PALMbit-Silhouette: A User Interface by Superimposing Palm-Silhouette to Access Wall Displays

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Abstract. In this paper, we propose a new type of user interface using palm-silhouette, which realizes intuitive interaction on ubiquitous displays located at far from user's location or interfered in direct operation. In the area of augmented reality based user interface, besides the interface which allows users to operate virtual objects directly, the interface which lets users to interact remotely from a short-distant location is necessary, especially in the environment where multi-displays are shared in public areas. We propose two gesture-related functions using the palm-silhouette interface: grasp-and-release operation and wrist rotating operation which represent "selecting" and "adjustment" respectively. The usability of proposed palm-silhouette interface was evaluated by experiment comparison with a conventional arrowhead pointer. We studied and concluded the design rationale to realize a rotary switch operation by utilizing pseudo-haptic visual cue.

Keywords: user interface, shadow, pseudo-haptic.

1 Introduction

Many recent studies of a user interfaces on wall-sized display environment discussed about how to augment large workspaces with mixed reality technology or advanced large-sized screen display technology[1]. In such wall display environments, as shown in Fig. 1, overcoming the difficulties to avoid directly touch virtual objects which are generated by projectors or large-scale displays and sometimes not preferable to be directly touched, and enhancing the intuitiveness of distant-access-interface are one of key issues to increase the usability and practical value of such studies.

In this paper, firstly we will discuss the metaphor of a shadow which is a cast of user's own hand and acts as an interface to connect the worlds of real and virtual. Then, we will introduce an experimental user interface of palm-silhouette casting for wall display environments and involving hand-gesture recognition methods. The proposed system, PALMbit-Silhouette, realizes a distant user interface which lets user to move an icon among distributed wall-based displays

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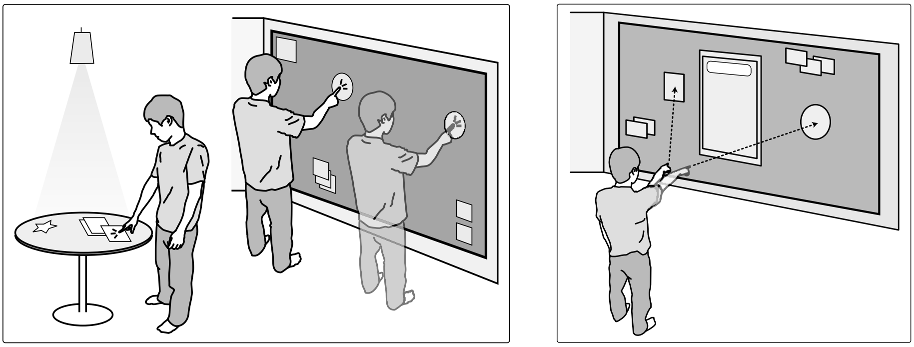

Fig. 1. User interfaces are categorized into two classes in wall interactive display environments; Type 1(left): users operate with directly touch; Type 2(right): a user operates from a not-reachable place

with natural hand gestures. Experiments with a prototype system showed that it enabled users to interact seamlessly with virtual objects in augmented distributed display environments[2,3]. The system interface also lets a user to adjust volumes by a gesture of rotation around his/her wrist joint. We also focus on the pseudo-haptic physiological phenomenon which makes a user feel something like touch sensation by visualizing different patterns of shadow projected. A shadowing users' palm is internally processed and a corresponding artificial shadow is actually projected like a real shadow. Therefore the user identifies it as his/her own body movement[4]. This paper describes experimental results of the cognitive effects of a controlled artificial movement in shadow representation.

2 Related Work

Some projection techniques have been studied, many of which focused on direct access through physically touching objects[5,6,7]. In a distributed display environment, it is possible that a user cannot physically reach the display which is far from his/her location or which may be interfered in direct operation. In order to solve this problem, we proposed an intuitive interface using the metaphor of the shadow. Since Pavani found that shadow is recognized as owner's physical extension[8], users may utilize their shadows as interfaces, feelings as if the shadows would be the part of owner's body.

