Research of Passive Mode Interaction in Pervasive Computing

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Abstract. Two modes of HCI are discussed in this paper: Active Mode Interaction (AMI) and Passive Mode Interaction (PMI). Closed-loop processing models of each mode are created and analyzed. Contradictory propositions about how to implement spontaneous PMI are identified, and a pipeline model of information transportation in PMI is proposed for a detailed analyzation of mental activity in PMI process. Based on the analyzation, three features of interaction medium that have implications for PMI are identified and principles for PMI interface design are proposed.

Keywords: Human Computer Interaction (HCI); Pervasive Computing; Passive Mode Interaction.

1 Innovation

Artificial Intelligent have greatly changed the way computer interact with human beings. In the previous days, computer operates on human commands, and output results. The human evaluates the outputs with respect to his original intention. If it is not fulfilled, then new directions will be given. It is the human being who takes control of the interaction process. The computer in this process has no difference with common tools without any consciousness. However, in an intelligent computer system, the computer gains the ability of context perceiving and decision making, and works much more conscious then before. It can make its own decision when context changes, and initialize a conversation process to contact the human being, in order to help the user accomplish their goals, or keep away from damages. It is for the first time that machine takes control of interaction process, and try to influence the user's behavior with its output. From the perspective of the human actor, we call the formal mode of human-computer interaction "Active Mode Interaction (AMI)", and the later "Passive Mode Interaction Process (PMI)".

The most significant difference between these two modes is the distribution of human attention in the interaction process. In [1], attention is defined as human mental activity that concentrates on a focused target. The concentration of mental activity is a necessary condition of human cognitive activity. The more attention the activity gains, the more efficiency the activity executes. In the AMI process, the user

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manipulates the whole process, and focus on it with almost all of his attention. While in the PMI process, the user may have been busy with other tasks while interacting with the computers.

The differences between AMI and PMI make some HCI technology developed in the old days work not so efficient in PMI. For example, years ago, we have developed a prototype of a Cooking Assistant pervasive computing service. It tries to help a novice cooker cooking a Chinese meal by providing advices of what spices should be added. It makes use of a set of sensors to trace the progress of the cooking process, and a PDA device to display the recipe and action directions. However, our prototype is rejected by the end user for at least two HCI related reasons:

1. PDA is not a familiar appliance for a cooker. And there is no spare time for a cooker to operate a PDA while busy cooking;
2. Recipes in text format takes time for reading. When the cooker understands what the recipe says, the meal may have burned.

Giving hints in a cooking process is a typical PMI issue. The hints are displayed by the system, and a conversation request is send to the cooker while he is concentrate on cooking. If the interaction request is accepted, the cooker will allocate attention resource for reading hints; if the request is neglected, the interaction process will not be initialized.

Although PDA is objected in our prototype, it is still a powerful HCI medium. It has been used in many applications successfully, e.g. the iHospital project [2], and will be more and more used in pervasive computing services [3]. Now the question is: why doesn't PDA fits for PMI in the Cooking Assistant service? What kind of medium shall be good for that? And how can we make PMI more acceptable by the user? Are there any rules for PMI interface designing?

With the wide spreading of AI, the pervasive computing systems will become more active and smarter than ever[4]. More and more interactions will be carried out in passive mode. If the questions mentioned above are not solved, the awkward interaction process may ruin the "transparency" feature of pervasive computing.

In this paper, we try to figure the features of PMI, and find some principles for PMI interface design. In section 2, we propose closed-loop models of AMI and PMI process, and identify several principles of PMI designing. In section 3, we illustrate four types of PMI process in pervasive computing, and discuss how to implement them; in section 4, we show our implementation of PMI process in the Cooking Assistant service.

2 Analyzation

In *Cognitive Engineering in User Centered System Design*, D.A. Norman proposed a common model of human activities [5]. The model explains how dose a human fulfill his intentions in a closed loop process. However, in Norman's model, the appliances operated by human beings are unconscious tools. The mode is insufficient to describe pervasive computing systems. In figure 1, we propose two closed-loop models in reference of Norman's activity model, to describe AMI and PMI process in pervasive computing.

