Interaction Design of the Family Agent Based on the CMR-FBS Model

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Abstract. The paper explores the function and contents design ontology for the interaction design of the family agent through design prototypes and models. Except for the FBS (Function + Behavior + Structure) Design Model for the agent product function design, the paper proposes the CMR (Contents + Mental/Interaction Model + Relationship/Requirements) Design Model for the intelligent agent and users Human-Robot Interaction contents design. For the Baidu Brand smart speakers case study, interaction design for agents' wake-up word modes combines FBS and CMR Design Models and also analyzes the transformation relationship between the function task and the description contents. The results show that the combination of FBS and CMR supports high agile live intelligent agent product design and data service interaction design, CMR is the key factors for providing high satisfaction user experience. Finding function and task requirements and construct HRI interaction relationship with the User Generated Contents creation is the new interaction design method for the intelligent products interaction design.

Keywords: Interaction design · Family agent · CMR-FBS model

1 Introduction

The interaction design of the family agent is divided into two parts: function and content. The FBS (Function + Behavior + Structure) Model is an ideal model proposed by Professor Gero et al. to describe the product conceptual design process [1, 2]. Since the FBS Model was proposed (1990), it has been widely studied, used in design and improved by scholars. Although it has solved the problem of fuzzy demand in the early stage of design and development, it mainly focuses on engineering design, architecture, architecture and product design. The field of software design, and mainly for product design of functions, lacks design for the family agent [2–9]. As to the intelligent agent product service system design, designers need expand FBS into the ontology to deal with the function design and contents design. For the lack of design method and model for the contents design, this paper proposes CMR (Contents + Mental/Interaction Model + Relationship/Requirements) Model for the intelligent agent and users Human-Robot Interaction contents design. Through the use of CMR-FBS ontology of designing

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model, the information communication and fusion of the material world and the digital world can be better realized, and a unified and consistent user experience can be created.

2 Function and Content Design

The scope plane in *Elements of User Experience* contains the functional specifications of product as functionality and the content requirements of product as information (see Fig. 1) [10]. Content is an important part of the user experience that can't be ignored, but we often lack the awareness of content experience in the design process. Content is the essence or meaning contained in things, and it is the sum of internal factors. The four major roles of interaction design are the exchange value of information, the communication medium of the interface, the sympathetic means of function, and the traffic evaluation of content [11].

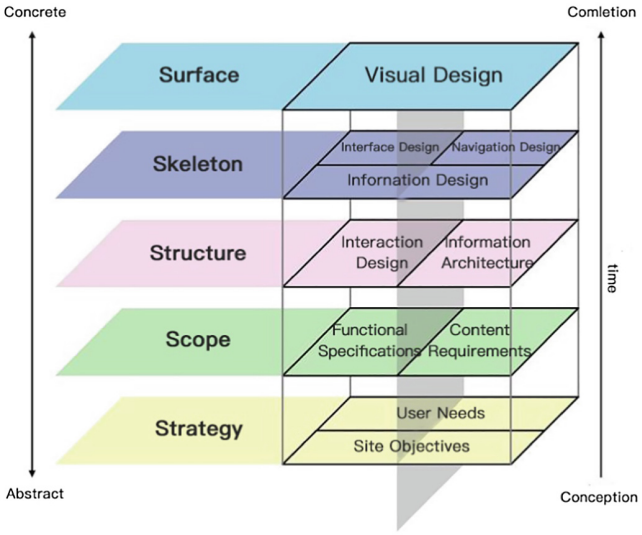

Fig. 1. The elements of user experience [10]

High-quality content can not only solve the needs of users, but content presentation is also a part of user consumption. Alibaba's design team defines content as pan-product information formed by processing and reorganization, which mainly includes four parts of text, goods, pictures and multimedia. The content itself is the flow of communication: from the production of content, to the reorganization of various platforms, to the presentation of content, and finally the content is consumed and transferred by users (see Fig. 2) [14].

