A Multi-user Interactive Public Display with Dynamic Layout Optimization

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ABSTRACT
In this paper, we propose a user interface that allows multiple users to obtain information interactively and perform simultaneous operation on a public display. Users can interact with the display using hand gestures, which enables many users to easily and remotely use the system. A window pops up when a user selects an item on the screen, and information about the item is displayed in the window. In order for each user to effectively use the screen and also not to be interfered with by other users, the system dynamically optimizes the position and size of each window. We created a map guidance application to confirm the effectiveness of the proposed user interface.

Author Keywords
Public display; multi-user interaction; hand gestures.

ACM Classification Keywords
H.5.2 User Interface: Input devices and strategies

INTRODUCTION
Public displays have been placed everywhere in commercial and public spaces. It is known that public displays that allow interaction by users are effective for attracting people [4]. Among such interactive public displays, especially with a large screen, the ones that multiple people can simultaneously use are desirable since the amount of information that is provided to users per unit time increases. In addition, we can expect the honey pot effect [3] that the number of users increases because they get interested when they see people who are actually interacting with public displays or are stopping to look at them.

As an example of public displays which can be simultaneously interacted with by multiple people, there has been a system which allows each user to select an item on the screen using a mobile device and that displays information about the item in a pop-up window [2]. However, there is a problem that pop-up windows can overlap when closely located items are selected at a time.

In contrast, there has been a public display system which provides separate operation area on the screen for each user [1]. The system allows the user to perform operation only within the area, preventing area overlap between users, and realizes simultaneous use by multiple users. However, even when only one user is using the system, the user cannot fully utilize the whole screen since the size of the operation area for each user is constant.

Based on these studies, we propose a user interface that allows multiple users to obtain information interactively and perform simultaneous operation on a public display. Users can interact with the display using their hand, which enables many users to easily and remotely use the system. The system pops up a window when a user selects an item on the screen, and information about the item is displayed in the window. In order for each user to effectively use the screen and also not to be interfered with by other users, the system dynamically optimizes the layout of windows.

USER INTERFACE DESIGN
The proposed user interface allows multiple users to interact with a large display using hand gestures as shown in Figure 1.

The screen components of the proposed user interface include windows, items, and pointers. A user can operate each pointer using hand gestures, and its color differs by user. Some items are displayed in the screen and each item can be selected by a user. Selection of an item is performed by stopping the pointer on the item for a certain time. When a user selects an item in the screen, the system pops up a window and displays information about the item in the window.

In order for each user to effectively use the screen and also not to be interfered with by other users, the system dynamically optimizes the layout of each window, which allows efficient and comfortable use of the system. In this paper, we assume each window to be rectangular, having parameters of position (x, y) and size (w, h). The width and height are limited to the halves of those of the screen. The
parameters $\theta$ are optimized to minimize the following cost function:

$$ f(\theta) = w_a C_a(\theta) + w_s C_s(\theta) + w_o C_o(\theta) + w_p C_p(\theta) $$

The functions $C_a(\theta)$, $C_s(\theta)$, $C_o(\theta)$, and $C_p(\theta)$ represent the costs about the area, shape, overlap, and position, respectively. The coefficients $w_a$, $w_s$, $w_o$, and $w_p$ represent the weights for the functions and show the importance of the elements in the optimization. $C_a(\theta)$ is defined to maximize the area of the window that has the minimum area. $C_s(\theta)$ is defined to maximize the sum of the roundness of the windows. $C_o(\theta)$ is defined to minimize the total overlap area with other windows and pointers. $C_p(\theta)$ is defined to minimize the total distance between the face position of a user and the center of the window for the user.

**IMPLEMENTATION**

We used a multi-display system with four 31.5 inches displays. An RGB camera was fixed on the multi-display and captures 1920×1080 pixel images at about 40 fps.

The system detects the positions of users’ faces and hands using OpenPose [5]. OpenPose is a library that can detect key points of multiple bodies that are overlapping each other using a deep learning based algorithm. When the distance between the face and the right hand of a user becomes below a threshold, the system starts tracking of the hand using Dlib (http://dlib.net/). Since the frame rate of face and hand detection using OpenPose is much lower than that of hand tracking using Dlib, the system searches the hand again using Dlib around the hand detected using OpenPose. The result of detecting and tracking multiple hands is shown in Figure 2.

We created a map guidance application as an application example based on the proposed user interface. The application displays major sightseeing spots as items on a simplified map. When a user selects an item, the system generates a window displaying detailed information about the spot.

Figure 3 shows the screen images when three users were using the application. Firstly, the users were operating pointers at the same time, and the user with the blue pointer obtained information shown in a blue window (Figure 3 (a)). Then, the user with the orange pointer selected an item and an orange window was generated (Figure 3 (b)), and the system gradually changed the position and size of each window to reduce window overlap. Finally, the size of the two windows became almost the same, and the windows were not overlapped (Figure 3 (c)).

**CONCLUSION**

We proposed a user interface that allows multiple users to obtain information interactively and perform simultaneous operation on a public display.

In future work, we will conduct usability testing to verify if each user can efficiently obtain information without being interfered with by other users in a multi-user scenario.

**REFERENCES**