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Mining the Customer's Voice and Patent Data for Strategic Product Quality Function Deployment

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Abstract. The goal of research and development for new product and service development is to satisfy customers. A company that satisfies customers with short life cycle products like smartphones that match or exceed expectations builds brand equity and a global competitive advantage. Companies are challenged with the task of identifying the market demand that evolves with technological innovations. Since many of the short product life cycle communications products are continuously changing, capturing and measuring the satisfaction of customers is increasingly difficult. One approach to accurately identify market demand and customer satisfaction with the functions of products is to listen to what is said among social networks. The Internet has empowered customers to express their opinions, attitudes, beliefs, and purchase intentions about products using community platforms, social media, customer blogs, and other networks. The words, expressed on these platforms, represent the voice of customers and provide collective and dynamic intelligence about the users' purchase intentions as well as experience using the products. Patent documents disclose the technological evolutions of a domain, and contribute to the features and characteristics of products that differentiate between brands and build customer expectations and loyalty. This research proposes a systematic methodology to combine collective intelligence using Internet web crawling and text mining to access the voice of customers. Patent information (retrieved from global patent search engines and analytic function mining of the patent content) provides critical information for planning strategic product repositioning and improvements that match the voice of customers and increase brand loyalty. The systematic extended QFD approach provides intelligent and dynamic demand-compliant strategies for developing new products and services.

Keywords. Patent analysis, Web-mining, Quality Function Deployment (QFD)

Introduction

For short life cycle products (e.g., smartphones), market demand is constantly changing with the rapid development of technology. Global enterprises face increasingly fierce competition and successful research and development strategies are critical. The goals of R&D for new products and services is to satisfy the customers and increase brand

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loyalty. Customer demand is dynamic and elusive, and the means to identify the wants and needs of costumer requires new methods of insight.

The number of Internet users accounts for over 40 percent of the world's population [1]. E-business offers many different electronic commercial websites for customers to purchase products or services. The Internet enables customers to express their opinions, attitudes, beliefs, and purchase intentions about products through different community platforms, social media, customer blogs, and social networks. The comments expressed by customers on these platforms provide collective and dynamic intelligence about the customers' purchase intentions and experience using the products, and serve as an important reference for strategic business development.

The world is entering the era of a knowledge-based economy where innovation oriented enterprises that own and utilize intellectual property are more competitive than production oriented companies. Patent documents reveal the technological evolutions of a specific domain and describe the features and characteristics of products that differentiate between brands and build customer expectations and loyalty. Quality function deployment is useful for product design and uses the voice of customers to determine the characteristics of products through market research. The method allows a company to identify the most important product features and improve products according to the needs of customers.

R&D efforts often fail to achieve short term results since they are often slower than the many new product lifecycles. This research proposes a systematic methodology to combine collective intelligence using Internet web crawling and text mining to access the voice of customers. Analytic function mining of patent content provides critical information for strategic product repositioning and improvements that increase brand loyalty. The extended QFD methodology provides intelligent and dynamic demand compliant strategies for developing new products and services and shortens the R&D product development cycle.

1. Literature Review

In this section, the literature related to patent analysis, customer perception, latent semantic analysis, and quality function deployment are discussed. Patent analysis is used in the research methodology to understand the technical focus of a company. Studying the customer's perception and buying behavior (e.g., satisfaction and dissatisfaction) helps to establish whether the company's marketing and product positioning is consistent with the customers' preferences. Latent semantic analysis is used to calculate the correlation between the voice of customers and the engineering functions which are derived from an analysis of the trade literature and patents. Finally, quality function deployment visualizes the combined research analysis results.

1.1. Patent analysis

According to World Intellectual Property Organization (WIPO), patent documentation is rich in technical knowledge which record 90% to 95% of the world's commercial products' research and development results. By analyzing and studying patent documents, the time and cost of research and development can be reduced by almost 40%. Patents helps companies make decisions for the product, technology, and service development, and avoid infringement. Many scholars use patent analysis methods to

gain insight into market opportunities. Li et al. use technology roadmaps and patent analysis to explore Cisco's business ecosystem [2]. Suh and Park propose a patent and service oriented technology roadmap to assist research and innovation [3]. Ernst and Omland propose two innovative patent metrics, degree of market coverage and technology relevance. Market coverage considers the worldwide sales of products protected by patents, and the degree of technical relevance considers the number of patents cited as the benchmark index of the patent. The two indicators can be used to quantify the value of patent assets [4]. Trappey et al. propose a model of patent quality assessment by using principal component analysis (PCA) method to extract patent indicators [5]. Further, innovations and IPs are often driven by market demands. Their correlations are analyzed by researchers [6].

