Research on intelligent lighting mode based on implicit human-computer interaction

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Abstract- In this paper, through the research based on implicit interaction elements, the important role of autonomous implicit feedback in intelligent lighting scenes is pointed out, and the lighting control method based on IILCM mode is proposed. The autonomous implicit feedbacks lighting system which is consisted of two components with sensors and MCU is designed and implemented. Describes the hardware structure and software module functions of the system, as well as the design principles of intelligent lighting products in the implicit interactive mode. The experiment shows that, for different users, the system can effectively adjust its brightness output adaptively, which can greatly reduce the burden of users using the equipment, and meet the requirements of the implicit interactive mode for light source brightness control.

1. Introduction
The fast development of the Artificial Intelligence and wireless communication technology has changed lifestyles, brought tangible network effect, and promoted new application scenarios for intelligent products. Many intelligent terminals are not only equipped with advanced sensors, but also processors with stronger computing power. The human computer interaction (HCI) technology is increasingly applied to smart lighting industry. The HCI of smart lighting products are primarily realized through two ways: the interface interaction including gesture interaction, and the voice interaction\textsuperscript{[1]}. Be it interface interaction or voice interaction, both are categorized as Explicit Human Computer Interaction (EHCI), which involves user into the process of “interruption – operation – proceeding” while using the product; and EHCI causes user distraction, comes with application limitations, as well as increases user cognitive load of the product\textsuperscript{[2]}. With the help of various sensor technologies, smart lighting products are provided with improved context awareness and user behaviors, which allows products conducting autonomous response and information processing and providing proper lighting environment to users with the self-adjusted lighting. And this composes a new way of HCI, namely the Implicit Human Computer Interaction (IHCI).

The research of implicit interaction includes information system, information processing, context awareness and reasoning. Among them, context awareness is a common hotspot in many fields. It is an essential step for computing systems to obtain action semantics from underlying sensors. Article \textsuperscript{[3]} considers the context information and uses the hierarchical hidden Markov model to recognize the hand posture. Article \textsuperscript{[4]} takes the learning results of users' activities in daily life as context information, and the system gives tips according to the context, so as to help users complete different activities in daily life. Article \textsuperscript{[5]}implements a distributed computing system, which can select the camera according to the user's face orientation and position. The system implemented in article\textsuperscript{[6]} can provide auxiliary
information based on knowledge base according to context information, which is determined according to people's location and medical schedule. In all the above work, context information is only used to guide the underlying information processing. Some work also considers that the context has a dynamic structure [7]. In the scene setting of users' continuous long-time visual operation, objects can move freely in the living environment and can be in any position in the room, which leads to the change of the scene. At the same time, users perform various activities in daily life and interact with the surrounding environment. Therefore, it is challenging to model context information in reading learning scenarios.

2. IHCI elements suitable for smart lighting

In the year of 2000, Albrecht Schmidt defined implicit human computer interaction as an action performed by the user that is not primarily aimed to interact with a computerized system but which such a system understands as input[8]. As a new way of HCI, implicit human computer interaction is user-centered and the implicity is based on two concepts: awareness and interpretation(Fig.1). The computing system, under given conditions, detects user’s movements, synchronously captures the context of the movements, then interprets user’s intention while implicitly inputting the orders into system. And the implicit output of the system, namely the service it provides to users, corresponds to the user’s surrounding environment. IHCI elements suitable for smart lighting include:

1. Setting of service scope
   Service scope refers to the range of the smart device’s application. Theoretically, there is no limit on adding non-lighting functions onto smart lighting product. Yet the exitance of non-lighting functions, such as sound box, digital clock, wireless charging, aromatherapy, humidifier, indicates not only the challenges from the compatibility between various subsystem, but also the increasing cost of secondary development of the product. In addition, the product’s main function, namely lighting, might subject to compromises in quality as a result of the disturbance and influences from the subsystems. In short, multifunction does not necessarily lead to better user experience. The paper believes that the scope of service should be determined by the main service user and context of use, which could contribute to better decision making when designing product’s function.

