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A Novel Framework to Achieve Innovative Product Design and Recommendation for Multi-Functional Tablets: A TRIZ Perspective

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Abstract. Recently, the boundaries between smartphones, tablets and ultrabooks are becoming much more blurred than before. To sustain in a fiercely competitive environment, global brand companies start to design multi-functional products to satisfy diverse consumer requirements. For instance, Asus and Lenovo design Padfones (a smartphone inside) and Yoga Pro3 (a micro-projector inside) to enhance visualization of smartphones and tablets, respectively. Meanwhile, Acer, Sony, and Fuji develop varieties of tablets like Padbooks (pad + keyboard) and Padnotes (pad + stylus pen) to enhance keyboard interface. In this study, a TRIZ (theory of inventive problem solving) based framework is presented to analyze these innovative ideas and indicate how innovative solutions tackle the trade-offs between the improving features and the worsening features. Thereafter, rough set theory (RST) is applied to elicit the causalities between user preferences for ergonomic features and demographic variables. Finally, product recommendation w.r.t. the niche segments can be accordingly achieved..

Keywords. TRIZ, rough set, innovative design, recommender system

Introduction

Today, smartphones, tablets, and ultrabooks are facing almost saturating and seriously declining product sales. It reveals that the conventional products in consumer electronics may not effectively capture dynamically changing customer desires because of limited capabilities and poor generalization. For convenience, the key features to characterize the conventional products are briefly described below [1][2][3]. Obviously, ultrabooks excel other alternatives in terms of “system performance”, “screen visualization” and “keyboard interface” while smartphones perform the best in dimensions of “wireless communication” and “portability”. In contrast, tablets tend to demonstrate a more balanced result in terms of the above-mentioned evaluation criteria. To satisfy diverse user groups, seeking a systematic way to design innovative alternatives is of importance to help firms survive in the area of consumer electronics. In the past, manufacturers provided products with high quality, low cost, and at most, courteous after-sale service to satisfy market majorities. Nowadays, for the purpose of

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target marketing, they need to offer customized products or services to fit diverse requirements of the ad-hoc segments [4][5]. In reality, dynamically changing customer desires coupled with rapid technology advances concurrently guide the trends of new product development. Theoretically, it is perfect to configure a product that is superior to competitors' alternatives at all of the dimensions, such as aesthetic attributes, functional capabilities, and ergonomic features. However, due to intrinsic design constraints, the fact that improving features accompanied with worsening features often results in a compromised solution in practice. To overcome the aforementioned difficulties, a TRIZ (theory of inventive problem solving) based framework is presented in this study to design innovative varieties of tablets. In particular, several critical issues are addressed and highlighted as follows:

- How to handle the trade-offs between improving features (i.e. loss of information and ease of operation) and worsening features (i.e. weight, area, and length) in product design?
- How to construct a rule-based decision support system to connect users' demographic variables with their diverse preferences?
- How to incorporate user preferences into the process of product recommendation for acquiring the distinct niche segments?

The rest of this paper is structured as follows. Section 1 briefly reviews the concepts of product innovation and product recommendation. Section 2 introduces the proposed framework. An industrial case study is illustrated in Section 3. Conclusions and future studies are drawn in Section 4.

1. Overview of product innovation and product recommendation

Thus, in developing attractive varieties of tablets, the objective of this study is to present a TRIZ based framework to help brand companies solve two critical problems: (1) innovative product design with consideration of the trade-offs between improving features and worsening characteristics and (2) user-driven product recommendation to acquire diverse requirements of ad-hoc segments.

