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Review

PiTaSu: wearable interface for assisting senior citizens with memory problems

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Abstract

Little research has been carried out on specialized wearable input interfaced designs to assist memory impaired senior citizens. This paper proposes and implements PiTaSu (Picture based Tapping on wall Surfaces) to realize a direct input interface system to offer visual feedback and tactile feedback. PiTaSu is based on a pictorial based Augmentative and Alternative Communication (AAC) system. PiTaSu consists of a body-worn or shoulder-attached mobile projector, a camera and an accelerometer wrist band. The projector shows information that will help assist the memory impaired senior citizen in their daily task. The camera and the accelerometer detect a tapping position and tapping trigger. Experimental results have demonstrated that a senior citizen can use PiTaSu without learning special skills, and the projection based user interface has potential. Therefore, PiTaSu can assist memory-impaired senior citizens as a daily task reminder.

Keywords: memory problems; senior citizens; wearable interface.

Introduction

Memory related illnesses are a common problem with senior citizens. A number of industrialized countries have a rapidly aging population, and consequently there is a corresponding rise in age related memory illness. This paper describes one part of a ubiquitous information support system for senior citizens with memory problems that can be realized through an intuitive wearable interface. The realization of such ubiquitous support services, such as the SESC (Smart Living Environment for Senior Citizens) project (1), acts as a key for providing comfortable living for both supported and supporting people.

Most senior citizens suffering from memory problems can determine their intentions, though they are weak in their acknowledgement of time events. If they can access the information they need, they can have the potential to live independently. To realize this support using computer power, an easy-to-use interface is necessary and important for the senior citizens. Currently, health care professionals use Augmentative and Alternative Communication (AAC) to help people with memory problems with their daily activities (2). The representation system used in AAC includes gestures, hand signals, photographs, pictures, line drawings, words and letters, but also different ways of managing computer aided communication tools. In this paper, a pictorial based system is used with image-printed tags or pictures that can be placed on walls or places and these are shown to other people. AAC methods that focus on picture communications using these tags or pictures are a common means to support memory-impaired patients perform daily tasks. The number of tags or pictures changes according to the complexity of the communication. It is difficult to make a deep conversation using physical real objects as tags or pictures without mobility.

This paper focuses on a user interface using projection-based wearable system for assisting senior citizens with memory problems as one of the AAC systems. Using mobile projectors, physical surfaces can become information displays, thus providing ubiquitous information in a daily living environment. There are three main advantages for using projectors compared with flat panel monitors. Firstly, projectors can achieve wide display areas originating from very small devices. Secondly, they are able to project information on many physical, flat surfaces. Thirdly, they provide a greater mobility that moves with the person rather than being confined to fixed contexts. These elements have potential for personal use applications embedded in mobile or wearable computing.

In this paper, a wearable PROCAMS (projector camera system) with a novel input interface, PiTaSu (Picture based Tapping on wall Surfaces) is proposed. The system accepts a tapping action onto wall surfaces as an input, as shown in Figure 1. It is thought that tap action is suitable as an interactive

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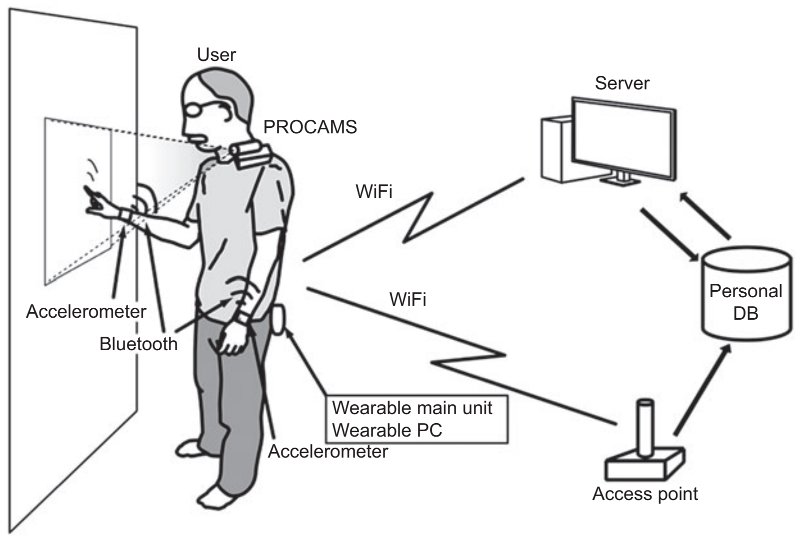

Figure 1 Conceptual smart living environment using the proposed projection based wearable system.
The wearable system, consisting of PROCAMS, an accelerometer and computer, connects with the server and access point via WiFi.

input interface because it is an operation that everyone is able to do easily. A contextual background system provides relevant information based on user's action history from a database (this part of the system is out of the scope of this paper).

