

## Research on Design Method of Intelligent Furniture

(Full Paper)

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### ABSTRACT

At present, the development of intelligent furniture has started, and intelligent technology has been initially combined with furniture products, therefore, some convenient and interesting intelligent furniture products have appeared on the market. Intelligent furniture provides more possibilities for modern life, and offers good interactive experience to users. The emergence of intelligent furniture can be called a major reform in the history of furniture since it has not only realized the diversification of furniture and provided higher scientific and technological content regarding furniture, but also injected fresh blood into people's home and living environment as well as made great changes in people's lifestyle. However, since it is still in its infancy, and there is a lack of systematic theoretical research and guidance, design ideas and technical content, therefore, through the analysis of the concept, composition, development issues and design principles of intelligent furniture, this paper puts forward and take effective measures to guide the design practice, which is conducive to the further development and design of intelligent furniture.

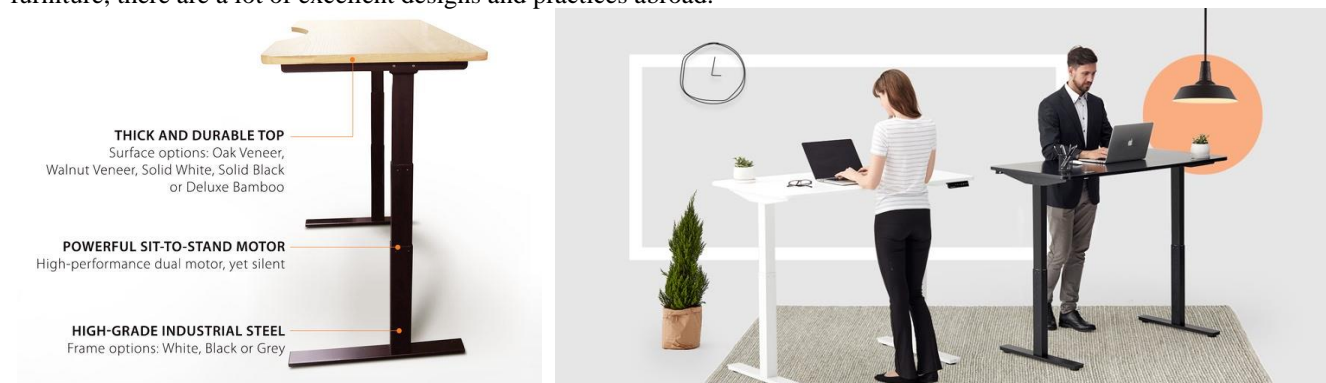
*Keywords:* Intelligent furniture, intelligence, design method, principle.

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### INTRODUCTION

With the development of network technology, Internet of Things technology and artificial intelligence technology, intelligence has become the mainstream trend of today's social development. "Smart home" has begun to enter the public eye through various media, household industry has begun to pay much attention to the application of intelligent control technology. Furniture, as a part of our home, is one of the daily necessities closely related to people's life, work, study, entertainment and other activities. The traditional production mode and function can no longer meet the needs of the intelligent age, so furniture design and manufacturing will gradually develop towards intelligence along with the advancement of society, which is an inevitable requirement for its development—the term "intelligent furniture" came into being.

In the environment of continuous development regarding science and technology abroad, intelligent furniture emerges endlessly. Designers give full play to their imagination and creativity, making furniture types diverse and styles different. The research of smart home in foreign academic fields focuses on human-computer interactions, and the corresponding product function settings are based on the analysis of user behavior. For example, in 2015, the intelligent desk "Autonomous Desk" (Figure 1), which can adjust the height, will remind users when the user's standing or sitting time exceeds a reasonable range of health. In addition, Autonomous Desk also has the ability to learn and communicate, and users can interact with Autonomous Desk through voice. In 2016, Italian designer Edoardo Carlino designed the Hi-CAN smart bed (Figure 2), which is equipped with a computer, TV and game system, turning the bed into a powerful entertainment system. In 2016, Vitra released a revolutionary intelligent adjustable sofa Lift Bit (Figure 3). It is a number of modular lifting hexagonal seat, which can be used alone or combined into various shapes, and the number depends on the user's needs. At the same time, it is equipped with a mobile APP, which can change the height and number of each seat through mobile phone operations, and switch between chairs, sofas and beds at will. In the field of smart furniture, there are a lot of excellent designs and practices abroad.



