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Design Distribution and Evaluation Model for Collaborative Design Chain

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Abstract: A collaborative design chain incorporates the different design activities performed by various design teams that may be located at different geographical locations. In a collaborative design chain, the different parts of a product can be designed by different design teams in a collaborative way. There exist different ways for distributing the different parts to the multiple design teams. If different ways are used for distributing the different part, the time for completing the design and the final functions of the product may vary. In this research, a design evaluation model for evaluating the collaborative design chain is presented. The presented new model is aimed at finding the best way for distributing the different parts to the suitable design teams such that the designed functional value of the product can be maximized. Also, the design cost composed of design operation cost and design communication cost in collaborative design is minimized. An optimized design distribution and evaluation model is presented by maximizing the total design value which is defined as the designed functional value minus the design operation cost and the design communication cost. Implementation and test results are presented.

Keywords: Collaborative commerce; SCM; Collaborative design; Design chain; Multi-plant

I. Introduction

With emerging e-business models in a global supply chain, the demand of new products from customers is growing and the time to market for a new product is shortening. As a result, the demand of new products with more new functions is increasing. In addition, the design cycle time for designing a new product needs to be reduced.

To satisfy the above demands, collaborative commerce models are introduced. In a collaborative design model, the different parts of a product can be distributed and designed by different design teams at multiple sites at various geographical locations. The main idea is that the different portion of a product can be assigned to a suitable design team which is specialized in designing the portion. In this way, the functions of the final product can be enhanced since each portion is designed by a specialized design team. Moreover, the design operations can be shared by the multiple design teams in a concurrent way to reduce the design time. The purpose of collaborative design is to distribute the design tasks to the suitable design teams to achieve the objectives of reducing design time and increasing product functional value.

A collaborative design chain integrates different design activities performed by various design teams in order to complete the final product. The design activities mainly include design operations and design communications required for performing the design tasks. In a collaborative design chain, there may be certain added value that can be gained as a result of a collaborated design activity. Also, there may be additional cost generated because of a collaborated design activity. The value and cost created by the collaborated design activities and the multiple design teams may be more complicated than a single design team. Therefore, the gained value and the additional cost occurred in a collaborative design chain need to analyzed and evaluated.

In this research, the total design value of a designed product can be evaluated by two main categories, the functional value that the designed product creates and the design cost that takes to produce the designed product.

The functional value of a designed product is created by the functions that the product can perform. If there is a good or a special function required by the customers, then the product can sell with a higher price. Therefore, it is a goal that the functional value can be increased.

However, a good functional value may be the result of a higher design effort. Therefore, more design operation time and more design communication may be needed in this type of a collaborative design model. Since a collaborative design chain is composed of different design teams, if a product is designed by different combinations, the product functional performance may be different. Also, because the different design teams may design the product differently, different design communication time may be required.

Therefore, for a collaborative design chain, it requires a systematic way to evaluate the total design value of the designed product. In this research, the total design value is defined by the designed functional value, the design operation cost and the design communication cost. This is represented as total design value = designed functional value – design operation cost – design communication cost. It is the purpose of the research to distribute the design tasks to the suitable design teams such that the total design value can be maximized. This can be represented as

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Max $\{D = (F - T - C)\}$,

where D = total design value,

F = designed functional value,

T = design operation cost,

C = design communication cost,

In the related research by Kvan [5], the meaning of collaborative design and computer-supported collaborated design is discussed. A recent review by Fuh and Nee [3] summaries the related works using the distributed CAD approaches using the latest IT tools to support the collaborative design activities. A comprehensive review of related work in research and development of software tools and methodologies to support distributed and collaborative design can be found in Li et al. [6]. Recent research focuses on three main topics: visualization of 3D CAD models, co-modeling of 3D CAD models, and developing distributed design environment. The related research work can be found in a web-based conceptual design prototype system presented by Qin et al. [8], a collaborative product conceptualization tool using web technology by Roy and Kodkani [10], a feature-based collaborative design by Wang et al. [13], a distributed object model for collaborative CAD environments by Barbosa et al. [1], and a process-oriented intelligent collaborative product design system, by Li et al. [7]. The related research by Tseng et al. [8] focuses on design module modeling and design task assignment in a collaborative design model.

