Optimizing Product Design in Cyberspace through Knowledge Mining Agents

Steven H. Kim, Hwa-Gyoo Park**, BongSug Chae*, SungWoo Shin*, TaeJong Lee**

* Korea Advanced Institute of Science and Technology, Seoul, Korea
** Electronic and Telecommunications Research Institute, Taejon, Korea

skim@msd.kaist.ac.kr

ABASTRACT

The rapid diffusion of the Internet and the World Wide Web is facilitating greater interaction - and potential opportunities for customization - between vendors and customers. For instance, virtual reality and multimedia technologies allow consumers to envision their designed products.

The increasing pace of the business environment highlights the need to deploy intelligent systems in all stages of product design and production planning. This paper deals with a system to generate an appropriate product design by adapting customer preferences and constraints using the case based reasoning methodology. Moreover, intelligent agents are integrated with virtual reality technology to provide a friendly user interface.

ACKNOWLEGEMENT This work was funded in part by the Electronic and Telecommunications Research Institute through Grant No. 98-16-P00540.

INTRODUCTION

In the past decade the business environment has changed dramatically. The world has become a small and dynamic marketplace as never before. This has put a tremendous demand on vendors to (1) lower total costs throughout the manufacturing process, (2) enlarge their portfolio of products, (3) improve product quality, (4) provide more responsive customer service, and (5) efficiently coordinate global demand, supply and production. To complicate matters, product lifecycles have become increasingly brief as a result of technological change and customer expectations.

A new paradigm, mass customization, is emerging in parallel with the traditional mode of mass production. This new paradigm allows consumers to design their own products and manufacturers to individualize their offerings. In addition, the rapid diffusion of the Internet and the World Wide Web is facilitating greater interaction - and potential opportunities for customization - between vendors and customers. For instance, virtual reality and multimedia technologies allow consumers to envision their designed products before actual fabrication or delivery.

The increasing pace of the business environment and the complexity of manufacturing processes highlight the need to deploy intelligent systems in all stages of product design, production planning and distribution. The goal of our system is to generate an appropriate product design by adapting customer preferences and constraints using the case based reasoning methodology. Moreover, intelligent agents can be integrated with virtual reality technology to provide a friendly user interface.

For concreteness, the concepts are presented primarily in the context of a software agent for designing a personal computer (PC). However, the key ideas are generic and therefore applicable to any product domain.

BACKGROUND

Many systems have been developed to support product design and process planning through artificial intelligence. In particular, expert systems have been adopted for automating product design and process planning in manufacturing industry.

However, the rigidity of the rule-based approach is inadequate for a rapidly changing environment. In a dynamic milieu, an effective

system must learn to accommodate novel requirements and constraints. Ultimately, a system must be able to provide a new product design automatically in accordance with customers' requirements.

Case based reasoning. Perhaps one of the most versatile approaches to learning in practical domains lies in case-based reasoning. Case based reasoning enables a software agent to learn from the experience of human planners and to update its domain knowledge dynamically. It also allows customers to obtain a product best tailed to his requirements and constraints.

Market segmentation. Market segmentation is the process of dividing a total market (e.g., the world or Korea) into market segments or groups consisting of individuals, groups, or organizations that have relatively similar product needs. A typical market segment is characterized by key factors relating to customer behavior like geography, requirements, demographics (e.g., age and gender), usage rate, and psychographics (e.g., motives, personality, and lifestyles).

WWW and multimedia. The Internet and its associated technologies have given rise to a new communication medium. Product design and distribution via the Internet is playing an increasingly important role in electronic commerce, and further increases in sales volumes are expected. Intranets utilize the same technology as the Internet to enable communication among an organization's employees, while extranets facilitate interaction with external partners and vendors. On the information highway, knowledge is available in diverse formats ranging from text to virtual reality.

Intelligent multimedia systems. An intelligent multimedia system combines multimedia with various technologies such as artificial intelligence, databases, computer networks and domain knowledge. The need for intelligent systems for multimedia design springs from the fact that material is being loaded onto online databases at a rapid rate. In addition to the sheer volume of material, the knowledge is available in diverse formats ranging from text to audio, and from video to virtual reality (VR).

CASE STUDY

Product Design & Database Marketing. The increasing pace of business and the globalization of markets has led to increased challenges for product vendors. In this dynamic environment, a manufacturer must strive to maintain a competitive edge through various strategies including the following:

- Reduction of product design time
- Reduction of process planning time
- Cost reductions
- Accelerated throughput
- Increased accuracy and consistency
- Increased flexibility in design and fabrication

The complexity of the marketing and manufacturing environment highlights the need to deploy a learning system for product design and process planning.

In this study, the realm of PCs is employed to illustrate how a learning system can support the task of product design. Much of the discussion focuses on the synthesis phase, involving the transformation of user requirements into a product configuration. For greater clarity, the discussion focuses on the design of a personal computer.

In the context of personal computers, customers have diverse needs. For instance, a student may desire a computer at a low price even if it entails a limited level of performance. On the other hand, a professional designer is likely to require a machine with high performance; price may be of little concern. Even for a particular type of customer, however, different individuals have differing requirements.