Source: <https://www.autonomous.ai>.

Figure 1: Autonomous Desk



Source: Baidu Pictures.

Figure 2: Hi-CAN



Source: Baidu Pictures.

Figure 3: Lift Bit

Due to the traditional production mode and functional characteristics, intelligent furniture has not established brand awareness in the domestic market. There are few companies specializing in intelligent furniture, some traditional furniture companies have launched intelligent furniture products, but the brand influence is low and technological innovation is not enough. The research on intelligent furniture in the Chinese academic field started late, far behind foreign countries. It was not until the beginning of 2000 that China began to study smart furniture. In 2005, Hongliang Wang, Jixiang Zhong, Jiaqing Tang and others explored the market of intelligent furniture, and tried to classify its types, but they have not yet conducted in-depth research. In 2006, HaiYan Duan's doctoral thesis "Research on intelligent furniture" established the theoretical framework of intelligent furniture, clarified the concept of intelligent furniture, summarized the characteristics of intelligent furniture, and summarized the design principles and steps of intelligent furniture. Afterwards, some experts and scholars put forward the application of intelligent control theory and technical methods regarding the specific furniture design to guide the design of intelligent children's furniture, intelligent hospital bed, intelligent kitchen furniture and intelligent office furniture, etc. Until now, the research direction of intelligent furniture has gradually become multidimensional, which has a reference function for the progress of intelligent products of today.

### **THE DEVELOPMENT STATUS OF INTELLIGENT FURNITURE IN CHINA**

In the context of intelligent industry, the development of intelligent furniture has begun to take shape. Various types of intelligent furniture emerge endlessly as having intelligent furniture has become a trend. It is not only the creative design of designers or furniture companies, but also the inevitable product of temporal advancement, social progress, economic development and technological innovation.

However, because it is an emerging industry, its development still lacks experience, and some fields are new and untouched technologies. Therefore, the development of intelligent furniture industry also has the following problems: 1) The design lacks innovation, some products simply add intelligent means such as a screen, audio-visual equipment, sterilization and disinfection facilities, as well as a temperature control system to the main body of the furniture. The combination is too rigid and fails to have a good integration. The use of new technology is only for the purpose of achieving intelligence, but not really convenient for people's lives. 2) The designed products are often complicated to operate, so users with good receptive ability may accept the used method relatively quickly, but users with poor receptive ability will experience a long period of learning to master. 3) Many of the intelligent furniture products are still in the conceptualization or experience stage, so it is difficult to mass-produce and put them on

