Intelligent Retrieval of Electronic Designs in Online Catalogs

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August 12, 1998
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Abstract
Design reuse is getting ever more important, especially for designers of electronic circuits. Talking about reuse, many open questions have to be addressed as there are: How to represent and store designs (database management issues)? How to find re-usable designs for a given task? How can a design actually be re-used? How can the copyright of designs (“Intellectual Property”, IP) be protected in a global distribution system, while a customer still gets enough information to select a suitable design?

This paper describes an intelligent search assistant for Electronic IP catalogs that helps the professional electronic designer in searching for a reusable IP for his specific application. The retrieval methods of this assistant are based on Case-Based Reasoning (CBR) techniques but incorporate some approaches that are new to most other CBR systems. Special care is taken to protect the intellectual property of IP designers while application designers are still provided the possibility to select a suitable IP precisely.

1 Introduction

Design Reuse. The design of electronic circuits is a discipline in which two contrasting tendencies can be observed: On the one hand, modern circuit designs get ever more complex and difficult to handle by electronic engineers. On the other hand, global competition requires a continuous reduction of development times. The correctness and reliability of the designs should, of course, not suffer from shorter development cycles.

These requirements have become so dominant that they cannot be met anymore without extensive utilization of design reuse. It is getting vitally important for an electronic engineer to re-use old designs (or parts of them) and not to re-design a new application entirely from scratch. At the same time, reusable designs are growing ever more complex and difficult to understand. To reflect this growing complexity, the term intellectual property (IP) has been assigned to those designs and the term reuse today means more than just to plug a component into a new environment (Lewis, 1997).
Electronic Commerce. The Internet is a very good medium for distributing such reusable designs. However, finding reusable designs in a database requires that the application engineer has enough experience and knowledge about existing designs, in order to be able to find candidates that are suitable for reuse in his specific new application. Because of the high complexity of such IPs, searching a database can be an extremely time consuming task. There are currently no intelligent tools to support the engineer to decide whether a given design can be easily adapted to meet the specification of his new application.

A simple but typical reuse scenario from the application developer’s point of view consists of a few main steps:

1. Make a specification for a new application.
2. Find a catalog of re-usable designs that contains IPs of the new application’s domain.
3. In the catalog, search for the IP that is best re-usable for the new application.
4. Obtain (buy) this IP from the IP provider.
5. Try to reuse the IP.

Concerning electronic commerce applications, it is the task of an online IP database to provide support for steps 2 to 4. This contribution is especially concerned with step 3 which proves to be a rather complicated task: As IPs are non-physical copyrighted goods, the vendor is not willing to provide much information on implementation details to the customer before he buys the design. Thus, there is a risk that similar IPs cannot be distinguished by the information contained in an IP catalog. But how can an engineer select the best of perhaps dozens of IPs if their publicly accessible attributes do not differ? The only solution is to leave the decision making process to an intelligent online retrieval system that has access to all the required information but hides it from the user.

The READEE\(^1\) project has been initiated to explore and realize new methods to overcome these problems. Unlike other reuse attempts, READEE does not try to incorporate a complete and mathematically correct model of the design process to decide whether an old design is reusable for a new specification. Instead, it employs Case-Based Reasoning techniques and uses a similarity-based approach that relies on suitable heuristics and makes decisions in a way very similar to the decision making process of a human designer.

Intelligent retrieval algorithms are essential for finding reusable components for a given task in large databases. Therefore the retrieval techniques described in this contribution are of major importance to online catalogs of reusable designs and IPs, where no human assistant is available to guide an electronic engineer searching for a product.

The following section gives a compact overview of existing approaches to the problem of finding reusable designs in databases. Section 3 describes the conceptional basics of READEE and explains how a user can find reusable designs for his specific tasks with this online system. In section 4 we give an outlook over the enhancements to READEE that can be expected to be realized in the near future. Finally, the conclusion summarizes the key achievements of this contribution.

\(^{1}\)READEE [‘redi]: Reuse Assistant for Designs in Electronics Engineering; funded by the foundation ‘innovation’ (Stiftung Innovation) of Rhineland-Palatinate, Germany; Corporate partners: Center for Learning Systems and Applications at the University of Kaiserslautern; Engineering office “Dr. Peter Conradi & Partner”; tecInno GmbH, Germany
2 Existing Applications

Until recently, reusable components in electronic designs have been limited in complexity to some extent that was still conceivable by application engineers. There was no need for database search assistants other than keyword search or other simple mechanisms. Reuse tools and databases for complex IPs are yet hard to find and the support they offer is still far from being sufficient.

