Peripheral Cognition Technology: Approach and Implementation

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***Abstract*— In this paper, we describe a novel information notification method, Peripheral Cognition Technology (PCT) that utilizes human cognitive properties including visual field narrowing and change blindness (or inattentional blindness). Information notification on a display for e-mail, micro blog, and application update, is becoming increasingly important in various environments such as offices, and the home. To develop a smart information notification, a user model-based approach and a peripheral display have been studied. However, building a user model is difficult and a peripheral display catches user attention. We propose a novel PCT for information notification. The PCT utilizes the human cognitive properties that a visual field narrows when he/she concentrates on a task, and that a human tends to be unable to recognize subtle and slow changes. The core idea of PCT is that a human does not recognize subtle changes in a peripheral area of cognition when he/she concentrates on a task, and he/she automatically recognizes the changes when not concentrated. By setting a software agent or a device of information notification with subtle changes in such a peripheral area, a user automatically and easily accepts the notification only when his/her concentration breaks. Also PCT provides a way to determine various properties of HAI such as agents appearances and positions. Two concrete implementations, "Peripheral Agent" and "Shape Shifting Notification", of PCT are introduced.**

I. INTRODUCTION

In the current office and home environment connected to the Internet, a user tends to frequently receive various *information notifications* [1][2] for e-mails, tweets, instant messages, and alerts of application updates on a display, cellar phones and smart phones (Fig.1). Although some notifications are quite emergent, most of them are not so emergent and a user should get the information only when he/she is not busy. Such a user state in which he/she can accept notified information and can access the information is called *interruptible*, and the opposite user state is called *uninterruptible*. A typical interruptible state is when a user is not involved in completing a task and has time to read the information.

A problem with such information notifications is they appear simultaneously as they are occurred, i.e., without the system being aware of whether the user is interruptible or not. If notifications arrive when a user is uninterruptible, they can cause significantly stress and reduce the user's productivity [3]. One way to deal with this would be to control the information notification period in accordance with the period the user is interruptible. In other words, this means a system would need to estimate user's interruptibility and send a notification only when he/she can be interrupted.

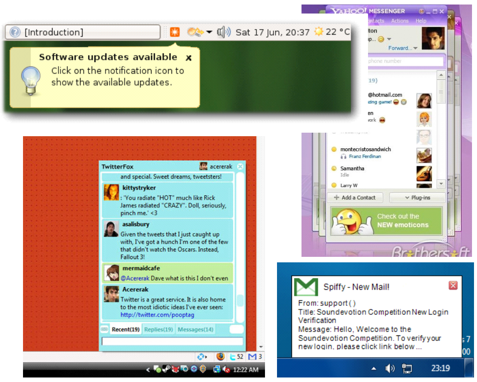

Fig. 1. Information notifications

In order to estimate user's interruptibility, various studies have been done [4][5][1][6]. Most of them applied machine learning techniques like classification learning, SVMs, Bayesian networks to identify whether a user is interruptible or not. The input to classification learning were implicit feedback including keyboard typing patterns, trajectory of the mouse operation, vision information of a user's face and posture. Although this approach provides a general framework which can be applied to other user state estimation like user's emotion, it is difficult to build a accurate model for user's interruptibility because a lot of training data is needed for training classifiers and user state estimation might be significantly dependent on individuals. Also, capturing the user's face and posture is problematic in terms of privacy.

Another approach to information notification does not estimate whether the user can be interruptible. A peripheral display [7][8][9][10] is such an approach. In this approach, information itself, not the notification, is constantly displayed on a small sub-window (or a sub-display) in the side of a main-window (or a main-display) in which a user achieves a main task. A user is assumed to recognize the displayed information and understand the contents while he/she achieves the main task. Since the user's understanding of the sub-task information is done in parallel to the main task and the cognitive load is small, a user can easily understand the sub-task information. Although this peripheral display has advantage that it does not need user state estimation, the general design policy has not been developed and ad-hoc implementations have been done in various fields. Also, since a notification is basically not used in a peripheral display and a user does not change the task mode from a main task to a sub-task, more complicated information difficult to understand the contents like e-mails, application updates, can not be dealt with in a peripheral display.