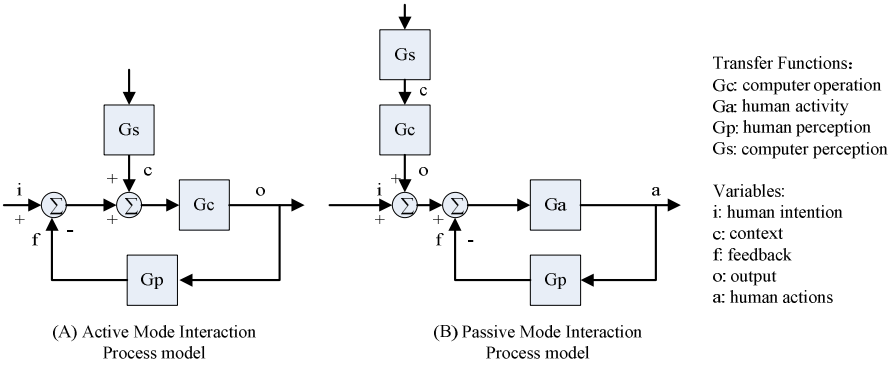


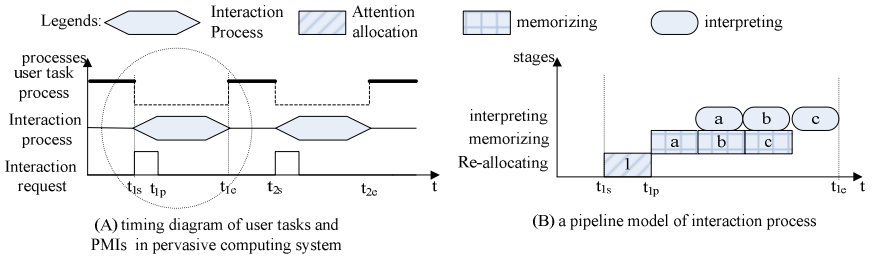
Fig. 1. closed-loop model of AMI and PMI process in Pervasive Computing

In Figure 1: i is the human intention; a is the results of human activity that can be inspected by both the computer and the actor himself; f is the feedback of human activity results, it is the output of human perception; o is output of the computer system that runs on user directions; c is the context information collected by the computer, it is an output of computers perception. Transfer function G_c describes the computing activities manipulated by the user; G_s describe computer's perception that is controlled by AI; G_p describes the inspecting activity of human perception; and G_a describes human activity.

2.1 Why is PMI Process Annoying

In the AMI model, the core of the closed-loop includes user intention, computer operates, user inspection and computer outputs. The sampling object of user perception is the computer outputs. Context information collected by AI is only a reference variable of G_c, and can not be perceived by the human operator directly. While in the PMI model, the core loop only includes activities and perceptions of the human user himself. The computer operates only on base of context information collected by its perceptions. The computer output acts as a forward interference of human intention. If the interference is strong, it will influence the operation of the human user. Otherwise, it may be neglected by the user.

Moreover, in pervasive computing systems, PMI request may interrupt human tasks from time to time. See the timing diagram in Figure 2 part (A). When the pervasive computing system detects a context changing event that is relevant to the human user, it may invoke an interaction request. If the request is accepted by the actor, then he will have to hold on his current task and allocate some attention resources for the coming PMI process. When the interaction is done, the allocated resource will be returned to the actor, and assigned to the user task again. It looks just like the interruption process in computer science. However, human beings have emotions. If their tasks are interrupted too long and too frequently, they may feel annoyed. Then they may neglect the PMI request intensively.