Based on the review, previous research work focuses on developing a framework for communication of design and exchanging of data using the internet and web-based technology. Although much has been accomplished on the internet framework, it shows that little work has been done on the planning and evaluating aspect of a collaborative design process. It requires a planning and evaluating model for decision-making of a suitable way to distribute the different parts such that the cost and functional performance of the collaborative design chain can be optimized. This research presents an evaluation model for a collaborative design chain for distributing design tasks to available design teams with a maximized total design value.

II. Design Task Distribution and Design Evaluation Model

The concept of maximizing total design value can be formulate as follows. To formulate the problem under investigation, the following notations are used.

Notations:

n : design task,

k_n : part in a product,

d : design team,

p : designer,

P_{G_d} : designer in design team d ,

$T_{pn(k_n)}$: the design communication cost,

$C_{pn(k_n)}$: the design operation cost,

$F_{pn(k_n)}$: the functional value (same unit with cost) obtained,

$x_{pn(k_n)}$: decision variable,

a_{nd} :decision variable ,

Objective function:

$$\max \sum_n \sum_d \sum_p \sum_{k_n} a_{nd} \times x_{pn(k_n)} \times F_{pn(k_n)} - \sum_n \sum_d \sum_p \sum_{k_n} a_{nd} \times x_{pn(k_n)} \times T_{pn(k_n)} - \sum_n \sum_d \sum_p \sum_{k_n} a_{nd} \times x_{pn(k_n)} \times C_{pn(k_n)} \quad (1)$$

Constraints:

$$\sum_p \sum_n \sum_{k_n} x_{pn(k_n)} \times C_{pn(k_n)} \le 1$$

$$F_{pn(k_n)} \ge 0$$

$$T_{pn(k_n)} \ge 0$$

$$C_{pn(k_n)} \ge 0$$

$$\sum_d a_{nd} \times (\sum_p x_{pnk_n} \mid p \in P_{G_d}) = 1$$

$$\sum_d a_{nd} = 1$$

$$\sum_n \sum_{k_n} x_{pn(k_n)} = 1$$

$$a_{nd}, x_{pn(k_n)} \in 0,1$$

The model is formulated with an objective of maximizing total design value which is defined as the designed functional value minus the design operation cost and minus the design communication cost.

The output information of the model is as follows:

1. The designer in a design team assigned to design a part,
2. The design completion time for designing all the parts in a module,
3. The design completion time for designing the product
4. The final product functional value.

III. Implementation And Test Results

Test software system has been developed on a personal computer to implement and test the presented model.

Several example products are tested. In this section, a mobile phone is used as an example product to show the model and the tested results in this study.

With the input information of the example product, the design distribution and evaluation model is performed. The model is solved using a linear programming solution method. The final results of design evaluation and distribution are shown in Table 1.

According to the model developed in the study, a maximized total design value can be obtained. From the example, it shows that the developed model presents a feasible evaluation method with an optimized result. It is observed that in practical cases, the presented model can be useful for most common commercial products to achieve the objectives.

IV. Conclusion

In a collaborative commerce model, a design may be distributed and performed by different design teams in a collaborative design chain. In this paper, a design evaluation model for evaluating the collaborative design chain is presented. In a collaborative design chain, different ways for distributing the parts of a product to multiple design teams may result in different design completion time and different product functional performance. In this research, the value and cost issues in a collaborative design chain are identified and defined. Based on the value and cost issues, an evaluation model is developed. The presented new model is aimed at finding the best way for distributing the different parts to the suitable design teams such that the designed functional value of the product can be maximized. An optimized design distribution can be obtained by maximizing the total design value which is defined as the designed functional value minus the design operation cost and minus the design communication cost. In future research, a more complete model can be developed with more detailed value and cost objectives for evaluating collaborative design chains.

Table 1. Test results of the example product.

Design task n	Part (k_n)	Part name	Designer (p)	Design team (d)
1	1	Upper case	P_1	D_1
	2	Back case	P_4	
	3	Keyboard	P_5	
2	4	Keyboard conductor	P_5	D_1
	5	Keyboard controller	P_2	
3	6	Earphone	P_9	D_2
	7	Speaker	P_9	
4	8	Microphone	P_{19}	D_4
	9	Power switch	P_{18}	
	10	Vibrator	P_{20}	
5	11	Battery	P_{10}	D_2
6	16	SIM card frame	P_{11}	D_3
7	12	LCD	P_{21}	D_5
	13	FPC	P_{24}	
	14	Backend IC	P_{25}	
8	15	PCB	P_{14}	D_3

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