Larger electronic companies try to develop their own reuse tools. The primary focus of most of these systems yet is on design representation issues and related database management problems. Publicly available or commercial intelligent selection assistants within such databases are not known to the authors.

The Internet, of course, provides some information on electronic components and sometimes IPs. For hardware components, the information sometimes is provided as data sheets. They contain all the information (and even more) that is needed to evaluate a product with respect to a special purpose. Browsing through the data sheets of certain product families and evaluating the information contained therein can take many days.

Information on soft IPs is much harder to find in the Internet and often it is so sparse that a designer can only guess whether the IP would be suitable for his purpose. IP providers have to be very careful to protect their intellectual property.

In July 1997 Design & Reuse (Behnam et al., 1998) launched an online catalog for IPs. This catalog was a great success right from the start which indicates that there is a big demand for reusable designs. The Design & Reuse “yellow pages” basically provides two different search facilities: First, there is a hierarchical IP taxonomy which serves as a selection tree for IPs and families of IPs, and second there is a keyword search that enables a user to search across the boundaries of the taxonomy.

There are general points of criticism that apply to these search techniques: Keyword search is only a syntactical search. A search for a “short cycle time”, for example, would fail to find components with a “high clock rate”, which is a more or less equivalent quality. In addition to that, more abstract information like “good for high fidelity audio applications” cannot be deduced from low-level attributes like “noise distance” and “dynamic range” by a syntactical search.

A taxonomy, on the other hand, holds some more information about categories of designs. A drawback of a purely taxonomical search is that there is no information about the relations (exchangeability or equivalence, for example) between two categories on the same hierarchical level. However, such information would be very beneficial to have in a reuse tool. Another problem with selection trees is that the user is forced to make decisions in a predefined order. If, for some reason, he cannot (or does not want to) make a decision at some point, he is forced to make several inquiries in sequence. Figure 1 illustrates this problem with an example taken from the Design & Reuse “yellow pages”.

![Figure 1: Part of a selection tree. A user looking for an 8 bit microcontroller is forced to make a decision (RISC or CISC) he rather would not care about. It is not possible to generally solve this problem because there might be another user looking for a RISC microcontroller, so the order of decisions cannot be globally optimized.](image-url)
3 The READEE Approach

All these arguments make clear that a database of reusable designs requires a search facility that possesses more intelligence and knowledge than currently available systems can provide. In the near future, electronic applications can be expected to grow so complex that their designers cannot be expected to be specialists in the reusable components they are going to employ for their project. So, retrieval assistants capable of providing real selection support (and possibly guidance in configuring the retrieved designs) are highly recommended.

The READEE prototype (introduced at DATE98\(^2\) (Vollrath and Oehler, 1998), online at http://wwwagr.informatik.uni-kl.de/~readee/) is an example of such an intelligent approach towards selection support for reusable components. This first prototype is specialized on digital signal processors (DSPs). A user can specify his requirements of a DSP both on higher and lower levels of abstraction. A typical low-level requirement would be: “supply voltage = 5V”. More abstract specifications could state characteristics of the intended application, for example: “I want to realize a Fast Fourier Transformation (FFT) with up to 512 samples per frame.”. Part of the consultation interface of READEE is shown in figure 2.

The key concepts of the prototype are

**Concept Similarities** READEE is developed upon the Case-Based Reasoning shell CBR-Works from tecInno\(^3\). The notion of similarities between different attribute values is heavily used to evaluate the quality of a design with respect to a given specification. This is very important in the area of reuse, where a designer often cannot expect to find a component that matches his specification exactly. Instead he will often be satisfied with a solution close to his requirements because his project typically is in a stage of development where he can still adapt either the environment or the reused component itself.

**Query Transformation** The problem specification (query) an application designer can give to READEE may contain information on very high abstractional levels (c. f. fig. 2). These abstract specifications have to be transformed into lower level requirements. The knowledge needed to perform this information transformation is represented by a hierarchical rule-base (Bergmann et al., 1996) that can generate low-level requirements and can modify the overall similarity measure according to the user’s application (Vollrath, 1997).

