Mining Innovation Opportunities for Handheld Device Cases Using the Fuzzy Next Method

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Abstract--**Many handheld devices, such as the smartphone and tablet, have become vital to many people's daily lives. Thus, identifying innovation opportunities for these handheld devices is important for academics and practitioners alike. In this study, we proposed a novel method – the Fuzzy NeXT method – for measuring the gaps between users' demands and technological availabilities, as well as possible ways to fill these gaps. To this end, we performed a literature review to identify criteria systems. Then, we evaluated current available products by assessing customer needs and core technologies. Finally we conducted a panel discussion to propose strategies to fill these gaps. The results showed that the Fuzzy NeXT method not only precisely measured the gaps between user demands and technological availabilities, but also stimulated participation and interaction between suppliers and customers. We postulated that this method may trigger additional co-innovation activities and can be useful for many applications, such as corporate foresight and service foresight.**

I. INTRODUCTION

A. Innovation of handheld devices

Handheld devices include but are not limited to cellular phones, the Global Positioning System (GPS), and the Personal Digital Assistant (PDA). The advance of system integration technology has led to some of these devices becoming embedded into the smartphone. Even so, it has been suggested that the tablet can be considered a competitor of the smartphone. A more recent addition to the array of handheld devices is the phablet, a mobile device designed to combine the functions of a smartphone and a tablet. Since Apple successfully introduced the iPhone in 2007 and the iPad in 2010, these innovative handheld devices have impacted feature phones and the personal computer industry. Specifically, with competition from low-cost "white brand" smartphones and computers, the shipments and sales of feature phones and traditional laptop computers have continuously decreased, and it is forecasted that such declines caused by disruptive innovation will continue through 2017 [1]. These decreased sales have forced some CEOs to leave the computer industry (e.g., Microsoft, Acer) because they failed to adapt to the new trend of handheld devices [2]. New innovative products continue to be introduced; in 2013 and 2014, new phablets were introduced at the Consumer Electronic Show. Thus, the boundaries between smartphones and tablets are becoming less defined, and some people believe that the growth and innovation of the smartphone has come to an end [3].

In this study, we used a fuzzy "needs based on conflicts between trends" (Fuzzy NeXT) method to evaluate the innovation opportunities for handheld devices based on supply-side and demand-side surveys. We proposed the following research questions: (1) What is the major gap between the technology trends and demand for smartphones and tablets; and (2) What is the best way to extract innovation opportunities and possible solutions from a discussion panel.

II. LITERATURE

A. Product innovation and new product design

Innovation has been studied for decades. Scholars have discussed the types of innovation and benefits of innovation at the microeconomic, macroeconomic, and global levels. Some researchers have even proposed "innovation foresight" and "innovation forecasting." However, do we know the sources of innovation? In particular, can we determine product innovation based on theorems we have learned? Several methods have been proposed to identify product creativity, which should not be confused with product innovation. The former could be an invention created from a non-existent idea, whereas the latter could be a new idea implemented from a well-defined product or process that offers a reference point for new product design (NPD). Thus, we postulate that product innovation can be planned or even forecasted based on existing product performance criteria.

B. NPD and product performance criteria

When conducting NPD research, a set of product performance criteria for measuring the feasibility level of product innovation is needed. However, different products have different product performance criteria. For example, the product performance criteria for a computer include information input, processing, output, and data saving. The product performance criteria for a bicycle include bicycle frame, handle, pedals, gears, wheels, and brakes. The term co-innovation is used if suppliers and customers work together in NPD activities. It is believed that such co-innovation can increase the value-added for a new product or new service.

C. New technologies for product innovation

Product innovation can be triggered by new technological innovation (also called technology push). For example, smartphones and tablets are designed by third- or fourth-generation telecommunication technologies that replace old-generation phones; hybrid cars are designed by dual engine systems that substitute partial conventional cars with gasoline engine. Product innovation can also be a new application with existing technologies. For example, radio-frequency identification (RFID) was applied to intelligent traffic systems (e-tag), and aircraft automatic braking systems were applied to automobiles. Of course, emerging technologies can also be applied to a new product, and if this technology eventually reshapes the current industrial supply chain, structure, and way of doing business, it is called radical innovation. However, we do not focus on this type of innovation in this study in the sense that there are no product performance criteria available for further analysis.

