Research on the Design Principles for Intelligent Products

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Abstract. With the rapid development of technology, more and more intelligent products have emerged. They perceive the external environment and internal state, automatically analyze and make decisions based on real-time data to provide people with a more convenient way of life. Compared with traditional products, the main difference is that intelligent products can be combined with technology such as the Internet and artificial intelligence to form a software and hardware service system not just hardware functions or virtual network space. Intelligent products have become one of the focus issues discussed at present. This research explains the definition and classification of intelligent products and discusses their current status and trends from the technical, commercial and user perspectives through quantitative text analysis and literature review. Then expound the current status and trends of intelligence products from the perspective of design. Based on the work above, this research identifies the design principles for intelligent products, which academics can do further investigate on this topic and practitioners may find something helpful in the process of design work. It is foreseeable that the wave of intelligent products is no longer limited to the deepening, generalization or internalization of the mobile Internet, but the terminal form of the service output and information perception in the age of artificial intelligence.

Keywords: Intelligent products · Design principle · Artificial intelligence

1 Introduction

In the era of the Internet of Things and big data, artificial intelligence will become the main force driving economic growth. Both the government and enterprises regard it as an important area of innovation. In terms of the growth of total investment in the industry, 2014 was regarded as the outbreak of smart products in China, which was 503% higher than that in 2013. From the perspective of market size, China's intelligent hardware market reached 331.5 billion yuan in 2016. The intelligent hardware market scale has maintained a stable growth trend. It is estimated from the Fig. 1 that by 2019, China's smart hardware market scale will reach 541.4 billion yuan.

According to the white paper of intelligent hardware industry development released by the China Academy of Information and Communications Technology, the number of worldwide mobile users has reached 7.6 billion in the first quarter of 2017. The number of globally connected intelligent hardware (smart phones) has reached 8 billion

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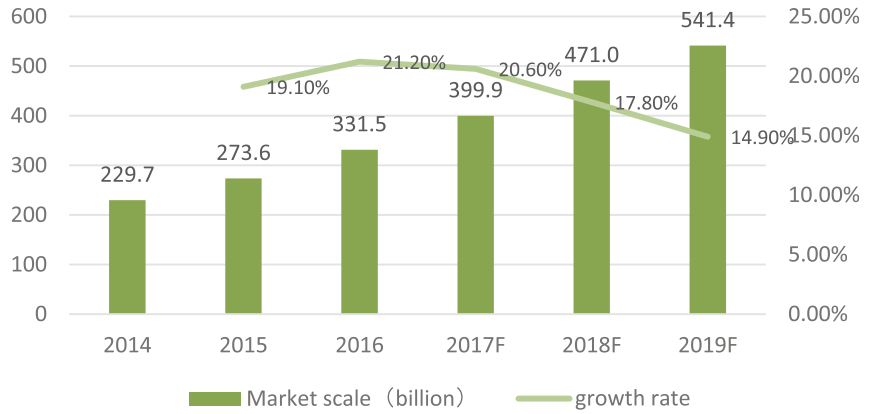

Fig. 1. The market scale of china intelligent products from 2014 to 2019

units, with a per capita possession of 1.1 units, which will rapidly increase to 1.5 in the next five years. From the perspective of data traffic, the mobile networking rate has reached 6.8 Mbps at the end of 2016 and will increase by three times in five years. From 2016 to 2021, the global public WiFi hotspots (including home hotspots) will grow six times [1]. All of this provides an excellent environment for the development of intelligent hardware.

However, in the design process of intelligent products, some problems have not been clarified: what kind of products are intelligent products and what kind of principles should be followed in the design of intelligent products. This study explores the intelligent products from the perspective of design by exploring the status and trends of intelligent products, and finally puts forward relevant design principles.

2 Theoretical Background and Literature Review

This section explores the definition and classification of intelligent products through literature review, and then analyzes the status and development trend of intelligent products from the perspective of technology, business and users. Figure 2 outlines the structure of this section, and gives an overall view of the topics discussed in the section.

2.1 Definitions and Classification of Intelligent Products

Compared with the traditional products, the major difference is that the intelligent products can be combined with technology such as the internet and big data to form a service system of software and hardware. The expectations of the consumer are the services and information provided. Therefore, Wuest et al. pointed out that the intelligent products allow the communication of large amounts of information from various product categories [2]. McFarlane et al. described that the intelligent products are physical and information-based items that may be processed or used and that generate the ability to act in an intelligent manner [3]. Apart from these definition, there are many other ways to define the intelligent products.