VIDEOPLACE[10] is the shadow-based interaction technique which not only projects silhouette but provides artistic expression of shadows by processing the image data and adding various graphical effects. However, still there is a difficulty for user to understand the correspondence between the generated artificial shadow and users' own body in the experimental environment. In our proposed interface, the artificial shadow is designed to be projected at the same location of the real shadow, utilizing shadow as a metaphor, and generating the feeling of correspondence between the generated artificial shadow and users' own body.

In some researches, Virtual Shadow[9] and Shadow Reaching[11] are utilized together with hand gestures to realize shadow interfaces, which could provide users intuitive operation by displaying natural shadows. The biggest disadvantage of these systems is that a hand shadow is covered by a body shadow since they require a light source behind user. Therefore, users can hardly operate naturally in front of the display. In our proposed system, we focus only on the hand shadow and aim to provide a user-friendly interface by displaying only palm-silhouette.

3 Silhouette Interface

Shadow is a common physical phenomenon where there is a point light source. We utilize shadow's characteristics in our user interface to access and interact with distributed-displays which are not directly or physically accessible by user, as shown in Fig. 2. With it, this interface could be intuitive since our daily experience so that its mental model is integrated.

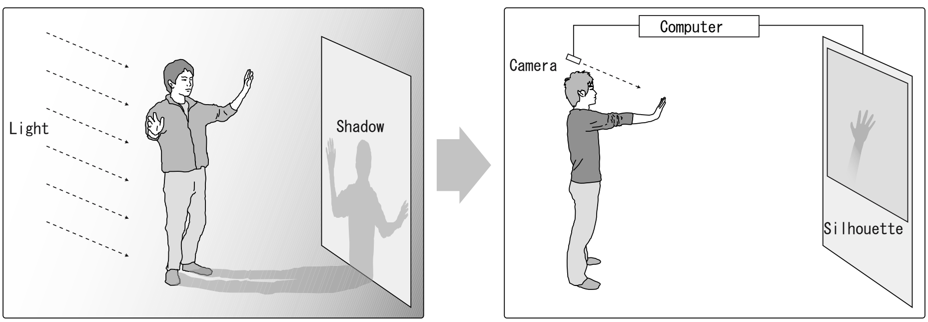

Fig. 2. Accessing wall displays that located where users cannot touch directly; left: physical shadow; right: artificially generated silhouette

In this paper, "silhouette" is defined as an artificial replacement of the shadow which shares some of the same characteristics of the real shadow. There are four major advantages of the silhouette user interface: First, a user does not need to handle and operate by hand any external pointing devices like a mouse or a trackball, though it is necessary to set a camera to recognize a user's hand position. Second, user can identify easily his/her own silhouette by the shadow movement from a distributed-display environment even where there are multiple number of users and several similar silhouettes, since the shadow and the computer-generated silhouette corresponding to the body movement based on the real shadow itself causes a natural and intuitive visual feedback. Third, it is a natural phenomenon that the shadow and its corresponding silhouette represent the user's body itself on distant surface, so silhouette interface is suitable for intuitive user interface of a remote operation. Finally, the computer-generated silhouette does not block visual information projected by optical projectors or generated by large-scale display like the real shadow since the transparency of the silhouette can be adjusted to superimposing.

Silhouette has some other useful visual properties than transparency. With graphical image combined, silhouette can be changed in some expressions: change of not only light-dark tone but also color or texture, scale change in arbitrarily defined environment, layer structure. Moreover, silhouette can also be intentionally deformed and modified in motion pattern. These features will be introduced into details in the following chapters.

We take the advantages of the above palm-silhouette characteristics to realize a distant interaction system for 10-foot user interface on wall displays. Figure 3 shows the conceptual idea of human-computer interaction with the proposed interface. On the other hand, since the displayed figure is not the real shadow but the artificial one, there may cause a processing lag which makes users feel unnatural.