2. Dynamic perception of context
   The dynamic perception of context is the first and foremost condition to the implicit human computer interaction of smart lighting products. The perception of context and user behaviors is relied on sensors such as infrared sensor, ultrasonic sensor, humidity sensor, visual sensor, and other dynamic sensors. According to functional requirements from different products, these sensors could be combined correspondingly (Fig.2). The multisensory fusion could improve accuracy of scene perception while enhancing product’s operational reliability. With these sensors, the product could dynamically capture contextual information on user behavior such as the status of the outdoor environment and people (including changes on ray of light, weather, and flow density), and the status of the indoor environment and people (including changes on ray of light, the positioning of product, and the positioning of user). Various perception inputs provide more choices and possibilities on outputs.

3. Being equipped with information processor(s)
   Information processors is the core of smart device’s computing competence and it is also a significant manifestation of the cognitive competence of the smart lighting product. Smart lighting products require chips with strong computing power to carry out the identification, analysis and calculation of the collected primary data which contains images and voice information on user behaviors. When it comes to more complicated smart computing and more natural human computer interactions[9], cloud computing with high speed internet connection is required. The combination of internet and cloud computing could realize the concept of Internet of Things. It could also gather the data on user behavior, by analyzing which, the software could be upgraded to offer better intelligent interactions.
4. Autonomous implicit feedbacks

Different from the request for information process from the persuasive and endorsing services in explicit human computer interactions, implicit human computer interactions bring no overload of information to users. If the smart lighting product uses implicit human computer interactions to provide lighting, then it is a necessary condition that the product gives automatic response to user behaviors, which is also the precondition of implicit feedbacks. Implicit feedbacks could be regarded as that the machine understands user behaviors, which is more user-friendly information output. Designing smart lighting product involves the building of software and hardware[10], as well as independent development or secondary development, which make it the hardest part of the research. Under insufficient software and hardware condition, in the earlier stages, the research manufactured the prototype using open source software and hardware. It could verify the design idea, try and error, iterate, as well as provide reference to further development of the product.

Fig.1 Implicit interaction model diagram

Fig.2 Implicit interactive information processing flow
3. Applying IILCM(Implicit interactive lighting control mode)

Featured by smart bulb, current smart lighting products interact by independent controller or mobile applications to control the on and off and adjust the luminance, color temperature, and colors. Either way of control requires user break off from the current work and operate on the controller or on mobile phone. The controller with independent pushbuttons belongs to traditional interactions. The pushbuttons are where the limitations lie in: the functions the product provide is decided by the number of pushbuttons that could be fit on the controller. As a result, the product has limitable responses to the various lighting scenarios and demands. On the other hand, the use of mobile applications increases user’s autonomy to some degree, but it comes with a price. Some applications over emphasize customer stickiness by requiring users spending much time learning how to connect to device, search for different functions, and remember the operating steps. It takes up too much time and leads users towards the predicament of “Screen Animals”. To make it worse, with the frequent information feedbacks and operation requests of some applications, users are passively interacting instead of actively interacting with the product[11]. This not only compromises the user experience, but could also results in negative influences such as invasion of privacy, out of control, and disturbance. To differentiate from the existing control mode of smart lighting product, the research team designed a smart desk lamp with implicit interactions. This paper will discuss the design, development and testing of the product. Research includes: (a, determining the actual user demand of the product by measuring and documenting user behaviors, the service environment, and product usage time; b, transforming the collected data to quantitative indicators which could facilitate the setting of service scope, context perception, information processing, and autonomous feedbacks.

In the scenario where users use the product for a certain amount of time, the lamp is designed to remind the user for a break by IILCM autonomous control itself. When the user uses the lamp to two hours without leaving it, the lamp will flicker twice, and reduce the luminance by 50% in 20 seconds. If user leaves the lamp at this time, it will enter into “Away Mode”, when the lamp will maintain 50% of luminance for 5 minutes, then reduce the luminance to 30%, and in 15 minutes the lamp will turn off. If the user chooses not to leave the lamp, after the lamp maintain 50% of luminance for 5 minutes, it will flicker one more time and goes back to 100% luminance (Fig.3). The above data conditions are taken as reference when drawing the flow chart of the control program. The prototype is manufactured using open source one chip microcomputer (Fig. 4).
1. The setting of autonomous feedback
   With implicit feedback comes the soft start function which allows progressive buffer time for the turning on and turning off of the lamp. The on and off of the lamp are set as a progressive increase or decrease in certain amount every 300 millisecond. The change of light is not detectable when the user is not focusing on the lamp and even if the user is staring at the lamp, the progressive changes of the lamp light are not abrupt. This setting avoids disturbance or disruption to the user. Same disturbance avoidance rule is followed in the adjustment of the luminance, color temperature, and the fade in and out the scenarios.