A wearable interface in smart living environment

Senior citizens have certain needs that designers do not normally take into account when designing new systems, as target groups often consist of a younger user base. Instead of requiring elderly people to understand deep and often complex structures of various mobile phone user interfaces, and the meaning of arbitrary icons and illogical functionalities created from bad design choices, the goal should be about simplifying things and taking advantage of the skills everyone learns as they grow up. Learning new things becomes slower with age (3) and senior citizen also have a tendency to reject new technological devices (4), even though they could offer benefits to their lives. The advantages of PiTaSu design choices, which is the proposal input user interface in this paper, is that the user is able to use it without learning new control methods, as opposed to hand markers based gesture navigation with adding color markers to fingers (5). Research on the wearable user interface needs focuses on Alzheimer's disease and its close, treatable variants. This is because a vast amount of different memory related illnesses require specific, customized designs. Other illnesses, such as semantic dementia, can present symptoms that are difficult or infeasible to assist with different technological devices. Choosing Alzheimer's is feasible because of the nature of the illnesses symptoms, such as episodic memory functioning problems (6) and its frequency among the elderly. Based on discussions with medical doctors and a neuropsychologist, it can be also considered feasible for these technological aids to improve the lives of the patients. It is also possible that such aids can assist in slowing down the rate of brain functions deterioration via memory supporting effects, environment, and through services originating both inside and outside of the living environment.

The user interface design used in this work is based on a path structured approach (7). The language reads from left to right, with the left most pane featuring the key needs of the user, e.g., 'I want'. This first pane can be filled with alternatives which are partly based on the senior citizens contextual situation. Once a picture is selected, e.g., 'I want', a second list of options is opened in the second pane, such as 'to go' or 'to call'. When one of these options is selected, the third pane is opened with a further list of options, and so on. The selected options which make up the activity are shown at the top of the graphical user interface (GUI), in this case 'I want to call Anna'. The language also works in the reverse, with health care professionals creating a message for the senior citizen which can be linked to a context. When the senior citizen is in that context, the message can be shown to them pictorially.

The main interactions with the wearable system are supported with two separate setups; one for the medical personnel or a trusted person, and another for senior citizen user. For example, the doctor can add appointments to the senior citizen's calendar via a computer interface or they can monitor current health or check the medical history of the user. A trusted family member can check if the senior citizen's calendar entries are acceptable and do not have any inconsistencies. Content on the graphical user interface for the senior citizen is built up of different modules. The *Communication* module has tools for video, phone calls and messaging. The *Guidance* module is a subset of two areas, home and outdoors, and handles information on routes, locations and instructions for tasks. The *Home* module is designed for home specific tasks, such as cooking or reminders. The *Scheduling* module is split for multiple users as data acquisition and entry is possible from different terminals. Finally, the *Emergency* module handles direct requests from the user or via automatic recognition and forwards these to the appropriate party.

PiTaSu: system overview

The PiTaSu (Picture based Tapping on wall Surfaces) wearable system combines an accelerometer with the projector camera system (PROCAMS) as shown in Figure 1. A user wears this projector-camera unit around the shoulder or chest, and wears the accelerometer on the wrist. It offers an intuitive interface that accepts tapping images on wall surfaces as input action. To realise the tapping interface, the system should detect the tapping trigger and a position of a finger-tip on the projected surface. The following describes how to detect a direct tapping input in the system. The method is divided into four steps: detecting the tapping trigger, calculating the homography matrix, recognizing a hand area, and estimating a finger-tip position, as shown in a flow chart of Figure 2.

Detecting tap-trigger

The vibration of a user's wrist when the user taps on a surface is detected from acquired accelerometer sequence data on user's wrist through the use of a fast Fourier transform (FFT). When a spectrum value exceeds a certain threshold in high frequency area, the action is recognized as tapping.

Calculation of homography matrix

To detecting the tapping position on a target surface, it is necessary to calculate the homography matrix. The homography matrix is calculated from four projected points on the surface. Some input hand motions, however, will intercept one of these points. Therefore, the system estimates a point from the relationship between three projected points on a wall surface. Then, a homography is calculated from these four points.

