2015 4th International Conference on Computer Science and Network Technology (ICCSNT 2015)

The User-resource-task Model in Intelligent Interaction Space*

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***Abstract*—The essence of intelligent interaction space is that humans employ resources to complete tasks. This paper firstly established the three element models of intelligent space, and put forward two key obstacles to the development of interaction technology, including the cognitive gap between tasks and resources, and the cognitive burden between users and resources. Then task analysis and ability matching method were proposed to solve the cognitive gap, and model inversion method was presented to deal with cognitive burden, whose usability was certified by demonstration experiments.**

Keywords—intelligent space; cognition; human model; ability matching; model inversion

I. Introduction

Human computer interaction (HCI) technology has achieved many innovative developments in recent years, which are mainly embodied at the poles, that is, interaction devices at the bottom and interaction concepts at the top. At the interaction bottom, more and more new-type HCI devices come into being and go out of laboratory into our daily life. Multi touch devices such as FTIR-based (frustrated total internal reflection[1]) platform and iPhone[2], somatosensory interactive equipment such as Kinect[3] and Wii[4], wearable computing devices such as Google glasses[5], and so on, represent the colorful and revolutionary progress of interactive devices, by which we can enjoy natural and harmonious interactive means, and can see the bright future in which HCI will shake off the yoke of mouse and keyboard.

At the top, many interaction concepts that lead HCI to realize breakthrough development were proposed; and many advanced interactive concepts from predecessors were enriched in recent years, including user-centered interaction, ubiquitous/pervasive computing, multi modal interaction, smart room, augmented reality, virtual reality, wearable computing, and implicit computing, and so on[6-11].

However, the development at the bottom isn't in line with this at the top. Commercial interactive devices have not been widely used. In fact, the disappearance of keyboard and mouse did not appear as we expected. The essence of HCI and intelligent space is that people utilize interactive equipment to solve the interactive tasks, so equipment, human and task are the three basic elements in smart space. The interference with the development of new-type interactive devices is the connection hardness of them with the other two. On the one hand equipment cannot solve the task easily; on the other hand, the devices cannot be operated by users conveniently.

II. Three-element Model in Intelligent Space

Smart interaction space is a work or living room which contains multi-modal interactive devices. It supports human to complete the work or life tasks that generate from inside or outside with high efficiency, high success rate and low burden. As a typical smart space, intelligent command post was the research example.

As we know, resources, users and tasks are the three core elements of intelligent interaction space, whose goal is to complete the interaction tasks with high efficiency, low load and high quality. High efficiency refers to short time; high quality means the result close to the expectation; low burden refers simple process to complete the task.

The user-resource-task model in intelligent interactive space is to be built in order to achieve the following goals: to clear the position and function of each element, to clarify the intelligent interaction mechanism, to capture the obstacles to the development of intelligent interaction, and to propose methods to solve the obstacles.

A. Resource Model

Smart space, to observe it physically, is various resources. A smart command post contains interaction, information, communication and fighting resources. In intelligent interactive space, the interaction resources need be arranged reasonably and adequately to help users accomplish tasks.

Resource modal can be represented by a seven tuple: Resource= (rid, name, direct, modal, Ability[], personality [], Environment[]). "Rid" is the unique number of the device. "Name" is the name of the device, and there can be more than one machine with the same name.

"Direct" property refers to that the device receives or sends interaction information, which values from "I" and "O". Correspondingly, interactive machines can be divided into input and output devices. Input devices receive multi-channel instructions from humans, and output devices export information in some modal. Those devices that can both receive and send information were assumed to be two devices for facilitative modeling in order that each modeled device can have single "Direct" attribute.

"Modal" is the medium of HCI, including speech, eyes, facial expression, lip movement, manual, hand gesture, head movement, limes gesture, touch, smell, taste, etc. Multi-modal interaction technique is convenient for natural and harmonious interaction, in comparison with traditional graphical user interface technology. In the view of HCI development target, each interactive channel should be two-way, e.g. the machine should also be able to output gesture information. But at present, some channels are one-way. According to the user experience and the existing technology summary, the frequently-used channels of output devices are vision and voice, and those of input devices are gesture and voice.