1.1. Production innovation

TRIZ (theory of inventive problem solving) has been widely applied to the top three areas, such as technical problem solving, product and technology innovation, and technology strategy [6]. A Soviet inventor named Genrich Altshuller, who analyzed over 400,000 patents, developed the TRIZ. It is composed of a contradiction matrix, 39 engineering parameters, and 40 innovative principles. Specifically, TRIZ includes a practical methodology, tool sets, a knowledge base, and model-based technology for generating new ideas to break through conventionally compromised solutions. The entire process of implementing the concept of TRIZ can be summarized as follows: (1) abstraction- converting specific problems into general problems, (2) mapping- finding typical solutions for solving general problems, and (3) concretizing- projecting typical solutions into specific solutions that can be tailored to specific domain problems. In brief, TRIZ presents a systematic framework for analyzing challenging problems where innovation is needed to provide a range of tools for finding innovative solutions. Today, TRIZ has been widely applied to different problems, including product development [7][8], process improvement [9], service innovation [10][11], and eco-innovative design [12]. Furthermore, some of the aforementioned studies have integrated QFD (quality function deployment) with TRIZ to analyze the interrelationships between customer requirements and engineering characteristics and the conflicts among them [13][14]. Obviously, TRIZ has become a powerful tool for generating inventive principles to solve the trade-offs between an improving feature and a worsening feature.

1.2. Product recommendation

Generally personal recommender systems can be classified into two main categories [15]: content based and collaborative filtering Content based filtering uses textual documents to search for items with contents which are the most similar to users' interests. In contrast, given a database of other users' preferences, collaborative filtering predicts respondents' preferences, which are typically expressed in terms of numerical evaluation scores [16]. Recently, powerful data mining techniques greatly assist companies in constructing personalized recommender systems [17][18]. These methods predict items of interest to one user according to the recommendations of other people who also use the recommender system. For example, a respondent is often asked to give ratings of popular movies or TV programs. Then, the system matches respondents to their close (nearest) neighbors who have already rated these items similarly to achieve recommendation. Despite recommenders' typical benefits, such as increasing the cross-selling probability, consolidating customer loyalties, and attracting prospect customers, usually require a big number of historical purchase database or transaction records to predict customers' future desires and buying intentions [3]. In other words, most conventional schemes conduct product recommendation in a supervised manner. Hence, they are incapable of handling a scenario in which users' buying profiles or interest ratings are insufficient or unavailable [3]. When a new product is initially launched into the market, it is not only difficult but also infeasible to gather sufficient training samples for constructing recommender systems. Various data-mining techniques are used in constructing recommender systems [19] [20].

2. Proposed methodologies

As mentioned before, this study proposes a TRIZ based framework to incorporate user preferences and performance ratings into the process of product design and recommendation. The proposed framework is described as follows: (1) A contradiction matrix originated from the TRIZ is used to seek innovative solutions for tackling the conflicts between improving features and worsening features, (2) RST (rough set theory) is employed to capture user preferences for ergonomic features (i.e. screen size, screen type, keyboard interface, and body color) of multi-functional tablets, (3) Managerial insights are generated to help companies construct a recommender system for acquiring the ad-hoc user groups. Rough set theory (RST) is regarded as a knowledge discovery system because it is powerful in performing feature selection, dimension reduction, decision rule generation and pattern extraction. Suppose an information system is represented by $IS = (U, C, D)$, where U is the universe of finite objects, C and D denote conditional and decision variables, respectively. The terminologies of RST include lower approximation ($\underline{BX}$), upper approximation ($\overline{BX}$), indiscernibility, positive region ($POS_C(D)$), dependency ($\gamma(C,D)$), significance ($\sigma_{(C,D)}(a)$), core, and reduct. They are defined as:

$$\underline{BX} = \{x_i \in U \mid [x_i]_{ind(B)} \subset X\} \tag{1}$$

$$\overline{BX} = \{x_i \in U \mid [x_i]_{ind(B)} \cap X \neq 0\} \tag{2}$$

$$POS_C(D) = \bigcup_{X \in U/D} \underline{CX} \tag{3}$$

$$\gamma(C,D) = \frac{|POS_C(D)|}{|U|} \tag{4}$$

$$\sigma_{(C,D)}(a) = \frac{\gamma(C,D) - \gamma(C - \{a\}, D)}{\gamma(C,D)} \tag{5}$$