2. Manufacturing and testing the prototype model
   Three prototype models were manufactured and the testing is yet completed due to the limitations
on test conditions. Based on initial test results (Fig.5 Fig.6), the experimented models have reached the initial target, namely, autonomous response without involving user’s operation. However, in terms of user experience, it is not satisfying and requires further iteration.

Fig. 5 Acceptance of principle prototype       Fig. 6  Reliability Statistics

4. Designing principles of the implicit interactive smart lighting products
From the above analysis, the implicit interaction theories and practice not only present natural and intelligent lighting effects, but also significantly reduces user’s burden. The main designing principles are as followed:

1. Reducing attention to the product
   To implicit interactive smart lighting products, the emphasis is on reducing user’s attention to the product itself. In terms of explicit interactive smart lighting products, user’s intention is explicitly conveyed to the product. Nevertheless, it is inevitable that users have to bear the physical and psychological burdens that arise during their interaction with the products. User’s personal work will be interrupted when they have to give explicit response to the request from the product system, or when the system gives over frequently requests to them. In comparison, implicit interaction requires no explicit input or response from user, which reduces user’s physical and psychological burden and making the interaction system not that annoying[12].

2. Self-adaption of the product
   Implicit interaction does not involve user’s active interaction with the smart lighting product. Instead, its smart system actively obtains user behaviors and interpret user’s potential demands[13]. By transforming gathered features of user behavior into instructions to the product, the product could predict user’s intention together with the scenario information, make decision and autonomously execute the input instructions. All is done without disturbing the user reading. Because the product could autonomously conduct analysis on user behavior, users are not involved with any interactive request from the product.

3. Providing dynamic and comfortable luminous environment
   With user’s different behaviors, the product provides accurate variations in lamination, which is not only in accordance with China’s illumination standards, but also a dynamic, comfortable, and healthy lamination environment that takes the changes of color temperature and color into consideration. In short, it fits for advanced lamination requirements.

5. Future prospects
The application of implicit interaction on smart lighting products is not merely lamination improvement for users; the underlying importance is the reflection on intelligent technology. Especially with the empowerment of big data, Artificial Intelligence could predict with much higher accuracy[14]. On one hand, the virtual and real intelligent products bring convenience to users; on the other hand, they cause physical and psychological influences, such as information overload, information disturbance, privacy infringement, cognitive load and etc. Implicit interaction helps to reduce, to some extent avoid, the influences.

With the continuous development of intelligence technology, there will be chips with stronger computing power and higher integration and AI will advance enormously. As a predictable result, the
data gathering, computing, processing and analyzing ability of smart products will elevate significantly. In addition to identifying and predicting the user behavior, environment, language and user habits, the smart products could communicate with users and “read” through user’s mind. These technological developments bring far-reaching impact on the morphology and function of smart lighting products. We hope that it will be a technology advancement and revolution that cause minor disturbance on human society’s value system[15]. Especially in the field of smart lighting products, implicit interaction with more advanced intelligent technology will provide a smarter and more user-friendly lumination environment[16] and that machines will become more human.

6. Conclusions
The paper describes the elements of implicit interactions that are suitable for smart lighting products. Based on current researches and actual design cases carried out by the authors, this paper also discusses features and methods of designing smart lighting products using implicit interactions. The paper ends with conclusions on principles of designing smart product with implicit interactions and the prospects in the future. With limited testing conditions, the scenarios in this research are relatively simple and lack diversification. The information processing and effect monitoring require further enhancement. These shortcomings need to be tackled in future research.

Acknowledgment
* This paper is co-sponsored by the Innovation Project (project No. 17XJA030) of Guangzhou Academy of Fine Arts.

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