Recognition of the hand area

A ray transfer model can be defined for PROCAMS where the brightness ray from the projector is reflected on a target surface and captured (8, 9). When it is assumed that the ambient light source and ratio of surface reflection are equal across the whole of the projection area, we can define a transfer ray and a ratio of reflection as a simple equation in each case (RGB). The equation for the transfer ray, I_c, is as follows:

$$I_c = R(I_p + I_0) \qquad [1]$$

where I_0 is an environment light source, R is the ratio of wall surface reflection, and I_p is the projection ray from the projector. In addition, the environment light source and the ratio of wall surface reflection are unknown variables. If it is assumed that the environment light source and the ratio of wall surface reflection are equal across the projection area, then we can define RI_0 as a ray of value 0 for projector brightness, and substitute $I_{cBK} = RI_0$ for Eq. [1].

$$R = \frac{I_c - I_{cBK}}{I_p} \qquad [2]$$

The ray from the projector has RGB values. Eqs. [3] and [4] are operated as follows:

$$R_* = \frac{I_{c*} - I_{cBK}}{I_{p*}} \qquad [3]$$

where * in Eq. [3] means a value of RGB light sources.

If we assume that I_{cR}, I_{cG}, I_{cB} and I_{cBK} are reflections from a wall surface, then we can calculate the transfer function of the PROCAMS model. Using the calculated transfer function, the brightness of the reflection on the surface can be estimated. The system compares this estimated brightness and

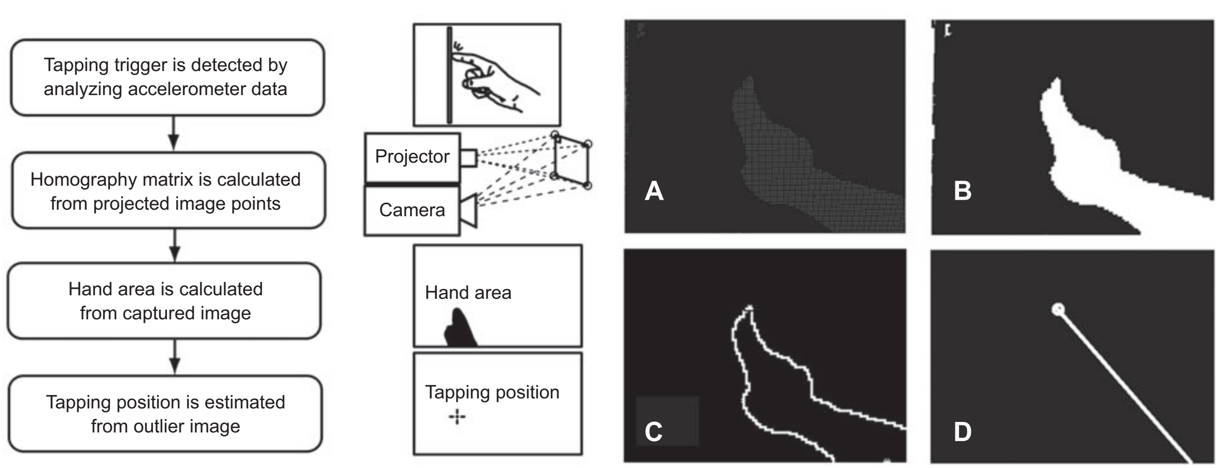

Figure 2 Detecting a direct tapping input in the system.
(Left) Flow chart of processing to detect tapping and pointing finger-tip position. (Right) Processed images in each step: (A) one of outliner images; (B) a result of labeling operation; (C) a outlier's edge; (D) finger-tip pointing position.

one captured by camera to judge the existence of an outlier. Only some of the projection rays are used in the calculation because comparing all of projection rays increases computational complexity.

Figure 2A shows and example of an outlier image. This image has noise from shadow and defocus. To recognize the hand area, the outlier image is processed with a labeling operation and the result is shown in Figure 2B. When it is assumed that an input action must incur on the projection area, the hand area has a captured-screen edge, the largest area that has a captured-screen edge is recognized as a hand area, and all else is considered noise.

Estimation of the finger-tip position

The recognized hand area image is processed with edge detection. Then, a distance from image-screen edge is calculated along with the hand area outline, as shown in Figure 2C. The furthest point on the outline is estimated to finger-tip direction, as shown in Figure 2D. Finally that same point is defined as the finger's tip position.