(A) timing diagram of user tasks and PMIs in pervasive computing system

(B) a pipeline model of interaction process

Fig. 2. models of human computer interaction process

2.2 Two Contradictory Propositions

Since the aim of PMI is to help the user with his tasks, or to help him away from potential damages, it is no good to drop a PMI request. The only way to reduce the interference of PMI process is to reduce the attention resources allocated for it. Therefore, there are two contradictory propositions:

1. Firstly, the PMI process should be attractive enough. It has to draw enough attention resources from other concurrent tasks, in order to complete the whole process;
2. Secondly, the total amount of attention resources assigned to it should be limited as little as possible. Otherwise, other concurrent tasks may be hold up by the user because of inadequate resources. More over, if a PMI process attracts too much attention, it may be raised to the current user task, and change into an AMI process.

In the book of Kahneman, he proposes a classic allocation model and some principles of human attention resources distribute among parallel processes [6]. It is said that: Human beings will concentrate more attention on emergent objectives, or something he is interested in. But in the long run, he tends to assign more attention on objectives that he is familiar with, although it may be a cumulative process. When initializing many concurrent processes, the user may estimate the required attention resources of each process. The less the attention required the higher priority the process may be assigned for resource allocation and runtime scheduling.

The model shows that there are different distribution principles in the task initialization and task execution phases. From this point of view, we can divide an interaction process into two phases and solve the contradictory proposition. The former phase is the initialization phase. During this phase, PMI request is accepted and attention resource prepared for the interaction process is allocated. The PMI request should be in the type of something interesting, so as to attract enough attentions, and avoid to be neglected by the user. The latter phase is an information transportation phase. It requires a huge amount of attention resources, in order to interpret information transferred in the interaction.

Although the total amount of attention resources consumed in the transportation phase can not be decreased, the amount of attention allocated from other concurrent tasks can be reduced, because the transportation can be done in a pipeline. We all have the experience of reading. During the reading process, we can not read the whole paragraph at one-time. Instead, we only memorize a short phrase at a glance, and try to understand it while reading the next phrase. The memorizing and interpreting operation iterates till we finished the whole paragraph. In short, the information

transportation in reading activity can be described as a two-stage pipeline. The same model fits for information transportation in PMI process either. That is to say, instead of allocate attention resource for information transportation all at once, we can invest only a piece of it, and reuse it in a pipeline in the info transportation phase. The pipeline will reduce the resources required for information transportation significantly.

Figure 2 (B) shows the information transport pipeline model. It is a detailed timing diagram of a complete PMI process, which can be found in the dotted line cycled region in Figure 2(A). The pervasive computing system detects a context event and creates an interaction request at t_{1s}, then the initialization phase starts. In this phase, the user re-allocates his attentions. He draws some resources from the user task, and assigns them to the interaction process. The attention resource is ready at t_{1p}, and then the pipeline of information transportation starts. The user memorizes a piece of information in his mind, and then tries to understand it while memorizing the next piece. This process iterated till the interaction ends at t_{1e}. Because of the pipeline, only a little amount of attention, that is enough to memorize and understand a piece of information, is required at each time during the transportation phase.

In conclusion, interaction request in PMI process must be attractive, and information presentation in PMI should be easy to be memorized and understood. If there is too much information to be presented, it should be divided into pieces to form a transportation pipeline.

2.3 Looking for Interfaces

The discussion above shows how to carry out a PMI process. Now the problem is what kind of interface fits for passive mode interaction. In the previous research of human-computer interaction, many kind HCI technologies have been developed, for example: GUI, context awareness, spontaneous interaction (natural language based interaction, hand writing based interaction and body movements based interaction, etc.). Many of them are developed for information input, such as body movement matching and hand writing recognition. PMI process in pervasive computing is mainly an info output process. If it requires interacting with the operator, it may attract too much attention resources, and change into an AMI process. From the experience gained form Cooking Assistant application, we find that three features should be cared while designing PMI interface: Expressivity, Permanence and Compatibility. The former two features have been discussed in [7]. We will append our point of view gained from pervasive computing system development.

Expressivity: Expressivity relates to the grounding of content [7]. Compared with text, the graphic media is more comprehensive for information expression, and is easier to be understood. Text is more powerful in quantification, conditionals and serialization, while it requires more mental activities for interpreting.

