw from both *ethnomethodology* and from *grounded theory*.

Ethnomethodology is an area of linguistics where communication theorists use transcripts to examine the conversational microdetails, whilst grounded theory recommends procedures through which categories emerge from the text during the process of descriptive analysis. The origin of both these research areas is that of conversational coherence. Conversational coherence has been defined by Craig and Tracy in the following way:

> Coherence refers to the fact that utterances produced by competent speakers in conversation are usually seen to be connected to each other in orderly and meaningful ways (4).

Thus, research in conversational coherence seeks to discover ways of describing the level of coherence a conversation has, one way in which this is attempted is through consideration of the alignment of the conversational dialogue.

Alignment in Conversational Coherence

In order to formulate a theory of conversational coherence we are forced, due to the domain complexity, to make some assumptions. Ragan as defined one of these.

> Conversational coherence makes the pre-supposition that the participants in a conversation talk in orderly, patterned, non-random ways enabling them to define and make sense of their conversational situation (26).

Researchers in communication theory have found that one of the most important factors for the participants in being able to make sense of their situation is the perception of their social identities within that conversation (15). For example, in a conversation where only one party, the knowledge engineer say, asks questions to which the other party, the domain expert, responds it is possible to assume that the relationship between the knowledge engineer and the domain expert is an asymmetrical one (i.e., one of the communicators is in a more dominant position than the other). The knowledge engineer

asks and the domain expert answers, and the domain expert responds to queries directly and concisely as a matter of course, as if this were the prescribed behavior in this situation. The knowledge engineer and the domain expert are conforming to conventional role behavior.

A technique developed for examination of conversational coherence by the symbolic interactionists Stokes and Hewett is that of *"alignment"* (30), which refers to the alignment actions as verbal strategies that communicators can use to align the context of their interaction with that of the person to whom they are conversing. In this way the communicators can repair the misunderstandings or descriptions in conversation. For example, when a knowledge engineer says, "What do you mean by that?", this can be thought of as aligning talk.

In analyzing transcripts, it is therefore useful to consider the role that alignment plays between the two participants.

Seven strategies that may occur in alignment have been identified in the literature. These strategies are very useful for categorizing knowledge engineer/domain expert interactions. We will now outline these.

1. Accounts (29)
   Accounts are statements offered to explain unanticipated or questionable behavior. All account consists of a justification or an explanation for conduct deemed untoward within or outside the context of an interview (26).
2. Formulations (12)
   Formulations are coded utterances that summarize previous utterances or offer interpretations-gists-of a conversation in progress (26).
3. Metatalk

This consists of items or utterances referring explicitly to the verbal properties of another message. Metatalk can focus on the speakers talk (e.g., "like I say") on the receivers talk (e.g., "you mean") or on the interview process itself (e.g., "could I ask you a few questions?") (26).

Metatalk is one of the most frequently occurring alignments actions and as such further refinements of this strategy have been made. Ragan has identified six categories of Metatalk.

(3.1) Clarifying
These are attempts to refine the meaning of a previously expressed message or to express the need for making the meaning clearer; rephrasing for the sake of clarify. For example, "I mean," "I assume you're talking about," "Your talking about" (26).

(3.2) Remediating
Attempts to express misunderstandings or mishearing provide apology, correction, or disclaimer for behavior that might otherwise be seen as untoward. For example: "I misunderstood you on that," It's going to sound funny," "Excuse me" (26).

(3.3) Directing.
Messages that masquerade as asking permission to perform certain speech behaviors while functioning in fact to perform these behaviors. For example, "Can I ask a question?," "Well, allow me to make a point if I can," "Let me interrupt you for a moment" (26).

(3.4) Requesting
Messages that make actual requests of the receiver or of his or her talk. For example: "What else can I respond to?," "Maybe you can describe that for me" (26).

(3.5) Agendizing
Messages that may also function as requests but requests that specifically announce an agenda for the interview stage or process. For example: "If you have anything that you would like to ask me or wrap up with" (26).

(3.6) Side Particles
Messages referring to or qualified prior to subsequent messages -- often an idiosyncratic speech habit. For example: "I said," "you mentioned," "you know" (26).

4. Side Sequences (16)
   These are conversational sequences that constitute a meta communicative break in the conversation, after which the ongoing conversation resumed. The sequences are used to ensure consensus on a point. For example, Q: "Do you follow that?," R: "Yes," Q: "Quite sure?," R: "Yes, that's fine" (26).
5. Metacommunicative digressions
   These are conversational sequences similar to side sequences in that they are metacommunicative breaks in the conversation but they are more elaborate and less ritualized than side sequences. Generally metacommunicative digressions consist of extended sequences of metatalk where conversation turns to peripheral information (26).
6. Digressions
   These are conversational sequences where the conversation totally digresses from the topic under discussion.
7. Qualifiers
   Qualifiers are coded words and phrases that indicate tentativeness, uncertainty and nonassertiveness such that the issue is evaded or the opinion expressed is diluted. For example, words of the form: "Kind of," "Somewhat," "Sort of."