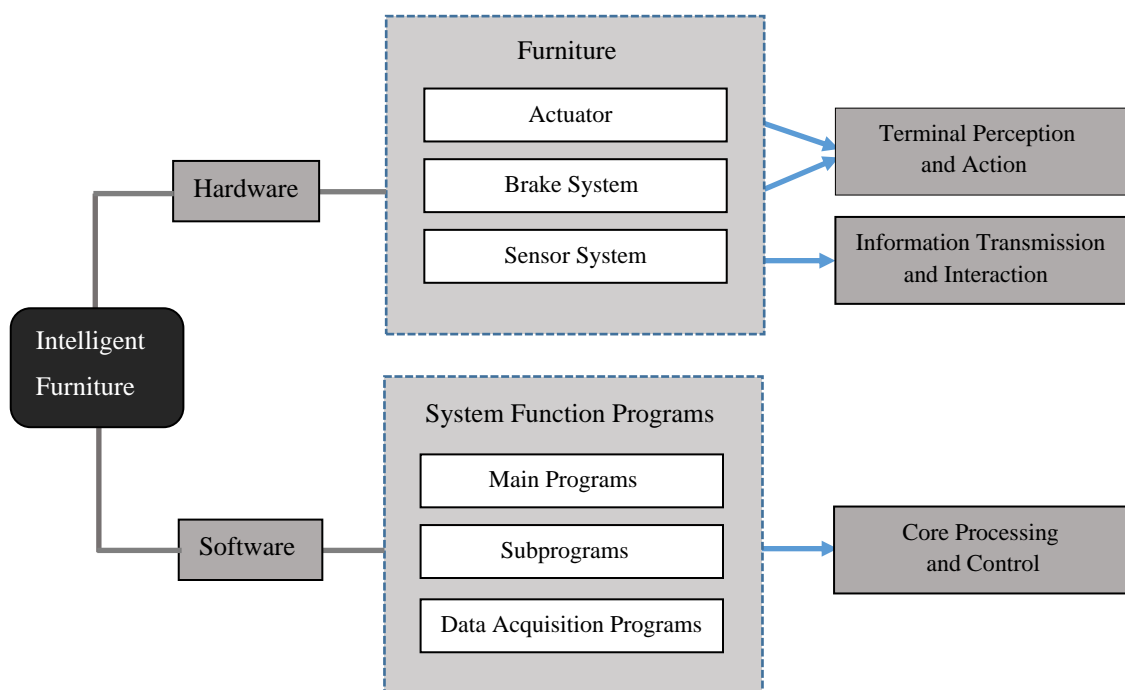
the market. 4) The hardware and software required for intelligent furniture are expensive to design and manufacture, such as voice recognition, sensors and other special intelligent components, which have strict requirements considering technology, quality and safety, thus resulting in high prices of intelligent furniture products. 5) Although there are many types of intelligent furniture products, all kinds of products in the whole intelligent furniture industry are still relatively isolated, and not well integrated into a complete and interconnected system. 6) The degree of intelligent furniture is low and the progress is slow, the transformation from traditional furniture to intelligent furniture is relatively difficult, and there is a large industry span in research, development and design. It is necessary to combine the intelligent sensing system, electronic equipment and other high-tech facilities with the design, materials and craftsmanship of traditional furniture.

### CONCEPT

Intelligent furniture is still in the early stages of research and experimental development. These smart appliances are based on modern furniture, comprehensively using multi-disciplinary and multi-field technical achievements, adopting modern digital information processing and communication technology. They collect various types of signals in real time, which are recorded, judged and fed back by the controller according to the predetermined program, and automatically reflect the needs of users. In a broad sense, intelligent furniture are devices that integrate high-tech into the development process of furniture design through system integration, realizing the optimization and reconstruction of furniture type, material, structure, process or function, endowing furniture with some functions that used to be completed by human beings. In a narrow sense, intelligent furniture apply the technical principles of mechanical transmission, sensor, single-chip microcomputer and embedded system to the furniture entity, turns ordinary furniture into smart items, and forms the interactive relationship between people and furniture. Compared with traditional furniture, smart furniture embodied more humanized features, with self-adaptive, self-sensing, intelligent, fashionable and multi-functional characteristics, making the home environment and life experience more convenient and comfortable. The intelligent design of furniture is the trend of future life.

### COMPOSITION

Intelligent furniture is an integrated control system, which is mainly composed of two parts: hardware facilities with intelligent functions and software facilities with an intelligent programming system. Hardware is the executive part of realizing intelligent functions, the transmission and realization device of intelligent effects, including an actuator, sensor system, brake system, and furniture body, etc., and the integration of mechanical transmission and realization devices for various automatic control of furniture.



Source: This study.