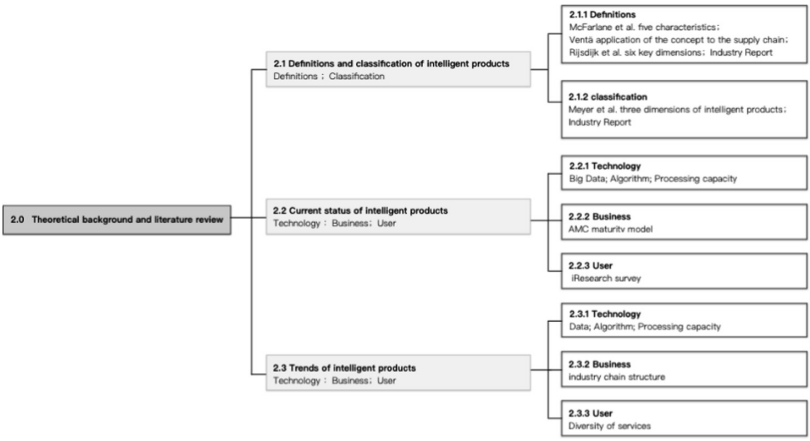

Fig. 2. An overview of the definition and classification of intelligent products

Definitions

The definitions of intelligent products vary from scholars and researchers. McFarlane et al. held the view that there are five properties for intelligent products: (1) possesses a unique identification; (2) is capable of communicating effectively with its environment; (3) can retain or store data about itself; (4) deploys a language to display its features, production requirements, etc.; (5) is capable of participating in or making decisions relevant to its own destiny [3]. McFarlane's theory didn't cover the embedded processing of products but only describe from the perspective of using RFID, which mainly used in the manufacturing and supply chain purposes.

Ventä describe the intelligent products from another four aspects: (1) Continuously monitor their status and environment. (2) React and adapt to environmental and operational conditions; (3) Maintain optimal performance in variable circumstances, also in exceptional cases; (4) Actively communicate with the user, environment or with other products and systems [4]. This definition considers the sufficient embedded computing power, which makes it possible to communicate with other information systems.

Rijsdijk et al. explored the relationships between product intelligence and consumer perception, conceptualizing product intelligence and smartness as comprising six key dimensions: autonomy, ability to learn, reactivity, ability to cooperate, human-like interaction, and personality [5].

Above these academic definition, some industry report also define the intelligent products in their own ways. Analysis define that intelligent products are a technological concept which through the combination of software and hardware to make the traditional devices to get intelligent function [6]. The hardware has the ability to connect and realize the surroundings to analyze and react. IResearch point out that intelligent products should do things in the human way such as reading, listening, thinking and acting via some technology support like Machine learning and etc. [7].

Thus, the intelligent product is a device that can retrieve data automatically and have the ability to learn, react and interact in the human-like way. In the next section, the classification will be discussed from the perspective of academic research and thematic report.

Classification

Based on the definitions from McFarlane and Ventä, Gerben G. Meyer et al. define a classification model of intelligent products shows in Fig. 3. which consist of three dimensions: level of intelligence, Location of intelligence and Aggregation level of intelligence. This model based on three orthogonal dimensions gives a more comprehensive classification of intelligent products which covers all the aspects of the field [8]. The level of intelligence descripts the ability of self-control from the basically manage its own information to completely manage its own life. The location of intelligence distinguished network and object like the relationship between application and hardware. The aggregation level of intelligence describes the difference between item and container, like the engine in the vehicle. This model is a more comprehensive classification and covers aspect from product itself to product lifecycle, which can be used to classify the products even it is brand-new.

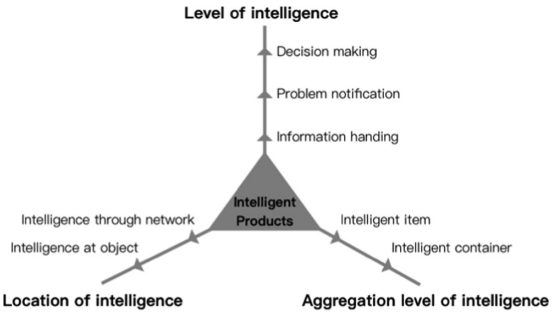

Fig. 3. Classification model of intelligent products by Gerben G. Meyer et al.