Thus, when considering the elicited representation (e.g., a transcript), the descriptions given above of the argument strategies and meta talk will benefit the knowledge engineer's understanding of the text and help in its breakdown.

Conceptual Analysis

The aim of conceptual analysis is to understand the position of a statement or object of language within the context of the domain the expert system is referring to. Through this, the knowledge engineer attempts to avoid variance in the analysis of elicited information, allowing for assumptions relating to the domain and analysis of the domain in light of the boundaries that exist upon it. Through the analysis of the relations between concepts and through classifying them, the distortion incurred through some other analysis techniques can be avoided.

The field of linguistics has produced a large literature of techniques to assist in the conceptual analysis process, e.g., erotetic logic, Question Answer Theory (21, 27, 28). The role of each being similar, to assist, through a structured framework, the development of a clear unambiguous understanding of the domain under analysis. We will now briefly consider two of these techniques.

Erotetic Logic

The logic of questions, erotetic logic, arose from the early work of Whately (34) who investigated the elements of logic and rhetoric. Whately defined the basis of an interrogative logic based upon the definition of a proposition:

> A proposition is defined logically 'a Sentence indicative' (or 'asserting') i.e. which 'affirms or denies.' It is this that distinguishes a Proposition from a Question, a command, etc. (34).

He then considered the subdivisions of propositions (sentences) as well as questions and commands. The formalization of which led to the development of the erotetic logic system (25).

The workers in linguistics, discourse and logic have provided an extensive literature upon text analysis and provided logics and structures that are of significant value to those investigating epistemology through text. In investigating the domains of knowledge engineering systems, through the medium of interviewing and transcript analysis, we can draw heavily from the workers mentioned above. The area can be considered from two perspectives:

i) The analysis of questions,
ii) The analysis of answers.

It is often assumed that a free dialogue, even in a structured interview situation, is the most expedite mode of knowledge elicitation. Research in discourse analysis however suggests that knowledge engineers may wish to take a more formalized approach to their questioning in order to obtain the quality of information they require from the domain expert. Lewis (18) has proposed an *imperative-assertoric* mode of question analysis that utilizes Belnap's assertoric operator *"you tell me truly that..."* (3), as he argues that questions involve linguistic requests (imperatives) rather than epistemic ones. Following this view, Åqvist defines a three-place relation of presentation that allows us to consider the composite aspects of communication that:

> Goes from one interlocur X (a "sender")
> Via a sentence S (a "message")
> to a second interlocur (a "receiver/addressee")

Further to this he argues

> that no adequate theory of pragmatics can dispense with such a basic relation of presentation and that efforts should be made to characterize it axiomatically with such a theory (2).

Thus, we can analyze conversational discourse to distill the informational content to the formality of erotetic logic, e.g.,

> X tells Y truly that P
> if there is a sentence S
> such that (i) X presents S to Y
> (ii) S asserts that P, &
> (iii) S is true

Following M. and A. Prior's paper on erotetic logic (25), the research in logic-linguistics has expanded vastly. However, in addition to the formal methods associated with the study of language, many phenomena are still difficult to address in pure mathematical forms. Some of which have been suggested by Hoepelman:

(i) Questions and argumentation
(ii) The role of negative questions
(iii) The function of the particles "yes" and "no" and their counterparts in other languages
(iv) The scope of questions
(v) The relation between interrogative pronouns and relative pronouns
(vi) The problem of asking equivalent questions
(vii) Questions, tautologies and contradictions (14).

We will briefly consider these points in relation to the knowledge engineering task.

The first of Hoepelman's assertions: *Questions & argumentation,* is central to the knowledge elicitation and knowledge acquisition processes. For without asking the right questions, we cannot elicit the information required. Hoepelman follows Åqvist who states that:

> Some questions seem to be logical consequences of others, two questions may be logically equivalent, a set of questions may be consistent, or inconsistent, and so on (1).

Thus, the knowledge engineer has to have an understanding of the nature and form of questions, firstly in order to elicit the desired information, and then secondly, in order to decipher and analyze the information contained within the transcribed interview texts. There are many types and components within questioning, e.g., assertive, consequence, incompatible-parts, each of which can be employed to elicit an appropriate or desired response.

Hoepelman's second assertion is based upon the role of *negative questions*. He states that we can give the same answers to negative and positive question, which although structurally correct could lead to problems in terms of the knowledge elicitation and acquisition process. The knowledge engineer may however wish to utilize this negative assertion approach to qualify questions or perform a consistency cross check.