1.2. Customer perception

Customer perception is an important issue to consider in market strategy development [7]. Customer perception can be influenced through the process of identifying needs, finding solutions to satisfy these needs, making purchasing decisions, interpreting advertising messages, and taking actions to make a purchase. Customer perception can be divided into three stages, exposure, attention, and comprehension. The exposure stage describes humans react to an external stimulus in the environment. Vision, under different environments, cultures, and ages will cause different interpretations. Different products with sounds or music can deepen the impression of customers. The sense of touch allows customers to feel the texture of products. The attention stage refers to the customer's reaction to various stimuli. The customer's comprehension of the message provides meaning to the received information. After information processing, customers will remember their experiences and subsequentially influence their future decision making [8].

Horn and Salvendy [9] note that customer perception can be significantly influenced if the product innovation conveys a meaning of importance and novelty. Lee et al. develop an ontology-based intelligent system for automatically classifying customer complaints. Using a case study of restaurant service provision, a customer complaint handling system was created. The system identifies the similarity among customer complaints so that managers are better able to link the causes to the history of operations including sources of supply and staff management [10].

1.3. Latent semantic analysis

LSA assumes that the meaning of a word is determined by other words that appear simultaneously in the document, rather than from the literal meaning of the word. Using this algorithm, the semantic or conceptual relationships within a document are expressed by the frequencies of words within documents. LSA does not consider the grammatical structure or pre-defined lexical meaning which reduces the bias caused by human interpretation [11].

Foltz uses LSA to map the semantic relevance of vocabularies to the text in a document with good results [12]. Kireyev et al. and Ozsoy also use LSA in a similar manner to define semantic spaces. The results show that LSA is more effective than traditional indicators [13]-[14]. Luh et al. develop a ranking algorithm for estimating search engine efficiency based on LSA and genetic algorithms [15].

1.4. Quality function deployment

The QFD methodology is used to develop a product or design a service by transforming the customer's needs into technology breakthroughs or service innovations. QFD combines the voice of customers (VoC) and the concept of quality control design innovative products, processes, or services. The applications of QFD are extensive and have been applied across many industry sectors. Improved QFD methods have been developed by using fuzzy theory, analytical hierarchy processes, and multivariable analysis. Liu suggests that when developing new products, QFD may be combined with the Kano model so that costs and materials may be chosen according to demand. The relative importance between elements can also be defined, which improves the production process [16]. Singh et al. note that QFD can be used to improve the technical aspects of management. Researchers must pay attention to the changes of customer preferences to match the market trends [17]. Sularto and Yunitasari apply the QFD approach to study the point-of-sale (POS) system of a restaurant to analyze customer demand and explore the metrics which influence the speed of processing orders and payment methods to attract customers and develop strategies [18].

2. Methodology and case demonstration

The methods used in the research are provided in this section. This research applies patent analysis, web data mining and latent semantic analysis to analyze online reviews of a target product. There are four procedures used in this research including patent analysis, secondary data collection of previous product analysis research and reports, latent semantic analysis, and the construction of a quality function deployment matrix.

Patent analysis is an effective way to define the technical focus of a company. The technical data of this research is collected from previous studies and trade literature related to the selected product. Latent semantic analysis is used to calculate the correlations between the voice of customers and the engineering functions. Quality function deployment visualizes the results of the combined research processes.

2.1. Patent analysis

This research selects the ASUS ZenFone2 (type: ZE551ML) smartphone as a target case study product. The scope of the patent search focuses on AsusTek Computer Inc., an international computer hardware and electronics provider. The global patent database search result shows that ASUS has a total of 239 patent families distributed in China, Taiwan, US, Europe, and WIPO. The largest number of product relevant patents are registered in China. Table 1 shows the result of the top International Patent Classifications (IPCs). ASUS holds significant numbers of patents in the following classifications: constructional details or arrangements, related to display configuration, internal electronic components and camera lens modules. Patent group 2 and 3 are related to temperature control. Patent group 4 and 5 are related to the assembly structure.