Figure 4: Composition of intelligent furniture (Drawn by author)

Software is the "soul" of intelligent furniture control, and with its basic content, it often includes system function programs such as main programs, subprograms, and data acquisition programs, as well as various module control programs, and subsidiary program for system detection, man-machine interface and peripheral equipment management. Hardware equipment is to embed the intelligent system into the original furniture, with executive functions; the software system can control the perception of hardware

devices embedded in the intelligent furniture body. The hardware device converts the received control information into an electrical signal and then sends it to the software for processing, the processing result is transmitted to the hardware to execute the command in the form of an electrical signal. Through the cooperation between software and hardware, a complete process from the command issuance to the final response is realized.

From the perspective of high-tech products, all the hardware and software components of the intelligent furniture can be broken up and reconstructed into three levels: terminal perception and action, core processing and control, as well as information transmission and interaction (Figure 4). Among them, the terminal perception and action refers to various discrete perception terminals and command action terminal nodes of furniture. In addition to maintaining the functional attributes of traditional furniture, it also needs to provide a variety of rich human-computer interaction interfaces, such as electronic operation panels, high-precision touch screen, etc.. The core processing and control as well as information transmission are basically the same as the software concept, as they are the core mechanism for various data processing. They are often placed inside the furniture as a core module, and connected to other terminal modules through the control bus to convey various "commands".

## CLASSIFICATION

### Mechanical Intelligence

Mechanical intelligence is that the mechatronics device composed of various parts is implanted into the furniture body, and the mechanical device or transmission mechanism is operated in a certain way through manual control. The transmission system converts the electric signal sent by the controller into action commands, and the motor provides kinetic energy through the friction or linkage between gears, levers, transmission shafts and other basic parts to drive the entire system to stretch, fold, flip, rotate, and move the furniture, components or assembly accessories to achieve the transformation or combination of furniture units and functions. Through a simple touch, light press and other actions, the user can initiate the automatic opening or closing of the furniture cabinet or drawer and automatic lifting, rotation, expansion and other functions of the desktop. In this way, it breaks through the limitations of traditional furniture in size, style and function, completes the upgrade and transformation of traditional furniture, realizes mechanical intelligence, and meets the needs of users for multiple specific functions.

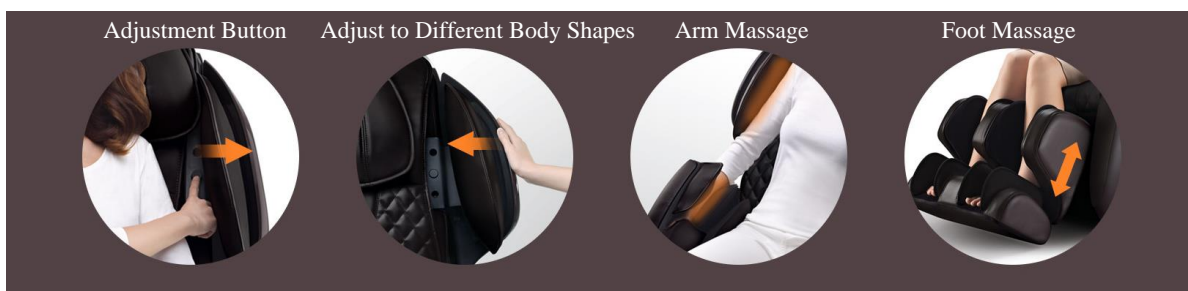
### Electronic Intelligence

Electronic intelligence is the combination of advanced and cutting-edge electronic technology products and traditional furniture through wired or wireless electronic remote control or touch control to realize the intelligent functions of furniture. The user only needs a simple touch action to control the automatic operation of the furniture through an induction device, and realize the adjustment of various functional parameters. Such as playing audio and video, turning LED lights on and off or adjusting the brightness of the light. Figure 5 is the OSIM smart massage seat. Through the control of the remote control or buttons, you can adjust the massage mode, massage position, massage strength, and adjust the seat size and angle according to the different body shape of the user, as shown in Figure 6. There are functions of heating and playing music, which is entertaining in the process of relaxation.