D. Unfulfilled demands for product innovation

Product innovation is not only stimulated by new technologies, but is also stimulated by unfulfilled demands. For example, if a new policy requires new vehicles to install anti-flattening tire sensors, it will inevitably create a new demand for tire innovation. Similarly, the anti-carbon emission treaty could create a new market for carbon quota trading. The change of population structure could also create new demands; for example, an aging society will trigger the development of many products and services for elderly people. Of course, new products and new services are often created in different economic cycles or different locations, such as computers sold for 100 dollars or simple cellular phones for the elderly.

E. Product innovation with gap analysis

Based on the abovementioned points, we propose that if a researcher can well define a set of product performance criteria, as well as new technologies (technology push) and unfulfilled demands (technology pull) for NPD, he or she can use this information to measure the gaps in innovation, hence leading to innovation opportunities. In Table 1, we illustrate the logic of gap analysis for product innovation. As can be seen, a gap for product innovation exists if there is an obvious difference between the impact level of a new or available technology and the satisfaction level of an unfulfilled demand. In this case, a customer's precise needs and how to improve the technology need to be determined. In addition, there are two other types of innovation gaps, which create an innovation gap between two technologies and an innovation gap between two demands. These gaps can be regarded as important references for product system design. The concept is like the roof of the house of quality.

III. METHODOLOGY

A. Product innovation

To conduct the literature review, the authors used "innovation opportunit*" combined with other key words (i.e., "product innovation," "service innovation," "process innovation," "technolog* innovation," "co-innovation") to extract related research papers in the ISI WOK and SCOPUS databases[1]. We found that few articles addressed the method or model used for measuring innovation or extracting innovation opportunities for NPD[2]. However, one of the most popular reported methods was the MRI model, which was developed by the Mitsubishi Research Institute. The MRI model analyzes the relationship between core technologies (supply-side) and market demands (demand-side) in a matrix, named the "seed-and-needs matrix." This method is particularly designed for NPD, and is widely used in Japan and other East Asian countries.

B. MRI model

In the MRI model, researchers use a matrix to analyze the relationship between core technologies and the needs of marketing for the conceptual design of a new product. Each relationship is divided into three levels: strong, medium, and low. New product development only stems from strong relationships. Although the MRI model can be used for both technological and market forecasting, it is a qualitative method of assessment, which makes it difficult to obtain an accurate measurement of the relationship levels. Therefore, Dr. Kobayashi refined this model, creating a new one called the "NeXT model."

C. NeXT conflict analysis

The NeXT model and MRI model have some similarities in that they both use matrices to analyze the relationship between core technologies and market demands. However, the NeXT model can be integrated with other analytical tools, such as fuzzy theory and statistics, and thus may be more suitable for quantitative analysis. Accordingly, the NeXT model can provide more detailed and accurate information for decision-making [4].

TABLE 1. MINIMUM PRODUCT INNOVATION AND GAP ANALYSIS

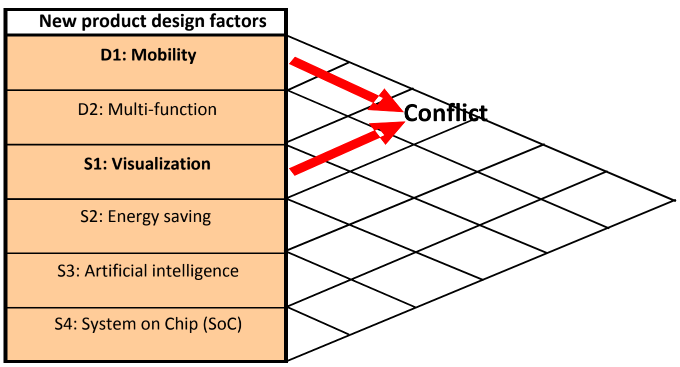
	Product performance criterion 1	Product performance criterion 2	Product performance criterion 3	Other criteria…
Impact level of a new or available technology	*High*	*Low*	*Medium*	…
Satisfaction level of an unfulfilled demand	*Low*	*High*	*Medium*	…
Gap analysis	*A gap exists; the customer's precise needs must be determined*	*A gap exists; it must be determined how to improve the technology*	*No difference; thus no gap.*	…

[1] The asterisk * stands for possible word variations such as "opportunity" and "opportunities."

[2] We found 117 articles in ISI WOK. Among these articles, some studies applied Delphi on product innovation. However, those papers used Delphi to stimulate creative ideas ("disensus") in a panel, which did not match with the objectives of this study.

