The Concept Database : A Design Information System for Concurrent Engineering with Application to Mechatronics Design

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Abstract : The Concept Database (*Cdb* - `http://best.ME.Berkeley.EDU/~cdb/`) is a multi-media, networked, conceptual design support tool. The Cdb maintains a repository of design information resources accessible by a set of retrieval tools. These resources include analytical models, textual and pictorial design documentation as well as electronic product catalogs. Based on state of the designer's knowledge of the current design problem, the Cdb applies appropriate deterministic or heuristic retrieval techniques, organized in a structured information filtering heirarchy, to navigate the designer through the information resources. Principal retrieval tools used include machine learning applied to case-based reasoning and natural language processing. Issues relating to the redesign of existing components, for example, when they fail to meet a specification set, in a particular manufacturing facility have been addressed to demonstrate the articulation of the cull of design data. The domain of application of the Cdb is mechatronic design with particular reference to electric motors.

Concept Database Progress to Date

Case-based reasoning techniques have been applied in prior work [5] to store and index cases of industry "best practices" and allow the user to browse, explore or pinpoint design case information. The organization of design knowledge impacts the quality of inference and support that a designer may derive from a case-based system.

The Conceptual Design Information Server [6] embodies a step forward in the use of case experience for conceptual design. Information is stored at the level of abstraction in which it was used during conceptual design, not as that embodied in the final artifact. The network standard WAIS provides a building block for implementing retrieval from a loosely structured set of design information. Design

documents are indexed as a collection of terms, with similarity among them defined by the co-occurrence of these terms among themselves or to user entered queries. We extend this method by applying a set of user-modifiable taxonomies to provide an essential structuring of the information without constraining the expression.

Machine learning over case-data can be used to create an intelligent interface between designer requirements and available design knowledge. Such an interface assists the designer in navigating the case-base for effective case-based retrieval. In [3], we have investigated two neural architectures based upon the Adaptive Resonance Theory, for the automated generation of design representations useful during the preliminary stages of case-based retrieval. Intelligent organization of archived design data also provides effective support in a new product design situation. In [4], we present strategies for rapidly developing approximate synthesis information for new designs from initial specifications by learning over archived design data. Besides identifying relevant past designs, the neural network architectures predict a specification set for the new proposed design.

The vast resources of design cases poses a complex problem in case retrieval - how to improve the recall of pertinent design information by guiding the designer toward information related to or critical for the analysis of the current problem. The premise of the research program presented in [4] is that the design specifications and solutions as communicated through design documentation are related to a model of the design. By learning these descriptions through principal noun-phrases in the documentation, we developed a system in [2] that induces a model of the design. Our learning algorithm is based upon natural language processing text analysis to extract content-carrying terms, and then applying techniques from machine learning to cluster inter-dependent terms and decompose the design into dependent elements using belief networks. Initial tests showed that augmenting retrieval queries over historical design documentation using the learned representation generally improved the recall of relevant information. The learned contextualization directed the search engine towards a large subset of relevant information that might not have been located without its assistance.

Information retrieval, however, not only involves decisions concerning which documents to retrieve but also meta-decisions concerning the formulation of the search strategy itself. For example, suppose the database contains a collection of documents relating to the design of automatic controls for mechatronic devices. Then, suppose the user, who does not necessarily know what information is contained in the database but knows exactly which document is required, poses a query such as *control in the complex plane*. In general, it would generally not be worthwhile to search the whole database to look for the "most relevant" document. At some point, the expected cost of further search would outweigh the expected benefits. The goal then is to focus the users' resources (query) towards those documents which would yield the most relevant information by (1) selecting among a pool of keywords that would reduce the uncertainty in selecting relevant documents; and (2) inform the user to stop querying when the cost outweights the benefits. A performance study has been carefully designed to determine whether the Expected Value of Perfect Information (EVPI) calculated for each particular word in the query permits the system to select keywords which more closely match the user's information objectives.

Besides information storage and retrieval techniques, we have investigated situations where no feasible design that satisfies customer specifications exists and a redesign of existing components is necessitated. A frame-work for custom-building motors based on customer specifications and the available manufacturing infrastructure has been developed [1]. Catalog motors that are most amenable to customization are first identified using a function-cost hypothesis, i.e., the cost of a product may be estimated from its principal function. Thus, a rough estimate of the customized motor may be estimated from the customer-specified torque specification (which is the principal function of electric motors). Using this estimate, the customization problem can be formulated as a non-linear discrete optimization problem with a minimum manufacturing cost objective. The cost function is estimated using domain

knowledge about the manufacturing infrastructure and the similarity method of cost estimation. The methodology developed is used to obtain optimal custom motor-designs from the standard designs of a family of brushless D.C. permanent magnet motors.

Publications:

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