Source: <https://www.osim.com.cn>.

Figure 5: Smart Massage Chair



Source: <https://www.osim.com.cn>.

Figure 6: Functions of Smart Massage Chair

### IOT Intelligence

IOT (Internet of Things) intelligence is to implant advanced intelligent systems or intelligent components (sensors, embedded systems, etc.) into the furniture body and connect intelligent hardware, APP software and data platforms through the network, with the network center and data center as the core. In addition, it also makes use of mobile intelligent terminal devices (mobile phone, tablet computer, etc.) and wireless network technology to realize data processing and the control of furniture. The application of Internet of Things technology can integrate the intelligent furniture control system into the intelligent home control system. Intelligent furniture can be regarded as a subsystem of the Internet of Things and developed into a kind of terminal, which can realize the deep interaction between humans and furniture and finally realize the intelligent operation of family life.

### Sensors

As a detection device, the sensor is usually composed of sensitive components, conversion components, signal conditioning and conversion circuit. These components can sense the information transmitted from the outside and convert it into a certain regular and specified form of electrical signals and other forms of output, in order to realize the transmission, processing, storage, memory, display, recording and control of information, and that is the primary link to realize intelligence. Sensors can identify the external environment information independently, so that objects can have the perceptive ability of vision, hearing and touch like human beings. Sensors are implanted into the furniture body, such as photosensitive sensors, sound sensors, temperature sensors, etc. in intelligent furniture. It detects or perceives the user's actions, touch and other information, so that the furniture has specific intelligent functions of automatic detection, automatic sensing and automatic control. Due to the application of sensor technology, furniture is transformed into multi-functional products, which is a great leap in the field of furniture. The smart wardrobe with smart fitting mirror is shown in Figure 7.



Source: Baidu Pictures.

Figure 7: Smart Wardrobe

### Embedded systems

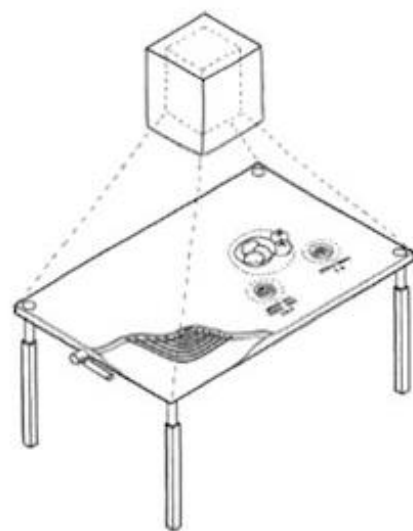
The microcomputer processing system is embedded in the furniture body. The embedded system is equivalent to the "central nervous system" of intelligent furniture, which is integrated by software and hardware, and mainly composed of an embedded processor, operating system, electromechanical devices and other supporting hardware and application software. The embedded processor is the core, and its performance determines the operating effect of the entire intelligent system. At present, embedded systems have been widely used in smart phones, digital cameras, household appliances as well as vehicle navigation systems, and its development also gave birth to the emergence of intelligent furniture. Embedded systems have been widely used in the field of furniture, and regarding its functionality, users can use mobile phones, tablet computers and other mobile terminals to control the specific functions of furniture through wireless network or remote control. Smart kitchen (Figure 8) can back up the data of

refrigerators, electric rice cookers, ovens, dish washers, microwave ovens and other devices to the data center, obtain the data from the data center with mobile phones, and set tasks for multiple devices, so that the liberation of kitchen labor can be easily realized.