D. Concepts

The NeXT model is used to find major conflict points between technologies and market demands. The conflict points usually occur in under-developed technologies, unfulfilled demands, or technological development that violates customer expectations. For example, a good visualization effect (e.g., large screen size) could violate old customers' demands on mobility (Figure 1). There is no conflict point if all core technologies completely fulfill all demands of the market/customers. Once major conflict points are discovered, managers can consider reshaping the portfolio of core technologies to improve the original technology and to reduce gaps as soon as possible until all major conflict points disappear.



Source: Kobayashi (2006).
Note: "D" denotes items in market demand; "S" denotes core technologies items.
Figure 1. A conflict point between a core technology and a market demand

E. Formulas

The NeXT model takes into consideration many demands and technologies to solve multiple criteria decision-making problems. The NeXT model has five steps:

1) Step 1: Propose the conceptual design of a new product. Determine specific technical areas and define their scope of involvement. Find suitable technical experts, marketing experts, consultants, or users to determine if the technical scope of the project is appropriate and clear.

2) Step 2: Define the product performance criteria. Think about the application of (new) technologies and the advantages/disadvantages. For example, increasing computer speed can increase productivity, yields, ease of use, and lower costs.

3) Step 3: Identify trends in market demands and core technologies. In this step, researchers identify core technologies and related market demands from the literature or discussion panels. Once identified, these items are placed in the first column (as shown in Figure 1), whereas product performance criteria are placed in the first row; thus, a matrix is constructed. The trends in core technologies and demands of a new product can also be determined in a panel.

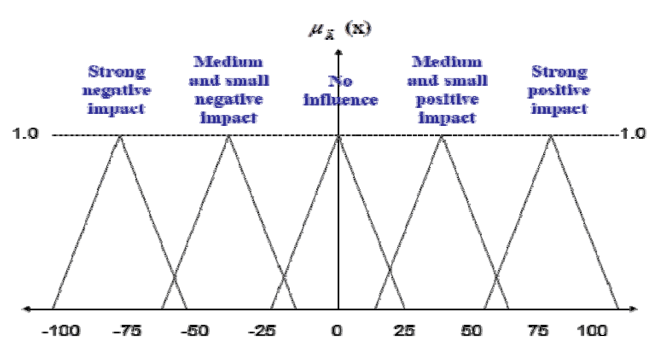
In the following paragraph, we define and explain the variables of the NeXT model; namely, degree of influence (**DI$_{ij}$**; vector), functional characteristic (**FC**; vector), and degree of conflict (**DC**; scalar quantity). We also explain how to use these variables in the subsequent formulas.

DI represents the weight of a specific technology or a demand "i" and a criterion "j." So it is used to measure the influence of a technology or demand for a specific criterion. It is denoted **DI$_{ij}$** because there are (i×j) cells in the matrix; thus, **DI$_{ij}$** is a vector. The weight of **DI$_{ij}$** can be measured on the scale of (-2) strong negative impact, (-1) medium and small negative impacts, (0) no influence, (1) medium and small positive impacts, and (2) strong positive impact.

In this study, we used the fuzzy measure theory, which can distinguish very slight differences between two seeds (technology) or needs (demand) with similar degrees of conflict, to extend the original NeXT measurements from (-2~2) to (-100~100), thereby allowing for 201 degrees (including zero) in our new scale. The -100~100 scale used in the fuzzy measurement is more accurate than a Likert scale. Thus, we were able to determine the importance of seeds or needs by measuring the fuzzy number (x) from a qualitative description (i.e., a linguistic variable), and we defuzzed the fuzzy numbers using the following equations:

$$DI_{\tilde{A}}(x) = \begin{cases} (x-L)/(M-L) & L \le x \le M \\ (U-x)/(U-M) & M \le x \le U \\ 0 & \text{otherwise} \end{cases} \quad . \qquad (1)$$

In Equation (1), a fuzzy number is defined as $DI_{\tilde{A}}$ (x), where x represents the input weight of tester A for a linguistic variable (we should notice $DI_{\tilde{A}} \neq$DI). The value of $DI_{\tilde{A}}$ (x) is between or equal to 0–1. L is the minimum number for a linguistic variable; for example, the value of L for "strong positive impact" in Figure 2 is 50. U is the maximum value of that linguistic variable (e.g., the U value of "strong positive impact" in Fig. 2 is 100). M represents an intermediate value for a given linguistic variable (e.g., the M of "strong positive impact" in Fig. 2 is about 75). Thus, the weight of a linguistic variable can be determined by calculating the average of L, M, and U.