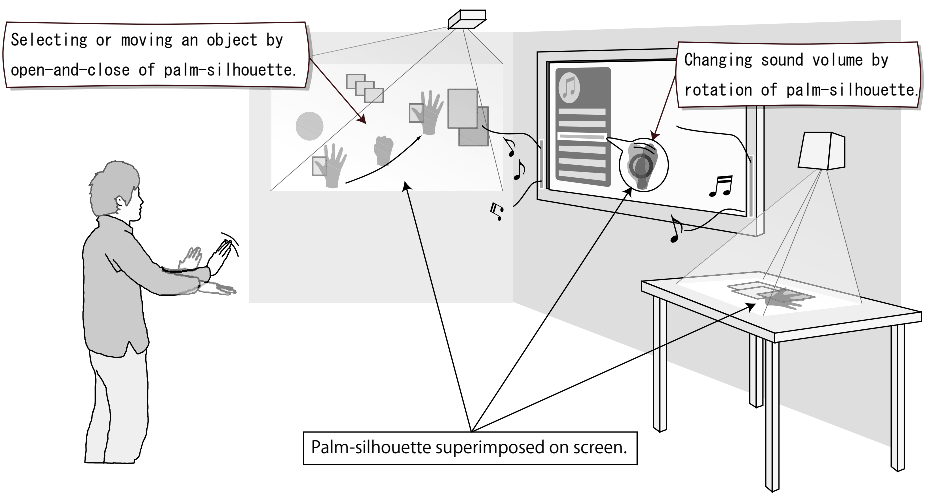

Fig. 3. Conceptual configuration of palm-silhouette interface; user is able to operate selecting or adjustment control with one's own silhouette

4 System Configuration

We propose a novel interface system with new intuitive accessing method by palm-silhouette display and hand gesture recognition. As shown in Fig. 4, the system consists of three elements: a camera and a projector and a screen. User's hand is captured by the camera and processed for gesture recognition. Palm-silhouette image is projected to the screen. The two operation functionalities we implemented in the system includes "selecting" and "adjustment" which are achieved by capturing palm-silhouette in real time. The detailed description about these operations is mentioned in the next section.

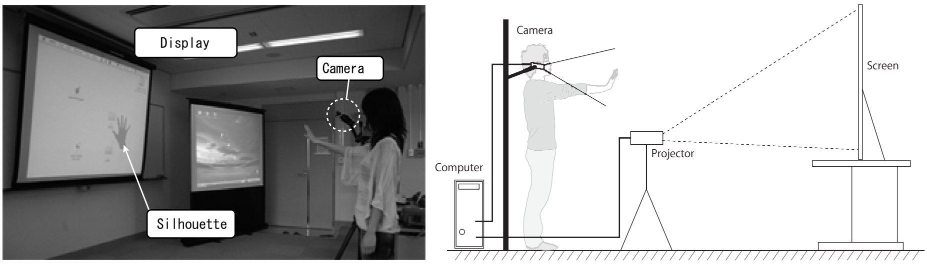

Fig. 4. System overview; left: experimental setup; right: system configuration

4.1 Two Types of Operations

Currently the proposed interface supports two operations: selecting and adjustment in Mac OS X and Windows XP. First, the selecting operation enables users to select an object on a display without using any pointing devices. This operation is implemented with grasp-and-release gesture based on the result of a preliminary experiment. Through this experiment, we found that test subjects accessed to an object on a display screen by grasping hand action. We confirmed that users could naturally move their own silhouette onto objects. We apply grasp-and-release operation for access a virtual object.

Second, adjustment operation enables some basic functions such as volumes control or rotary switch. The rotation movement is one of possible parameters by the joint rotation of our body. The controllable joint positions we could use for adjustment operation are: shoulder, cubital region, wrist and finger. There are the advantages and drawbacks for each joints. Requiring users of body movement such as rotation in the shoulder joint is likely to leads users fatigue. On the other hand, recognizing small changes in hand posture makes image processing complicated. Therefore, we decided to use the rotation in wrist, since its rotation does not require large movement which gives physical burden. Also, we applied the wrist rotation to adjustment operation such as controlling continuous quantity and multi-step selection.

4.2 Image Processing

A palm-silhouette is projected onto the screen by the projector after capturing and processing hand motion images. The processing is performed in three consequent steps: recognition of hand region on captured images, analyzing hand gesture and tilt parameter, creating CG images of palm-silhouette. First, the system acquires color images from the camera. Using skin color extraction, it makes captured color images be binarized as hand region. Second, some necessary parameters are calculated from the binary images. To detect palm-silhouette position on the screen, it finds the center of palm with excepting wrists or arms region from the binary images. The system also detects hand posture for select operation and calculates palm sway parameter for adjustment operation. Finally, CG image of the palm-silhouette is generated in correspond to these parameters, and it superimposes the silhouette image on screen or PC desktop.