2.2 Current Status of Intelligent Products

At present, intelligent products are still mainly in the monitoring and control stage (Fig. 4). The development of intelligent products relies on the support of technology and the promotion of business power to provides a good experience for the majority of users. Therefore, this section discusses the current state of intelligent products from the perspective of technology development, business status and users.

Intelligent Products View of Technology

The underlying support of intelligent products is artificial intelligence technology. When it comes to technology, it is inseparable from big data, algorithms and computing power.

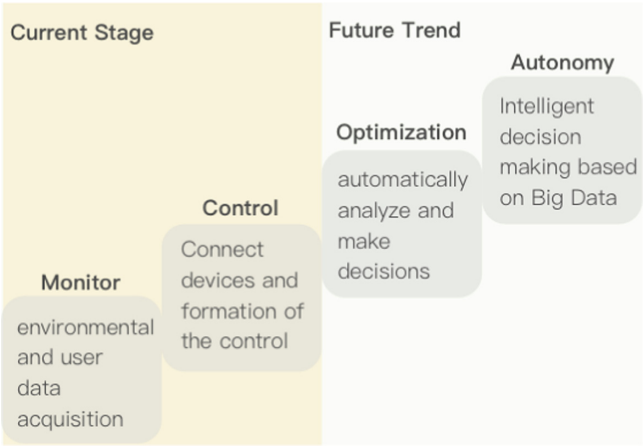

Fig. 4. The development of intelligent products via iResearch report

- *Big Data.* The famous consulting firm McKinsey pointed out: "Data has become an important production factor through the penetration of various business areas in various industries." The properties of "Big Data" have been concluded as "5Vs theory" and the most famous 3Vs are volume, variety, and velocity, which were introduced by Gartner analyst Laney D in a 2001 META Group research publication [9]. Recently the other 2Vs, called variability and value is added. The explanation of 5Vs are as follows in Fig. 5. Intelligent products are the main source for obtaining big data of users in the era of IoT. By collecting and concentrating data, a large amount of data is formed, sometimes even the sample is the whole data. The analysis result of big data may not only create a better user experience, but even achieves commercial success.

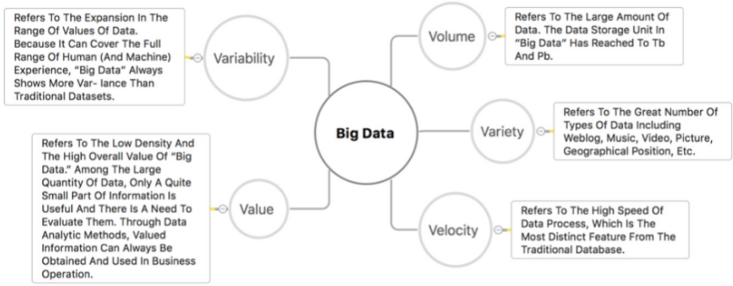

Fig. 5. 5Vs model of big data

- *Algorithm.* While science fiction often portrays AI as robots with human-like characteristics, AI can encompass anything from e-Commerce prediction algorithms to IBM's Watson machines [10]. The engineering approach and modeling approach are

two ways to improve AI and the mainstream algorithm is machine learning. The algorithm of machine learning is very different. The input is the data and the desired results, and the output is the algorithm model. Through machine learning, the computer can generate its own model, and then provide the corresponding judgment to achieve the artificial intelligence [11]. We put together a list of classical algorithms in Fig. 6. Based on those algorithms, Forrester has just released a TechRadar report on artificial intelligence, which introduce the 9 aspects that using artificial intelligence to support decisions, namely Natural language generation, Speech recognition, VR/AR, AI-optimized hardware, Decision management, Deep learning platforms, Robotic process automation, Text analytics and NLP as well as Visual recognition.