Source: Revised study
Figure 2. Triangular fuzzy numbers represent the membership of this study

The membership function of the five levels of each linguistic variable measures the weight of each technology or demand item and criteria, thereby allowing the measurement of the weight of each seed (technology) or need (demand). Each linguistic variable can be denoted by a triangular fuzzy number (TFN), or evaluators can subjectively assign weights to linguistic variables. If there are m evaluators, the fuzzy performance value of evaluator k toward seed or need item i under criterion j is calculated according to Equations (2)–(7). The signs ⊙ and ⊕ denote fuzzy multiplication and fuzzy addition, respectively.

$$Eijk = (LEijk, MEijk, UEijk), j \in S \quad (2)$$
$$Eij = (1/m) \odot (Eij1 \oplus Eij2 \ldots \oplus Eijm) \quad (3)$$
$$Eij = (LEij, MEij, UEij) \quad (4)$$
$$LEij = (1/m) \odot (\sum_{k=1}^{m} LEijk) \quad (5)$$
$$MEij = (1/m) \odot (\sum_{k=1}^{m} MEijk) \quad (6)$$
$$UEij = (1/m) \odot (\sum_{k=1}^{m} UEijk) \quad (7)$$

In Equations (2)–(7), Eijk represents a congregation set for an input weight of seed or need item i for criterion j evaluated by evaluator k. Thus, LEij, Mij, and Uij represent three congregation sets for linguistic variables L, M, and U, respectively. Defuzzification occurs by determining the DI of the best nonfuzzy performance (BNP) value for criterion i, shown in Equation (8).

$$DIi = BNPi = [(UEi - LEi) + (MEi - LEi)] / 3 + LEi, \forall I \quad (8)$$

4) Step 4: Evaluate the DC for each pair of items

The **FC** is a set of weights for a specific technology or a given demand. $\boldsymbol{FC_i}$ represents the weight of product performance criteria (assuming there are n criteria) for a specific technology or demand item "i"; thus, **FC** is also a vector, and is represented by the following formula:

$$FC_i = (DI_{i1}, \cdots, DI_{in}) \quad (9)$$

Then, the conflict points can be extracted by calculating the DC, which is the "gap" (difference) between a given technology-demand, technology-technology, or demand-demand. Thus, *DC (i, j)* is the degree of conflict between $\boldsymbol{FC_i}$ and $\boldsymbol{FC_j}$; the formula of *DC (i, j)* is represented by Equation (10).

$$DC(i, j) = \|FC_i\| \bullet \|FC_j\| \bullet (1 - \cos\theta) \quad (10)$$

We should note that *DC (i, j)* is the multiplication of two vectors ($\boldsymbol{FC_i}$ and $\boldsymbol{FC_j}$); thus, it is a scalar quantity. The value of DC is maximized when two vectors are heading in the same direction. In contrast, the DC value is minimized if two vectors are heading in opposite directions. Therefore, it is clear that the value of DC is determined by cosine (the angle between two vectors); the maximum cosine value is 1 and the minimum cosine value is -1. Since there are (i×j) cells, there are (i×j) DC values. Researchers may determine major conflict points in the panel (i.e., 5% or 10% leading DC values).

5) Step 5: Discuss possible solutions to release the major conflict points.

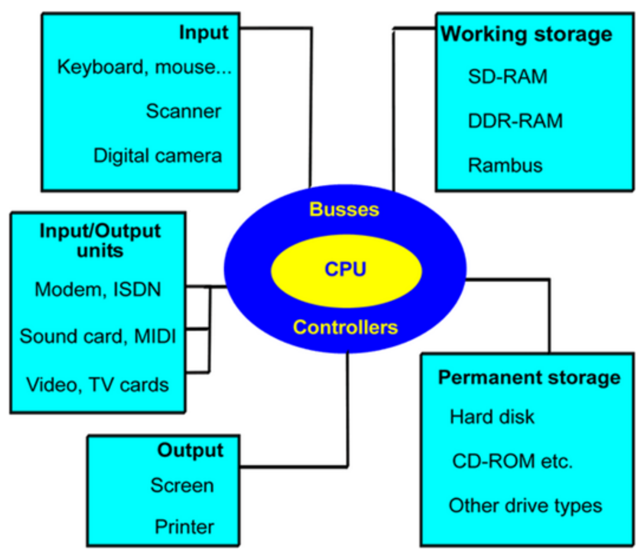
Finally, researchers and experts should discuss possible solutions to the major conflict points in the panel.

In this study, we determined the solution to conflict points through in-depth interviews with discussion panels and experts.

