行政院國家科學委員會專題研究計畫成果報告
特徵式設計的搜尋系統之開發
Development of a feature-based design retrieval system

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一、中文摘要

工業用的設計元件經常是非常相似的，如有不同，也常是幾何形狀及尺寸的些微差距。因此，當開發一新設計時，就應參考先前已有的設計資訊及經驗，以免遭遇相同的難題。若能藉由修改先前的設計而完成新設計的開發，則新產品就可以很容易地達成產品規格化的目標。同時，開發成本也因著生產工具及製造程序的相似而大幅降低。然而，大多數的設計者很難知道哪些是已開發過的相似設計元件，除非有一適當的工具可以對舊有的設計作有效率的分類、儲存、及搜尋。為了將產品開發的時間縮短以快速反映市場的需求，發展一有效率的設計搜尋系統，就成為此一領域的重要課題。

因應上述的需求，我們將發展一特徵式設計的搜尋系統，以達到快速設計的願景。首先，我們利用特徵式的方法(feature-based method)來作為設計元件的表示法，因為特徵式的方法已廣泛的被應用在相當多的領域如製程規劃及檢驗計劃等。其次，我們針對特徵式表示法，發展一個在輸入不完整資訊時，還能找到相似設計的搜尋演算法。我們利用特徵關聯性(feature association)及模糊式順應性震盪理論(fuzzy adaptive resonance theory)來作為搜尋機構。此一研究所提出的特徵式設計存取系統，可以實際地被工業界所採用，並達到快速設計的目標。

關鍵詞：快速設計、設計存取、特徵式表示法、特徵關聯性、模糊式順應性震盪理論

Abstract

Industrial parts often differ from one another only by a small geometrical change or dimensional deviation. It is necessary to refer previous designs, information, and experience when considering a new part. If a new part is designed through minor modification to previous parts, the goal of product standardization and cost minimization can be easily achieved. However, most designers may not know all past designs unless there is a suitable tool to classify, store, and retrieve designs in databases. To response the rapid change of today's market, development of a design retrieval system that can efficiently refer to similar designs becomes an important research issue.

In this research, we develop a feature-based design retrieval system. First, each design case is indexed by popular feature-based method. Then, a flexible searching algorithm for feature-based representation is developed to find similar designs in a large database, even when provided query is incomplete or erroneous. In the algorithm, we combine feature association and fuzzy adaptive resonance theory (Fuzzy ART) as the searching mechanism. Our experiment shows that the proposed system is practical enough to industry for achieving rapid design.

Keywords: Rapid design, Design Retrieval, Feature-Based Representation, Associative memory, and Fuzzy Adaptive Resonance

1. INTRODUCTION

There is no doubt that design is one of the most interesting, complicated, and challenging problem-solving activities that human beings encounter. For a corporation, developing a brand new design is very time-consuming and costly. Its expenditures are not for product development only but for new equipment purchasing, facilities planning, process planning, quality control, and documentation. This situation could be worse in a make-to-order type company when a mass of customized products are manufactured. In fact, parts often differ from one another only by small geometrical change or dimensional deviation. Previous design, information, and experience are necessary to be reused and retrieved when considering a new part design. However, most designers are unaware of the existence of similar designs in corporation's repository. It is common to find that similar parts are redesigned for several times unless there is suitable design retrieval tools in used.

Currently, the GT based design retrieval approach, powered by coding and classification techniques, is one of the most popular industry approaches for design indexing [1][3][8][14]. However, one of the major problems is that GT based methods simultaneously conduct the tasks of indexing and classification. This makes the methods hard to adjust the level of similarity. Besides the GT based approaches, many design indexing approaches, such as bitmap image methods [7][13], skeleton methods [11][15], and others [2][9][15][12] have been proposed in the past few years. These systems, however, reveal their own problems and limitations. Some major problems include the availability of a query image, the disappearance of internal features, and the selection of a proper viewpoint for each design. Additionally, bitmap image and skeleton methods transfer the shape of a design into a custom index *after* the component has been produced. This tremendously increases the time required for constructing a design case database.

Except the problem of choosing a proper design indexing approach, deploying a searching algorithm that can mimic the association capability of designers' is also required. Currently, most searching algorithms developed is based on traditional information retrieval system. The search statement can be specified by traditional Boolean logic, proximity, contiguous word phrases, fuzzy searches, term masking, and natural language etc. [10]. Although information retrieval techniques are successful in many applications, their use for design retrieval is not prominent. For instance, a design, usually presented by its topological structure and geometric shape, is hard to describe by "words" or "text" for accommodating textual representation in the information retrieval environment. Additionally, using classic information searching techniques such as Boolean operations for design searching is also inappropriate. The Boolean retrieval process is based on a match or no-match selection between query terms and index terms of a file [6]. However, the design searching process should be an associative activity in which designers retrieve similar design based on *overall* similarity [5].