Table 1. Top IPCs

Patent group	IPC	Definition	Patent family count
	G06F	Electric digital data processing	
1	G06F/116	Constructional details or arrangements	29
2	G06F/120	Cooling means	9
	H05K	Printed circuits; casings or constructional details of electric apparatus; manufacture of assemblages of electrical components	
3	H05K/720	Modifications to facilitate cooling, ventilating, or heating	14
4	H05K/716	On hinges or pivots	10
	H04M	Telephonic communication	
5	H04M/102	Constructional features of telephone sets	11

2.2. Data collection

The customer comments for the ZenFone 2 were retrieved from Amazon.com, the most popular e-commerce platform during August, 2016. Four hundred and eighty-three sets of negative reviews (e.g., one star to three stars out of five stars) were collected and text mining was used to extract the key terms with the highest frequency of occurrence [19]. After the secondary customer dissatisfaction data were collected, this research sets up two rules to select key terms. First, a comparison is made between the proportion of key terms appearing in the positive and negative comments. If a given key term appears more in positive comments, then the term is excluded. Second, if a key term appears in over fifty comments as part of a negative statement, the term is included in the data set. As Table 2 shows, the result are divided into hardware and software. Hardware contains components such as the power system, screen, camera, and RAM. Software involves applications (Apps), bloatware, and the performance of the product.

Table 2. Top frequency key terms of negative reviews

Type	Category	Key terms
Hardware	Power system	drain, battery, battery life, charge, power, remove battery
	Signal and connection	connect, text, call, message, sim, bluetooth, internet, miss, lost
	Camera	camera, light
	Display	flicker, glass, screen, touch, shatter
	Design	button, vibrate
	Memory	ram
	Sound and audio	voice
Software	Software	softwar, app, bloatware
	Performance	slow, fast, perform

QFD requires that the engineering functions be well defined. This research constructs an ontology of the selected product. Figure 1 highlights the functions of a smartphone which consists of a screen, outer casing, battery, speaker, antennas, and printed circuit board. There are 12 key functions defined in this study. The function of the motion sensing chip signals the direction and movement of the handset to provide somatosensory operations. The power management Integrated Circuit (IC) and battery management IC deal with the distribution of most the power supply resources, and control the voltage, temperature to ensure safety and service life. The camera lens module contains CCD/CMOS, filter, and transparent lens, the transparent lens focuses the light on the CCD/CMOS via the filter, then processes the light from the rear end.

The transceiver IC converts the analog and digital signals. The power amplifier IC amplifies and sends out the signal so cell sites can receive the phone signal. The brightness sensor adjusts the screen brightness according to the environment. The wireless signal IC is used to handle digital and analog signal conversion. The G-sensor and E-compass capture the acceleration caused by external force and control the built-in compass. The application processor integrates the CPU, GPU, RAM, USB, and the SD card are the core elements enabling the mobile phone to function. The speech codec IC codes and decodes received sound and converts the digital signal to drive the speaker or headphones. The touch sensing IC measures actions using the changes of voltage. The related literature and reports of each functions are collected for the construction of the QFD matrix.

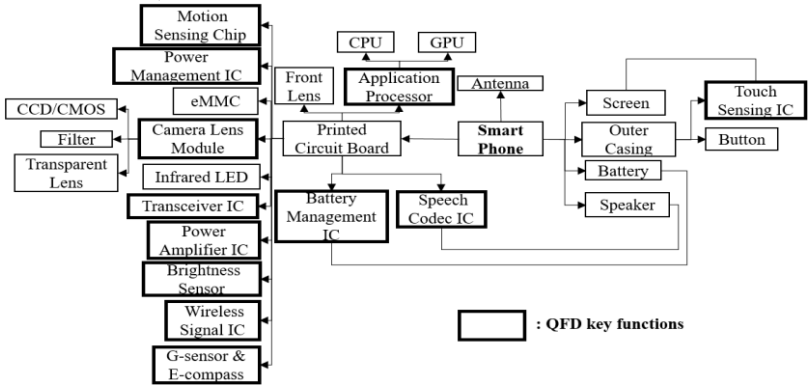


Figure 1. Ontology of smartphone

2.3. Latent semantic analysis

The first step of LSA is to establish a symbiosis matrix (word by document). The two-dimensional matrix models the relationship between the vocabularies and the documents. The elements in the matrix represent the count of vocabularies appear in the documents. Since this is usually a high-dimensional sparse matrix, the matrix contains many null values (0). Singular value decomposition is applied to reduce the dimension of the symbiosis matrix and map the high dimension space to the low dimension vector space. The cosine similarity between the vocabularies and the documents is calculated.