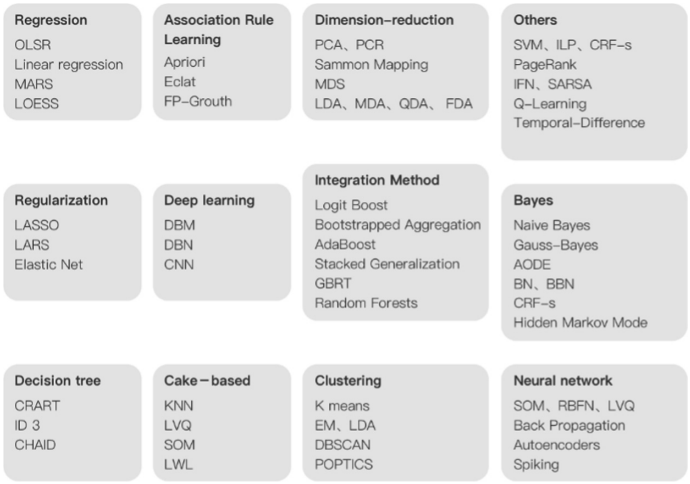

Fig. 6. The list of classical algorithms

- *Processing capacity.* Apart from data and algorithm, another basic condition of AI is processing capacity. Graphics processing units (GPU), general purpose processors (GPP) and field programmable gate arrays (FPGA) are required to efficiently run AI-oriented computational tasks [12]. Nowadays GPU have evolved aggressively due to Moore's speed. For example, the number of NVIDIA TeslaV100 core transistors has reached 21.1 billion in 2017 exactly for deep learning, which increase 40% from Pascal (15.3 billion) released one year ago. The performance of Tensor floating-point computing is 12 times than that of Pascal; the cost is also significantly reduced. For example, the GTX1080 chip widely used in the market, the cost of one billion floating-point operations per second has been drop to a few cents according to its release price and nominal peak performance.

Intelligent Products View of Marketing

From the marketing perspective, the AMC model proposed by Analysys can be used to classify the intelligent products [6]. This model distinguishes the products by four development stage: exploration period, Market start-up period, high speed development

period and market mature period. In this perspective, the Health Care, Consumer Robots, Domestic Robots, Smart Cars, UAV and AR devices is bracket in the exploration period. The VR devices, Industrial Robots, Wearable Devices and Smart Home are grouped in the stage of Market start-up. This classification is in market view and show the development of great potential for different products. As the intelligent products industry chain extends to various fields, more possible profit models will be explored in the future (Fig. 7).

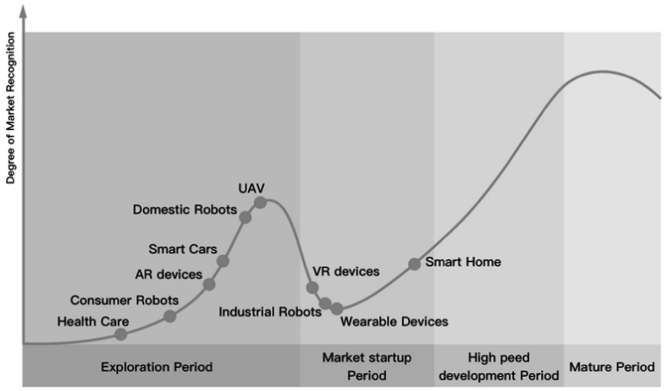

Fig. 7. The AMC curve of intelligent products in china (2017)

Intelligent Products View of User According to the iResearch report about Chinese intelligent products [7], about 40% of people show great concern about the intelligent products and 20%–34% of people have direct contacted with products. The top 2 products ranked by sales volume variance are wearable deceives like Band and smart home products like Robot vacuum cleaner and etc. and just accordance with the curve of ACM. The 70% of intelligent products consumers is male aged from 25 to 35, who are the High-income Groups and have strong consumptive power. The consumer focus on the better quality of life and fashion trend. Therefore, the intelligent products just provide a new experience and convenient way of life (Fig. 8).

2.3 New Trends of Intelligent Products

As mentioned above, the future tend of intelligent products will focus on how to achieve Optimization and Autonomy, which means the products will be smarter to automatically analyze and make intelligent decisions.

The View of Technology

- *Data.* On the one hand, comprehensive data will be collected through the development of IoT to train the model and boost the performance. While on the other hand, some scholars believe that current AI are overly dependent on big data, lack a self-idea function, and are complicated [12]. In the reality word, human being can

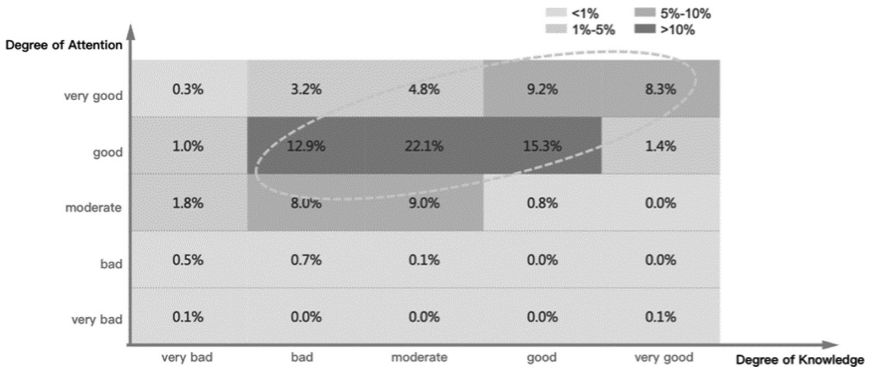

Fig. 8. A survey of Cognition of Chinses people on intelligent products, N = 2019, from online questionnaire in 2015

learn and create diversity of things only through limited knowledge and information. So, we believe that with the development of data volume, the value of data will also get some people's attention at the same time.