IV. EMPIRICAL CASE

A. Product performance criteria for handheld devices

Handheld devices can be deemed small personal computers. The basic architecture of the modern personal computer can be traced to a study by von Neumann in 1945. In the von Neumann model, a computer is divided into five major components; namely, central processing unit, input, output, working storage (similar to Random Access Memory), and permanent storage. Von Neumann proposed the concept of the memory device, which eventually triggered the later development of a computer in the 1950s and 1960s. Surprisingly, von Neumann's model is still applicable today, although it was updated in 2005 (Figure 3) [5, 6]. We used its components and sub-components as our product performance criteria.



Source: Karbo (2005)
Figure 3. The von Neumann model

B. Criteria of market demands

Smartphones and tablets have caused many consumers, in particularly young people, to become more dependent on such mobile devices. The continual growth of these devices is regarded as an essential trend in the computer market. A study on emotionally interactive products identified the following essential demands from mobile device users: vivid interaction, novel content, attractive stories, personification, learning and growth, digital video, memory-aiding, multilingual translation, voice recognition and response, script display, diagram interface, emotionally refreshing, portability, convenient operations, and friendly design, amongst others [7]. People in today's society tend to have more than one mobile device [8]. Okazaki (2009) proposed a new demand for multi-device management [9]. Furthermore, both security and privacy are vital to mobile device users. Yet, the issue of price also plays an important role in customers' decisions to buy a mobile device [10].

Therefore, we used the abovementioned variables as major demand items in this study. These major market demands included emotionally interactive products, management of information across multiple devices, management of risk of cyber-physical systems, and price considerations.

C. Technology criteria

Handheld devices are high-precision products that contain many components. The Industrial Technology Research Institute (ITRI) forecasted that important technology development will continue until 2015 [11]. The items denoted "H" & "S" are shown in Tables 2 and 3. We adopted the category and definition from the ITRI report to define the core technology items (seeds) in this study. These included the advanced display system, advanced electronic materials and components, cloud, integration multi-product, green technologies and management, and new communication.

D. Factors system (Steps 1-3)

Through a literature review, we collected a set of variables for product performance criteria, core technologies (supply indices), and market needs (demands indices) for this study. They are shown in Tables 2 and 3.

TABLE 2. PRODUCT PERFORMANCE CRITERIA FOR PERSONAL COMPUTERS

PC Product Performance Criteria			Criteria Detail
H: Hardware	H1	Input	Keyboard, touchpad, mouse, microphone, scanner, barcode reader, camera ...
	H2	Working Storage	DRAM, SRAM, MRAM
	H3	CPU	Arithmetic Logic Unit (ALU), control unit
	H4	Permanent Storage	Disk drive, floppy disk, hard disk, moble hard disk
	H5	Output	Monitors, projectors, speakers, printers
	H6	Power	Battery, power connector
S: Software	S1	System Programs, SP	Operating system (e.g., Windows, Mac, Linux, Andrio, iOS); Utilities (e.g., Disk Defragmenter, file compression software); Language translation program (interpreter, compiler)
	S2	Application programs, AP	Packages software (e.g., public room software, video player software, and network related software applications); project development software (e.g., Staff Chu queuing systems, ticketing systems, accounting systems)
O: Other	O1	Input/ Output Unit	Modem (ISDN), sound card (MIDI)、video card (TV card)

Sources: The Von Neumann Model (2004), Foundations of Software Technology and Theoretical Computer Scienc (2009), modified by the authors of this study.

TABLE 3. TRENDS OF CORE TECHNOLOGIES (SUPPLIES) AND MARKET NEEDS (DEMANDS)

NO	Factor	Sub No.	Key Issue of Factor
D1	Emotional interactions	1-1	Vivid Interaction
		1-2	Personification Behavior Identification
		1-3	Multilingual Translation
		1-4	Portability
		1-5	Convenient Operation
		1-6	Friendly Interface
		1-7	Other
D2	Information across multiple devices	2-1	Integration management
		2-2	Other
D3	Acceptable risk	3-1	Security & Privacy
		3-2	Other
D4	Price	4-1	Affordable price
		4-2	Other
S1	Highly integrated ICs (multiple-core)	5-1	Multiple-core Central Processing Unit technology
		5-2	SoC design technology
		5-3	Other
S2	Advanced display technologies	6-1	E-paper (flexible & touching panel)
		6-2	3D projection display
		6-3	Other
S3	Advanced electronic materials and components	7-1	Lightweight (light alloy) Smart materials
		7-2	Other
S4	Cloud computing	8-1	Cloud computing (IaaS, PaaS, SaaS)
		8-2	Other
S5	Integration multiple products	9-1	Integration multi-product
		9-2	Other
S6	Green technologies & energy management system	10-1	Green supply chain (Energy management system)
		10-2	Other
S7	Communication	11-1	Communication technology (4G and beyond technologies)
		11-2	Other

Sources: Lee *et al.* (2012), Beets and Wesson (2013), Okazaki (2009), Dedrick (2010), ITRI (2009, 2013), revised by the authors of this study.