2. OBJECTIVE

The objective of this research is to solve the problems associated with current retrieval systems that are incapable of providing proper design representation for design retrieving task, incapable of retrieving designs with incomplete query, and incapable of retrieving similar designs using different similarity levels. Specifically, we try to develop a proper design representation and corresponding retrieval mechanism that can search similar designs based on provided similarity level and can tolerate a certain degree of incomplete query input.

3. AN IMPLEMENTATION CASE

Twenty-four mechanical components shown in Figure 1 have been selected as design cases in the current implementation example to demonstrate the capability of the proposed system. Meanwhile, twenty-two prismatic form features utilized in a feature library are shown in Table 1

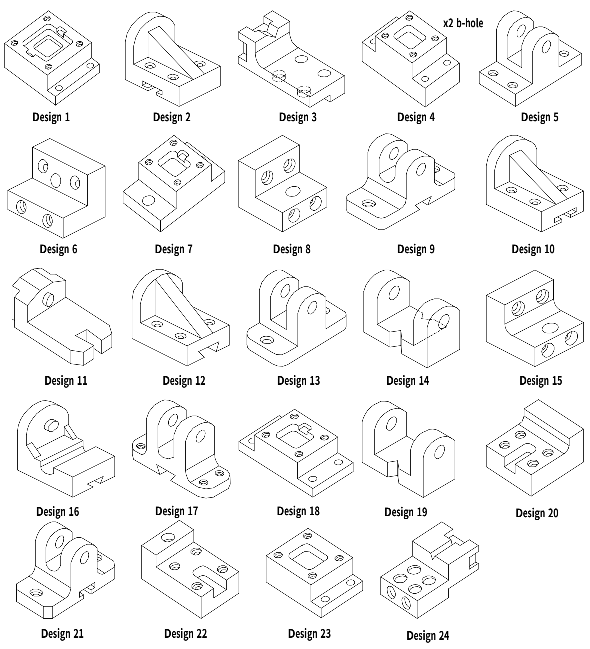

Figure 1: Design cases in the implementation example.

Table 1: Twenty-two form features in a feature library.

i	Name of Form Feature	i	Name of Form Feature
1	*Non-Threaded -Through -Hole*	12	*Open-Pocket*
2	*Threaded-Through -Hole*	13	*Sharp-Corner-Slot*
3	*Non-Threaded-Blind-Hole*	14	*Cylindrical-Slot*
4	*Threaded-Blind-Hole*	15	*T-Slot*
5	*Through-Counter-Bore*	16	*Dovetail-Slot*
6	*Blind-Counter-Bore*	17	*V-Slot*
7	*Through-Counter-Sink*	18	*Chamfer*
8	*Blind-Counter-Sink*	19	*Fillet*
9	*Pocket*	20	*Arch*
10	*Sharp-Corner-Step*	21	*Boss*
11	*Round-Corner-Step*	22	*Rib*

A Rod Support of an industrial product, shown in Figure 2, is provided as a target design to be searched. Designers select a number of form features from the feature library to form a query. Those form features are two non-threaded-through-holes, two threaded- through-holes, two sharp-corner-steps, three sharp-corner-slots, two fillets, and two arches.

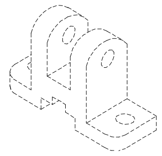

Figure 2: A Target design.

Since each pair of form features is related in geometric or functional aspects, the strength of the relationship can be evaluated by a membership grade among 0 to 1 and recorded in a feature relation. If two features are strongly related, a higher membership grade (close to 1) is assigned; conversely, if two features are not related, a lower membership grade (close to 0) is given. Part of the fuzzy relation R is illustrated in Table 2, where the numerical numbers x and y are the number of form-feature i listed in Table 1. By conducting fuzzy max-min composition [16] to R and the query, fuzzy feature relationship is embedded to the query.

Table 2: The fuzzy relation R.

y / x	1	2	3	4	5	6	…	22
1	1	.9	.6	.5	.7	.4		0
2	.9	1	.6	.7	.7	.3		0
3	.6	.6	1	.9	.5	.6		0
4	.5	.7	.9	1	.4	.8		0
5	.7	.7	.5	.4	1	.8		0
6	.4	.3	.6	.8	.8	1		0
…							…	
22	0	0	0	0	0	0		1

After fuzzy feature association is applied, a Fuzzy ART network [4] can be initiated to search associated reference designs. To demonstrate the work, assume that designers want to broadly search designs similar to the target design. In this case, a lower value of similarity parameter of a Fuzzy ART network is suggested, say 0.4. The Fuzzy ART network then returns design case 5, 9, 13, 17, and 21 as reference designs. If designers wish to receive fewer reference designs, they might provide a higher similarity parameter to the Fuzzy ART network. For example, they may give similarity parameter 0.9 for the network and have design cases 9 and 21 returned. One can also conclude that design cases 9 and 21 have higher similarity to target design than design cases 5, 13, or 17. Part of searching result is shown in Table 3.

Table 3: Lists of retrieving results for the target design.

