Using Dedal to Share and Reuse Distributed Engineering Design Information

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INTRODUCTION

The overall goal of the project is to facilitate the reuse of previous design experience for the maintenance, repair and redesign of artifacts in the electromechanical engineering domain.

An engineering team creates information in the form of meeting summaries, project memos, progress reports, engineering notes, spreadsheet calculations and CAD drawings. Design information captured in these media is difficult to reuse because the way design concepts are referred to evolve over the life of a project and because decisions, requirements and structure are interrelated but rarely explicitly linked. Based on protocol analysis of the information seeking behavior of designer's, we defined a language to describe the *content* and the *form* of design records and implemented this language in Dedal, a tool for indexing, modeling and retrieving design information [1].

We first describe the approach to indexing and retrieval in Dedal. Next we describe ongoing work in extending Dedal's capabilities to a distributed environment by integrating it with World Wide Web. This will enable members of a design team who are not co-located to share and reuse information.

BACKGROUND: INDEXING AND RETRIEVAL IN DEDAL

Dedal is a tool to help designers index, model and reuse design information. It uses an *conceptual indexing language* [3] which combines concepts from a model of the designed artifact with a vocabulary representing generic task-dependent classes of information covered by design documents such as *function, operation, alternatives*.

Design information is indexed by a set of conceptual indexing patterns. A conceptual index can be seen as a structured entity consisting of two parts: the body of the index which represents the *content* of a piece of information, and the reference part that points to a region in a document. For instance: "The inner hub holds the steel friction disks and causes them to rotate" is part of a paragraph on page 20 in the record: report-333. It can be described by two indexing patterns:

<topic *FUNCTION* subject *INNER-HUB* level-of-detail *CONFIGURATION* medium *TEXT* in-record *REPORT-333* segment *20*>.

<topic *RELATION* subject *INNER-HUB* and *STEEL-FRICTION-DISKS* level-of-detail *CONFIGURATION* medium *TEXT* in-record *REPORT-333* segment *20*>

The queries have the same structure as the body of an index and use the same vocabulary. A question such as: "*How does the inner hub interact with the friction disks?*" can be formulated in DEDAL as:

<get-information-about topic *RELATION* of subject *INNER-HUB* and *FRICTION-DISKS*>

An indexing fragment can refer to a segment of information of different size: a paragraph, a page, a section, a chapter or a document [1]. In addition, the indexer can define *relations* among the design concepts. This enables the system to explore relations among decisions, requirements and alternatives to extend the query when a retrieval fails.

The retrieval module takes a query from the user as input, matches it to the set of conceptual indices and returns an ordered list of answers related to the question. The retrieval proceeds in two steps. The first step is to find indices which match the query exactly. If no exact matches are found then the relations in the indexing model are used to reformulate the query and step one is repeated. The retrieval procedure and a set of retrieval heuristics are described in [1]. Following is an example of retrieval in Dedal.

Designer's question is: *Why is the maximum force in this damper design 500 lbs?*

Query to Dedal: topic: *RATIONALE* for the subject: *MAX-FORCE of DAMPER*

Dedal first tries to find an indexing pattern: <topic: *RATIONALE*, subjects: *MAX-FORCE of DAMPER*> in any media and level of detail. If no indices are found, retrieval heuristics are activated. It looks for requirements associated with quantities that influence the *MAX-FORCE of DAMPER*. In this case, the indexing model indicates that the force of the damper depends on the *current* in the *solenoid* which itself depends on the *power* of the car *battery*. The system finds a constraint on *power* of *battery* documented in page 24 of "progress report 10/90". From this Dedal returns an answer like:

> Maximum-force is a requirement on force of damper, force of damper depends on the current of the solenoid, the current of the solenoid depends on the power of the car battery, there is a requirement on power of the car battery that is documented in page 24 of progress report 10/90.

Thus far Dedal has been used on two industry scale design projects. The first project was the redesign of a continuously variable damper. Results of this study are discussed in [2]. The second project was the design of a Bioreactor. In this project, the design records were indexed during the design process. Table 1 summarizes the characteristics of these design projects.In case of the Damper and the Bioreactor projects both the design teams and the document database were co-located at a single site. With a new project called STEP, we are extending Dedal so that it can support situations where both the design teams and the design records are distributed.

USING DEDAL IN A DISTRIBUTED ENVIRONMENT

Design teams in industry like NASA are multidisciplinary and distributed geographically. Therefore for smooth progress of the design project the teams should be able to collaborate efficiently. To address this concern we are extending Dedal so that it can support a distributed scenario. In this scenario, designers who are geographically distributed are able to collaborate by indexing and retrieving sharable documents. To provide this capability we are integrating Dedal with World Wide Web (WWW) [4]. WWW is a distributed hypermedia system designed to provide access to documents distributed over different sites. It uses the HyperText Markup Language (HTML) to represent a hypertext document, and the HyperText Transfer Protocol (HTTP) to request and transmit documents over the network. WWW is accessible via a variety of browsers. We are working with Mosaic, a platform independent browser, and thus will be able to support collaboration between designers working on different platforms such as Unix, Macs and PC's. Mosaic also supports various media types and is suitable for sharing audio, video and information in other media.

Dedal's integration with Mosaic will provide designers with the following functionality:

- Accessing information at other locations.
- Making information available for team members at other locations.
- Organizing information at the local site using Dedal's indexing method.

TABLE 1. Application domains of Dedal. 'Real time' refers to whether the indexing happened during the design process or not. 'Designer indexing?' states whether the indexing was done by a member of the design team or not. In all the three cases the indexing task is done by a designer (from or outside the design team), not by a knowledge engineer as is typical in such systems.

