TRACKER: A FRAMEWORK TO SUPPORT REDUCING REWORK THROUGH DECISION MANAGEMENT

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Abstract: The Tracker project is studying rework in systems engineering projects. Our hypothesis is that providing decision makers with information about previous relevant decisions will assist in reducing the amount of rework in a project. We propose an architecture for the flexible integration of the tools implementing the variety of theories and models used in the project. The techniques include ethnographic analysis, natural language processing, activity theory, norm analysis, and speech and handwriting recognition. In this paper, we focus on the natural language processing components, and describe experiments which demonstrate the feasibility of our text mining approach.

Keywords: Decision management, rework, natural language processing, text mining

1 INTRODUCTION

In the Tracker project, the fundamental industrial problem that we are tackling is the need to reduce rework in systems engineering projects. Rework through changing requirements is inevitable in large projects but we believe that a significant amount of rework arises as a result of communication failures between decision makers and, hence, inappropriate or incorrect decisions. By reducing rework, we reduce the risk of cost and schedule overruns and allow better use to be made of skilled and experienced staff. The general problem of rework has been addressed through technical approaches, tools and techniques such as specification languages and requirements management tools. These have mostly addressed the problem of rework through changing requirements. These tools support the process of carrying out rework but do not help to *avoid* rework through inappropriate decision making.

Our research hypothesis is that the amount of rework in a systems engineering project can be reduced by providing managers with information about their own decisions and decisions made by other project managers. This information will make decisions visible and will simplify decision impact and risk assessment. By helping managers understand the wider implications of their decisions and by avoiding premature or delayed decisions we will reduce the number of decisions that necessitate subsequent rework.

The capture of design rationale is a critical element in the development of a design rationale system. Capturing rationale represents an early investment of resources which needs to be traded off against potential later benefits. Design Rationale capture uses Computer Supported Co-operative Work (CSCW) tools or meeting technologies. They include, for example, telephone, tape recorders, video cameras, shared applications or e-mails to capture both oral discussions as well as writings and drawings exchanged by designers. CSCW capture techniques can be classified into two categories: user-intervention oriented and user-interventionless (automatic) oriented. The distinction lies in whether rationale is recorded manually by a designer or automatically by the design rationale system. Automatic capture uses unstructured representation while non-automatic capture uses semi-structured or structured representation (Regli et al 2000, Shipman and McCall 1997, Fischer et al 1995).

In automatic capture, everything is recorded. Raw design rationale capture is free form, full of digressions and disorder – designers digress and discuss diverse (sometimes irrelevant) topics such as social life, weather, politics etc which has no contribution to the design task (Shipman and McCall, 1997). For a large project, design rationale quickly grows into large and unmanageable size. Audio and video records may run into thousands of hours. By using this approach, structuring is delayed to a later date.

In negotiation by e-mail, issues are raised and members respond to them. For each issue, members respond generating as many responses (e-mails). Though modelled around collaborative discourse, negotiation by e-mail is remarkably different in practise. In meetings, there is proper coordination of discourse (interjections occur, but order is quickly restored and debate continued); only one designer contributes at a time, others listen. If the rest of designers agree with the argument, they conclude the issue and move on to the next one. This way, issues are quickly resolved. In contrast, designers using e-mails can respond all at the same time and with similar arguments. As more issues are deliberated, the rationale snowballs into unmanageable size. Documentation quickly becomes unwieldy, full of redundant and irrelevant information.

By postponing structuring, it becomes increasingly difficult to determine decisions. This is due to two main reasons: decisions become deeply buried in raw information and secondly, information leaks as staff leave. Even with a verbatim record, it is possible that some information will be ambiguous and clarification sought during the reconstruction of design rationale. Replacing the designer does not necessarily recover the lost rationale. These issues can frustrate the designers' effort and lead to abandonment of structuring process altogether, preferring to use raw information. As a result, automatic capture may fail the test for supporting design rationale.