E. Data analysis (Steps 4-5)

Ninety-eight conflict points were generated in our analysis. However, we only analyzed the top 10%. Hence, as determined in the panel[6], 10 conflict points, which had degrees of conflict of over 6,000, were further analyzed. Among them, there were nine conflict points between demand and supply items, and seven conflict points between supply and supply items. Descriptions of these major conflict points are shown in Tables 4-9. In general, experts felt that the differences between the smartphone and tablet were not obvious. We probed for some conflict points in these two devices, and they are shown in Figure 4.

In Figure 4, the data format is very similar to that of a real-time Delphi survey [12], indicating that real-time Delphi could be used to collect data for innovation gap analysis. On the other hand, innovation gap analysis could be used to further examine the results from a real-time Delphi survey (i.e., vector Delphi).

Conflict Factor		H1	H2	H3	H4	H5	H6	S1	S2	O1	Degree of Conflict
D1S5	D1	75	75	75	75	75	50	50	75	50	9,128
	S5	0	0	75	0	50	75	50	50	0	
D1S10	D1	75	75	75	75	75	50	50	75	50	6,176
	S10	50	0	0	75	50	75	50	50	50	
D1S11	D1	75	75	75	75	75	50	50	75	50	7,645
	S11	0	50	50	50	0	50	50	50	50	
D3S5	D3	50	75	0	0	0	0	50	50	0	10,687
	S5	0	0	75	0	50	75	50	50	0	
D3S10	D3	50	75	0	0	0	0	50	50	0	10,156
	S10	50	0	0	75	50	75	50	50	50	
D6S8	D6	75	0	0	0	75	75	50	50	0	9,278
	S8	50	75	75	75	50	50	75	50	50	
D6S11	D6	75	0	0	0	75	75	50	50	0	9,926
	S11	0	50	50	50	0	50	50	50	50	
D7S8	D7	50	0	0	0	50	75	0	0	0	10,534
	S8	50	75	75	75	50	50	75	50	50	
D7S9	D7	50	0	0	0	50	75	0	0	0	8,034
	S9	75	50	50	50	75	50	75	75	50	
D7S11	D7	50	0	0	0	50	75	0	0	0	9,886
	S11	0	50	50	50	0	50	50	50	50	

Figure 4. Conflict points for smartphones and tablets

TABLE 4. CONFLICT POINT (D1*S5)

No.	1*5 (1a5a, 1b5a, 1d5a)
Conflict Points	**Emotional Interaction**: vivid interaction, personification behavior identification, multilingual translation, convenient operation, friendly interface
	Highly Integrated ICs: Multi-core CPU, SoC design
Description	Both multi-core CPU and SoC design technologies focus on technical performance with regard to computation speed and quantity. However, the emotional interaction is more complex and requires artificial intelligence technologies that are not currently available, and may not be for another 5 years. However, new product design may consider starting from multilingual translation, because translation technology is relatively ready for commercialization and has a direct relationship with the development of a new CPU. Hence, a new CPU can support a translation function in a personal computer and handheld device.

TABLE 5. CONFLICT POINT (D1*S10)

No.	1*10 (1b10a)
Conflict Point	**Emotional Interaction**: personification behavior identification
	Green energy: fuel cell, dye sensitive solar cell etc.
Description	Emotion probing and analyzing could consume lots of energy. Thus a new energy-generation strategy is needed for small handheld devices.

TABLE 6. CONFLICT POINT (D1*S11)

No.	1*11 (1b11a, 1c11a, 1d11a)
Conflict Point	**Emotional Interaction (market demand):** **Personification behavior identification** **Multilingual translation** **Big data and clouding** **Convenient operation**
	Communication technology (i.e., fifth-generation technology).
Description	If emotional interaction products can be realized in upcoming years, they will need to be embedded with fifth-generation communication standards.

[3]The experts we invited included Dr. Hsu of ITRI, Dr. Chang of MoEA, Mrs. Shue of Dell, and Mr. Sun of MIRDC.