"Ability[]" is a group of parameters related to "Modal". For example, Ability[] of output device as vision modal includes resolution, size, dimension, precision, mobility, and operation way; Ability[] of input device as gesture modal includes hand distance, auxiliary, and gesture dimension, etc. "Personality[]" is the personalized features of the equipment different from other devices with the same Name. "Environment[]" includes position, authority, etc.

B. Task Model

Task is closely related to the field of intelligent space. Command and control (C2) is the task of intelligent command post, i.e. daily or wartime work. Task modal can be expressed by a six tuple: Task= (Tid, Name, Type, SubTask[], Action[], Environment[])."Tid" is the unique number of task. "Name" is the name of the task, which don't have to be unique, because the same task may be repeated.

SubTask[] is the subtasks decomposed from the task; Action[] is the spare operation groups to complete the task; Environment[] is the environmental variables, which include the "Completer", the completion "State", the "Repeatability", and the "Source".

C. Human Model

User modeling is the core issue in user-centered interaction and pervasive computing, both of which are the main theoretical features of smart space. Human modal can be expressed by a seven tuple: Human= (Hid, Status[], PhysicsParameters[], PhysiologicalParameters[], PsychologyParameters[], personality [], Environment[]). "Hid" is the unique number of human. Status[]= (Name, Rank, Position), representing the user's name, level and position.

PhysicsParameters[], PhysiologicalParameters[], and PsychologyParameters[] are three arrays that contain human model parameters in the respect of physics, physiology and psychology. Personality[] is on behalf of the user's specific characteristics. Environment[] includes the user's "Position", the responsible "Task", the responsible device group, and the devices in use.

Environment[] parameters of task, human, and resource elaborate the mutual relation of the three elements, and the position and role of each element in the space. For example, the "Source" of the task in command post has three types:

- Trigger from intelligence resources, e.g. sudden discover of incoming enemy aircraft or missile would directly trigger situation assessment and threat analysis tasks.
- Trigger from communication resource, which refers to the command from superior command post, or business transmitted from other entity.
- Order from commander, from which most tasks come in the command post.

Fig.1 shows the relationship among the three elements in intelligent command post. Resources triggers or humans assign task; tasks are appointed to or match to human, and then allocate or match resources; and eventually humans employ the resources to complete the task.

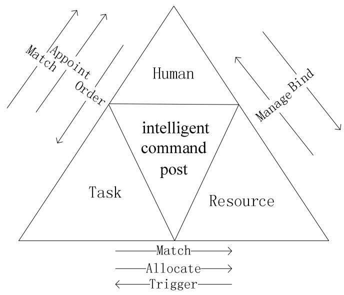

Fig. 1. Relationship among three elements in intelligent space

III. OBSTACLES TO THE DEVELOPMENT

There are two obstacles to the development of interaction technology, including the cognitive gap between tasks and resources, and the cognitive burden between users and resources.

A. Cognitive gap Between Tasks and Resources

It is difficult for users to directly map the received task to device level. There is a big gap between the complex semantic of tasks and the simple semantics that devices can understand. The mapping between the device and the task is achieved as shown in Fig.2. Manufacturers focus on the tasks that devices can solve relying on their ability, as the function f(dt) in Fig.2, so as to promote their products. Rather, manufacturers rarely research from the task to gain its solution by their devices, as is the realization of function g(td) in Fig.2.The phenomenon limits the wide application of the equipment.