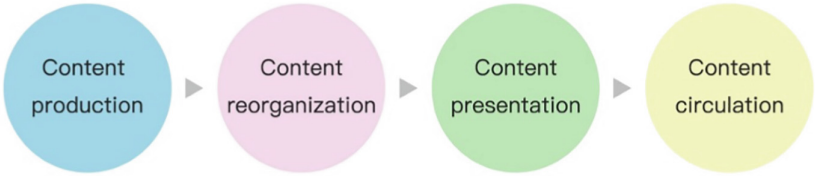

Fig. 2. The elements of user experience [14]

3 The FBS Design Model and Its Optimization

The FBS ontology framework (Gero 1990) models designing in terms of three basic classes of variables: function, behaviour, and structure [1, 12]. In 2004, Gero et al. improved the model and introduced the concept of design requirements. Later, Cascini added the concept of requirements and requirements to the problems in the FBS Model [22]. Gero further described the FBS framework and its relationship to design and design ideas in a 2009 paper (see Fig. 3) [12]. The goal of the design of this process is to transform a set of functions into a set of design descriptions (D). The function (F) of a designed object is defined as its purposes or teleology; the behaviour (B) of that object is how it achieves its functions and is either derived (Bs) or expected (Be) from the structure, where structure (S) is the elements of an object and their relationships [12]. The three ontological categories are interrelated: function is linked to behavior; behavior is linked to structure; there is no connection between function and structure.

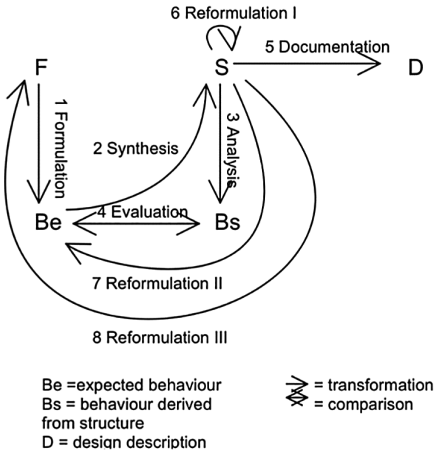

Fig. 3. The FBS ontology of designing (after Gero 1990) [12]

Based on these articulations, the FBS framework proposes the basic processes in eight designs, specifically: [12]

1. A formulation which transform functions into a set of expected behaviours;
2. A synthesis, wherein a structure is proposed that is likely to exhibit the expected behaviour;
3. An analysis of the structure produces its derived behaviour;
4. An evaluation process acts between the expected behaviour and the behaviour derived from structure;
5. Documentation, which produces the design description;
6. Reformulation type 1: modifies the structure state space, based on a re-interpretation of structure;
7. Reformulation type 2: modifies the behaviour state space, based on a re-interpretation of structure;
8. Reformulation type 3: modifies the function state space, based on a re-interpretation of structure and subsequent reformulation of expected behaviour.

Since the FBS design model was proposed (1990), the model has been used as the basis for modeling design (design results) and design processes (design activities) in many design disciplines, including engineering, architecture, architecture, and software design [2–9]. The FBS Model solves the problem of "how to do it", which starts with the function and ends with the structure, and does not cover the content requirements well [15]. And the expression of the concept of variables in the FBS Model is rigid, that is, the expression of non-zero or 1, so in the design and development process of the model, the demand must be clear [2]. However, in fact, the iterative update of technology, the ever-changing relationship between people, things and things makes the user demand multi-level and dynamic change characteristics, so the design front-end needs have certain ambiguity [2]. To this end, the majority of scholars have carried out extensive research and development, mainly through the introduction of other theories and supplements with other models in the early stage of user demand, such as used natural interaction as a solution to fuzzy requirements, and used QFD models to establish a direct mapping between user requirements and product design requirements to ensure a high degree of consistency between user requirements and product design requirements [2, 16]. However, the current application of the FBS Model is mostly for functional entity products, and research on information products is lacking. User needs include not only functional aspects, but also physical, psychological and subjective feelings. This makes the FBS Model have a vague boundary between the interpretation of the objective material world and the thinking space, information space and cyberspace.

4 The CMR Design Model

Because the FBS design model is lacking in content design, Prof. Yan Jingyan found the variable categories corresponding to the content design level for the three ontological categories in FBS, and proposed the CMR (Contents + Mental/Interaction Model + Relationship/Requirements) Design Model [4], the corresponding relationship is shown in Table 1.

Table 1. Correspondence relationship between FBS and CMR's variables.