$$CORE(C) = \bigcap REDUCT(C) = \bigcap_i B_i \tag{6}$$

$$\gamma(B_i, D) = \frac{|POS_{B_i}(D)|}{|U|} = \gamma(C,D) \tag{7}$$

Basically, the set of lower/upper approximations contain the elements undoubtedly/possibly belonging to the associated set. The positive region of the partition U/D with respect to C, $POS_C(D)$, is the set of all elements of U that can be uniquely classified to the blocks of the partition U/D by using U/C. Hence, the degree of D depending on C can be either full dependency ($\gamma = 1$) or partial dependency ($0 \leq \gamma < 1$). The conditional variables that have positive significances are recognized as the "core" features and they are mathematically equivalent to the intersection of all possible reducts. Notice that the "core" features are not sufficient to complete the entire decision (classification) process. Only the "reduct" (B_i) can achieve the whole process since it preserves full dependency (like using all of the conditional variables). Specifically, both coverage (defined by $(if \cap then)/then$) and strength (defined by $(if \cap then)/if$) are adopted to measure the effectiveness of decision rules. Here, the "Intersection" means the concurrences of the "Antecedent" and the "Consequent".

$$Strength = \frac{\#\{antecedent \cap consequent\}}{\#\{antecedent\}} \tag{8}$$

$$Coverage = \frac{\#\{antecedent \cap consequent\}}{\#\{consequent\}} \tag{9}$$

3. An example for designing and assessing varieties of tablets

A global Taiwanese brand company attempts to accomplish product portfolio management by developing multi-functional tablets, such as padfones (pad + smartphone), padbooks (pad + keyboard) and padnotes (pad + stylus pen). For convenience, Figure 1 and Figure 2 demonstrate several varieties of tablets which were designed to accommodate different scenarios. To enhance reliability and validity of this survey, the questionnaires were sent to diverse user groups (268 respondents). For convenience, their demographic profiles are shown in Table 1. Actually, they act as domain experts to carry out marketing assessments on multi-functional tablets.

3.1. Applying TRIZ to generate creative ideas for designing multi-functional tablets

Let's look at the details of the contradiction matrix in Table 2, three improving features (i.e. #6- area of a stationary object, #24- loss of information and #33- ease of operation) and three worsening features (i.e. #2- weight of a stationary object, #4- length of a stationary object and #6- area of a stationary object) are selected. After consulting industrial domain experts, several potential solutions are extracted, including principle 1 (segmentation), principle 5 (combining), principle 7 (nesting), principle 15 (dynamicity), and principle 30 (flexible shells or thin films). For clarity, let us quickly overview representative industrial cases to validate the-above mentioned principles (see Figure 1 and Figure 2 again). For instance, Asus's transformer series and Acer's Switch 10 are Padbooks (characterized by separable keyboards) which adopt principle 1 (segmentation). Meanwhile, Asus's Padfone series are the result of principle 7 (nesting). In addition, for enhancing smartphone's or tablet's visualization while keeping portability, principle 5 (combining) and principle 30 (flexible shells or thin films) are adopted to generate Lenovo's Pro3 and folio. Furthermore, principle 15 (dynamicity) is used to explain Fuji's rotatable design and Sony's sliding design in padnotes. Although padnotes are not comparable to Padbooks or Padfones in terms of portability, they provide powerful system performances and friendly user interface to accommodate diverse requirements of different groups.

3.2. Conducting RST to incorporate user preferences into the process of product recommendation

Again, RST is conducted to 268 invited respondents to capture user preferences for ergonomic features, namely, screen type, screen size, keyboard interface, and body color (see Table 3). Despite statistical Chi-square test can be applied to test the interrelationship between demographic variables (i.e. age, gender, and user categories) and user preferences, however, it does not demonstrate the causalities among the aforementioned variables. Thus, RST is adopted in this study to reveal the hidden causation and achieve the goal of product recommendation. As indicated in Table 4, six significant decision rules are derived by RST. In order to justify the validity of decision rules, two metrics like "coverage" and "strength" are measured. To simplify the analysis, the thresholds of the strength and coverage are set by 0.2 and 0.6, respectively. Obviously, distinct user categories possess different requirements for EFs. For example, educators prefer a tough screen with a pen, to support their instruction in class. In contrast, gamers favor a big-sized screen and a separable interface for convenience. Similarly, business users also need a stylus pen, a big-sized screen and a separable interface for reporting their information. Finally, home users merely require a medium-sized screen and a sliding interface to support video or movie watching while they do not concern the stylus at all. Very interestingly, "age" does not present any specific pattern but "gender" reveals useful information. Male users prefer a big-sized screen and gray body color while female users prefer a medium-sized screen and white body color. Very surprisingly, a small-sized screen is not favored by all of the surveyed participants because of the popularity of a "big-sized" smartphone (bigger than 5.5 inch).