Implementation in Virtual Reality. To date, virtual shopping malls on the Internet have relied primarily on 2-D graphics. However, a better approach utilizes the 3-D capabilities of virtual reality which offers consumers more realistic renditions of the products at hand.

To illustrate, consider the selection of a 17'' monitor by the knowledge system. The device can be displayed using virtual reality capabilities to provide a more "solid" impression to the customer than can be achieved solely through 2-D techniques.

Due to current limitations in computer processing power, VRML browsers render objects with only partial realism. For instance, curved surfaces are portrayed through a fine – but perceptibly granular – mesh of polygonal surfaces. However, limitations such as this are an artifact of hardware speed rather than inherent drawbacks of virtual reality techniques. In the years ahead, rapid advances in hardware as well as improved

algorithms will lead to increasing realism rendered for the user in real time.

Methodology. Case based reasoning was selected for use in this study because of its flexibility. First, CBR is closely related to human learning: people take account of observations and utilize them for future decision making. Second, the CBR methodology can be effective even if the knowledge base is imperfect. Certain techniques of automated learning, such as explanation-based learning, work well only if a strong domain theory exists. In contrast, CBR can use many examples to overcome the gaps in a weak domain theory while still taking advantage of the domain theory. CBR can also be used when the descriptions of the cases, as well as the domain theory, are incomplete. Third, CBR is the relative ease of combining techniques with other approaches. An example of such compatibility is a system which uses case reasoning to solve problems whenever possible; otherwise it resorts to heuristics to decompose a problem into a simple one (Maher, 1991).

On the other hand, the limitation of CBR is its susceptibility to the misinterpretation of the knowledge in its case base. This is a perennial hazard in any field of endeavor, automated or otherwise. One way to address the problem in CBR is to encode deeper-level domain knowledge in addition to the surface features of various cases.

Case retrieval and adaptation are essential functions in case-based reasoning systems (Kolodner, 1985). Retrieval refers to the identification of a particular case from memory.

The data set used for this study consisted of a total of 55 cases. Of these, 35 cases were used for the training set and the remaining 20 cases are used for the target set. The data set incorporated three broad categories of features: demographic factors, user requirements and brand loyalty. The demographic category included sex, age, income level, occupation, and educational level. The category of user requirements included price, performance, design and after-sale service. Because of its singular importance, the final category consisted of a single factor: brand loyalty.

Experimental Results. The design system analyzes a set of user requirements and demographic characteristics obtained through on-line interaction. The system recommends a PC design based on precedent cases. The system is designed to provide a graphic interface using virtual reality.

The performance of the CBR system is presented in Table 1. For instance, the final row in the table indicates that the population based approach using 3 candidates yielded a hit rate which was 20 percent higher than the solitary or individual approach. The outcome indicates that the population based approach outperformed the solitary approach for each of the three scenarios in the table.

CONCLUSION

A learning system was constructed for use in the design of custom-built computer systems. This study indicates that case based reasoning is a highly pertinent approach for the task of design. The study shows that case-based reasoning for product configuration provides an attractive paradigm for product design: the system improves the effectiveness of the designer by applying old experiences to solving new problems.

The problem domain in this study - custom-built computer systems - is a relatively simple domain in the industrial realm. A promising direction for the future is to apply the learning system to more complex domains and to produce a full-fledged adaptive system for product design and process planning.

REFERENCES

Britanik, J. and Marefat, M. "Case-Based Manufacturing Process Planning with Integrated Support for Knowledge Sharing." Proceedings of ISATP'95, 1995: 1-14.

Kim, S. H., Designing Intelligence, Oxford University Press, 1990.

Kim, S. H., Learning and Coordination. Dordrecht, Kluwer, Netherlands, 1994b.

Kim, S. H. and M. B. Novick, "Using Clustering Techniques to Support Case Reasoning". International J. of computer Applications in Technology, Vol. 6, Number 2/3, 1993, pp. 57-73.

Kolodner, J. L. Case-Based Reasoning. Morgan Kaufmann Publishers, Inc., 1993.

Maher, M.L. (1991) "Machine Learning in Design Expert Systems", in J. Leibowitz (ed.), *Expert Systems World Congress Proceedings,* Volume 1, Pergamon Press, pp.728-736.

Tsatsoulis, C. and Kashyap, R.L. A Case-based System for Process Planning. Robotics and Computer-Integrated Manufacturing,

4(3/4):557-570, 1988.
Watson, Ian. Applying Case–Based Reasoning Techniques for Enterprise Systems. Los altos, CA: Morgan Kaufmann Publishers, 1997.
Zdrahal, Z., and J. Domingue, "The World Wide Design Lab: An Environment for distributed Collaborative Design", Proc. International Conference on Engineering Design, Tampere, Finland, August, 1997, "http://kmi.open.ac.uk/kmi-abstracts/kmi-tr-45-abstract.html".

< Table 1> Accuracy of clustering versus solitary approaches using case based reasoning.

Candidates	Population based Approach	Individual based Approach	Superiority
1	75%	45%	30%
2	85%	65%	20%
3	95%	75%	20%