Source: Baidu Pictures.  
Figure 8: Smart Kitchen

The "2025 Concept Kitchen" project launched by IKEA was in collaboration with the design company IDEO and students of Lund University and Eindhoven University of Technology. IKEA assumes that the kitchen in the future will integrate more application scenarios, and a single tool may connect more functions. IKEA has designed an integral part of the kitchen 'A Table for Living'. The dining IKEA table plays an important role in our daily lives where individuals come together to share not only food but also experiences. As such the table will not only be used to dine, but will also serve as the hob, the preparation table, and not only this; it will also act as a table for work and play. "A Table for Living" (Figure 9, 10) is a smart home that combines technology and creativity, and it is called a kitchen control center rather than table, it looks simple and plain, with IKEA's consistent style. The table recognizes the grocery items kept on it, through a camera located above, and suggests recipes involving these ingredients. The idea is to waste less and engage with the food in order to be more mindful and live sustainably. With the table, you no longer have to worry about cooking, for example, putting potatoes and tomatoes together, you will know how to turn them into delicious dishes, you can also import a recipe and the table will guide you step by step. Magnetic coils below the surface enable the table to be used as an induction top for different dishes to be prepared simultaneously. It is very convenient to make a cup of coffee and charge the phone, while heating the food, it can also be used for children to play, and they do not have to worry about being burnt. In short, the aspect that makes this table efficient is its quality of unobtrusiveness since different features have been integrated without any visual heaviness, enabling it to be used in a flexible manner.



Source: Baidu Pictures.  
Figure 9: A Table for Living- IKEA Table



Source: Baidu Pictures.  
Figure 10: Functions of the Table

### DESIGN METHODS AND PRINCIPLES

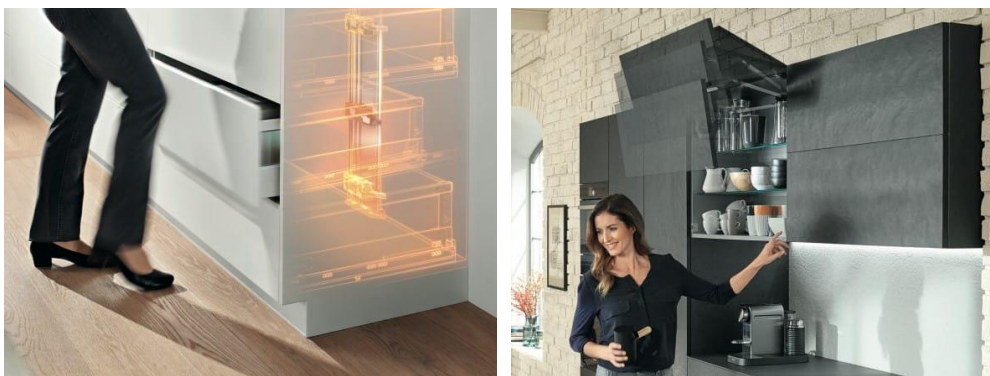
Compared with traditional furniture, the design of intelligent furniture is an innovation in itself. In addition to following the principles of traditional furniture design, it is also necessary to introduce intelligent technology in a clever and reasonable way, by means of using modern science and technology to endow it with new functional characteristics, or improve its material and structure. Besides, it is important to transplant or learn from the design of other fields to realize its own innovation, so that traditional furniture and intelligent technology can be perfectly integrated, as well as it is desired to avoid to have one-sided pursuit of innovation and too rigid combination. It is necessary to design furniture products that truly meet the needs of users, conform to modern aesthetics, facilitate daily use, and improve people's quality of life. Therefore, the design of intelligent furniture should meet the following principles.

#### Safety Principle

Safety is the first consideration in intelligent furniture design since it is directly related to the safety of users and home. The security here includes not only the physical security of people using furniture products, but also the privacy security of users. Therefore, security is particularly important.