5 Grasp-and-Release Operation

We design grasping operation so that a virtual object can be operated by closing users' hand where the object on the screen and the half-transparent palm-silhouette are overlapped with each other. Also, release operation is designed so that the object can be released when users open their hand. Figure 5 shows grasp-and-release operation sequences. Like how we handle real objects by our hands in the real world, we can operate virtual objects by our palm-silhouette. We evaluated of grasp-and-release operation in following experiments.

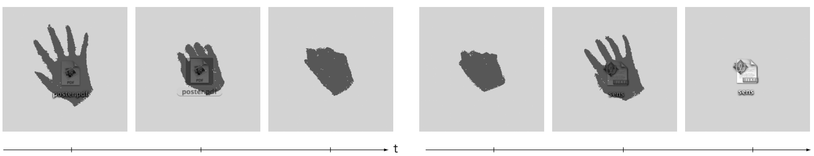

Fig. 5. Grasp-and-release operation by closing and opening hand through palm-silhouette; left: Grasp operation; right: Release operation

5.1 Experiment 1: Usability Evaluation in Displaying Palm-Silhouette

We agree that users may recognize the pointing location by looking at his/her own palm-silhouette in the same way of a cursor pointer indication. The most important advantage of using silhouettes to be expremirated, is that users can confirm the transition between opening and closing their palm. In order to understand the effect of the difference between visual information which users get through using both the conventional arrowhead pointer and the palm-silhouette, we conducted following experiments.

Test subjects are asked to perform the following task by both arrowhead pointer and palm-silhouette respectively. The task is "to replace four icons, two of which are located on the right half (Group A) and rests are on the left half (Group B), so that icons in Group A goes on the left and those in Group B does on the right."

Subjects are 16 students in the total males and females who major in the computer science in their twenties and are asked which visualization they feel to operate easily.

Results showed that subjects' answers to be the question which palm-silhouette or arrowhead pointer to be used easily; 91% "palm-silhouette," 3% "arrowhead pointer," and 6% neither. Also users gave following positive feedbacks:

- Silhouette lets a user understand operations intuitively.
- Since silhouette gives palm states such as opening and closing, it is easy to adjust how to grasp.

We obtained a finding that operativeness has been improved through the visual feedback in palm states such as opening and closing because visualizing the palm-silhouette is expressible of the shape variation according to the palm movement operation.

5.2 Application

We created an application in which users can move arbitrary icons on a conventional computer desktop in the same way users move real objects on the real desktop. Users can access GUI objects a the computer desktop through the silhouette. With image processing, proposed system recognizes hand gesture in each frame: the hand is recognized as open when the system identifies five fingers, the hand is recognized as close when the system does no finger. Real time gesture recognition realizes virtual object selection and movement function.

Even in the environment where are several computers and several displays, it is easy that users grab and move the virtual objects visually and intuitively by using networking systems. This enables seamless data transfer among multiple displays by using consistent operation in distributed-display environment.

6 Wrist Rotating Operation

In this section, we will describe how to realize adjustment function by palm rotation for both continuous operation such as volume control and descrete multi-step function such as rotary switch.We used hand the following hand gestures in our system for adjustment operation as shown in Fig. 6. It is easy to enable functions such as a tuning-knob operation, however such continuous operation provides user with monotonous haptic feeling because a user is not actually touching the object.To realize multi-step rotary type adjustment, we included visuo-tactile operation, which lets a user feel the resistance on one's hand by imposing movement restrictions on palm-silhouette. The following experiments show how to design rotary operation using palm-silhouette.

In one of experiments, we make the virtual shadow rotation angle larger than actual hand rotation angle as shown in Fig. 7. By such processing, a user perform rotation operation in relatively larger range with relative less body effort. We designed the virtual rotation angle range within an acceptable range within which user will not have feeling of incompatibility. We assume that it makes a user operating in range of large rotation angle with small rotation hand gesture easily. Through the experiment, the suitable ration of rotation angle stretch parameter was confirmed about 1.5. Also, we have confirmed that suitable hand gesture rotation range is about 80-degree.

