Knowledge-based Class Analysis for building Quality Function Deployment

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Abstract

This paper presents a knowledge-based approach for constructing, classifying and managing HOQ charts in QFD. A HOQ chart base classified by similar cases of QFD is analyzed together to reduce the time and effort when we develop a series of HOQ charts to design a new product. Rule typed knowledge base is used for retrieve a similar HOQ chart for a new product.

1. INTRODUCTION

Many firms are facing rapid changes due to technological innovations and changing customer demands. Getting high-quality products to customers in a timely manner is crucial for their survival and prosperity in the competitive marketplace. Quality function deployment (QFD) is a new product development process which stresses cross-functional integration. QFD brings various advantages to companies such as fewer and earlier design changes, reduced product development cycle time, fewer startup problems, and above all, customer satisfaction. QFD is accomplished through a series of charts , usually called a house of quality (HOQ), which are a conceptual map, providing the means for interfunctional communications. HOQ relates the variables associated with one design phase to the variables associated with the subsequent design phase.

There are many researches to support successful implementation of QFD. An analytic hierarchy process(AHP) framework has been established for prioritizing customer requirement[Armacost 1994]. An approach based on multiple-attribute decision analysis method has been introduced for the prioritization of engineering characteristics[Franceschini and Rossetto, 1995]. The concept of *Deployment normalization* was extended to properly account for dependency which may exist between engineering characteristics [Wasserman 1993]. Also, a few computerized QFD systems have been reported for managing the information contained in the HOQ charts. Hypertext-based system was developed to support group decision process during QFD planning process [Wolfe 1994]. Based on multi-criteria decision making model, a decision support system was developed [Moskowitz and Kim, 1997].

One of the major difficulties of QFD in practice, is the large size of the HOQ. Even for a simple product design, the size of a HOQ can grow very fast. This implies the need for a huge amount of time and effort to develop as well as fill out the HOQ chart. Notwithstanding the rapid growth of QFD methodologies on the specific procedure, development of efficient methodologies for developing the HOQ charts has scarcely been addressed. Thus, This paper suggests a knowledge based approach to build a HOQ chart for a new product. The main idea of our suggested methodology is as follows:

1. Similar products have similar attributes of HOQ charts like customer requirements, engineering characteristics, and so on. If similar HOQ charts are built into a same class, managing the HOQ charts is more efficient.
2. HOQ charts in the same class are classified into a rule tree according to their similarity degree. The main reason is to locate more similar charts nearby for the efficient selection.
3. IF-THEN typed knowledge retrieves the more similar HOQ chart from the selected class base for a new product. Based on the retrieved HOQ charts, human experts can modify the chart with ease. If one HOQ chart is not enough, more than two charts will be used for a new product. In that case, the criteria of selection is degree of similarity of a rule tree.
4. More QFD analysis is performed, the knowledge base and case base becomes more richer. That means more suitable HOQ chart(s) may be provided for a new product.

2. DECISION CLASS ANAYSIS

QFD is accomplished through a series of HOQ charts, so we regard HOQ charts of a specific product design problem as a QFD model of that problem. In most cases, the QFD model (i.e., HOQ charts) is usually applicable to only one specific design problem, even though developing QFD model needs much time and effort from multiple functional groups. However, we often investigate that some prior knowledge from the experience of developing a QFD model can be utilized to resolve other similar QFD situations. From this investigation, we can consider a class analysis to combine the prior knowledge so that we handle a set of similar QFD situations simultaneously. Although a concrete example or definition of *similarity* is not found[Holtzman 1989], QFD class concept would be helpful in modeling HOQ charts in an efficient way.

We suggest a class analysis which regards a QFD analysis as an integrator of QFD knowledge and treats a set of QFD having some degree of similarity as a single unit [Jung, et.al. 1992]. For this purpose, we should consider two problems: one is about how to define a class of decisions, and another one is about how to implement a decision class analysis. To solve a first problem, we develop a rule tree, which represents a set of similar QFDs at a taxonomy hierarchy. And for the second problem, IF-THEN typed knowledge based approach is suggested.

2.2 Defining a class of similar QFD cases

Products are characterized by n attributes such that an individual product is completely characterized by its attribute values; that is, a product p is structured by n tuple $(d_1, d_2, ..., d_n)$ of attribute values. Let D_i be the domain of a_i, which is the set of legal values for a_i. A domain is called an *ordered domain* if a strict total ordering relation is defined on it. For instance, a domain of the set of integer numbers is an order domain, on which a strict total ordering relation '>' is defined. A domain is called a *clustered domain* if a directed tree structure is defined on it. For instance, suppose products have an attribute denoting the television set, whose domain contains values of customer's age, customer's monthly income, market region, and so on.

Designing a decision class involves many trade-offs. If the decision class is too narrowly defined, it will represent too few individual products; if it is defined in a general manner, its corresponding class analysis will lose the benefits of domain specificity and may be prohibited expensively. Therefore, it is necessary to design a decision class that is neither too restrictive nor too comprehensive.

2.3 Construct a rule tree for the class

Each product has a number of attributes and can be classified into a particular subclass. The induction algorithm or splitting algorithm attempts to find a tree of rules (in the form of IF ... THEN clauses) which will correctly classify all the products on the basis of their attribute values. In this research, STIG (Splitting using Total Information Gain) algorithm [Kim, et al 1993] is used to construct a rule tree. Figure 1 illustrates the rule tree of the domain of television.

