Intelligent Computer System for Jewelry Design Support

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ABSTRACT

The paper presents a framework of intelligent computer system to generate the primitive jewelry designs. The emphasis of this paper is to outline of methodology and architecture to develop the system, which depends on classifying the elements influenced in the conceptual design stage. The proposed system provides as tool for designers to generate design alternatives according to designer's preferences. Thus the designer can explore more alternatives and generate designs with his/her styles from sketch quickly and systematically. Accordingly, the system can enlarge CAD process to cover the conceptual design phase in early stage of the design process. Furthermore, the system also takes into account of manufacturing, and costing. The system thus acts as assistant tool for designers to make decision of their designs. The illustration of the proposed design methodology is also included in this paper.

Keywords: Expert system, Conceptual design, CAD, Concurrent engineering, User-system interaction, and Jewelry design.

1. INTRODUCTION

Jewelry design involves various aspects such as analysis, creativity, and development. In the design process, the designers have to deal with all of these aspects in order to balance the beauty and functions of the products. This job requires the information such as jewelry classes, jewelry styles or customer classes, jewelry types, casting materials, gem's types, and gem's size. Moreover, creativity of design typically depends on knowledge, experiences, and perceptions of the designers. Meanwhile, they have to consider their designs in term of possibility in production.

So far up until now, there are few computer-aided tools that designer can employ to facilitate in the conceptual design process. Most of the works during this stage are carried out solely by a designer. Therefore, it is highly motivating and useful to develop an intelligent computer system for supporting the designers to generate their ideas since conceptual design stage. The tool is used to link between computer aided design (CAD) system and designers. It can help designers to shorten the time working on CAD.

This tool also would be beneficial for both designers and customers. When designers would like to propose their ideas to market, the tool could be used to help them to generate concept of the jewelry products, especially for unfamiliar groups of customers such as exported products. On the other hand, in the case of the customized products, the customers would like to have jewelries designed exclusively in their own styles. A common problem in this case is that customers are not good at design and they may not be able to tell the designer what they want. The tool can help customers to design by themselves and also for designer to capture the actual needs and styles of customers.

To develop the intelligent computer system for design support, Expert System (ES) or Knowledge-Bases System (KBS) is considered as one of the most intelligent technologies that are efficient for design tasks. ES have been used to solve a wide range of problems in domains such as medicine, mathematics, engineering, computer science, and business. Within each domain, they have been used to solve problems of different types. They depend on how to choose the knowledge representation and reasoning methods given characteristics of the problem.

In addition, the concept of Concurrent Engineering (CE) could be applied in this tool to integrate the related activities such as manufacturing, and costing to the design process. This is helpful for designers to take into consideration of manufacturing, and costing aspects of their designs. The success of developing ES and concurrent engineering appear in various researches, some of them are briefly described as follows.

Zha et, al. [1] employ an agent-based framework to develop an expert system for concurrent product design and planning for assembly. This intelligent system provides systematic assistance for assembly design and planning in the early stage of product development. Shelab and Abdalla [2] present an intelligent knowledge-based system for modeling product cost. They apply hybrid knowledge representation techniques such as production rules, frame, and object–oriented, to represent manufacturing knowledge. Fuzzy logic-based knowledge representation is applied to deal with uncertainty in the knowledge of cost model to generate reliable cost estimation. Zha and Du [3] develop a system based on the generic product assembly model, STEP-based strategies and agent concepts are used for agent-based concurrent integration of design and assembly planning.

More information of ES are available in other researches such as [5], [6], and [7].

The main objective of this paper is to outline an intelligent system used in the conceptual design stage with jewelry design considerations. To achieve the above objectives, three main steps are undertaken:

- Classification of the elements influenced in the conceptual design stage,
- Design the framework of the system,
- Integration of the relationship among design, manufactures, and cost.

2. CAD SYSTEM FOR CONCEPTUAL DESIGN OF JEWELRY

Conceptual design is an early stage of the product development process, includes jewelry design process. The conceptual design stages typically have characteristics of fuzzy problems with a high degree of uncertainty. During the conceptual stage of design, designers generate ideas and turn them into quick sketches with pencil and paper. CAD systems are not much used at this stage of design, because they generally require the complete, concrete, and precise definitions of the geometries, which are only available at the end of the design process.