We propose a novel information notification method, Peripheral Cognition Technology (PCT) that utilizes a human cognitive properties like visual field narrowing and change blindness (or inattentional blindness). The PCT provides an information notification by utilizing a human cognitive property that a visual field narrows when he/she concentrates on a task intently. Also PCT utilizes another cognitive property similar to change blindness, in which a human tends to be unable to recognize subtle and slow changes. The core idea of PCT is that a human does not recognize subtle changes in a peripheral area of cognition when he/she concentrates on a task, and he/she automatically recognizes the changes first when not concentrated. By setting a software agent or a device of information notification with subtle changes in such a peripheral area, a user automatically and easily accepts the information notification only when his/her concentration breaks. Two concrete implementations of PCT with different subtle changes are introduced. We are developing PCT as an elemental technology of HAI application to information notification, and it provides a way to determine various properties of HAI like agent's appearances, positions, and so on.

II. PCT: Peripheral Cognition Technology

Peripheral Cognition Technology (PCT) is cognitive interaction design for information notification. The "cognitive" interaction design means a design method of interaction utilizing human cognitive properties [11]; e.g. visual field narrowing, change blindness, inattentional blindness. By using such human properties, we can design an effective user interface that does not force a high cognitive load without learning ability such as an adaptive user interface [12].

VFN (visual field narrowing) [13][14] is a primary human cognitive property utilized in PCT. A visual field is an area which an individual can see when looking straight ahead without moving the eyes or gaze. It can be measured in degrees from the fixation point; the normal vision field is about 160-180 degrees horizontally and 120 degrees vertically. This visual field is significantly affected by cognitive load or concentration on a task [13]. When a human concentrates on a hard task and the cognitive load becomes heavy, his/her visual field significantly narrows. This phenomena is call *visual field narrowing* and studies have been done to investigate it in various tasks [13][14].

Change blindness [15][16] is also a human cognitive property utilized in PCT. The change blindness is a psychological phenomenon that occurs when a change in a visual stimulus goes unnoticed by the observer because the change is very slow and subtle. For example, an individual fails to notice a slight difference between two images that are almost identical. The reasons these changes usually remain unnoticed by the observer include obstructions in the visual field, eye movements, a change of location, or a lack of attention [15]. Change blindness has become a highly researched topic due to newly discovered implications in practical applications such as improving the accuracy of eyewitness testimony and reducing the number of distractions while driving.

Inattentional blindness [17] is also related to a human cognitive property which can be utilized in PCT. All of the information in the visual environment is potentially available for attentive processing. However, without attention, not much of this information is retained. Inattentional blindness means that without attention, observers do not recognize visual features of the environment at all. In addition to PCT implementation "Peripheral Agent", "Shape Shifting Notification" will be introduced in IV. We think this inattentional blindness might be more adequate for supporting the effectiveness of the shape shifting notification.

We define these human cognition properties above that occur in the abstract peripheral areas of "cognition" and define the interaction design utilizing such human cognition properties as Peripheral Cognition Technology (PCT). We think this interaction design policy can provide concrete implementations for application of HAI in various ways. For example, PCT-based life-like agents, determining positions in which an agent should appear, and this enables us to design the appearance of an agent such as the shape, the color, and the size. Two concrete implementations of PCT will be introduced in the remainder of this paper.

III. Peripheral Agent

Peripheral agent is an implementation of PCT by using Visual Field Narrowing (VFN). The peripheral agent has a simple human-like appearance and notifies information like e-mail arrival, twitter, application updates (Fig.1) to a user by appearing on a display in an appropriate position. The functions can be summarized in the following.