FBS	CMR
Function (F)	Content/Container (C)
Expected behaviour (Be)	Mental model (MM)
Behaviour derived from structure (Bs)	Interaction model (MI)
Structure (S)	Relationship/Requirement (2R)

The CMR Model designs the container of information flow, material flow and capital flow according to the theory of supply and demand (see Fig. 4). C represents the Container carrying the content. C consists of the tangible and intangible (consciousness, ethics and aesthetics) two facets, and the two are in the interactive and balanced relationship. M establishes a mapping relationship between 2R (relationship & requirement) and design requirements of products, with users' mental model of a single line and a double line as the subject, interaction model being the object, which is a five-layer information architecture having two kinds of information, digital information and non-digital information. CMR emphasizes that the content needs matched mental model and interaction model. The defined threshold lead to what users want and need, afterwards the supply-and-requirement relationship is exported, hence forming a moderation relationship among person, things and objects [17].

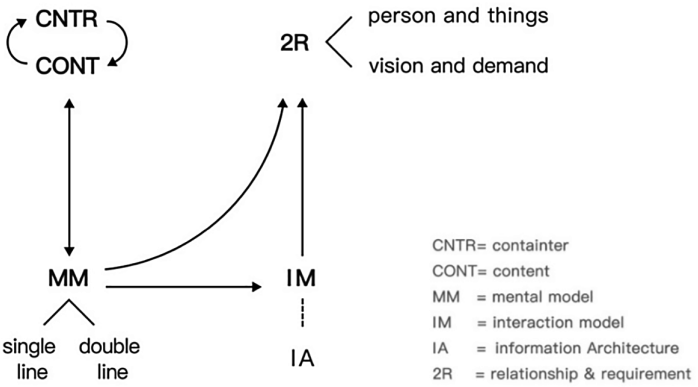

Fig. 4. The CMR ontology of designing

Before using the FBS model for product development, the CMR model is first used to define the threshold, guide the user's vision and needs, derive the supply and demand relationship, and then use it as the functional element of the FBS model, and based on this, develop the FBS model design process. The fusion application of CMR and FBS establishes the connection between user requirements and other variables (F, B, S), making the factors considered in the design process more comprehensive, and it is easy to analyze user requirements from multiple angles [23]. Therefore, the function and content factors of the final design result can be balanced, and the integration of information flow, material flow and capital flow can be realized.

5 Research Methods and Processes

Based on CMR and FBS Model, the "container-contents-function", an integrated application patter of CMR and FBS Model is set. It can guide innovative design of products much more better. The specific research process of in an integrated application of CMR and FBS Model are as follows: (see Fig. 5)

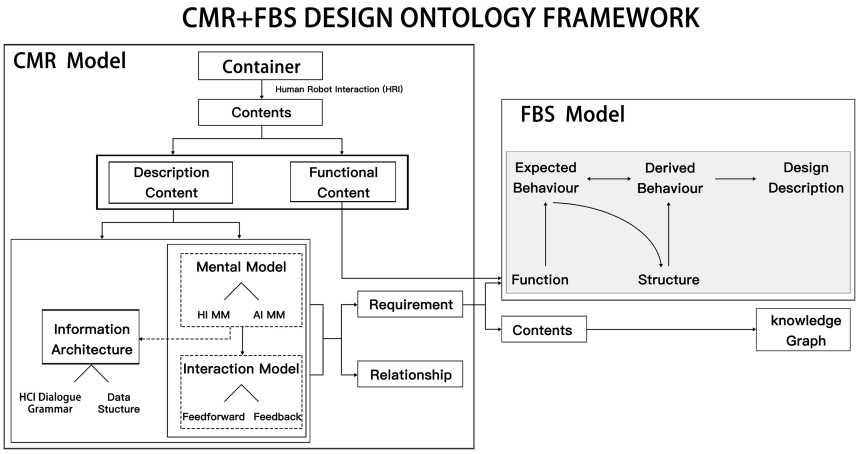

Fig. 5. CMR + FBS Design Ontology Framework

1. Establishing a container of human-computer dialogue and calculating the dialogue content;
2. Exploring the user's content requirements and functional requirements from the content of human-computer interaction feedback;
3. The cognitive calculation of functional requirements in the container is conducted according to the FBS method;
4. The dialogue semantic content calculation of content requirements in the container is conducted according to the CMR method;
5. Inductively constructing the user's mental model in the dialogue semantic content and making cognitive judgment decisions on the content;
6. Reorganizing the mental model with artificial intelligence involved according to the user's mental model to form a mental model of the double loop;
7. Matching a human computer interaction model according to the double-loop mental model of human intelligence and artificial intelligence;
8. Defining the content threshold of the human-computer interaction dialogue jointly by the mental model and the interaction model and distinguishing the functional content and description content of the new interaction content;
9. The supply and requirement relationship of the interaction function is exported by the functional content, and feedforward-feedback dialogue relationship of content interaction is exported by description content;