As for the physical safety of intelligent furniture, since the intelligent effect needs the support of electronic and mechanical components, intelligent furniture is more prone to electrical and mechanical safety problems. It includes two aspects: first, there cannot be any potential safety hazard in the furniture during design, and the location of the circuit and the electronic mechanical device has to be reserved in advance. In order to reduce the risk of an electric shock, intelligent furniture should adopt a voltage safe for humans as much as possible, install leakage protection devices, and overload protection measures, as well as try to use materials with good insulation properties. Second, the application process of furniture has to be safe, electronic chips and machinery will emit heat during work, so a heat dissipation system must be installed to prevent high temperature caused by burning components and leakage. For example, some automatic trigger devices, such as the upturned door and drawer of intelligent kitchen systems provide electric energy for itself through batteries instead of the traditional circuit.

About the privacy security of intelligent furniture. The development of the internet and cloud services has made people's lives surrounded by huge amounts of data, although the concentration of data is convenient for query, it also increases the risk of information leakage. The design of intelligent furniture also needs to strengthen the management in terms of data security protection, adopt the technical means of identity authentication, biometric recognition (fingerprint recognition, iris recognition, facial recognition, etc.), access control and data encryption to improve the system security and prevent the leakage of user's information and data.



Source: <https://www.blum.com/cn/zh/>  
 Figure 11: Automatic Uprturned Door and Drawer

### Easy Operation Principle

The design purpose of intelligent furniture is to meet the needs of people's daily life and work. In the design, the target consumers and their acceptance range should be fully considered. The easy-to-understand operation interface and the concise way of use can make people clear at a glance, enable users to have a good user experience, and establish a "harmonious dialogue" that facilitates communication between users and products. Although most of the intelligent means are high-precision technology, in the design, interaction design, interface design and ergonomics should be used to transform complex intelligent systems into intuitive and easy-to-use methods. Intelligent furniture liberates human hands to a certain extent, and realizes the operation of intelligent furniture through buttons, smart phones and touch screens, etc., which brings convenience to people's lives and makes users feel that "smart" is integrated into "life" .

### Humanity Principle

While intelligent furniture is based on the characteristics of practicality, more humanistic concepts should be incorporated into the design, combined with the principles of ergonomics, emerging technologies, and the use of green materials. At the same time, from a psychological point of view, the design of intelligent furniture also needs to meet the psychological and aesthetic needs of users, adhere to the humanized design principles, reflect all the "human" relationship closely related to the product life process, and achieve the best coordination and unity with users with the help of high technology.

For example, in the design of intelligent seats, our common seats are designed according to the human standard scale or typical scale. This scale is generally based on the average value of a certain stage, although this is an emphasis on the principle of humanity, but we can further improve and upgrade the humanized design in combination with new technologies and new methods, and apply ergonomics to the design of intelligent seats in a more flexible and targeted manner. It is necessary to fully consider the needs of different ages, the needs of different users, the needs of different usage scenarios and the needs of different usage methods as well as other situations. The scientific and reasonable "adjustable" size is adopted in the design of intelligent seat, so that users can make multi-directional and multi-angle adjustments of the back, armrest, and sitting surface according to their body size, environment and state at any time to feel comfortable and relaxed, as it is shown in Figure 12. Intelligent furniture will serve people's feelings, safety and health more humanely.



Source: Baidu Pictures.  
 Figure 12: Intelligent Adjustable Seat



### Aesthetic Principle

Because of its special intelligent expression, intelligent furniture should pay attention to the matching degree between the intelligent system and the furniture body. In the design, the addition of intelligent components should be considered in advance, and the electronic components should be hidden or integrated into the furniture skillfully. Due to the complexity of the internal organization, the relationship among the components must be carefully considered during the design process to prevent electronic components from affecting the aesthetics of the furniture. At the same time, the addition of modern intelligent technology can further enhance the aesthetics and value of the furniture itself, electronic display technology and mechanical technology can be used to add visual effects such as sound and light to furniture. In addition, intelligent identification technology and interactive technology can be used to give furniture vitality, so as to realize the interactive communication between humans and machine, and enhance the fun of use.