A user-intervention oriented capture reduces (or eliminates) noise like that identified in automatic capture. A scribe discriminately records important points of debate by using semi-structured or structured representation. Semi-structured or structured techniques represent decisions in an orderly manner even when the deliberations themselves were not. Minutes can be turned into a semi-structured design rationale by incrementally structuring into Issue-Based Information System (IBIS) (Kunz and Rittel, 1970) or Question Option Criteria (QOC) (MacLean et al, 1991) representation. By using a structured or semi-structured approach, we insure against decision 'burial' and 'leak'. The quality of decisions also improves because rhetoric is explicitly represented. While difficult to extract meaning from, the capture of raw CSCW sessions and project meetings is the most convenient approach for the raw archiving of design rationale.

Our previous experience with a decision support system developed in conjunction with Matra Marconi Espace (Monk et al., 1995) showed that decision makers often do not have time to enter information into these systems after the decisions have been made. We therefore believe that real-time decision capture (i.e. where decision information is captured when the decisions are made) will extend the overall usefulness of the system. We are investigating how to capture decisions from handwritten notes taken during meetings and how to make these decisions available, without delay, in the decision management system. We believe that this is now technically feasible and that its successful implementation will dramatically improve the usability and general applicability of a decision management system.

We will employ two approaches to capture rationale: (i) implicit capture and rationale reconstruction and (ii) structured capture. In the first approach, we will use direct handwriting capture for raw information and natural language analysis to reconstruct design rationale. In the second approach, we will develop and use a design rationale language using XML schemas for decision capture during meetings. Our goal is to provide decision makers with electronic tablets so that decisions can be captured in real-time and made available immediately. We will also link decisions with information captured from electronic whiteboards.

A set of natural language processing tools will be used in this project to investigate the syntactic and semantic patterns associated with the decision making process and discover any hidden semantic associations that could help support the problem of rework. These have a high success rate especially when applied to technical documents and we are convinced that they can be used in this context to capture decision information. We will use an off-the-shelf handwriting recognition system in the decision capture tool. Handwriting recognition systems are mature and have an acceptably low error rate for most writers with only minimal training.

2 RELATED WORK

As far as we are aware, this project is taking a new approach to the problem of rework and there is virtually no other research that has been concerned with decision management. Related areas include decision theory and models, decision support and requirements management.

Decision theory is not a single theory but is defined (Heylingen, 2002) as

> *Decision theory is a body of knowledge and related analytical techniques of different degrees of formality designed to help a decision maker choose among a set of alternatives in light of their possible consequences.*

It is therefore an integration of work on the nature of decisions, decision trees (Pidd, 1996) and quantitative and qualitative decision support. Most work on decision theory has focused on supporting individual decision making and on quantitative methods for multi-criteria decision making. A notable exception to this is work by Rosenhead (1989) who has looked at the relationships between decisions and this is of particular relevance to the work here. He proposes the concept of decision robustness that is a measure of the 'flexibility' of a decision i.e. to what extent is the decision immune to changes in later decisions.

There are two complementary models of decision making namely the analytic model and the naturalistic model. The analytic model, exemplified by Bayesian techniques, proposes that decisions are made by explicitly identifying options and desirable criteria, explicitly comparing the options against the criteria then choosing the option that best satisfies most criteria (French, 1988). By contrast, the naturalistic approach (Beach, 1996, Zsambok et al, 1997) proposes that decisions are experience-based and that analytic comparisons of decisions are secondary to experience-based judgements. In systems engineering, we believe that a mixture of both these approaches is used for decisions. In our system, we intend to represent experience as decision patterns analogous to design patterns (Alexander et al., 1977, Gamma et al., 1995).

Analytic systems for decision support are either quantitative, where users associate some value with a range of alternatives, or qualitative, based on theories of argument. Quantitative approaches (Belton, 1990) require the decision makers to agree on a set of criteria that will be used and a set of weights that will be applied to reflect the relative importance of the different criteria. Then each alternative is rated against each criterion. The overall score of an option is the weighted sum of its ratings against each criterion. Examples of methods that have been developed to support this approach include SMART (Edwards, 1997), Problem Analysis, suggested by Kepner and Tregoe (1968) and the Analytical Hierarchy Process (AHP), developed by Saaty (1996) and later refined into the Analytical Network Process.