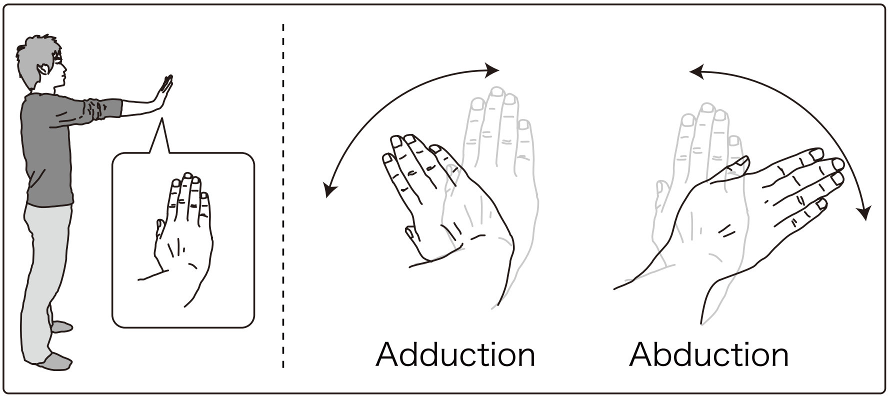

Fig. 6. Hand rotation around a wrist joint point

We also studied how many points can be selected by rotary-switch like discrete operation as shown in Fig. 8. Multi-step control can be realized by discretizing of movement of palm-silhouette which is supposed to match the actual rotation of hand palm continuously in a natural way if there is no physical resistance. By discretizing virtual shadow's movement into steps, users can have visuo-tactile feeling of resistance and they can feel that they are actually operating a rotary switch. It is necessary to find out the minimum value of width of tuning angle quantum with which a user can realize they are doing discrete adjustment operation. Through the experiment of finding a width of tuning angle quantum, we confirmed that the minimum value is about 5-degree, so it is possible to build up about 40 points of discrete adjustment. Also, the results show that silhouette movement with large width of angle quantum have a risk of recognizing as a response delay.

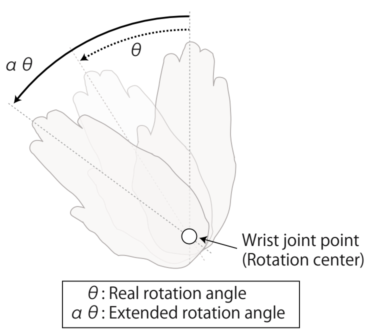

Fig. 7. Angle expansion that palm-silhouette rotation angle is more stretched than real hand one

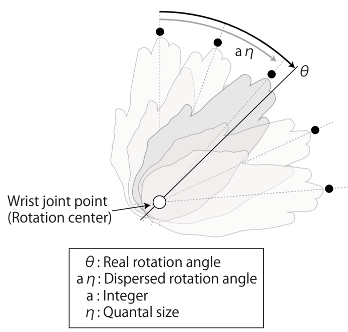

Fig. 8. Discrete palm rotary motion to select from multi-step control like rotary switch

7 Conclusion

In this paper we introduced a novel user-interface which let user to execute intuitively access interfaces which are far from user's location or which may be interrupted in direct operation, especially in multi-display environments. Shadow is used as the ideal interaction metaphor to connect real and virtual worlds. The "shadow" called in the proposed system, may occlude visual contents shown on display or projected by an optical projector because it is computer-generated artificial shadow, which we call "silhouette" in this paper. Such silhouette is generated from a hand image which is captured by a camera installed on user's arm. As users can move the artificial shadow naturally in real time, they could feel that the computer-generated silhouettes were their own shadow experiments. We proposed two gesture-related functions; "selecting" function by grasp-and-release operation and "adjustment" function by wrist rotating operation. We evaluated that the usability of proposed interface comparing a arrowhead pointer. Through another experiment, we studied and concluded a design rationale to realize a rotary switch operation with utilizing pseudo-haptic visual cue.

Shadow is a natural phenomenon occurring where there is a light source, no special training is needed to control it extended through our daily experience.

In the future, we will build a extended silhouette interface for targeting multi-user case. We will also evaluate the usability of wearable silhouette implementation of interface. Artificial shadow could connect the real and virtual worlds. We believe this human-computer interaction technique based on shadow metaphor can be applied to useful many practical domains.

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