The advantages of CAD process, in terms of time and cost savings, in comparison to non-CAD process has been proved for the detailed design phase of the design process, but still not for the conceptual design phase [5]. Therefore, we develop the ES that can extend capability of CAD software to cover the conceptual design phase in early stage of design process.

In this paper, we utilize the existence CAD package by link to the system. This approach is faster and saver (in terms of cost and time) comparing to newly start the construction of all elements in the system.

The emphasized aspects of CAD activity in this work are *Visualization* and *Representation*: in geometrical modeling 2D, and 3D.

The approach to develop the intelligent computer system for the conceptual designs in the jewelry design process is developed from Durkin's approach [4], which consists of five main phases, briefly described in Table 1.

Phase 1: Problem assessment	- Discussing and brainstorming with jewelry designers and company to obtain and refine the main problems that related to the other tasks.
Phase 2: Knowledge acquisition	- Interviewing the jewelry designers. - Acquisitioning design consideration and factors from designers.
Phase 3: System Design	- Designing the structure of the system prototype. - Designing Database. - Designing User Interface.
Phase 4: Building System and User Interface	- Construct the KB or Database. - Develop user interface.
Phase 5: Experimental Testing	- Testing with designers to evaluate the system.

Tab. 1. The development approach of the proposed intelligent computer system.

3. DESIGN CONSIDERATION OF JEWELRY PRODUCTS

In phase 2, tasks in knowledge acquisition are capturing design considerations and factors used in the conceptual jewelry design process from the expert designers.

Interviewing and observing methods, the most common techniques of knowledge acquisition, are used in this phase. The results of the interviewing sessions and the observing designers' working process are analyzed and concluded in terms of design consideration and factors. The proposed system requires these design factors to generate the concept alternatives. Design factors used in the conceptual jewelry design process are jewelry class, jewelry styles, jewelry type, casting materials, gemstone types and sizes, jewelry making techniques and process, and cost, which each is explained as follows.

3.1 Jewelry Classes

In the conceptual design stage, jewelry designer starts designing from the classes of jewelry that generally classified into two major classes:-

1) *Gemstone Jewelry*: In this class, the jewelry products typically made from the high-value casting metal such as platinum, gold and etc. and the genuine gemstones such as diamond, sapphire, etc. that lead to

getting the high prices. In the jewelry field, this class is called "*Precious Jewelry*".

2) *Fashion Gemstone Jewelry* or *Costume Jewelry*: The jewelry product in this class mostly made from the synthetic gemstones, the color stones, the lower-grade of genuine gemstones and the casting metal mixed with some alloys. Thus the jewelry products in this class mostly are lower prices comparing to the first class. This class by its name, the jewelry usually is used for fashion and costume purposes that always dynamically change follow the fashion styles in any period. In the jewelry field, this class is called "*Semi-Precious Jewelry*".

3.2 Jewelry Styles

In this study, jewelry style is one of the most important design considerations. Due to it can be used to classify the main structure and skeleton of jewelry. Jewelry styles actually have been classified by several factors such as materials, history, and making process. For this study, we categorize the jewelry into five main styles based on the main characteristics of jewelry and name them by the customer groups. Each style is described as follows.

1) American Style: Jewelry products generally are made in large size decorative with gemstones and diamonds.

Fig.1. Examples of American Jewelry Styles. Source: Jewelry Catalogue of Beauty Gems Company, Thailand [9].

2) European Style: In the case study, most of customers are in Germany and Italy that jewelry products in this style would be simpler comparing with American style. They mostly have been decorated with fewer gemstones and diamonds in smaller size comparing to American style. This style is relatively difficult to design because they need little decorative with higher creativity.

Fig.2. Examples of European Jewelry Styles. Source: Gioie, Italian Jewelers [10].