10. Determining the supply and requirement relationship and the dialogue relationship, designing the intelligent robot's supply and requirement relationship between human-robot interaction scene and content of that;
11. Interactive transforming between interaction function and interaction behavior and information architecture transforming between interaction behavior and data structure of are based on requirements and relationships;
12. The HCI dialogue grammar between the user and the agent is jointly defined by MR and FBS, and the function and content of the dialogue enter the next round of HMI feedforward feedback.

The threshold definition in the CMR Model is obtained by matching the content with the interaction model, and transforms it into a supply and demand relationship according to the CMR Model. The content needs to be translated into a specific implementation and user interaction, matching the interaction mode. Construct a link-graph of user supply and demand relationship and design requirements, analyze the relationship between user supply and demand relationship and family agent design requirements, and extract and summarize the key design requirements. Then through the analysis of the relationship data, the key design requirements of the product are determined, and the inductive analysis is carried out to guide the FBS mapping process as a functional element of the family agent. By using the link technique of Goldschmidt (1990), it is possible to identify connections between unrelated fields. We have selected a user dialogue about the family agent design and analyzed it. Then built a link- graph by key design requirements as an example (see Fig. 6).

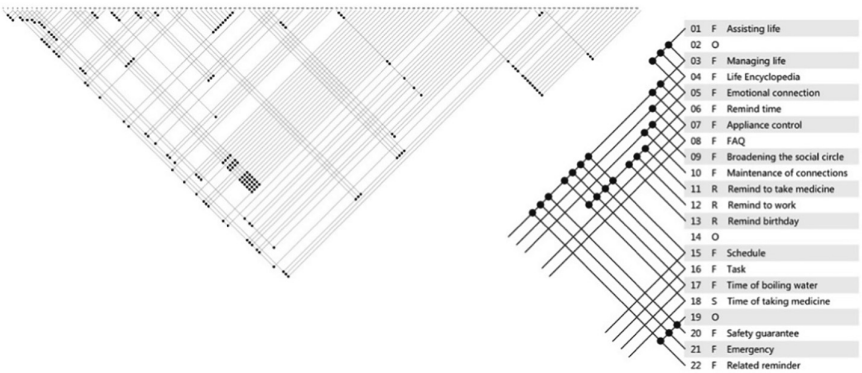

Fig. 6. Linking the segments

In the two mapping process of FBS, the following points should be observed [16]:

1. In the function-behavior transformation process: one behavior conflicts with another behavior, that is, the two behaviors cannot be performed simultaneously; one behavior is similar to the other behavior in form or space, and the two behaviors can be integrated.

2. In the process of behavior-structure transformation, the contradiction between behavior and behavior requires certain restrictions on the execution of these structures to avoid conflicts; a behavior may require multiple parts to be combined, and the user's behavioral scale is required to be considered. Rational distribution of these structures; a structure that can perform multiple functions requires consideration of similarities and differences between two behaviors, using analogy-based reasoning to generate innovative structures.

6 Interaction Design for Agents' Wake-up Word

With the advent of the industry 4.0 era, smart mobile terminals and cloud big data technology have laid the foundation for the new era. The market for skilled products has opened its doors, and now smart products have entered thousands of households [18]. The germination and development of artificial intelligence, along with the development of human-computer interaction technology and interaction design, from human-computer interaction technology to human-centered experience design, to attention consciousness, artificial intelligence to enhance situational awareness and awareness Perception and emotional perception, and finally form a meaning-centered interaction design method [19]. Artificial intelligence can effectively deal with the interaction elements of big data flow, information flow, knowledge flow, material flow and capital flow, and use this data to form subversive innovations from system, information, control and coordination, dissipation, mutation etc. form a subversive innovative thinking [20]. Therefore, in the design of intelligent products, in addition to the traditional function, behavior and structure of the weapon design, it is necessary to fully consider the container design that carries the data information.