The third assertion, the use of *yes* and *no* as abbreviations for the assertion or negation of the questioned sentence, leads the knowledge engineer to consider shades of affirmation or negation. Is the answer in response to a general property of the question or the specific question asked. The knowledge engineer thus must be clear in his questions for which a *yes* or *no* response is elicited. The knowledge engineer should consider whether or not a two valued logic is sufficient to devote an answer to *sensitive* questions.

The area of question inclination and stress is an important factor in the interview process, as through the use of vocal stress, one can indicate which element of the sentence it is that is actually being questioned. However, the problem remains as to how we know that the stress placed by the questioner in the statement is the one understood, and therefore answered by the recipient of the question. This problem is amplified when the language of communication is not the questioner or answer's native language, or when the dialogue is technical, or the text is diagrammatical/visually focused. The transcription process can in this circumstance benefit from the use of an increased grammatical syntax that shows the inflection in the spoken words being transcribed.

The focus of Hoepelman's sixth assertion is that of *equivalent* questions. For example, the questions:

(i) Does two plus two equal four?
(ii) Does three plus one equal four?

are logically equivalent sentences but not equivalent questions. This aspect of questioning needs to be carefully considered during the elicitation and acquisition phases of development, and the knowledge engineer must clarify answers through alternative questioning strategies. Similarly, Hoepelman

points out that it makes little sense to ask a contradiction or a tautology. Therefore, when analyzing text, these questions can be disregarded, and in performing elicitation the knowledge engineer should avoid asking questions of this type.

On Questions and Answers

The erotetic logic can, we feel, act as a base for the development of a formal language with which to conduct and then later analyze elicitation. However, prior to this the knowledge engineer may wish to utilize a pragmatic yet theoretic approach to elicitation and acquisition. This pragmatic approach is in itself based upon the principals laid down in the formal notations of linguistics and communication. Workers such as Walton have proposed semantic and pragmatic definitions for *Question-Reply* argumentation that considers the domain of assumptions, goals and inquiry (31). Walton and others have proposed several approaches that can be utilized by the knowledge engineering community:

i) The Categorical Approach
This approach supposes that questions are to be considered as functions from categorical answers to propositions (14).

ii) The Propositional Approach
In this approach questions are identified as a list of sentences, with possible answers. Questions are denoted through answers that belong to a proposition set greater than two, while statement sets are singular (10).

iii) The Epistemic-Imperative Approach
Proposed by Åqvist and Hintikka (1, 13), the approach advocates the use of a transformation to propose questions in a form that asserts the response to provide only a true or false answer.

Fundamental to all of these approaches is the following request, formulated by Walton:

> Give me a set of propositions that I (the questioner) accept that imply the proposition queried in my question (31).

In order to satisfy this request different categories of question types have been suggested, including:

i) wh-questions (who-questions)
ii) yes-no questions
iii) alternative questions

Harrah goes further and proposes the following question types:

- whether,
- yes-no
- which
- what
- why
- deliberate
- disjunctive
- hypothetical
- conditional
- given-that (11).

Each of which can be employed advantageously by the knowledge engineer in a question-answer dialogue within the knowledge elicitation task to extract and elicit the type of information required.

Task Analysis

The third analytical category that we can utilize when performing knowledge acquisition from text is that of task analysis (5, 6). The major component of which is the analysis of a domain task from as many differing viewpoints as possible in order to obtain an overall perspective of that task. The task under consideration can therefore be considered from several perspectives, each of which can be broken down into sub-tasks and again considered from differing viewpoints. The relationships between the elements and objects of the tasks and sub-tasks can be examined in an attempt to establish a conceptual framework for the domain under consideration.

SUMMARY

In this paper we have considered the role of discourse analysis and computational linguistics in the knowledge engineering and acquisition process. We have noted that techniques such as protocol analysis, conversational coherence and erotetic logic are central to both of these tasks. To understand knowledge acquisition through text is to understand better how the techniques themselves can be used during the course of elicitation. We conclude therefore that increased utilization of these linguistic techniques will significantly improve the knowledge acquisition process in the future. Further, we deduce that the increased awareness of the processes underlying discourse analysis such as those discussed would be of significant benefit to the knowledge elicitation process -- providing the basis of powerful elicitation procedures that would then be amplified through a complimentary acquisition phase. The whole development being underlined by formality and rigor, thus increasing system quality.

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FAX (405)744-5180

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Robert T. Plant, Ph.D.
Department of Computer Information Systems
University of Miami
P.O. Box 248818
421 Jenkins Building
Coral Gables, Florida 33124-6540

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Dear Dr. Plant:

We are pleased to accept your article for publication. It is scheduled for publication in the Winter 1994-95 issue.

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