3) Japanese Style: This style mostly looks like European style with small size, simple design and decorate with pearls, fewer gemstones and diamonds, whereas superb quality is needed.

Fig.3. Examples of Japanese Jewelry Styles. Source: Jewelry Catalogue of Beauty Gems Company, Thailand [9].

4) Arab & Indian Style: This style is obvious and distinct, especially Tribal Indian. Jewelry products in this style generally are large size and decorate with a large number of gemstones. They are composed of many components that assembled together. Every components or assemblies firstly are produced and then combined to the main parts using assembly technique in the production process, which is relatively difficult.

Fig.4. Examples of Arab & Indian Jewelry Styles. Source: Crafts in India, www.craftsinindia.com, New Delhi, India [11] and www.arabicnews.com.

5) Antique Style: To design the antique styles, designers have to learn and understand about history, culture, and tradition in each area for capturing the concepts, evolutions and developments of each style in different area. The antique style thus is relatively difficult to design, draw, and paint, because it needs deep details.

Fig.5. Examples of Antique Jewelry Styles. Source: Antique Jewelry, Antiquing On Line [12].

3.3 Jewelry Types

The jewelry products generally could be categorized into 7 types, which as in table 2.

3.4 Casting Materials

There are several casting metals used in the jewelry casting process, this study considers only some materials shown in table 2. These metals are used in the main

proportions, which are mixed with specific alloys to obtain several mixture grades and casting's weights.

3.5 Gemstone Types

Several gemstone types are used to decorate on the castings. Some types are the genuine gemstone and the others are the synthetic gemstone shown in table 2.

3.6 Gem's Sizes

Another important factor in the conceptual jewelry design process is the gem's size. Gem's size is various depending on the design, the size of casting, the manufacturing process, etc.

3.7 Jewelry Making Techniques and Process

Most of jewelry designers have the knowledge of jewelry manufacturing process, but not in details. In some case, the jewelry designs are limited by some constraints of manufacturing process. Thus, designers require an assistant tool that provides the information of the manufacturing process of their designs.

3.8 Cost of Jewelry Products

Mostly, marketing and finance sections take responsibility in pricing and cost modeling. In some case, not only the design of product, price of product also influences on customers' decision making to buy. When price is one of the design factors, it is essential for designers to know how much the cost of their jewelry designs. This is to avoid the iterative design.

Jewelry Classes	Precious Jewelry, Costume Jewelry
Jewelry Styles	American, European, Japanese, Arab& Indian, Antique
Jewelry Types	Ring, Earring, Bangle, Bracelet, Brooch, Pendant, Necklace
Casting Materials	Platinum, Gold 18 Karat, Gold 14 Karat, Silver
Gemstone Types	Diamond, Amber, Pearl, Emerald, Agate, Sapphire
Gem Sizes	0.1, 0.2, 0.3, 0.4, 1, etc. (carats)

Tab. 2. Summary of jewelry variations in jewelry design.

4. THE ARCHITECTURE OF INTELLIGENT SYSTEM FOR JEWELRY DESIGN

The architecture of the proposed system consists of seven main elements: Knowledge Base, Explanation Facility, User Interface, Working Memory, Design Module, Manufacturing Process Module, and Cost Module. The relationships among those elements are illustrated in Fig.6.

Knowledge Base contains the knowledge used in conceptual design stage that consists of jewelry catalogue, manufacturing process, and estimating cost, shown in Fig.7. Each unit in KB consists of three main knowledge types:

- Jewelry design stored in JPEG format and CAD file,
- Manufacturing process required for that design,
- Estimating cost of that design from the related costs (such as material cost and manufacturing cost).