### Easy Processing Principle

The ultimate goal of smart furniture design and development is to go to the market, so the production and processing links should be considered in the design. When designing, standardized universal modular units are advisable, which can bring great convenience to the production and processing of intelligent furniture. Uniform molds, parts, and materials can all bring about the optimization and upgrade of the intelligent furniture design, make it easy to process and produce. The use of expensive and complicated parts should be avoided, thereby simplifying the production process to achieve mass production. Combined intelligent technology can also be used in the design process to make each function into a separate module component, so users can combine them according to the modules when purchasing, while satisfying individualization. The types of modules that need to be processed in the manufacturing process are reduced, which facilitates mass production and reduces processing costs. With the advancement of science and technology, intelligent materials come into being and its application can reduce the use of non-renewable resources and optimize the whole process of furniture products to a certain extent.

### Functionality Principle

As a new intelligent product, compared with traditional furniture, the most prominent feature of intelligent furniture is more emphasis on function. It mainly includes the inherent functions of furniture and the new functions brought by intelligence. Intellectualization is an upgrade of traditional furniture, which is based on the functional theory of traditional furniture, moreover the extension and expansion of furniture functionality under the promotion of science and technology development and the needs of the times. Furniture is no longer an immutable static object, but a product of artificial intelligence with more possibilities. In the process of design, functionality and intellectualization are master-slave relationship, and intellectualization must be carried out on the basis of obedience to functionality. Different consumers will have different needs, after clarifying their needs, so we can design and improve the functions in a targeted manner. On this basis, intelligent design is carried out, giving it new functions or reducing or even replacing some human activities through intelligent devices, so that it can better integrate with the furniture to meet user needs.

First of all, the original functions of furniture can be deepened. For example, the function of the bed is to provide a good sleep environment, however, the development goal of the smart bed should be to make sleep more comfortable and smarter. Sleep can be divided into bedtime, sleep state and waking up, correspondingly smart bed should have the functions of helping sleep, reminding people to sleep, improving sleep quality and waking up. Secondly, it can expand new functions and combine the functions of intelligent devices with traditional furniture to meet people's needs in an all-round way. For example, the bedside table can be equipped with wireless charging and music playing equipment, and tea table can have the functions of refrigerator and intelligence. Finally, under the new requirements, according to the existing products and the relatively mature technological achievements, carry out, imitate, transplant or modify, and innovatively design products with different functions and types, it is possible to provide new design ideas for intelligent furniture. For example, the dehumidification and sterilization function of intelligent wardrobe imitates the indoor dehumidifier.



Source: Baidu Pictures.

Figure 13: Intelligent Bedside Table and Tea Table

## CONCLUSION

Intelligent furniture is the trend and direction of functional product development in the future furniture industry, is an exploration attempt of the furniture industry in the field of information technology, and it is the collision between the traditional industry and the emerging industry. The design and manufacture of intelligent furniture requires the interdisciplinary and comprehensive application of multi-disciplinary and multi-field technical achievements. It is based on the modern fashion furniture, combining traditional furniture design and production with modern digital information processing together with other technologies, as well as using modern technology to enhance the aesthetic and value of traditional furniture. It enables intelligence to enter people's, which will make the intelligent functions brought by technology visible and tangible.

With the rapid development of economy, it is an inevitable trend for furniture to realize intelligent functions, and as the development of intelligent technology and intelligent materials, intelligent furniture will become more "intelligent" in the future, it will be more convenient to operate, and there will be smoother human-computer interactions, as well as it will be more convenient for actual use, which will gradually transform furniture from static and inanimate to dynamic, interactive and even intelligent control. While satisfying the basic functions, intelligent furniture is more in line with the needs of modern users, expand the scope of the consumers, integrate science and technology with furniture, give users a fresh feeling and a better user experience brought by the new intelligent technology that truly meets all the needs of people for furniture.

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