Qualitative approaches are generally known as systems for managing design rationale and they have their roots in a fundamental theory of argumentation (Toulmin, 1958) that established a formal structure to represent arguments as a linked network of claims derived from observations, warrants and associated supporting evidence and rebuttals. The IBIS system extended Toulmin's work to cover multiple issues (Conklin, 1988) and was the basis for a commercial product for group decision support (QuestMap[1]). Other approaches to design rationale include the 'Decision Rationale Language' (Lee et al., 1991) and its supporting tool called SIBYL (Lee, 1990) and the Questions-Options-Criteria (QOC) model developed in an ESPRIT project called Amodeus (MacLean et al, 1991, Shum, 1991).

Design rationale systems are the basis for a number of experiments concerned with decision rationale. Potts and Bruns (1988) discuss the importance of recording design decisions and Cimitile et al. (1992) discuss the use of decision rationale for maintenance. Wild et al. (1991) also address this issue. In the EC-sponsored Proteus project, our own work was concerned with the direct linking of design information with associated decision rationale (Hadley et al 1990, Twidale 1993). We applied this approach with Matra Marconi Espace to support evolution decisions for embedded spacecraft systems (Monk et al., 1995).

3 TRACKER FRAMEWORK

The Tracker team has developed the T-model architecture which allows any of the tools for input analysis and feedback to be integrated flexibly. The architecture is asynchronous, distributed and has a central database service to store documents for analysis, see figure 1. Analysis programs are satellite services. The decision capture module is intended to capture audio and video streams, data from Mimio[2] and participants notes, and allow submission of related documentation e.g. agendas, minutes, and presentation slides. The streams will pass through character and speech recognition

[1] see www.gdss.com/omq/

[2] Mimio is a whiteboard clip-on device for electronic capture of handwritten notes and drawings, see www.mimio.com

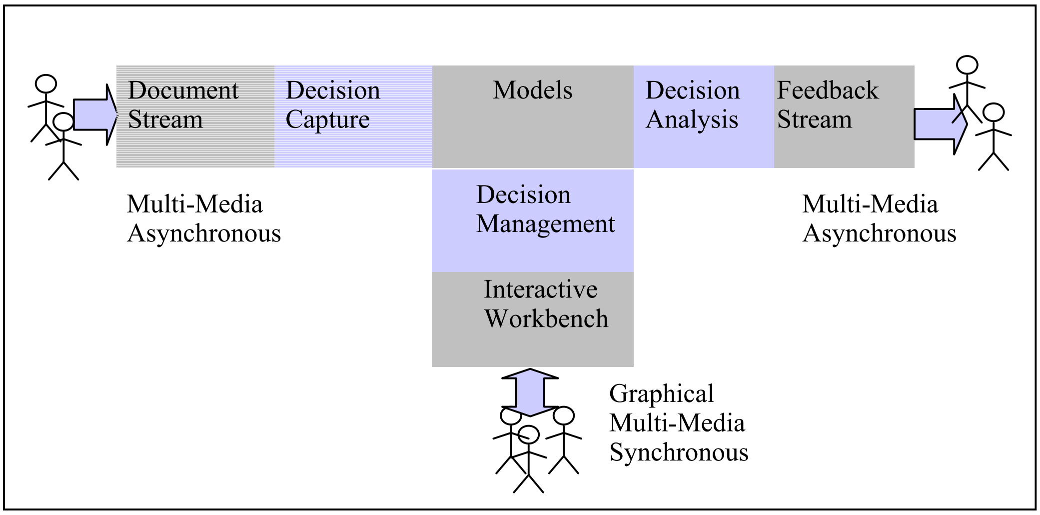

Figure 1 The T-model

systems. We will make use of natural language processing and information extraction technologies to populate the Tracker database. The database instantiates four key models:

1) *decision model*: models decisions and their inter-relationships,
2) *project model*: models the project that is designing and constructing the end system and meetings within the project,
3) *system model*: models the end system and includes requirements and implementation as sub models,
4) *document model*: models the various documents that have been submitted and the subsequent language analysis applied to them.

The T-model is agnostic in relation to the range of theories and methods that can be included as models and which can inform decision capture, analysis, and management. Members of the Tracker team are applying ethnographic techniques to study decision making in large organisations, activity theory to derive the requirements for future decision support systems, and norm analysis to develop methods for documenting actions as a result of decision-making processes.

The remainder of this paper will focus solely on the work undertaken regarding the document model.