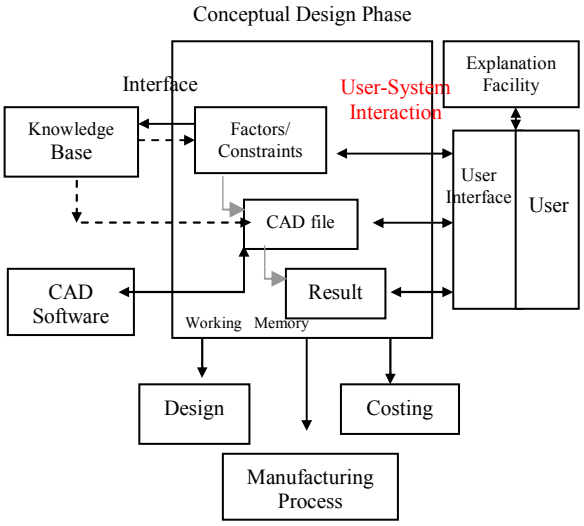

Fig.6. The architecture of intelligent design system.

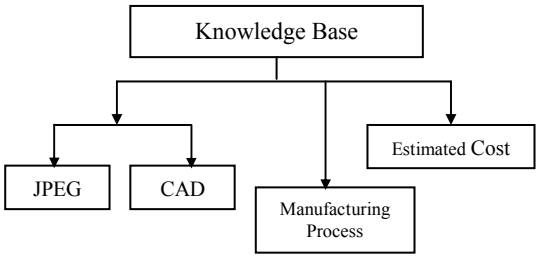

Fig.7. Knowledge Base and its components.

The overall procedure of the proposed methodology is illustrated in Fig.8 and briefly summarized as follow. In the conceptual design phase, the system allows designer to input design preferences through the design module. KB uses this design consideration to solve the design problems, and provides the alternatives in form of JPEG format. When designer choose any alternative, the system then retrieves CAD file, of that alternative, from KB and links to CAD software, which allows designer to manipulate the designs in 2D and 3D.

As designer obtains the desired design, he/she can retrieve the information of manufacturing process and estimated cost from KB.
The concept of the proposed methodology is described in the next section.

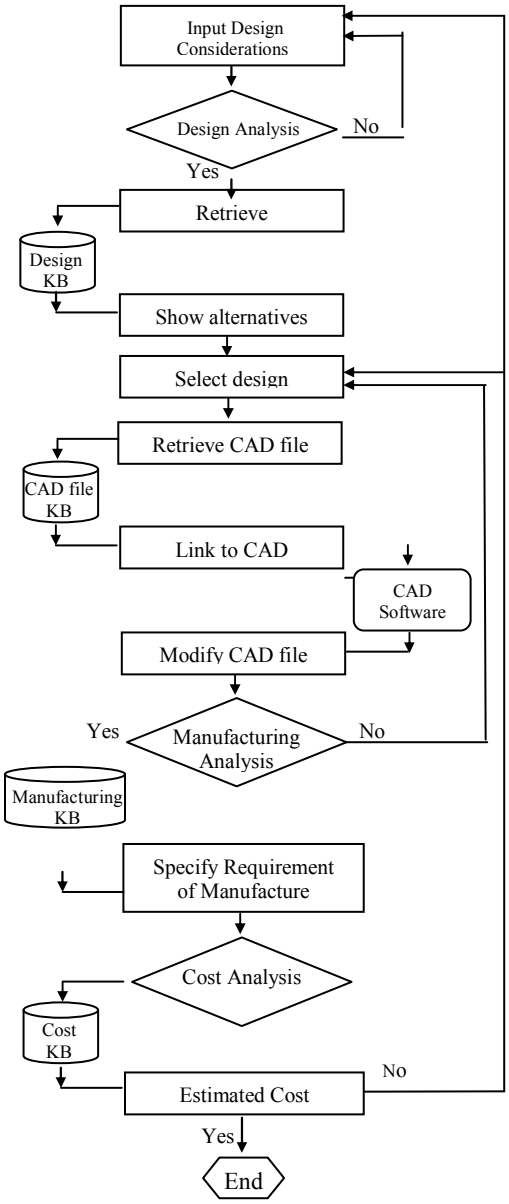

Fig.8. The overall procedure flowchart of the proposed methodology.