TABLE 7. CONFLICT POINT (D6*S8) (D6*S11)

No.	6*8, 6*11 (6b11a)
Conflict Points	**Advanced Display** (i.e., 3D projection display)
	Communication technology (i.e., fifth-generation technology).
Description	3D projection realization could involve fifth-generation communication technologies and standards to support the operation of a new display system.

TABLE 8. CONFLICT POINT (D7*S8), (D7*S9), (D7*S11)

No.	7*8(7a8a), 7*9(7a9a), 7*11(7a11a)
Conflict Points	Advanced electronic materials and components Lightweight (light alloy)
	Cloud (technological supply) Integration multi-product (technological supply) Communication (technological supply)
Description	These items appear to be uncorrelated.

TABLE 9. CONFLICT POINT (D3*S5), (D3*S10), (D6*S8), (D6*S11)

No.	3*5(3a5a), 3*10(3a10a) , 6*8(6a8a) , 6*11(6a11a)
Conflict Points	Acceptable risks of cyber-physical systems (market demand): Security & Privacy
	Advanced display: e-paper
Description	These items appear to be uncorrelated.

V. CONCLUSIONS AND SUGGESTIONS

A. Innovation opportunities for handheld devices

The conflict points for handheld devices (Figure 4) can be summarized as follows: First, the major gaps between customer needs and available technologies are human interaction, display, and sustainable energy. Thus, we expect new displays, sensors, and real-time data storage and accessing (e.g., clouding and big data) to lead to the development of lucrative innovations.

Second, customers do have a long wish list. However, current handheld devices cannot satisfy them (e.g., probing people's emotion and thoughts). For example, users would like to know what he or she can buy in a specific area. A smart handheld device should be able to offer real-time guidance and virtual shops in the area, and give product information and sale information. If someone is afraid of a snake or dog, the device should be able to provide an early warning such that the person can avoid such a risk (similar to traffic danger warnings). If a "Mr. Right" or "Mrs. Right" meets up with a person who is perfectly matched, can a truly smart device tell? Remote consultation, education, and medical care should be integrated into a "smart" handheld device. In short, current smart devices are not really smart enough. They are too heavy, have a short lifespan, and cannot probe emotions and thoughts. A smarter device will depend upon reliable artificial intelligence, new material, and energy-efficient chip technologies.

Third, how can we probe human emotion and desire? Currently, sensors are used in cameras (CCD), for face recognition, fingerprint recognition, and detection of eye movements, to name a few. However, these sensors are passive and inaccurate. It would be even better if sensors could be used to probe heartbeats, pulses, brainwaves (i.e., alpha, beta waves), or even detect DNA.

Fourth, current devices are not convenient to transport and can be harmful to one's health. For example, devices that have a screen size over 6" are not convenient to carry in a pocket; however, smaller devices strain the eyes. A better idea would be to have information projected to glass.

With regard to the problem of short-lived batteries, a possible short-term solution could be the use of an energy management system (EMS) and autosaving. There are many opportunities to charge handheld devices outside the home, such as in the office, in restaurants, and at gas stations. In the long run, other possible solutions could include fuel cells, dye-sensitive solar cells, and nano flexible batteries.

Currently, many users are dissatisfied with the state of current smartphones. However, the good news is that newer technologies are being developed around the world. A university in Taiwan announced that they have developed a virtual and interactive touring guidance system that can offer users real-time travel information through clouding data. The Chunghwa Telecom Company, a leading telecommunications company in Taiwan, has launched a "future letter" service to customers. Yuan Ze University has developed a small robot with real-time communication and diagnostic functions for tele-homecare. With regard to the 3D display, Google has proposed a plan to implement this by 2019. The ITRI has successfully developed a paper-like amplifier and display that can be applied to a handheld device. In addition, many car manufacturers have started working with smartphone companies to develop smart electronic cars, in which an information communication technology product can be installed into a vehicle platform. Thus, the problems of short endurance and small displays could be partially solved. So many technological efforts are underway that we believe that technology will soon be able to realize consumers' desires for emotional perception and interaction functions from their smartphones.