- *Algorithm.* Currently, learning expressions extracted from essential information of observational data via a deep neural network with a large number of layers is the mainstream on deep learning research. While in the situation of multitask learning and divert learning, it is still insufficient. For this reason, AI models based on unsupervised learning and shallow neural networks will become trends in future [12]. As mentioned above, the engineering approach and modeling approach are two ways to improve AI performance. The modeling approach simulates the biological mechanism of human and other creatures will inspire people to create greater algorithm (Table 1).
- *Processing capacity.* The core requirements of computing are energy efficiency and low latency. Therefore, infrastructure upgrades such as system clusters, as well as instruction sets, dedicated function libraries, and software frameworks need to be deeply integrated with specific applications to improve the computing power of single-chip platforms to meet the needs of complex intelligent hardware application scenarios such as low power consumption and real-time performance. The general chips like CPU and GPU will develop the interface and processing capacity even integrate the quantum computing to laying the foundation for the construction of computing framework system.

Table 1. Two ways to improve the performance of artificial intelligence

Engineering approach	Modeling approach
Traditional programming and data processing experience to improve performance	Simulates the biological mechanism of human and creature like genetic algorithm and neural network

The View of Business

As the AMC curve shows, the market scale of intelligent products will gradually increase and the corresponding business model will emerge. Take several companies in China as an example: JingDong (JD) Ecology provides a full aspect of support services for hardware entrepreneurs and helps the development of the hardware industry with an open and win-win mentality; Xiaomi uses the mobile phone ecological chain to take the Xiaomi box as the entry point to enter the field of intelligent product industry; Firebird connects designers and consumers with design innovation mode, and has already obtained Pre-B round investment and initiated joint acceleration plan. Rokid also launched full-stack voice open platform to provide one-stop voice solutions for the industry. 1 On the one hand, artificial intelligence enterprises with technical capabilities provide intelligent services to downstream enterprises by providing AI API, open source AI development framework, and open cloud computing capabilities, and become terminal industries together with component companies and OS enterprises. On the other hand, the influence of intelligent service providers will gradually increase. Just like the OEM companies have the same relationship with upstream storage, display and other device manufacturers. Large enterprises can create a smart ecosystem through their own resources, and SMEs can also participate in it as a member of the industry chain (Fig. 9).

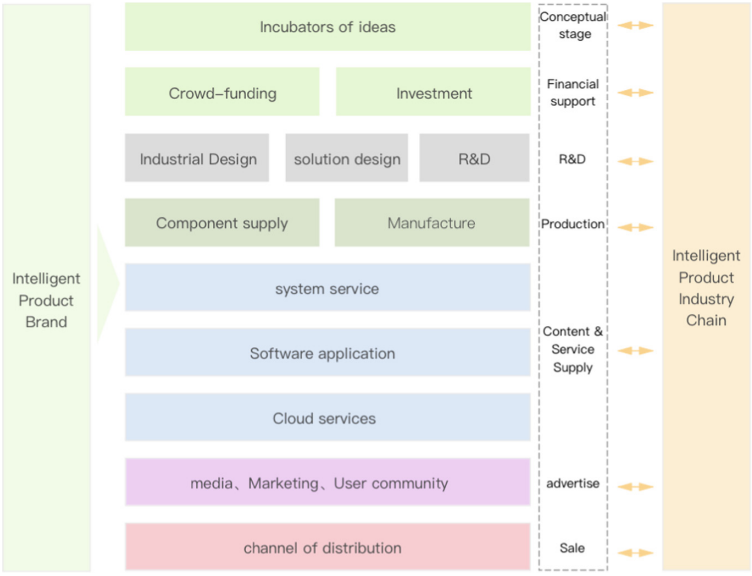

Fig. 9. The industry chain structure of Intelligent product

The View of User

There is no doubt that the number of users using other intelligent products is much less than the that use of smart phone. Therefore, smart phones are still the core terminals in the intelligent hardware system, and there is no precursor to being replaced by new terminals [1]. While the intelligent products that follow human's perception, assist