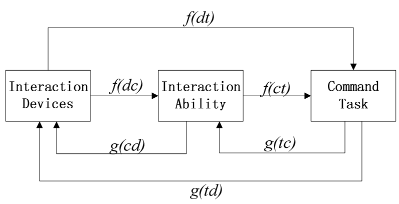

Fig. 2. Mapping process of equipment and tasks

B. Cognitive Burden Between Resources and Users

The large-scale emergence of interactive equipment has brought about colorful HCI. But whenever a new machine enters the smart space, the users must learn the interactive method and rules of the device, thus resulting in great users' cognitive burden. In traditional HCI, the person in the eye of the device is very simple. In the interaction mode of mouse and keyboard, human has only an eye and a finger in the sight of computer; while the computer is very complicated in the view of human, and need solid training for human to be handled. That diversity of interaction devices leads to user's cognitive burden does not conform to the requirements of the user-centered interaction.

IV. Ability Matching for Cognitive Gap

The nature of cognitive gap is that devices cannot understand the semantics of tasks, so the tasks should be transformed into a form that devices can understand by task analysis technique, and then be mapped to the device level by ability matching method.

A. Task analysis

Task analysis is an important research content of HCI, and has achieved good development. Task decomposition is a most common method of task analysis, which get the Subtask[] and then get Action[]. The tasks that can be solved through task decomposition usually have the following characteristics: repeatability, clear solving methods, solving process, and final results. We call this kind of task process task. Correspondingly, these tasks without clear solving methods and process are called creative tasks.

The solution of process task depends on the knowledge base, and the solution of creative task depends on creative thought. The final output of creative task is the view, and view flow runs through the solution of process task. The periphery of creative tasks takes advantage of brainstorming, the rules of which are maintained by interaction system. The internal mechanism of creative tasks is idea flow. The interaction system should motivate users' creative thoughts to make ideas prosperous.

B. Ability Matching

The ability matching between task and device includes device output ability matching and human output ability matching, as shown in Fig.3. The latter solves the cognitive burden. The former completes two tasks: interactive device selection and interactive content determination. Take vision modal for example, the display screen should be selected among several display devices, and display content should be settled. Fig.4 shows the generation process of task solution in intelligent command post.

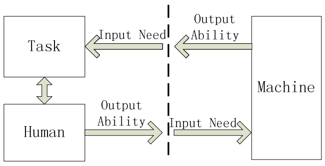

Fig. 3. Task and equipment matching in intelligent space

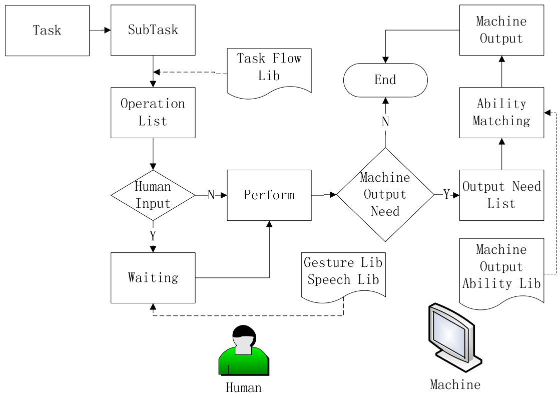

Fig. 4. Task complete flow chart

V. Model Inversion for Cognitive Burden

The user model and resource model have actually a mutually exclusive development relationship, and they should recognize each other to complete tasks. In order to reduce the user's cognitive burden, it should be transferred to the devices. The model reverse, i.e. simple user model and complex machine model, can greatly reduce the user's cognitive load and drive the evolution of HCI. In fact, the development of HCI is the gradual deepening of model inverse, as shown in Fig.5. The method of model inversion is to reduce the parameters of device model and increase the elements of human model.

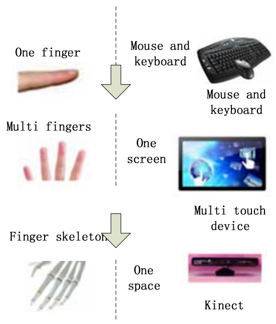

Fig. 5. The gradual deepening of model inverse

A. Simplification of Resource Model

The simplification of equipment model is consistent with the implicit calculation. The ultimate of modal inversion in intelligent is entire user model and disappeared equipment model. In this case, the HCI becomes interaction between human and the space, and there is not equipment in the eyes of user.