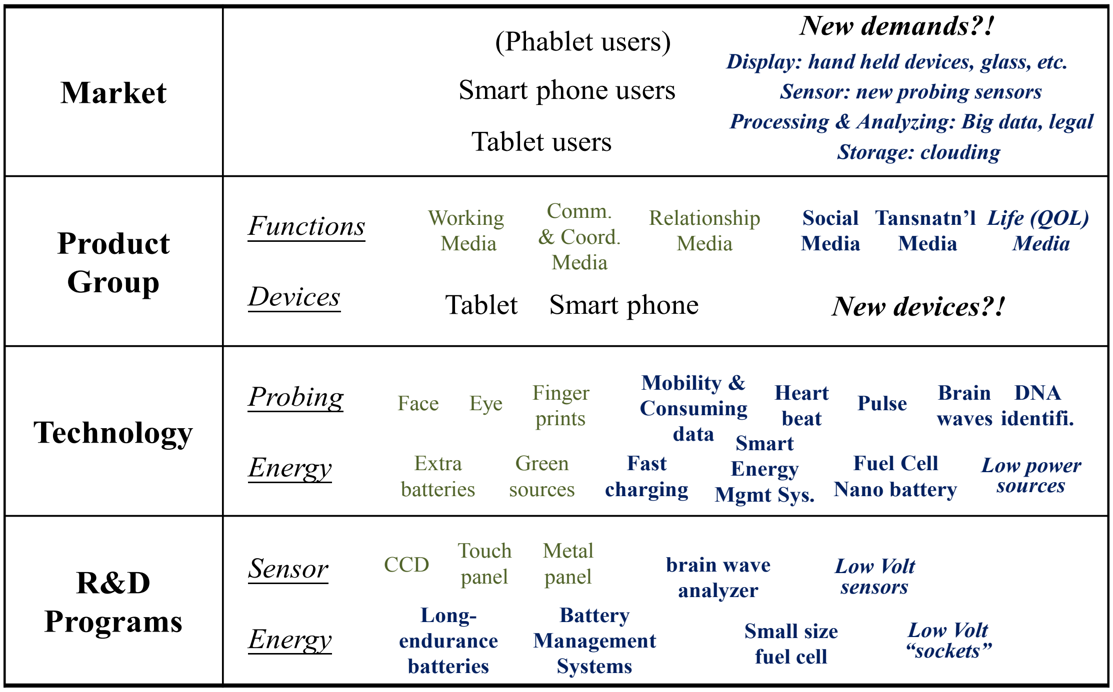


Figure 5. Technology roadmap for emotional perception and interaction

Based on the results of our analyses, we discussed possible technological roadmaps for the major conflict points in the panel. For example, the conflict points in D1, S5, and S10 show that current smart devices are not as smart as customers want. Some roadmaps have been proposed to solve these gaps. In Figure 5, we can see that many research and development efforts are needed for smarter handheld devices (e.g., long endurance, multiple sources, fast rechargeable batteries, sensitive and accurate responsive sensors). This result can be used as a reference for the design of tomorrow's handheld devices.

B. Benefits and limitations of the Fuzzy NeXT method

The Fuzzy NeXT method can quickly measure conflict points with Microsoft Excel. Therefore, it is an efficient and inexpensive tool. Furthermore, the method can help researchers immediately analyze the logic and solutions of conflict points with appropriate experts. Thus, this method is suitable for quantitative and qualitative research. However, if there are many conflict points in a survey, researchers can only measure and analyze major ones. In this sense, it is beneficial to use Fuzzy measurement because it helps to amplify weight, thereby allowing minor differences among conflict points to be seen. However, it also increases the complexity of the survey, and gives rise to other issues, such as independency and expert bias.

1) Uncorrelated conflict points

Through this case exercise, we found that the Fuzzy NeXT method is useful for extracting innovation gaps. However, there are also some potential issues in measuring conflict points. First, this method is used to probe the gaps between item and item in a matrix, and some are even independent, such as any two unrelated technologies or demands (i.e., items in Tables 8 and 9). We suggest that researchers pre-explore each cell that is constricted by two unrelated items; thus, they can skip those cells in their survey. Second, some conflict points seem unrelated but might be related in the future. Therefore, it might be necessary to conduct surveys from time to time to probe the changes and trends of innovation by measuring conflict points, so that innovation opportunities will not be missed.

2) The subjective issue of experts

Because each individual expert has his/her subjective viewpoint, an in-depth expert interview could generate unnecessary survey bias. Therefore, we suggest that researchers also give surveys to a discussion panel to get more objective results. In this case, researchers may calculate average credit points for each cell (i.e., Steps 1 to 10).

C. Suggestions

The fuzzy NeXT method can be considered an extension of the real-time Delphi survey. We believe that there are many research opportunities in foresight and forecasting areas. Finally, during our discussion with the panel, experts proposed a new trend of demands called "SoLoMo"(socialization, localization, and mobility), which are not included in our survey items due to space limitations. However, we believe that these criteria should be explored in future studies.

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