5. BUILDING INTELLIGENT SYSTEM FOR JEWELRY DESIGN

Based on the principles and architecture from the previous sections, the intelligent system prototype is developed for supporting the conceptual design stage in jewelry design process. The intelligent system can be developed base on ES. The integration of design, manufacturing, and costing can be implemented by using a blackboard structure with multiple cooperative knowledge-based systems and multi-agent design systems. Agents can be employed for representing the intelligent systems that can be designed in the example as below:
Agent 1: The Conceptual Design System.
Agent 2: CAD Tools.
Agent 3: Design for Manufacturing.
Agent 4: Costing Models.
etc.

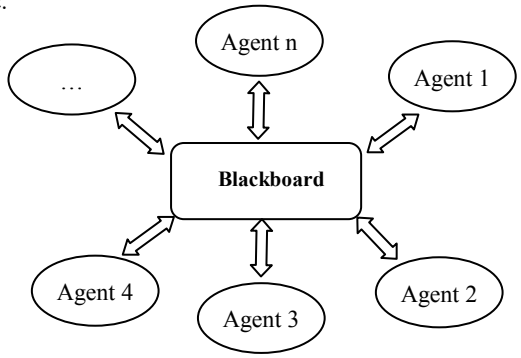

Fig. 9. The integration of design, manufacturing, and costing.

From the problem characteristics, the problem solving technique is used in this study based on the idea of using of solutions to previous problems for solving new ones or case-based reasoning [18]. This technique is similar to the aspect of human reasoning, which refer to past experiences for guidance in solving the current problems. Then, the previous designs include their information are stored in case base. The system analyzes a problem and retrieves the store cases through the indexing system, then, match the current problem constraints. If a retrieved case or solution is not match in the range, it requires modifying the case. In case, the case is not adequate, it requires establishing the new cases to cover more problems.

6. CONCEPT ILLUSTRATION

In this section, the example of ring design is demonstrated to explain the concept of the intelligent system. Starting from the first module of the system is the design module, shown in Fig.11.

Fig.10. JewelXpert: Expert system for Jewelry Design.

The system requires the design considerations used in conceptual design phase via the design module. In this example, the design factors input to the system are:-

Jewelry Class:	Semi-Precious
Jewelry Type:	Ring
Jewelry Style:	American
Gem Type:	Diamond
Gem Size:	0.2 carat
Metal used:	Gold 18 karat
Price of Product:	41-60 $

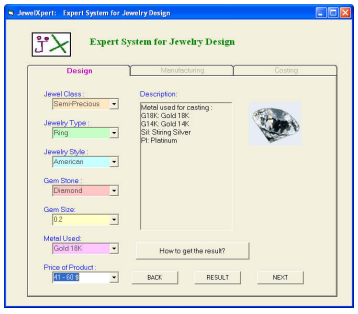

Fig.11. Design Module: user inputs design considerations used in conceptual design phase.

Fig.12. The result from the input factors in conceptual design phase. Ring pictures from jewelry catalogue of Beauty Gems Company [9].

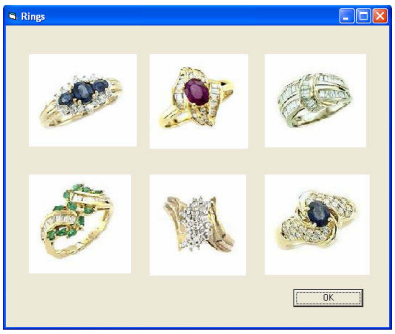

Fig.13. Other alternatives of the same factors. Ring pictures from jewelry catalogue of Beauty Gems Company [9].

After the user inputs the design factor, the constraint-based design technique generates the result that shows in Fig.12 and other alternatives in Fig.13. The system can be linked to CAD software and allows the user to manipulate any alternatives, see in Fig.14.

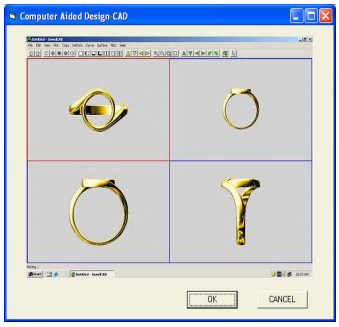

Fig.14. Retrieve CAD file and link to CAD software. Picture from JewelCAD Software [13].