3. A PROCEDURE

This paper suggests a knowledge-based methodology to implement a class analysis of QFD. The methodology is consists of the following five phases:

Phase 1: Build a class of similar QFD cases.
Products are characterized by attributes like customer's age, customer's monthly income, market region, etc such that an individual product is characterized by its attribute values.

Phase 2: Construct a rule tree for the class
Each product has a number of attributes and can be classified into a particular subclass. STIG algorithm [Kim, et al 1993] is used to construct a IF-THEN typed rule tree.

Phase 3: Classification of a new QFD situation into a proper class using a rule tree.
IF-THEN typed knowledge retrieves the very similar HOQ charts from the selected class base with a new product .

Phase 4: Based on the retrieved HOQ chart, human experts can modify HOQ charts with ease.
The retrieved HOQ charts have proper customer requirements and engineering characteristics for the new product, but some part of them may be modified or deleted. New requirements and characteristics may be added. With the retrieved HOQ chart, human expert can save time and effort at a considerable amount.

Phase 5: Updating the class base, knowledge base, and data base by adding a new generated HOQ chart to the class for the later use.

4. AN ILLUSTRATIVE EXAMPLE

To illustrate a proposed procedure, we provide a supposed data of television, which is contained in the following Table 1. The last column indicates the class, QFD model. The remaining column names identify the attributes to be used in arriving at a classification decision. Each row of the table represents one example.

Table 1. An illustrative example set of QFD model for television

Example No.	Attributes						Class
	customer's age	monthly income	usage	existence of competitor	satisfaction factor	region	QFD model
1	50	300	H	E	P	KO	WM32
2	40	400	H	N	F	AS	WM32
3	50	400	O	E	F	AS	WM32
4	30	300	H	N	A	EU	W24
5	30	200	O	E	S	AM	W24
6	20	200	H	E	P	KO	G24
7	20	100	H	N	A	KO	G24
8	20	100	H	E	A	EU	G24
9	30	200	H	E	P	EU	G32
10	40	200	H	N	F	AM	G32

Marketing strategies for a new product are to be used as attributes of QFD model. We divide the marketing strategies into six factors that is presented in Table 1. Customer's age is divided into five categories, 10(below 20 years), 20(from 20 years to 30 years), ... , 50(above 50 years). Customer's monthly income is divided into five categories 1(below $1,000), 2(from $2,000 to $3000), ... , 5(above $6000). Usage of the product is grouped into two division, H(to be used at home) and O(to be used at office, etc). Existence of competitor for the product is divided into E(exist one or more product that is similar to a new product to be developed) and N(not-exist). Customer satisfaction factor customer satisfaction factor which motivate the customer to buy the product is divided by four factor, A(appearance), F(function of TV), A(additional function), S(screen quality) and P(price). Region in that the product is sold is grouped into four categories, KO(Korea), AS(Asia), EU(Europe), AM(America)

The stopping rule of existing studies about ID3 test each subclass whether more splits are possible, until only one terminal subclasses remain. Although these stopping rules constitute reasonable heuristics, they may create many problems if used alone. As these stopping rules only consider whether the splitting of each subclass is statistically significant or not, it may produce a biased or bushy rule-tree, so that it is necessary to control the size, the level and the number of terminal subclasses of a resulting rule-tree. Because STIG algorithm has a supplementary stopping rule which considers the total amount of information gain(or reduction of uncertainty), it is suitable for our purpose. A resulting rule-tree of a set of examples of Table 1. is displayed in Fig 1. A set of production rules derived from the rule-tree generated from STIG algorithm are shown in Fig. 2..

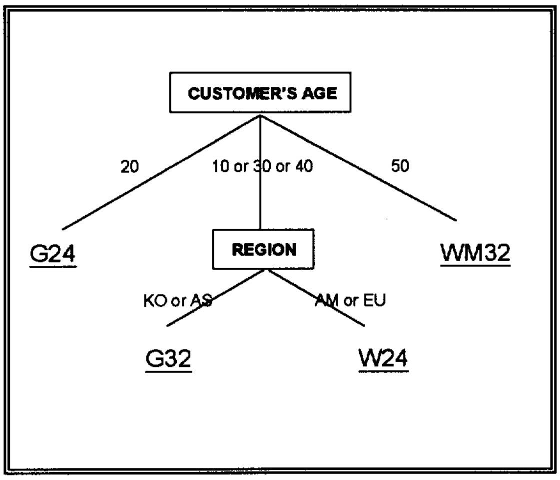

Fig. 1. Rule Tree generated by STIG

Rule 1 : IF Customer's age is 20
THEN QFD model is G24

Rule 2 : IF Customer's age is 10 or 30 or 40
AND Region is KO or AS
THEN QFD model is G32

Rule 3 : IF Customer's age is 10 or 30 or 40
AND Region is AM or EU
THEN QFD model is W24

Rule 4 : IF Customer's age is 50
THEN QFD model is WM32

Fig. 2. Rule-base from the rule tree

5. CONCLUSIONS

This paper suggests a knowledge-based methodology that is able to build HOQ chart during the new product development process. In a situation of new product development, many similar QFD cases developed previously will be used effectively. We use marketing strategies as the attributes that is to classify QFD models. However, the attributes presented in the above section is not enough to represent all aspects of marketing strategy. It is a current tendency to develop a new product from the market data. So our suggested methodology implies that developing HOQ charts starts from the customer's requirement of similar products.

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