4 NATURAL LANGUAGE PROCESSING

There are two principle natural language approaches being employed to analyse the documents being studies in the Tracker project. The first is systemic functional linguistics- a socio-semantic functional theory of language (Halliday 1985, Martin 1992). It is being currently applied to decision-making processes (Clarke 1991, Fulop et al 1999) as they are realised in meeting transcripts. It is also being applied to refining the categories of decisions, actions, and issues, which underpin Tracker's decision model.

Our second natural language approach is to use text mining and corpus annotation techniques (Garside et al, 1997) to the transcribed texts, meeting minutes and other documents, to discover the semantic associations between decisions, actions and issues. Our starting point is that as listener/reader goes along s/he parses the text into sentences and each sentence into its conceptual constituents (CC)[3] and for each conceptual constituent s/he builds up the appropriate propositions. The documents are subjected to the following text mining tasks:

1. grammatical and semantic classification of individual words and conceptual constituents,

[3] Each conceptual constituent is a group of words.

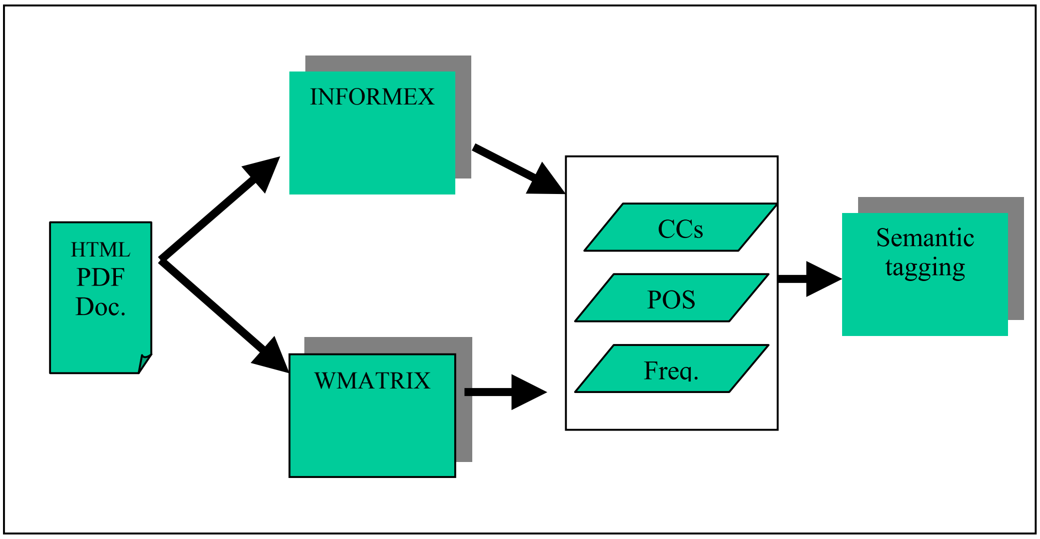

Figure 2 The Natural Language Processing architecture

2. identification of the conceptual constituents associated with the decision making process, rework and systems engineering,
3. investigation of their co-occurrences,
4. identification of their patterns of usage and patterns in the annotation, and
5. discovery of the semantic relationships between these conceptual constituents.

By grammatically and semantically annotating the documents we aim to discover patterns of language to enable robust extraction of decisions and actions. By discovering the semantic relationships between the conceptual constituents we hope to find useful clues and decision patterns and thus understand the linkages between real time decision making, risk assessment and rework. Our approach proposes to combine natural language techniques with text mining techniques. This approach of using texts to form hypotheses about a given topic has been applied very successfully in the area of biomedical literature (Hearst, 1990, Swanson, 1987, Swanson et al., 1997, Ramadan et al., 1989). The linguistic annotation of text using robust statistical techniques has been applied successfully in the area of requirements engineering (Sawyer et al, 2002).