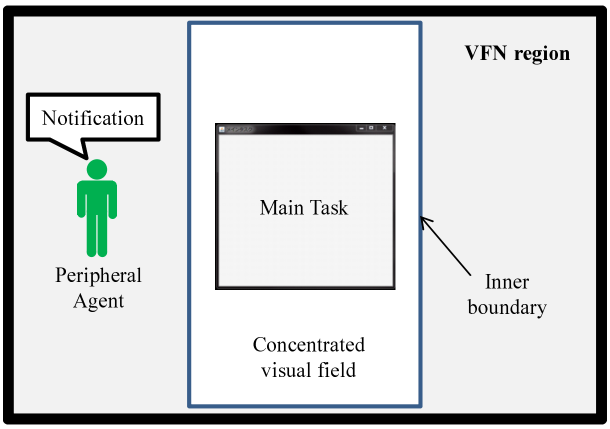

Fig. 2. Peripheral agent

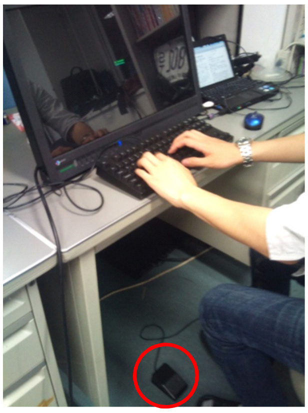

Fig. 3. Experimental environment

1) A peripheral agent appears in a *VFN region* simultaneously as information to be notified occurs.
2) If a user clicks the peripheral agent, it will display the content of the information by opening a sub-window.

We define the VFN region above as a peripheral visual field which can be narrowed by VFN phenomena. Fig.2 shows a concentrated visual field when a user concentrated a task and is uninterruptible, a VFN region outside of the concentrated region with the inner boundary and a peripheral agent. When we can adequately place a peripheral agent in the VFN region, a user does not notice an information notification when he/she is uninterruptible and he/she automatically notice the notification just when he/she becomes interruptible.

We conducted preliminary experiments with participants to investigating the VFN region. First, we define the VFN region as a square region on a display and gather data indicating the positions at which a user notices the appearance of a peripheral agent. We used a dark room-like editor with black background and asked participants to just typing letters scrolling horizontally in a white box in the center of the display. This typing is a main task in this experiment and we can control the difficulty by changing the speed of the scrolling. In this preliminary experiment, we set the scrolling speed so that a user may be interruptible for determining the inner boundary of a VFN region in Fig.2. The shape and color of the peripheral agent was also tuned.

We made a peripheral agent to appear in various positions from the far to near the center of the display. Since the dark room-like editor is considered to be an extreme situation in which a user most easily notices a peripheral agent, the estimated VFN region corresponds to the smaller limit region. Thus, in practical application in a display with a practical desktop and a certain background image, the VFN region becomes lager than this estimated one. An experimental environment with a display, a keyboard and a foot switch with a red circle is shown in Fig.3. A participant was asked to turn on the foot switch immediately just when he/she noticed the peripheral agent.

Data of the inner boundary of the VFN region obtained from 12 participants are plotted on the x-y coordinate of a display like Fig.4. The broken line connects the average positions in the eight directions, and we verified a VFN region in a display from these data of this preliminary experiment.

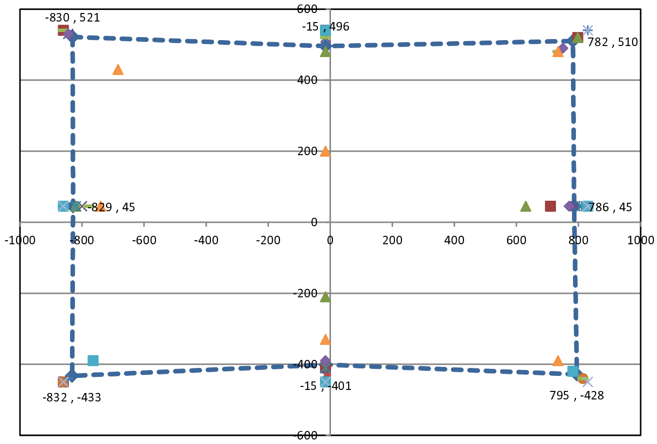

Fig. 4. VFN region data

We are currently conducting a large experiment to investigate VFN region more precisely. After building a VFN, we will determine the adequate position of a peripheral agent in the VFN region, and conduct an experiment for evaluating the effectiveness of the peripheral agent by comparing with a conventional notifications such as a balloon-like notification in the corner of a display.