In the two phases of PMI process, graphical media is a better choice of the initialization phase. Interaction request in graphic type is more striking and interesting. It can attract enough attention resource to complete the initialization phase. However, interaction interface for the information transportation should be selected according to the information content. If the amount of information is too much, image that requires one-time attention allocation may consume too may resources.

Video and animation is a kind of enhanced graphical media. It makes up the lack of serialization of graphical media. Vocal or natural language is the reinforcements of text format media. Benefits from the in-directivity of voice, it is much more flexible then pure text format info. However, both video and vocal are dynamic media type, and the lake of permanence limits their utilization in PMI process.

Permanence: The permanence feature is an abstraction of the revisability and reviewability features [7]. Static media type such as image and text can be reviewed at anytime as the user wishes, thus it supports unsynchronized interactions. This feature is important for the initialization phase of PMI process. The PMI process is initialized by an interaction request generated by the computer system. When the request appears, the user may be concentrate on his user tasks. The request must be presented in a static media type, so that it can be accepted at a delayed time.

Compatibility: Compatibility is not the feature of interaction media, but a property of the interface medium. It is a level of accordance between the PMI interface and the running user task.

The research of common sense has revealed that each kind of user task has a rather static array of activities and a collection of appliances [8]. If the PMI medium has something related to a member in the appliance collection, we can say that the medium is compatible with the user task. If the medium is included in the collection, then we say that they are fully compatible. A medium with compatibility will be more acceptable by the user in the PMI process.

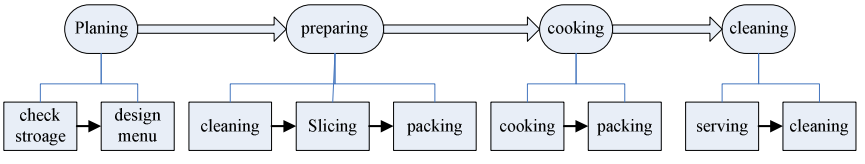


Fig. 3. Activity array and appliance collection of a cooking task

For example, Figure 3 shows the activity array and appliance collection of cooking a meal. From the experience we gained in smart home application developing, we know that if we take a PDA as PMI medium device in a cooking task, the end user will object our system. However, if we take a condiment bottle as a medium to show hints to the cooker, the user will accepte it. The condiment bottle is appliance that compatible with the cooking task. Because it has a property that is the same as the member appears in the applicance collection: in the kitchen.

2.4 PMI Interface Based on Perceived Affordance

The concept of "Object Affordance" is proposed in [9] to refer to the actionable properties between an object and a human actor. D.A Norman discussed it in [10], and proposed "Perceived Affordance" in [11]. Perceived affordance is about the actions a

user perceives to be possible, it may not the actions that the object really has. Perceived affordance is influenced by the knowledge and experiences of the actor.

Members in the appliances collection of a user task have strong properties of "Perceived Affordance". When the human user sees a member object, he may think of activities in the activity array all at once. For example, when a patient sees his drug box, he may think of taking medicine; when a cooker sees a kitchen knife, he may think of slicing meets and vegetables into pieces.

Perceived affordance is useful in passive mode human-computer interactions. Objects with perceived affordance property can be used as an interaction medium. It works like a kind of enhanced graphical interface. The media of the medium is its shape, color, or other object properties, and the information content is its perceived affordance. Compared with other kind of medium, a perceived affordance medium is fully compatible with the user task in nature.

3 PMI in Pervasive Computing

From the previous discussion, we know that in order to implement a successful PMI process, we need a brilliant interaction request, an efficient way of information transportation and a compatible interaction medium. These are only principles for PMI designing, and the detailed implementation depends on the information transported in the process.

Based on research of smart home pervasive computing systems, we sort out four types of PMI process in pervasive computing: activity reminds, status reminds, information service and emergency alert. In this section, we will discuss the features of them, and give some proposals for the implementation.

Activity Reminds: In an activity reminds PMI process, the pervasive computing system tries to remind the actor of some activities that he may forget. The interaction request of it may be emergent, but the amount of information transferred is tiny. An abstract icon image or several words about the activity is enough to remind the actor about it.