Our approach takes advantage of two existing systems, INFORMEX (Sharp, 1990) and WMATRIX (Rayson et al, 2000), the former extracts the conceptual constituents in the document for information extraction purposes whereas the latter provides annotation by part-of-speech tagger, semantic-field-tagger and a lemmatiser (Figure 2). Early experiments, carried out to test the feasibility of this approach on a document in the area of decision making and rework, revealed positive results. The document was fed into the conceptual parsing component of INFORMEX which extracted its conceptual constituents. An example of the output is given below revealing the co-occurring terms found in the document.

theme	conceptual constituents
decision	decision theory, decision architecture, decision making, decision robustness, decision rationale, decision management, key decisions, delayed decisions, decision implications, …
project	earlier project, project management, high value project, project activities, project resources, project costs, systems engineering project, …
system	system integration, system requirements, large systems engineering applications, computer based support systems, critical systems engineering, …

Table 1. A list conceptual constituents (type: noun compounds)

Each conceptual constituent was analysed and classified into one of the fourteen semantic categories namely agent, activity, location, process, product, time, instrument, purpose, cause, measurement, theme, property, situation, goal.

This experiment is particularly useful in discovering local phenomena, that is certain conceptual constituents of type noun compounds occur close to each other in the document, namely decision management systems and information, decision making and requirements. The relationships between the conceptual constituents and between their corresponding semantic tags must still be determined.

We define a decision in this context as the intent to consume a resource in order to realise a goal. An action is a strategy adopted for the realisation of the goal. Actions come as a result of a substantive decision taken previously.

For example, if one goal in system development is to develop a scalable system, then a decision to build an n-tier system, separating different concerns such as application logic, database or presentation may be used.

An example of the output from WMATRIX, in XML form is as follows[4]:


```
- <action identity="2" document_identity="2765">
- <paragraph>
- <s>
  <w id="48.1" pos="-" sem="PUNC">-</w>
  <w id="48.2" pos="NP1" sem="Z1mf">Paul</w>
  <w id="48.3" pos="TO" sem="Z5">to</w>
  <w id="48.4" pos="VVI" sem="Q1.2">write</w>
  <w id="48.5" pos="TO" sem="Z5">to</w>
  <w id="48.6" pos="NP1" sem="Z99">BLT</w>
  <w id="48.7" pos="NN2"
      sem="S5+/S2mf">members</w>
  <w id="48.8" pos="CC" sem="Z5">and</w>
  <w id="48.9" pos="VVI"
      sem="Q2.1">inform</w>
  <w id="48.10" pos="PPHO2"
      sem="Z8mfn">them</w>
  <w id="48.11" pos="IO" sem="Z5">of</w>
  <w id="48.12" pos="AT" sem="Z5">the</w>
  <w id="48.13" pos="NN1"
      sem="T1.1">appointment</w>
  <w id="48.14" pos="IO" sem="Z5">of</w>
  <w id="48.15" pos="AT" sem="Z5">the</w>
  <w id="48.16" pos="NP1" sem="M7">XYZ</w>
  <w id="48.17" pos="." sem="PUNC">.</w>
  </s>
  </paragraph>
  </action>
```


From early trials of the system on a set of 13 documents consisting of minutes from meetings in a research project, we identified language patterns for the extraction of decisions and actions from the text. Decisions were selected on the basis of concepts related to 'agreement' including variants indicated by the lemmatiser which maps word forms onto dictionary head-words. Actions were selected on the basis of a template '*agent* to *infinitive verb* …'. The agent slot in the template matches names, roles and places identified by the semantic tagger (Z1 tag), and the infinitive verb slot is selected using the annotation provided by the part-of-speech tagger (VVI tag). An example decision extracted by the system is:

It was agreed that all confidential information would be removed from ABC minutes Web space and will be replaced by a "reserved business" comment.

A follow on action extracted would be:

Web Administrator to migrate the minutes.

5 CONCLUSION

This paper has described our approach to the problem of reducing rework through decision management and presented the T-model architecture which allows the capture of real time decision making. Once captured a set of natural language processing tasks are carried out to analyse the linguistic manifestations of the decision making processes and of their impact on rework. Early experiments deploying components from two existing systems, INFORMEX and WMATRIX, demonstrated the feasibility of our text mining approach. In future we plan to apply this approach on the captured i.e. real-life documents, and further study the resulting semantic associations between these conceptual constituents involving both the noun compounds and verb constituents.

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[4] Further information on the *pos* (part-of-speech) and *sem* (semantic) tag labels is available at www.comp.lancs.ac.uk/ucrel/

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