Table 1. The demographic profiles of the surveyed respondents (268 samples).

Demographics	Descriptions (in percentages)
Age	Below 30 (40%), between 30 and 50 (45%), Above 50 (15%)
Gender	Male (60%), Female (40%)
User group	Gaming users (25%), business users (28%), educators (26%), home users (21%)

Table 2. TRIZ's innovative principles for designing varieties of tablets.

		Worsening feature	
Improving feature	f6. Area of a stationary object	f2. Weight of a stationary object → P2, P14, P18, P30	f4. Length of a stationary object → P7, 9, 26, 39
	f24. Loss of Information	f2. Weight of a stationary object → P5, P10, P35	f6. Area of a stationary object → P16, P30
	f33. Ease of operation	f2. Weight of a stationary object → P1, P6, P13, P25	f6. Area of a stationary object → P15, P16, P18, P39

Table 3. Ergonomic features (EFs).

	Specifications (levels)	Descriptions
Ergonomic features (multi-levels)	E1 Screen type (2)	Touch with a pen (E11), Touch without a pen (E12)
	E2 Screen size (3)	7-8.4 inch (E21), 8.5-10.1 inch (E22), 10.2-12.2 inch (E23)
	E3 Keyboard interface (3)	Separable (E31), Slider (E32), Rotatable (E33)
	E4 Body color (3)	Black (E41), Gray (E42), White (E43)

Table 4. Conducting rough set theory to seek the attractive portfolios of EFs

Rule	Antecedent	Consequent	Strength	Converge
R1	(Screen type=E11) and (Screen size= E23) and (Keyboard interface= E33)	Educator	24.3%	77.9%
R2	(Screen size= E23) and (Keyboard interface= E31)	Gamer	22.6%	61.3%
R3	(Screen type=E11) and (Screen size= E23) and (Keyboard interface= E31)	Business	26.8%	65.7%

R4	(Screen type=E11) and (Screen size= E22) and (Keyboard interface= E32)	Home	27.7%	71%
R5	(Screen size=E23) and (Body color= E42)	Male	32.1%	81.4%
R6	(Screen type=E11) and (Screen size= E22) and (Body color= E43)	Female	29.7%	74.8%

Asus's Padfone (smartphone inside)

Lenovo's yoga Pro3 (micro-projector inside)

Lenovo's yoga Folio (folding screen)

Figure 1. Various design of multi-functional tablets.

Acer's Switch 10 (separable interface)

Fuji's Lifebook T936 (rotatable interface)

Sony's VAIO Duo13(sliding interface)

Figure 2. Various design of keyboard interface.

4. Conclusions

The emergence of TRIZ has stimulated a creative way of rethinking and redesigning new concepts for tackling multi-functional product design. In general, TRIZ provides a systematic framework to help product planners or industrial practitioners find innovative solutions (potential design concepts). Meanwhile, TRIZ also offers a good way to avoid human psychological inertia and break the conventional mindset. In this study, two improving features (#6- area of a stationary object, #24- loss of information and #33- ease of operation) and three worsening features (#2- weight of a stationary object, #4- length of a stationary object and #6- area of a stationary object) are considered for designing multi-functional tablets. With the aid of TRIZ's contradiction matrix, several potential solutions are suggested, including segmentation (principle 1) for designing Padbooks, combining (principle 5) for designing a tablet integrated with a micro-projector, nesting (principle 7) for designing Padfones, dynamicity (principle 15) for designing sliding or rotatable Padnotes, and flexible shells or thin films (principle 30) for designing folding or bending tablets. Industrial examples include Acer's Switch 10 (principle 1), Lenovo's Yoga Pro3 (principle 5), Asus's padfone (principle 7), Fuji's Lifebook or Sony's VAIO Duo 13 (principle 15) and Lenovo's Folio (principle 30). In summary, this paper presents a user-driven framework to help firms generate decision rules to accomplish product design and recommendation. In future studies, user-rating based social-media mining and co-creation based concurrent design deserves to be further explored to conduct advanced product recommendation.

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