Similarity Parameter σ	With fuzzy feature association	Without fuzzy feature association
0.4	5, 9, 13, 17, 21	13, 21
0.5	4, 5, 13, 18	9, 17, 21
0.6	9, 13, 17, 21	9, 21
0.7	9, 13, 21	None
0.9	9, 21	None

If feature association is not operated for the query, the searching ability will be dramatically reduced. As shown in Table 3, under the same level of similarity parameters, fewer designs are retrieved. Even if a lower similarity parameter of 0.4 is provided, only two design cases 13 and 21 are returned. Designers may not find choice to select according to their preference such as the cases when similarity parameter is 0.7 or 0.9. In addition, it is noted that design cases 5, which is also visually similar to target design, will never be retrieved.

5. SUMMARY

There is no doubt that design is one of the most interesting, complicated, and challenging problem-solving activities that human beings encounter. Design is a highly knowledge-intensive and ill-structured problem. Most the practical problems we face in design are either too complex or too ill defined to analyze with conventional approaches. To achieve the rapid design for today's market, this research develops a design retrieval system that can efficiently refer to similar designs. In the system, a feature-base design representation and fuzzy association searching mechanism are proposed. Our experiment shows that the proposed system is practical enough to industry for achieving rapid design.

6. SELF-EVALUATION

We completed almost all the research goal we have proposed. The accomplished jobs is shown as the follows:

1. Understanding the procedure of introducing feature-based methods as design representation in a design retrieval system.
2. Constructing a feature library and a feature-based design database for a certain industry.
3. Constructing a searching algorithm for our feature-based representation.

Since this project is executed in a limited half year, some of the following jobs is still in progress. It includes:

1. Understanding required features in a certain industry for building up a feature library.
2. Comparing our methodology with other research methods.

7. REFERENCES

[1] Ben-Arieh, D. and Triantaphyllou, E. (1992), "*Quantifying data for group technology with weighted fuzzy features*," in *International Journal of Production Research*, Vol. 30, No. 6, pp. 1285-1299.

[2] Bradley, S. R. and Agogino, A. M. (1994), "*An intelligent real time design methodology for component selection: an approach to managing uncertainty*," in *Journal of Mechanical Design*, Vol. 116, No. 4, pp. 980-988.

[3] Candadai, A., Hermann, J. W., and Minis, I. (1996), "*Applications of group technology in distributed manufacturing*," in *Journal of Intelligent Manufacturing*, Vol. 7, No. 4, pp. 271-291.

[4] Carpenter, G. A., Grossberg, S., and Rosen, D. B. (1991), "*Fuzzy ART: fast stable learning and categorization of analog patterns by an adaptive resonance system*," *Neural Networks*, Vol. 4, No. 6, pp. 759-771.

[5] Chang, C. A. and C.-Y. Tsai (1997) "*Using ART1 neural networks with destructive solid geometry for design retrieving systems*," *Computers in Industry*, Vol. 34, No. 1, pp. 27-41.

[6] Cortez, E. M., Park, S. C., and Kim, S. (1995), "*The hybrid application of an inductive learning method and a neural network for intelligent information retrieval*," in *Information Processing & Management*, Vol. 31, No. 6, pp. 789-813.

[7] Escobedo, R., Smith, S. D. G., and Caudell, T. P. (1993), "*A Neural Information Retrieval System,*" in *International Journal of Advanced Manufacturing Technology*, Vol. 8, No. 4, pp. 269-274.

[8] Gill, A. and Bector, C. R. (1997), "*A fuzzy linguistic approach to data quantification and construction of distance measures for the part family formation problem*," in *International*

Journal of Production Research, Vol. 35, No. 9, pp. 2565-2578.

[9] Greska, W., Franke, V., and Geiger, M. (1997), "*Classification problems in manufacturing of sheet metal parts*," in *Computers in Industry*, Vol. 33, No. 1, pp. 17-30.

[10] Kowalski, G. (1997), "*Information Retrieval Systems: Theory and Implementation*", Kluwer Academic Publishers, Boston, MA.

[11] Lin, Z.-C. and Tsai, P.-C. (1995), "*The application of the fuzzy similar matrix in the design of a sheet-bending expert system*," in *International Journal of Advanced Manufacturing Technology*, Vol. 10, No. 6, pp. 396-403.

[12] Myint, S. and Tabucanon, M. T. (1998), "*The framework for an expert system to generate alternative products in concurrent engineering design*," in *Computers in Industry*, Vol. 37, No.2, pp. 125-134.

[13] Smith, S. D. G., Escobedo, R., Anderson, M., and Caudell, T. P. (1997), "*A deployed engineering design retrieval system using neural networks*," in *IEEE Transactions on Neural Networks*, Vol. 8, No. 4, pp. 847-851.

[14] Venugopal, V. and Narendran, T. T. (1992), "*Neural network model for design retrieval in manufacturing systems*," in *Computers in Industry*, Vol. 20, No. 1, pp. 11-23.

[15] Xue, D. and Dong, Z. (1997), "*Coding and clustering of design and manufacturing features for concurrent design*," in *Computers in Industry*, Vol. 34, No. 1, pp. 139-153.

[16] Zadeh, L. (1965), "*Fuzzy sets*," in *Information and Control*, Vol. 8, pp. 338-353.

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