Evaluation experiment

The prototype system is developed and the usability of the tapping interface is evaluated through user testing with elderly users. The performance evaluation was also verified to confirm an input response time, resolution and robustness to different environment conditions.

The prototype system consists of a projector (3M™ Micro Professional Projector MPro110, SVGA, USA), a camera (Logitech QuickCam Vision Pro, 960×720 pixels, Switzerland), an accelerometer (ATR-Promotions WAA-006, Kyoto, Japan), and a computer (Lenovo ThinkPad X61, 271 g, China), which weighs 271 g excluding the computer. Figure 3 shows the prototype system and a graphical user interface design for the system. At first, the camera is calibrated using Zhang's method (10) to produce undistorted images. The projection image has a color marker at left-upper side to detect a hand area. The color marker consists of four colors; Red (255, 0, 0), Green (0, 255, 0), Blue (0, 0, 255) and Black (0, 0, 0) in RGB color space. Using this color marker, the system calculates RGB color transformation matrices in each frame. Then, four points at corners of a projection image are used to calculate a homography matrix.

Evaluation of system availability

To confirm robustness to different environmental conditions, the projection experiment was tried on a variety of surfaces. In this experiment, five materials were chosen as the projection monotone wall surface. These surfaces' properties (material and Lab color space measured by a chroma meter, Konica Minolta CS200, Tokyo, Japan) are as follows: red drawing paper (56.26, 61.98, 29.59), green drawing paper (97.75, 3.86, 89.56), yellow drawing paper (61.48, –38.4, 16.98), mat surface wooden board (112.4, 8.03, 17.74), and shiny surface wooden board (73.88, 13.06, 43.08).

A projection and a tapping input, as fundamental system operations, were conducted on each material surface. There were problems for the green drawing paper and the mat board, although the system operated normally for other materials. The result for green drawing paper shows that the acquisition radiance value of the color marker was low. The mat board produces interference in the distinction between the wall and the hand area.

Evaluating reactions

In this usability test, a senior citizen subject is given a simple task that is to select projected images (Figure 3 right shows

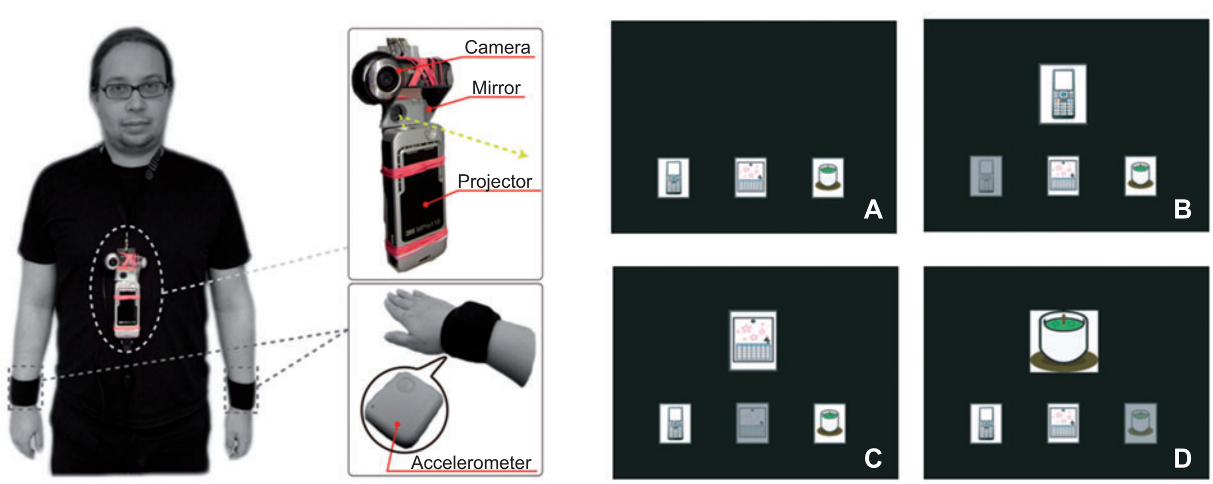

Figure 3 Prototype system and a graphical user interface design for the system.
(Left) Prototype system; a projector-camera unit is hanging from the user's neck. An accelerometer is worn on the user's wrist by a wristband. (Right) Graphical user interface: (A) initial screen, there are three selectable pictures in the bottom; (B–D) the top bigger picture is presented according to user selection.

the user interface design of the experiment). There are three selectable pictures in the bottom of the screen, and the user taps one of these pictures. Then, the system presents at the top area of the screen according to a tap-selected picture.