human computing and rely on human knowledge models and decision-making experience will appear in large numbers. As intelligent products will provide diversity of services based the daily life, more and more people will use intelligent products. For example, in a scene where keyboard input and screen attention cannot be performed for a long time, speech recognition and gesture recognition can be used to help people operate, which greatly expands the usage time of home appliances, automobiles, drones, and consumer robots. Moreover, with the attention to user perception and emotion, the services and content provided by intelligent products will more evoke the resonance of users. For example, previous research in our institute is to integrate the factors of user's emotional expression and cognition to the intelligent information recommendation system [13, 14].

3 Current Status and New Trends of Intelligent Product Design

Since the intelligent products are different from traditional products, the design process and design content also show certain uniqueness. This chapter will discuss the design activities of intelligent products from the perspective of current status and trends.

3.1 Current Status of Intelligent Product Design

Engineering Design

Engineering design is the activity of finding solutions to technical problems by applying insights from natural and engineering sciences, at the same time taking into account the conditions and constraints of a given task [15]. In other words, transform empirical and rational knowledge into practical deployment is the primary function [16]. According to the definition summarized in Sect. 2, the engineering design of intelligent products need to concern about the six modules to achieve certain specific functions as well as the collaborative work of hardware and software (Fig. 10).

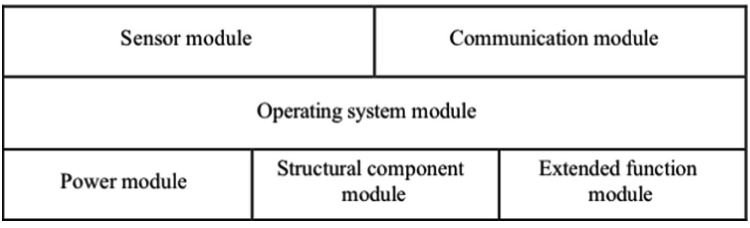

Fig. 10. Six modules of intelligent products

Industrial Design

Design is an interdisciplinary subject that involves many fields of knowledge. The main contains of industrial design is the practicality and beauty of the products. It combines art and technology from the very beginning. For the design of intelligent products, the

biggest difference from traditional products is the technological factors. In the concept stage of the product, it is not only a creative sketch to illustrate the shape and structure, but also needs to consider the application of technical elements. At present, the intelligent transformation of product is still at the functional surface, and has not yet touched the revolution of human basic computing needs. New hardware such as VR/AR, intelligent robots, and drones cannot challenge the status of PCs and smart phone in general computing terminals in the short term [1]. Therefore, taking the smart phone as an example, there is no significant difference in appearance of phone. The full screen design and multi-camera design based on technical support have become the hot topic at present.

User Centered Design

Features that a product receive during the manufacturing process, even if they fulfill technical and functional requirements, are not worth much if they do not respond to a client's expectations [17]. Some failed products add many grandiose features but of no practical use, such as Baidu smart chopsticks. Therefore, user-centered design emphasis the important of user research to find out what is user demand. The general methods of user research are summarized in Fig. 11. Designers often do market and design research, pay attention to the feedback information, summarize and summarize, and constantly think about how to do the good design.

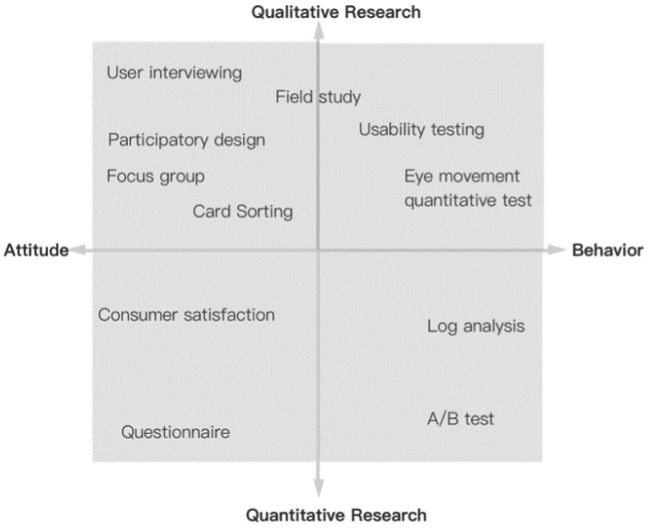

Fig. 11. General methods of user research

3.2 New Trends of Intelligent Product Design

Engineering Design

As Jonson suggests, "CAD may foster new patterns, relationships, or aesthetics expanding, rather than reducing designers' creative options". To do this, however,

future systems need to help the visualization of function in the early stages when the geometry is not fully defined [18]. In the case of rapid prototyping techniques, a prototype is produced directly from a digital model of a product and the time of obtaining the prototype is usually much shorter than by use of conventional manufacturing technologies [19]. While using the VR technology, the time shortening effect is achieved mostly through implementation of so-called virtual prototyping, meaning creating a digital prototype highly similar in some aspects to a real product, and then performing necessary tests and studies on it, without the necessity of building a physical prototype [18, 20].