Interface based on perceived affordance is another good choice. We can notify the user with flashes or sounds. And as soon as he sees the medium object, the affordance property may tell him what to do.

Status reminds: In a status reminds PMI process, the computing system tries to show the running status of the user task, in order to help the user restore an interrupted task. The interaction request is not as emergent as in activity reminds, but the amount of information transferred may be greater. Graphic or text based interface are all acceptable in this type of PMI process.

Information Services: Information service is a kind of agent program. The pervasive computing system collects and refines information on behalf of the user, and presents it in a way that is easy for reading. PMI process in information service is not emergent. It even does not need an interaction request. But the information presented must be permanent, and can be visited at any time the user wants. The interaction medium should be compatible with the user living habits. For example, if the user

used to see if it is raining when he tends to go outside, then the detailed weather forecast information should be displayed on a screen beside the door, or directly projected on the window in his house.

Emergency alert: Emergency alert is not a pure PMI process. It requires emergent interacting with the user. The PMI process will shift into AMI process when the user accepts the interaction request. A GUI on a embedded device, or natural language based interface will be good in this type of PMI.

4 Implementation

Based on the discussion above, we rebuilt the Smart Cooking Assistant context-aware Service (SCAS) mentioned in section 1.

The SCAS maintains a knowledge database of Chinese meal recipes. The recipes are collected from internet automatically. Before cooking a meal, a menu should be input to the service. This is an AMI process, and can be completed on a desktop computer, or on a smart phone.

SCAS inspects the cooking process by a set of pressure sensor. The sensor is attached to the bottom of each condiment bottle. When the cooker begins to deal with the meal, SCAS will tell the cooker what kind of spice should be added, and how many spices he has added. This is a status reminds PMI process. Information delivered in the process shows the status of cooking a dish.

SCAS takes condiment bottle as the interaction medium. We have attached two led lights to each condiment bottle, one is group light, and the other is status light. The group light on means that this kind of spice is included in the recipe of the dish. The status light shows whether the spice has been added to the dish. In short, spice in a condiment bottle with both group light and status light on, should be added to the dish.

A detailed description of the implementation of SCAS can be found in [12].

5 Related Works

In recent years, many progresses have been made in HCI research. Among them, the most important achievement for pervasive computing is multi-modal interaction. Since human interactions are multi-modal in nature, interaction in pervasive computing can not be restricted within desktop anymore. It requires spontaneous interaction in multi-channels.

The topic of multi-modal interaction has been discussed over and over in the region of artificial intelligence. In the series work of Steve Whittaker's group, they evaluated varied communication channels and proposed a set of principles of multi-modal interaction [13,14,7]. AAAI symposiums [15,16,17] discussed the relationship and interaction between human user and intelligent systems. The achievements made in AI research improve the interactivity of pervasive computing systems, and implement implicit interaction channels with explicit GUI based interaction channels [18]. Many experimental systems have been built in recent years, and interaction models were proposed corresponding to the systems, e.g. [19,20].

Besides, interactions on limited size screen are also a hot spot in HCI research, on account of the repaid progress of mobile computing and ad hoc networks. In paper [21,22] the authors developed pervasive applications running on smart phones. And in [3], mobile network terminals such as smart phones are considered as an ideal interacting medium for pervasive computing.

Since that HCI is a communication process between computer and human user, improvements made in technical region is inadequate to implement successful spontaneous HCI. Discussions about human nature are also necessary. AAAI symposium [23] discussed the issue about initiative in HCI. In paper [24], the authors discussed the mental activity in pervasive computing HCI, and propose a multi-modal interaction framework. Paper [25] reviewed the development of human-computer interaction technology, and discussed the influence of culture and habits.

Most of the research mentioned above, focus on providing methods and devices that facilitating the accession of a cyber world maintained by the computers. However, not all of the tasks in our everyday life can be accomplished in the cyber world. How to communicate with the human actors when they are busy doing these tasks, is an issue seldom discussed previously. In this paper, we propose the concept of Passive Mode Interaction, and try to answer the question from our point of view.

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