IV. Shape Shifting Notification

We are developing another implementation of PCT, *shape shifting notification* as a novel information notification method. This shape shifting notification utilizes a human cognitive property, change blindness (or inattentional blindness) [15][16] (described in II). The basic idea on shape shifting notification is to change the posture of a notification device sufficiently slow so that a user may notice it only when he/she is interruptible.

We experimentally developed a device for providing a shape sifting notification shown in Fig.5. A user can put any information terminal like a smart phone or a PDA on the device, and it covers the terminal at the initial state. When the information terminal receives a call, e-mail or

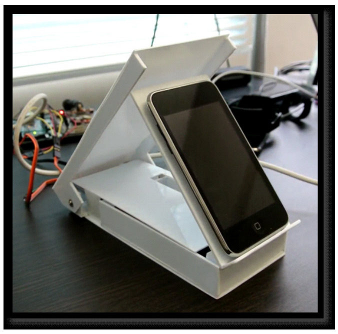

Fig. 5. Device for shape shifting notification

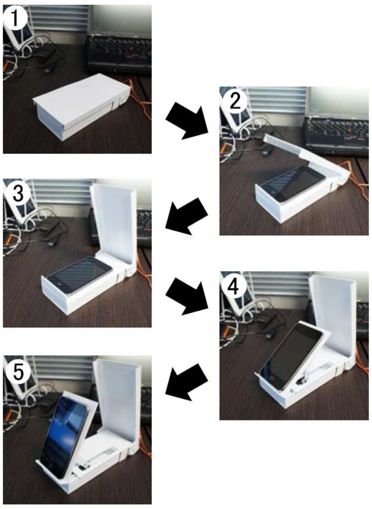

Fig. 6. Slow shape shifting

tweet, the device begins to open the top and gets up with the terminal very slowly for three minutes. All of the motions are executed by a servomotor and Fig.6 shows such behaviors of the device. Since the motion of the device is sufficiently slow, a user notices the information notification only when he/she is interruptible.

We already conducted a preliminary experiment with a single participant. In this experiment, the device was located 45cm from the display and the participant could see it in the peripheral visual field. It is not important that the device is in the peripheral field because the sufficiently slow motion of the device makes a user unaware of the notification even though the device is nearby. The participant actually used the device for two weeks in the office. The device notified a user randomly from a minute to 30 minutes and questionnaires on the notification timing and they were asked about interruptibility just after every notification. The questionnaires obtained promising experimental results; The hight ratio of notification without bothering and the low ratio of bothering a participant were obtained experimentally.

We are currently developing the next version of this device for shape shifting notification by improving its execution noise of a servomotor and adjusting the position. After the improvements, to evaluate the effectiveness of the device we will conduct experiments by comparing it with a device that gets up quickly.

V. Conclusion

We proposed a novel information notification method: Peripheral Cognition Technology (PCT), which utilizes a human cognitive properties including visual field narrowing and change blindness (or inattentional blindness). Information notification on a display for e-mail arrival, micro blog, and application update, is becoming increasingly important. In contrast with conventional approaches to the information notification like a user model-based approach and a peripheral display, PCT does not need to estimate a user state and it can deal with notification for complicated contents.

The core idea of PCT is that a human does not recognize subtle changes in a peripheral area of cognition when he/she concentrates on a task, and he/she automatically recognizes the changes when they are not concentrating. We think PCT provides an effective design policy for various properties of HAI like the appearance, the shape, and the positions and so on. Two concrete ongoing implementations of PCT, “Peripheral Agent” and “Shape Shifting Notification”, were introduced and preliminary experiments for them were conducted.

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