7Y-03

# Smart-home control by using half-reflective AR mirror display

ZIQING FENG† Mana SASAGAWA† Itiro SIIO† Yasushi MATOBA †
Graduate School of Human and Social Sciences, Ochanomizu University

## 1 Abstract

In this paper, we present a smart-home control interface system by using a half-reflective AR mirror display. When the user stands in front of the half-mirror display, the user can see reflected images of target IoT devices such as smart-home lamps. The user can manipulate these devices by touching the mirror surface, selecting a menu that appeared at the touchpoint. We also have a user correction method for our system, the user can move the reflection position anytime to correct the reflection position. The display has a couple of stereo cameras at both sides of the frame, and a touch sensor on the display surface. Because the system is made of an all-in-one configuration, the calibration and registration efforts are reducing significantly.

## 2 Background

With the development of technology, smart home technology and augmented reality technology have become an indispensable part of our lives. In the field of smart home, most of what we know is to control smart-home furniture through voice, such as Siri Home pod[1], Amazon Alexa [2], Xiao Ai[3], and so on. In the field of augmented reality, many software developers have developed very successful AR applications, such as Pokémon Go[4], which is very well-known in the game field, or Ikea place[5] developed by a smart home company Ikea, which is helping people choose more suitable furniture for their room.

It would be great if AR and smart home systems could be integrated, so we thought about why can't the mirror be made into a smart home touch control system? Before this research, there were already some reality augmentation researches for mirrors. For example, the MR-Mirro[1], which allows users to interact with virtual objects in front of the mirror, and Mirror Mirror[2], which allows users to see different clothes designs in front of the mirror through projection, etc.

## 3 Proposed System

Figure 1 shows our proposed system. When the user stands in front of our system, the user can see the reflection point of the loT devices behind the user like figure 1 right, and user can touch the screen to manipulate those devices as figure 1 left. Figure 2 shows the actual screenshots from a user's view. She can locate the target device by touching the surface, and selecting a menu to control it.

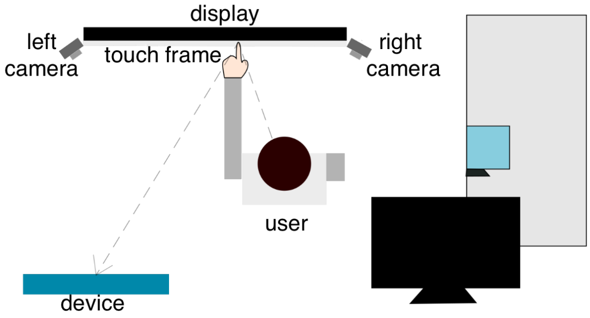


Figure 1: Left: Top view Right: User's view


Figure 2: Screenshots from a user's view.

### 3.1 System Configuration

Figure 3 shows our proposed system configuration Our system is consists of 4 sections, the first section is a display for showing target marks and menus at their reflection position prepared by a computer, the second section is the half-mirror for reflection as a mirror but also can let the user see the display screen, the third section is a touch frame to get user's touch position, and the last one is two cameras for getting the user's head position.

### 3.2 Data Processing

The data processing flow of this system is shown in figure 5. First, two stereo cameras obtain the user's image, and then the 2d coordinates of the user's head are obtained through openpose [6] ,

[1]https://www.apple.com/jp/homepod-mini/
[2]https://developer.amazon.com/ja-JP/alexa
[3]https://xiaoai.mi.com
[4]https://pokemongolive.com/ja/
[5]https://apps.apple.com/us/app/ikea-place/id1279244498
[6]https://github.com/CMU-Perceptual-Computing-Lab/openpose