Domain	Project duration	Platform	Capture Medium	Real time?	designer indexing?
Damper	7 mon	symbolics	vmacs	No	Yes (On Team)
Bioreactor	9 mon	unix	Maker	Yes	Yes (Outside Team)
STEP	2+ yrs	unix	Mosaic	Yes	Yes (On Team)

- Creation of an indexing model of the designed artifact.
- Maintaining vocabulary consistency among the different teams.
- Accurate retrieval of distributed design records using Dedal's retrieval engine.

Figure 1 describes the architecture of Dedal in the distributed scenario. As seen in the figure the documents reside at the local site with their indices. The indexing model defines relations among the indexing terms used by the design teams and resides at a central location, accessible and modifiable by all sites. This common model facilitates consistency in the vocabulary design teams use to describe their designs. We are starting to index and model design records from the project STEP (Satellite Test of the Equivalence Principle). We are working with two design teams, one located at Stanford University and the other at JPL (Jet Propulsion Laboratory, Pasadena) to support their collaboration and information sharing.

In the beginning the designers organize their documents by filling out a template (shown in figure 2). This template is implemented in Mosaic. It lets the designer create an index at the level of individual documents. Keywords in this form are the indexing terms that are project dependent. These keywords are related in the central indexing model of the project. As we integrate more of Dedal's functionality with Mosaic, designers will be able to index their documents at various levels of detail.

SUMMARY

Using Dedal in the continuously variable damper domain showed that Dedal accurately retrieves design records indexed using the conceptual indexing method. The experience in applying Dedal to the design of the Bioreactor showed that it is possible to index and model in real time, i.e. while keeping pace with the generation of new information, without undue burden on the designer. With STEP we are extending Dedal to a distributed scenario in which case designers themselves will index the design information they generate.

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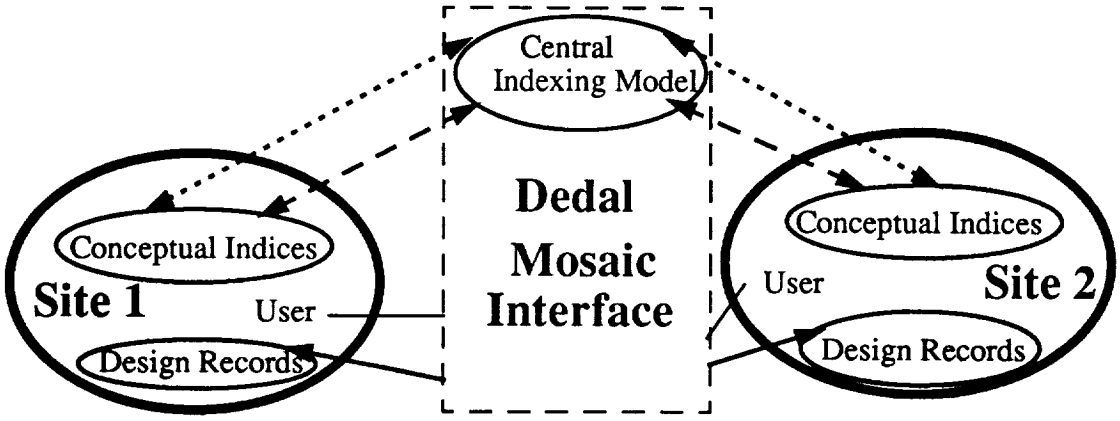

Figure 1. Architecture of Dedal in a distributed scenario. The solid arrows represent the sharing of information between designers at site 1 and 2 using the interface with Mosaic. Dashed arrows represent the creation of the index model by designers at both the sites using the local conceptual indices. Dotted arrow represents the access of the central index model by designers at both the sites for retrieval as well as creation of the index model.

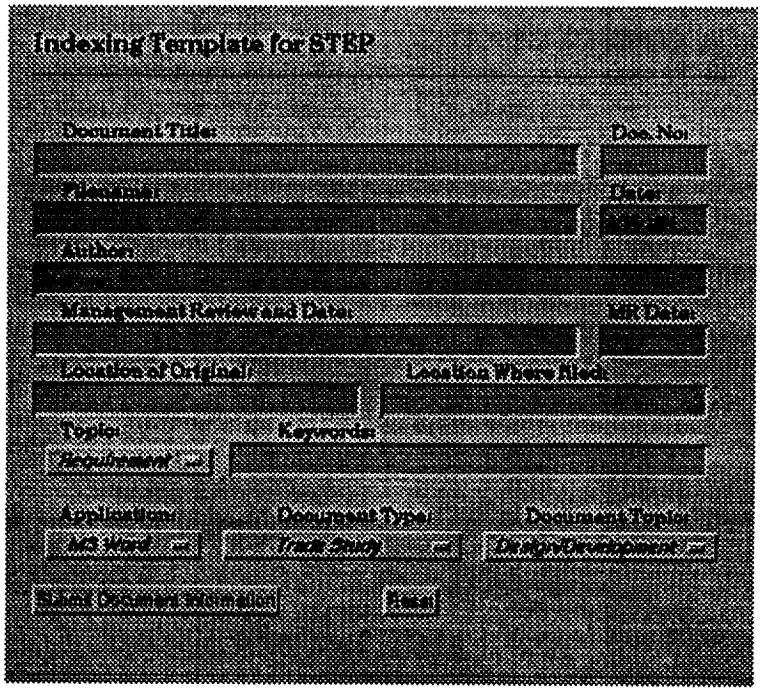

Figure 2. Template for indexing design records at the level of individual documents. This template is available as a form in Mosaic. Topics in this form are the domain independent conceptual indexing terms. Keywords are domain dependent conceptual indexing terms.