Industrial Design

The important mission of industrial design is to create a product or system with practical value in social life. When intelligent products change the way of information acquiring and cognitive, the complexity of intelligent products sets several challenges to the designer. This increasing complexity need more collaborative work. Designers are no longer merely exchanging geometric and mathematical data, but more general knowledge about design and the product development process, including specifications, design rules, constraints, and rationale [21]. Moreover, they also need to expand into considerations of product complexity, multidisciplinary, integration of domains, and consideration about globalization trends, etc.

User Centered Design

The future trends will be the construction and development of specific and precise models to offer more insight into the cognitive processes [22]. In the process of getting information about the user, the researchers began to introduce the implicit measurement methods in the basic research fields such as psychological mechanism and neural mechanism into the user research to explore the real needs in order to compensate for the weaknesses of explicit measurement and enhance the reliability of user research [23]. There are some common methods of implicit measurement like implicit association test (IAT), electroencephalograph (EEG) and functional magnetic resonance imaging (FMRI) [24]. While these methods are confined to laboratories, the more effective way to get the intention of user is collect data through user behavior log mining. The product collect the information through user's input and sensor part to generate the user behavior log to help people analyze the correlation between each point of behavior. Moreover, there are some new attempts the like generate design process that transfer user-centered design to user participation design. "Thanks to the support of ICT (Intelligence Computing Technology) technology, Generative Design, which is currently taking shape, is triggering a new generation of behaviors, based on protocols and rules, based on digital manufacturing conditions. Design approach to deep involvement in the product generation process: the designer uses a system, such as a modeling grammar rule set, a computer program, with mathematics, with user intervention or some degree of autonomy or self-organizing features of the system itself. A product that defines functionality and meaning. Generating rule design and parameterization are its main technical features [25].

4 Design Principles for Intelligent Products

Based on the review of the definition, trends and design of intelligent products, this paper proposes the following three dimensions of intelligent product design principles (Fig. 12). From the individual point of view of the product, technical support is needed to give the product the ability to be smart and interact naturally; from the perspective of the overall network, products need to be interconnected to form a service network; from the perspective of service content, it is necessary to determine the real pain points and user needs in order to avoid bad user experience and service quality.

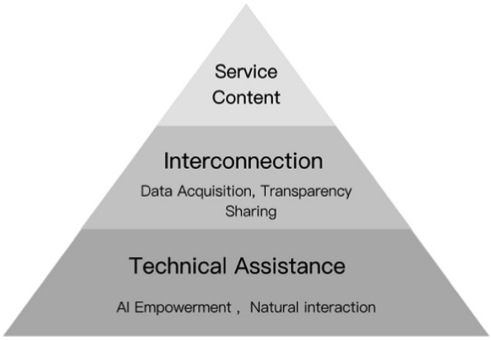

Fig. 12. TIS model of design principles for intelligent products

4.1 Technical Assistance

AI Empowerment

Terminal devices will also be coupled with AI technology. Traditional electronic devices simply use the sensors to collect data with not analyzed. The application of deep learning technology accelerates the development of artificial intelligence sensing technologies such as speech recognition and image recognition, enabling intelligent products to initially possess visual, auditory, tactile and other active observation and sensing capabilities, such as cameras, laser radar, millimeter wave radar, microphones, fusion sensors, etc. The device directly acquires external data such as images, video, audio, and position, thereby implementing functions such as face recognition, speech recognition, video analysis, and semantic understanding.

Natural Interaction

Donald A. Norman pointed out that the mouse and keyboard seem to interact naturally but actually they are not natural, and intelligent products bring us more possibilities to explore. Steve Ballmer, CEO of Microsoft pointed out that we expanded beyond the mouse and keyboard and started incorporating more natural forms of interaction such as touch, speech, gestures, handwriting, and vision [26].