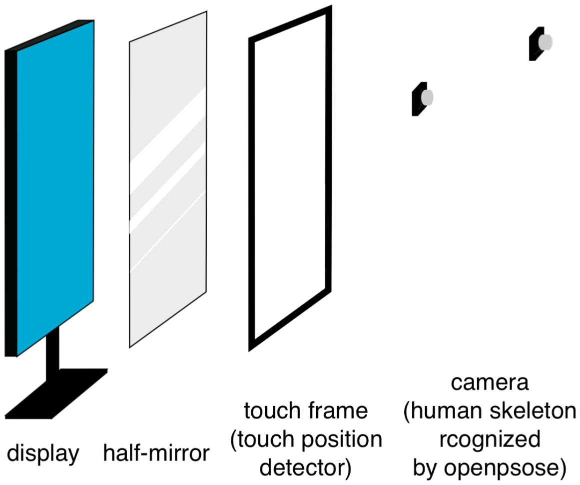


Figure 3: System Configuration

and then 3d coordinates in space are calculated by using the method of our research (will be explained in the next chapter). At this time, the 3D coordinates of the user's head will be transmitted to the processing program through MQTT [1]. In the processing program, the user's touch position is obtained through the touch-frame, and then it is judged whether the user has touched the reflected point. If touched, the menu is displayed, and the user can control the smart home through the menu. The processing program issues commands to control devices such as smart LED lights through Apple the HomeKit library.

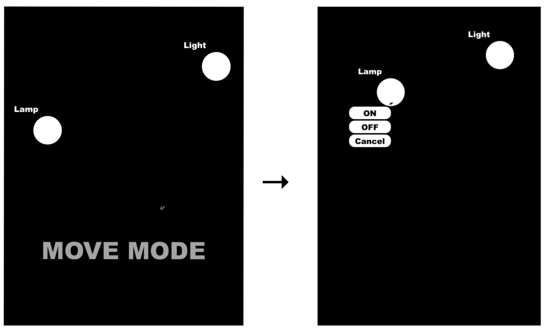


Figure 4: Move Mode and Menu

Our system also has a function for the user to correct the reflection position for the target device on the mirror, as shown in Fig. 4. A user can enter the "move mode" by double-clicking the screen and then manually moving the reflection point for target devices. This eliminates efforts for registering device locations before initial use.

### 3.3 Calculation of Space Coordinates

Every camera has some distortion. The distortion of the camera used in this paper is shown in the

[1]https://mqtt.org

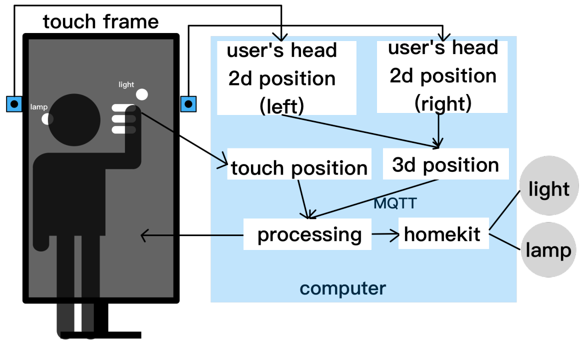


Figure 5: Data Processing Flow

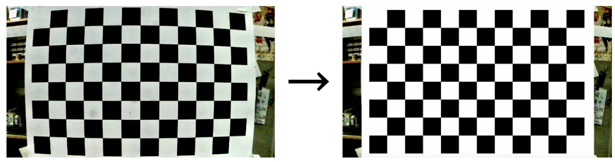

Figure 6: Undistortion

figure 6. Therefore, before the calculation, the camera distortion must be corrected first so that the subsequent calculations are more accurate. To correct the distortion of the camera on the left side of the figure 6 to the right of figure 6, we used 2nd order distortion calibration by determining parameters from the checker pattern.

Now we get the correct 2d coordinates through distortion correction. Then, we can calculate the user's head position of space coordinates. Through measurement, the distance between the two cameras is 65cm, the height is 162cm, and the horizontal deflection angle of the camera is 25 degrees to 30 degrees (26 degrees is used in this study because 26 degrees has the highest accuracy). From the two direction vectors to the user from each camera, we have determined the user's position by stereoscopic calculation.

## 4 Future Work

As mentioned above, our system provides a "move mode" to register device positions. We will improve the function so that the position of target devices will be gradually precise through everyday use of the system. This will also be effective to track devices that might be moved by a resident of the smart home.

## References

[1] Sato, H., Kitahara, I., Ohta, Y.: MR-Mirror: A Complex of Real and Virtual Mirrors; Proc. HCI International '09, pp.482–491 (2009).

[2] Saakes, D., Yeo, H. S., Noh, S. T., Han, G., Woo, W.: Mirror Mirror: An On-Body T-shirt Design System; Proc. CHI '16, pp.6058–6063 (2016).