After obtaining the desired design, the user can go to the next module, 'Manufacturing' module. In this module, on-screen shows the jewelry manufacturing process of the selected design, see in Fig.15.

The next module is 'Costing', which requires information of the customer class and number of lot size to estimate 'cost of the product', see in Fig. 16 and 17.

After the user satisfied and finished all steps in the system, he or she can save the information of the new design into the database inside or outside KB of the system, see in Fig.18.

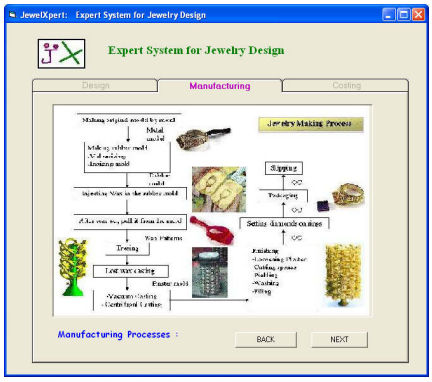

Fig.15. Specify requirement of manufacturing process. Picture from [14], [15], [16], [17].

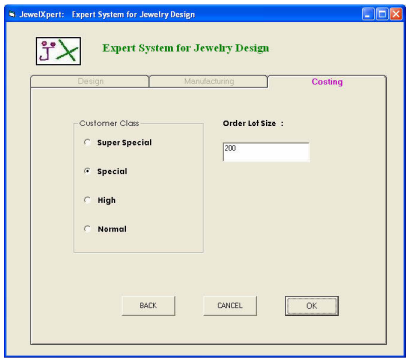

Fig.16. Costing module requires information of customer class and number of lot size.

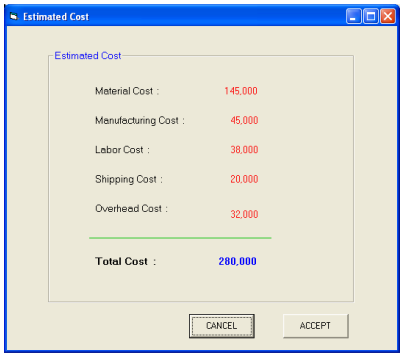

Fig.17. Estimated cost of the selected design.

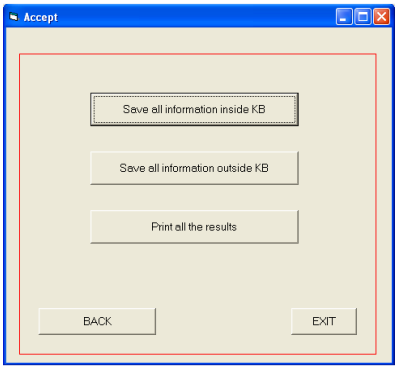

Fig.18. The new design can be saved in database inside or outside KB of the system.

7. CONCLUSIONS

This paper proposes the framework of the intelligent computer system for supporting the jewelry design, which can be used since the conceptual design stage. The system is developed to improve the efficiency of product development process. The proposed system adopt CE concept, as a result, the system functions cover design, manufacturing process, and costing. The system assists a designer to explore alternatives and generate designs with his/her style, from some design preferences and constraints in the conceptual design phase.

The system serves as a tool in the conceptual design phase and enlarge CAD process to cover the conceptual design phase that can compress time to find, search, and collect information and offers designers to work on it. As a result, designers can rapidly transfer their conceptual design ideas and approved product modeling into CAD packages to promptly realize detailed design and manufacturing process. The system also provides the information of manufacturing process and estimate cost of the selected design for design consideration.

The proposed system is in the development stage and still requires some improvements in design, manufacturing and costing modules, which each needs to be deeply studied. The system also can be developed base on other intelligent technologies to improve the system efficiency.

8. ACKNOWLEDGEMENTS

The authors would like to thank Cifac Company Limited, Bangkok, Thailand, for their supporting the useful and valuable information of jewelry design, manufacturing process, and costing. Without the

supports from the company, this research might be incomplete.

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