The senior citizen has no previous experience or training in the use of the system. The senior citizen subject is an 84-year-old man who has never been tested for dementia. He cannot raise his arms much above shoulder height because of discomfort. The experiment consists of two steps. The first step is to confirm that the projected images allow the subject to tap them like a button without previous training. The second step is to confirm that the senior subject can use the tapping interface and to ascertain any issues they had in using the interface. After the tapping tasks, the subject answers three questionnaires.

Through the action observation of the senior citizen subject in step 1, he can touch the projected images as the input action, without any explanation on how to use it. After training, the tap task of 40 trials is given to the subject to calculate the tap recognition rate. In the result, there were 22 successes (55%), a false detection of nine times, and the remaining nine were not detected. The following are answers to the questionnaire:

- Does wearing the device feel strange or uncomfortable to you? *"Not really. The device is not heavy and I can imagine wearing it throughout the day. The device does feel a bit loose, though. It should be more stable. The picture displayed swings around the wall as the device moves."*
- When inputting with the device, do you feel any strange or difficult points? *"Not really, but I would imagine that if I will use the system the whole day, my fingertips might become sore. I thought that maybe I will need some kind of protection for my fingertips."*
- Anything else about the system? *"All the icons did not look like what they supposedly were representing. The teacup looked like a candle and the cellphone looked like a door. The calendar icon, however, was easily recognized."*

Discussion

The performance of this system and its user interface was confirmed through two experiments. In the first experiment to confirm system availability, the system had weak points according to surface condition. On the surface of green drawing paper, the system cannot process the necessary calculations for projection because the radiance value of the projected markers cannot be observed through the camera. It is thought that as this material is of a dark shade, consequently it has the characteristic in which the projector light cannot be strongly reflected. One solution is to have much stronger projector light and such projectors are becoming readily available. On the other hand, the prevalence of light interior surfaces (especially wall surfaces) ameliorates this considerably. With mat surface wooden board, the system cannot distinguish the presence of a hand, as the reflection surface property of the mat surface board is similar to one of the hand. Therefore, wooden products in the house cannot be target objects for projection. These problems, together with the influence of ambient light, cannot guarantee the quality of this system from this experimental result. A new prototype system might be made with a bright light projector and an experiment that includes ambient light as one of its components is necessary in the future.

The second experiment in which the senior citizen subject had used the system, has been set to confirm a usability of a proposal direct manipulation interface based on projection. The result of the intuitive tapping task shows that the projected icons have an affordance to let the user tap onto the icon naturally, where training is deemed unnecessary. Therefore, it is expected that this projection-based wearable system can offer senior citizens AAC anytime and anywhere. After understanding the usage, the usability of the system for the senior citizens was evaluated by observation of the subject during the tapping recognition task and by a follow-up questionnaire.

Other areas of improvement include the process where the tap action is extracted from a sequence of the accelerometer data. In the prototype system, it is defined that a spectrum value of a high frequency area rises above a particular threshold. It is necessary to find some theoretical strategies suitable for analyses of the tap action to raise the tap recognition rate. Another issue is the process of estimating a finger-tip position. The estimation method that depends on a distance edge to finger-tip has the possibility of causing a gap between a true tapping position and an estimated tapping position. The gap is sometimes caused when two fingers or more are used to do the tap action. To compensate for this, new solution methods will presume a tapping finger-tip and expanding the tap reaction area.

Conclusions

This paper presented a wearable PROCAMS with an intuitive tapping interface (PiTaSu). The prototype system can detect finger-tip position on the target surface by comparing estimated reflection with the captured reflection. The system can offer users with memory problem an easier to use system with its haptic and visual feedback as the user taps the projected images in the ubiquitous information environment. In smart living environments offered by P-SESC, the proposal system becomes the most important interface on the user side. Through the user testing, it is shown that the proposed system with PiTaSu helps to assist memory-impaired senior citizens without learning special skills. Additionally, the senior citizens subject had no feeling of discomfort by using a wearable system, and it was confirmed that he tapped onto the icons naturally. Future work will include a more comprehensive user testing planning for the senior citizens with memory problem. This would then help to determine the viability of establishing this system and this user interface technology in future smart living environments.

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Conflict of interest statement

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