As the basic unit of society, the family is the place where the concept of good and evil in the social value system is concentrated. The family agent is a special robot that serves human beings. It is not a simple home or electronic product. It is a family member who is integrated into family life and acts as a "life steward", "intimate friend" and "exclusive nanny". Therefore, the design process of the family agent can not only consider the traditional function-behavior-structure, but also combine the consciousness, ethics and aesthetics of the family form, and use the big data and artificial intelligence algorithms to form the synergistic symbiosis between group intelligence and experience sensibility [17]. However, the design of current home intelligence bodies mostly stays on the realization of functions, and lacks the design of content. From UGC (user-generated contents) to PGC (professional-generated contents) to OGC (occupational-generated contents), there is a lack of knowledge mapping semantic pragmatic grammatical context analysis, environment-aware computing, consciousness-aware computing and emotion-aware computing, lack of storytelling and integrity. The experience of the family agent is poor, and it cannot be well integrated into the family life. Let it becomes a part of the family.

In order to better understand the user's perception and demand for home intelligence, we first received 142 valid questionnaires for the smart product demand survey, covering the consumption level of 18–71 years old, 20 provinces and 4 stalls.

19 groups of three families conducted in-depth interviews and recorded the user's discourse. Through the statistics of the word frequency in the user's discourse, the word size was arranged according to the frequency of occurrence, forming a word cloud (see Fig. 7). With the word cloud of user interviews, we can see the content of users with more demand. From this we can see that users have a large amount of content and information level requirements for family agents.

Fig. 7. Word cloud of user interview

Wake-up as a necessary function of the family agent, the awakening of the speech design needs to be considered from the content level. The family agent acts as a carrier of content, and awakening speech is what it needs to carry. There are two models of mental model and interaction model in the process of interacting with the agent's voice. Only by finding the balance between the two can the user experience be optimized. Therefore, the voice wake-up method of the agent is similar to the way people communicate with each other. For example, one morning, when you go out to see the outside is cloudy, you worried that it will rain and then shouted "Mom" to your mother who is doing housework. When your mother heard it, she stopped doing work and turned his face to you. Then you ask, "Is it going to rain in the sky?", your mother recalled the weather forecast, "No rain, it is cloudy." But the human mind model will actually be more complicated, you may call "Mom", "Mother", or a look of an eye, even without a direct inquiry, your mother can understand that you are talking to her, but the agent is still not as human wisdom, many behaviors can't attract their attention. Therefore, we need to define a word that switches the product from standby to working state, which is the "wake-up word." The wake-up word is the result of matching the mental model with the interaction model.

Take the Baidu Brand smart speakers as an example. When using a smart speaker equipped with the DuerOS system, it is necessary to hand over its name "Xiaodu, Xiaodu" to switch it to work. The success rate and false wake-up rate of the agent identification after the wake-up word is recognized is the most basic consideration for the realization of the wake-up function. In order to improve the recognition rate of the agent and reduce the false wake-up rate, we need to define the threshold of wake-up and wake-up words. For example, you must call two times "Xiaodu" continuously within 3 s, and the interval between multiple rounds of dialogue for a unified task is no

more than 8 s. These are all based on the functional level design. If you want to further enhance the user experience, It is necessary to combine content and function design.

After applying the CMR + FBS design ontology model to explore the user's content requirements and functional requirements, it is necessary to summarize the mental model of the user in the semantic content of the dialogue, and make cognitive decision judgments on the content. According to the user's mental model, the mental model of artificial intelligence intervention is reorganized to form a dual-loop mental model, which then matches the human-computer interaction model. For example, in addition to the functional implementation, factors such as the combination of wake-up words and voice intonation can affect the user experience. Studies have shown that the combination of overlapping words and the combination of "Xiao + words" are more likely to be enjoyed by Chinese users [23]. Therefore, the wake-up words of Baidu's smart products are set to "Xiaodu, Xiaodu".

7 Conclusion

In this paper, the application research of the CMR + FBS Design Ontology Framework is carried out for the internal design problem in the process of interaction design. The optimization and improvement of the FBS Model is completed. The application of the CMR Model is studied through the design example of wake-up words of family agent, which is used for user demand extraction. The combination of FBS and CMR supports high agile live intelligent agent product design and data service interaction design, CMR is the key factors for providing high satisfaction user experience. Finding function and task requirements and construct HRI interaction relationship with the User Generated Contents creation is the new interaction design method for the intelligent products interaction design. It provides a new design idea and method to help the user's user needs analysis method in the interaction design process, and expands the application of the FBS model.

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