- Data interaction is not just about numbers, but about all the resources that can be digitized, including text, images, sounds, and more. The data stream is passed through the input of the intelligent products, causing the system to respond, manipulating the device or feeding back the output information to the user.
- Image interaction is based on the development of technical support for machine vision systems. Intelligent devices obtain the perception of the content itself through image recognition, thereby further analyzing the relevant target attributes and guiding the next judgment and behavior. At present, the widely-used applications are OCR, face recognition and so on.
- Voice interaction is a natural way of interaction. About 75% of human communication is done through voice interaction. Therefore, if the intelligent products have natural language recognition function, it can greatly reduce the operating cost of the smart device and enhance the user experience.
- Behavioral interaction is based on human motion capture to obtain information. Through natural gestures and physical location information acquisition, intelligent products can quickly understand the user's intentions. Touch-based products are almost always designed to let users zoom by finger through the screen.

4.2 Interconnection

Data Acquisition

Various intelligent products perceive different data to form a multi-dimensional intelligent perception network. Through data uploading, data analyzing, data storage in the big data cloud platform, the platform gives feeds back, achieving the integration of calculation and information (Fig. 13). When massive data is transmitted to the big data platform, it need to be calculated by the processing framework and the processing engine, which involves technologies such as cloud storage, distributed scheduling, distributed computing, and finally data interaction through the form of an interactive interface.

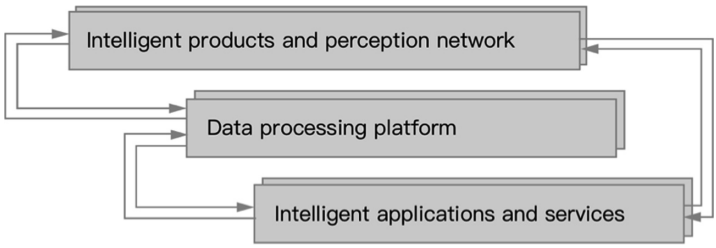

Fig. 13. The framework of Intelligent products and data processing system

Transparency

Only by achieving interconnection and interoperability can a powerful functional system be formed. Enabled by the increasing number of interconnected objects and people, the fusion of the physical and virtual world enables a new form of information transparency [27]. Through linking sensor data with digitalized plant models, a virtual

copy of the physical world is created. Context-aware information are indispensable for IoE participants to make appropriate decisions. Context-aware systems accomplish their tasks based on information coming from the virtual and physical world. Examples for information from the virtual world are electronic documents, drawings, and simulation models. Examples for physical world information are the position or conditions of a too [28]. In order to create transparency, the data analytics' results need to be embedded in assistance systems that are accessible to all IoE participants [29].

Sharing
As we mentioned above, the communication module is one of the most important part of intelligent product, which make it possible to connect objects and share information. Based on the IoT, products can interact with each other, cooperate with their neighboring "smart" components to reach common goals through unique addressing schemas. The communication module is the node of data transmission between independent devices. Currently widely used communication technologies include Wi-Fi, Bluetooth, ZigBee, RIFID, ultra-wideband (UWB) and mobile communication like GPRS, 3G, 4G and even 5G technologies. Through the multi-method communication technology applications, a diverse network of perceptions will be created. Machines, devices, sensors, and people are connected over the IoT and IoP (internet of people) and form the IoE (internet of everything) [30, 31].

4.3 Service Content

At present, one of the most familiar intelligent product is Xiaomi bracelet, which has the embedded three-dimensional rhythmic motion sensor to collect user's motion information, and the data such as the amount of exercise, the number of steps, the quality of sleep, and the calorie consumption. When users use such wearable devices, their own various sensory data, psychological data, and experience data will be transmitted to the back end, and give user feedback about how to improve the health status through the analysis and calculation of the server. Sometimes even recommend related products and more through shopping channels. With the development of intelligent products, the services provided will cover more aspects of life, from smart traffic to health care and etc. The assistance of intelligent devices gradually extends from simple operations in complex environments to fine work to liberate the labor.

5 Conclusion

This paper contributes to the ongoing discussion about intelligent products within both the scientific and the practitioners' community. The paper's practical contribution is put forward the design principle of intelligent products to help people avoid many problems of existing products, such as over-reliance on mobile phone, failure to make full use of the data, frustrated with the user experience and etc. The limitation is that we do not focus on specific product or industry but give the general conception. For example, it is quite different to design a smart car and wearable devices. All in all, Intelligent Products will have a visible impact on humans and society in the future.

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