2.4. Construction of QFD

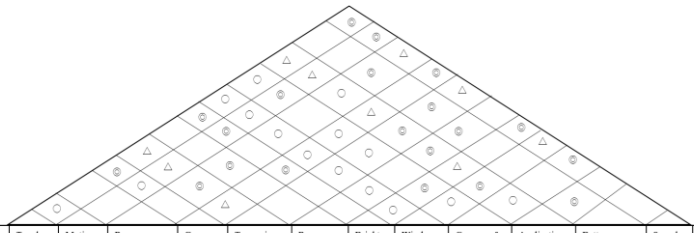
The matrix model for the voice of customers and the engineering functions are defined during the data collection stage. The similarity between these two axes is calculated using the latent semantic analysis method whereas the key terms of VoC are compared with the collected functional literature. The QFD roof shows the correlation between engineering functions. The similarity values are sorted by sequence and the VoC-function relationships (strong ◎, fair ○, or weak △) are assigned according to the percentile distributions (≧75%, 50-75%, or 25-50%).

Normalized Term Frequency-Inverse Document Frequency (NTF-IDF) evaluates the importance of a term for a set of documents. The methodology filters out common

words and keeps important ones by considering term frequencies and document length simultaneously [20]. The average NTF-IDF value of each category is collected and by using the weights of each category, the terms are ranked. The rule for ranking the engineering functions is to sum up the weighting. The QFD matrix is shown in Figure 2.

The highest ranked priority for improvement is the camera category and the most relevant functions are touch sensing, lens module, and brightness sensing. These functions require additional development to better satisfy the customers. The second highest ranked priority for improvement is the memory category. Almost every instruction requires memory to process, which in turn is strongly related to power, battery, and amplifier functions. The signal and connection category ranks third in priority. This category is related to the cellular network and involves the signal of a call, message transmission, and image resolution. The most relevant functions are touch sensing, lens module functioning, and brightness sensing.

This study adds a patent dimension at the bottom of QFD to map the distribution of key functions to the case company's patents. The patent groups were defined in section 2.1. The case company's patents are less focused on the most important functions (e.g., top importance rating functions) defined by this research. Most of the patent groups are related to the application processor which defines the configuration and cooling methods.



Function / Category	Avg. NTF-IDF	Touch Sensing	Motion Sensing	Power Management	Camera Lens Module	Transceiver	Power Amplifier	Bright-ness Sensor	Wireless Signal	G-sensor & E-compass	Application Processor	Battery Management	Speech Codec	Total Score	**Improve Priority**
Power system	71.48		△	◎		○	◎		○	△	○	◎	△	1929.96	9
Signal and connection	109.75	◎	○		◎	△		◎	△	○	△		○	2963.25	**3**
Camera	154.06	◎	○		◎			◎	△	○	△		○	4005.56	**1**
Display	117.55	◎	○		◎			◎	△	△			○	2703.65	4
Design	109.52	◎	○		◎			◎	△	△			○	2518.96	7
Memory	142.14		△	◎		○	◎		○	△	○	◎	△	3837.78	**2**
Sound and audio	88.35		△	◎		○	◎		○	△	○	◎		2297.1	8
Software	95.78	◎	○		◎	△		◎	△	○	△		○	2586.06	6
Performance	99.27		△	◎		○	◎		○	△	○	◎	△	2680.29	5
	Total score	25	19	20	25	14	20	25	17	15	15	20	18		
	Importance Rating	**1**	**3**	**2**	**1**	**7**	**2**	**1**	5	6	6	**2**	4	**Patent family count**	
	Patent group 1			√	√				√		√		√	29	
	Patent group 2										√	√		9	
	Patent group 3				√						√	√		14	
	Patent group 4							√			√			10	
	Patent group 5					√			√				√	11	

Figure 2. Quality function deployment

3. Conclusion and Future Research

In the era of demand-driven marketplace, rapid product deployment based on the dynamic needs of customers is critical. The combined voice-over-the-web and patent mining for QFD can efficiently and precisely identify correlations between the voice of customers, the demand-driven technical functions, and the patented innovations of the

enterprise. The multi-dimensional mapping of customer demands, engineering functions, and company's patented IPs is helpful when developing R&D strategies for new product development and deployment. A company can find future directions of product improvement reflecting the market needs to enhance its global competitiveness. In the future, competitor analysis will be taken into further consideration. Also, the selected product deployment can be applied to the similar products (or product lines) using the similar IPs with similar customer demands for further strengthening their global market position in the sector. The research hopes the proposed methodology can be designed as a computer-supported system platform for its extensive applications.

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