We can simply resource model as following: merging the models of different devices with the same channel; unitizing the similar parameters of different devices; reducing the operation interface of devices.

B. Enrichment for User Model

The user model here refers to model of average people. User modeling includes physical modeling, physiological modeling and psychological modeling. Physical modeling is the modeling of human body shape and behavior. Physiological modeling is to obtain the physiological indicators of humans by body sensor network. Mental modeling is the analysis and modeling of the user's inner world. The establishment of psychological model is the important basis for the realization of active interaction, and can stimulate the subjective initiative of users.

C. *Inversion of Context Model*

The context model is the modeling of user's differentiation. Context model inverse is to richen human's personality[] and simplify resource's personality[]. The computer-centered HCI require users to adapt to different devices, and user-centered HCI demand devices to adapt to different users, as shown in Fig.6.

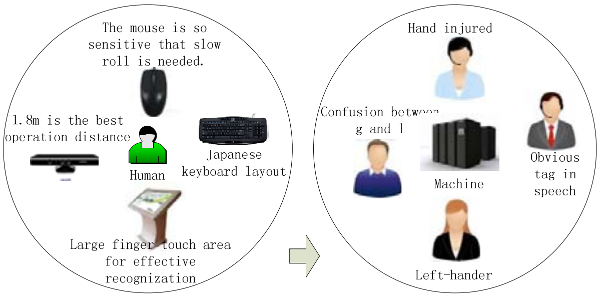

Fig. 6. Device context to user context

VI. USABILITY EXPERIMENTS

The modal inversion method was verified through usability experiments. For a smart room that exists three gesture interaction devices, including FTIR-based[1] multi-touch platform, Kinect[3] and Wii[4], detailed modal inversion measure is unified gesture. We prepared two rooms configured with same hardware. A room ran unified gesture interaction method, noted as the experimented system (ES); in another room the devices ran respective gesture interaction method, called comparative system (CS). Three experiments tested the three aims of smart room.

Experiment 1 tested the cognitive burden. 10 undergraduates without experience of three devices were sent a list of interactive tasks and task instructions. Record the time after students successfully completed all tasks. 5 students tested ES, and another 5 tested CS. Test results are shown in table 1, which demonstrates that ES can reduce users' cognitive burden.

TABLE I. TEST RESULTS ABOUT STUDY TIME

	study time(min)	Average(min)
ES	45,41,42,49,51	45.6
CS	67,62,49,72,75	65

Experiment 2 tested the efficiency. 10 undergraduates with experience of three devices were sent a list of interactive tasks, and their time to complete the tasks was recorded. 5 students tested ES, and another 5 tested CS. Test results are shown in table 2, which demonstrates that UIS can improve users' interaction efficiency.

TABLE II. TEST RESULTS ABOUT SYSTEM EFFICIENCY

	task time(s)	Average(s)
ES	89,97,88,102,159	107
CS	211,287,301,187,111	219.4

Experiment 3 tested the quality. We recorded the numbers of interaction failure that occurred when students were completing tasks in previous two experiments. Statistically, failure occurred 17 times in ES and 39 times in CS. It shows ES can improve users' interaction quality.

VII. CONCLUSIONS

This paper established user-resource-task model of intelligent space, and presented two key obstacles and corresponding solutions, including task analysis and ability matching method for the cognitive gap between tasks and resources, and model inversion method for the cognitive burden between users and resources. Demonstration experiments proved the usability of the solutions. The solutions involve many methods, some of which have been practiced, while some of which have not been carried out. The methods without practice are our future work, such as the user's psychological modeling.

ACKNOWLEDGMENT

This work was funded by the National Natural Science Foundation of China under Grant No.61272336.

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