**Evaluation Models** These models include knowledge about abstract key features of the components in the database. A complex design typically has certain qualities that are difficult to extract – even for experts – from the component’s data sheets or from a complex design description. However, an intelligent retrieval assistant must know about these qualities if they are important for the selection decision of a human designer.

The evaluation models compute to which extent a certain DSP has the quality addressed by them, with respect to the user’s specification of his application. For DSPs, for example, one of the most abstract qualities of this type is “The processor must run a specific algorithm as fast as possible.”. To judge how good this quality is fulfilled by a specific DSP regarding the user’s specification, the retrieval assistant needs suitable models of:

- Algorithms that are likely to be implemented on a DSP
- Execution times of operations that might be used within those algorithms

\(^2\)DATE98: Design, Automation and Test in Europe, Conference 1998

\(^3\)http://www.tecinno.de/
Figure 2: The User Interface of the READEE Prototype for DSP selection.
It is not necessary, however, to feed the retrieval assistant with a complete model of possible realizations of the execution units of a DSP. An application designer neither does need to care about the number of pipeline stages of the floating point unit, for example, nor is he interested in details about the data paths between functional parts of the DSP – if only he knows how long the processor takes to perform his application specific algorithm, or perhaps a certain set of instructions.

READEE accounts for these decision criterias of human designers and internally represents only the kind of information that is relevant for the selection of reusable designs. Some of this information may not be explicitly found in data sheets and has to be provided by a human expert by the time of filling the database. This human expert ideally is the designer of the reusable design or IP.

After the individual ratings of these high level qualities have been assessed by the evaluation models they are combined to an overall similarity value (a real value in the range \([0, 1]\)) which is a measure for the expected reusability of the DSP with respect to the user’s application. Additional low-level requirements, such as “low cost” or “low power consumption” are also taken into account by the overall similarity value.

The result of a READEE consultation is a list of reusable IPs sorted by their similarity to the user’s specification, i.e. the design with the highest estimated reusability appears at the top of the list (see fig. 2). The user has the opportunity to further refine his specification in case his initial specification was not precise enough to produce a satisfying result. The system also has the ability to explain what makes the proposed IPs similar to the specification.

4 Future Steps

The READEE prototype shows the applicability and suitability of knowledge- and similarity-based retrieval methods for catalogs of reusable design components. However, it should be pointed out that the intelligence of such a system comes at the cost of reduced generality. The READEE-prototype specialized on DSPs, for example, is not suitable for completely different types of designs (e.g. memory blocks). Designs for other application areas require the assessment of evaluation models for the abstract key-features of the respective application.

A more general catalog of IPs would therefore consist of a collection of application specific retrieval assistants (or agents). Suitable concepts for the integration of these individual specialists still remain to be explored. A first solution could be to integrate them into a hierarchical selection tree much like Design & Reuse’s tool. This decision tree should have a depth of at most three (e.g.) decision steps and leave the remaining search to application specific search assistants like the READEE prototype.

Another issue to be addressed in the near future is the representation and retrieval of parameterized IPs: Some commercially available designs are configurable by instantiating certain parameters of a limited design space. Possible parameter values are constrained by IP specific relations. The extension of similarity measures and evaluation models to be able to cope with such parameterized designs (“generalized cases”, Bergmann (1996)) stands at the first place of the agenda of the READEE project.

5 Conclusion

This contribution explained why existing search mechanisms for data bases of reusable designs are not sufficient for the needs of professional electronic engineers. This also holds in general for other online catalogs of products where the customer is required to have detailed knowledge about the type of products in the data base in order to be able to evaluate the product’s suitability for his specific needs.

The READEE prototype takes a similarity-based search approach that depends on a medium amount of knowledge about the design’s application domain. The power and flexibility of this approach therefore
comes at the cost of some additional knowledge acquisition. However, it is not necessary to include a complete model of the design process of such IPs into the retrieval assistant to get good retrieval results.

The prototype described in this paper is a first result of the REAEE project. It has been introduced at DATE98 and the positive feedback has clearly shown that the project targets a problem of high current interest and that its approach to the problem’s solution is really worth to be followed and further refined. However, there still remain important issues to work on – both for the REAEE project and for commercial catalog providers. Future research of the project will target at the retrieval of parameterized IPs and their configuration (adaptation) for an application designer’s specific task. We are currently working on the representation of dependencies between values of different parameters with constraints and their integration into CBR-Works.

References


