A drone-based movable smart remote control for household appliances

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Abstract: As various Internet of Things (IoT) devices have been developed, "smart remote control" products are attracting attention. A smart remote control enables controlling multiple conventional household appliances, i.e., controllable by an infrared remote control but incapable of WiFi/Bluetooth connectivity, from mobile devices like smartphones. One of the drawbacks is the difficulty of covering a whole indoor space with one smart remote control since infrared signals could be sheltered by physical obstacles such as walls, pillars, and furniture. Consequently, users are forced to control manually or install multiple smart remote controls. To solve this issue, we propose a drone-based movable smart remote control. The proposed system enables covering a broader space with a single smart remote control and makes it easy to adapt to the change in the position of household appliances. As a proof of concept, we conducted an experiment with actual devices and confirmed that the drone-based smart remote control makes infrared signals reach a wider area than placing a smart remote control on the wall.

Keywords: drone, smart remote control, IoT, infrared signals

Classification: Network System

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1   Introduction

As part of the recent broadening of Internet of Things (IoT) devices, some products called "smart remote controls" have been put into practical use. A smart remote control is for controlling multiple conventional household appliances, i.e., controllable by an infrared remote controller but incapable of WiFi/Bluetooth connectivity, from mobile devices like smartphones. It is typically designed for installation on the wall.

Covering a whole indoor space with one smart remote control is difficult. Infrared signals are sheltered by physical obstacles such as walls, pillars, and furniture. Even if the room shape is simple and there is a desirable position to install, i.e., it has good visibility, the installable place could be limited for several reasons, like rental housing rules and impairing interior scenery. Consequently, users are forced to control part of household appliances manually. Installing multiple smart remote controls could improve this problem, but there are still some drawbacks, such as increasing cost and labor for installation and operation. Besides, there is a problem that the suitable installation position changes when household appliances are moved.

To address these issues, we propose a drone-based movable smart remote control. The proposed system enables covering a broader space with a single smart remote control.

This letter is an extended version of [1] presented in IEICE General Conference 2021. The differences include detailed explanation of the proposed method and related works.

2   Related work

Recent home appliances are capable of network connectivity. We can control them from mobile devices or voice with AI such as Amazon Alexa and Google Assistant [2]. These cannot be directly applied to conventional household appliances that do not support network connectivity.

For controlling conventional household appliances, infrared signals are widely used. There are several existing studies on developing smart remote controls that send infrared signals according to commands from mobile devices [3, 4, 5]. While they make conventional household appliances controllable with mobile devices, the issue that physical obstacles shelter infrared signals exists.

3   Proposed method

Due to the characteristic of infrared signals, it is not easy to cover a whole indoor space with one smart remote control. Even if we install multiple smart remote controls, there are still some drawbacks, as mentioned in Section 1.

To address those issues, we propose a drone-based movable smart remote control. The idea is to make a drone move instead of users who are conventionally forced to move and control manually. Figure 1 shows an overview of the proposed system.
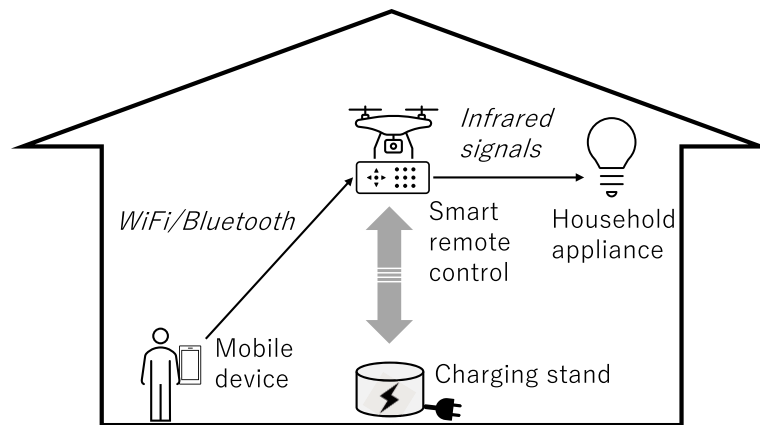
Fig. 1. Architecture of the proposed system

The proposed system integrates a smart remote control with a drone. A user sends control signals to the smart remote control via WiFi or Bluetooth. Upon receiving the signals, the drone moves automatically to an appropriate position with good visibility for a target household appliance. Subsequently, the smart remote control sends infrared signals to the household appliance. After completing the above procedures, the drone moves back to a charging stand. Note that we assume that the smart remote control receives electric power from the battery of the drone.

To make the drone learn the appropriate position for each household appliance, we assume the following steps.

1. The user sets a marker on the floor, which the drone can recognize with its camera.

2. The user starts the position learning process from an application of a mobile device.

3. The drone takes off and searches for the marker by moving in a pre-defined regular pattern.

4. Once it finds the marker, it moves to just above the marker and remembers the relative coordinate from the start point (the charging stand).

The above procedure is conducted in addition to the learning process of infrared signals that is generally needed for smart remote control products. Once the drone learns the appropriate positions as initial configuration, it can move there directly according to user operations.

The proposed system enables covering a broader space with one smart remote control. Hence the charging stand does not need to be placed in a position of good visibility, the problems of conventional smart remote controls are improved. Namely, it is less influenced by electric outlet location, easier to install in rental housing, less impairing interior scenery, less labor for operation, and easier to adapt to the change in the position of household appliances.

4 Evaluation

As a proof of concept, we conducted an experiment with actual devices listed below.

Drone Tello EDU (Shenzhen Ryze Technology Co., Ltd.)

Smart remote control RS-WFIREX4 (RATOC Systems, Inc.)

IR receiver OCR-05W (OHM ELECTRIC INC.)

Tello EDU is light and small, suitable for using indoor environments. In addition, it includes markers called "mission pads" and can recognize them for utilizing in programming the behavior of the drone. OCR-05W is a power plug that can switch between ON and OFF according to infrared signals.

To confirm the fundamental superiority of the proposed system where the smart remote control can send infrared signals at a free position, we measured the success rate for controlling household appliances. Here, the success rate is the ratio of the number of positions where an infrared signal is successfully received to the number of places where the IR receiver is set. We compare two cases; sending infrared signals from the air using our prototype system with the above equipment and sending them from the smart remote control installed on the wall.

In our prototype system, RS-WFIREX4 is bonded to the bottom of Tello EDU by double-sided tape. Since there are sensors for flight control at the bottom of Tello EDU, we fixed RS-WFIREX4 so that preventing interference. RS-WFIREX4 is connected to a power bank by a USB cable that is much longer than the flight altitude of Tello EDU. This power supply style is not practical for actual use but does not interfere with the experiment. As described in Section 3, we assume that the smart remote control receives electric power from the battery of the drone in the future practical system. Regarding the movement of the drone, we control it by manually specifying the positions in Fig. 2.

As shown in Fig. 2, we use a room of 7.9 meters by 7.5 meters with an inner room of 4.1 meters by 3.6 meters. The formers are the vertical lengths of the figure. There are 12 desks and chairs: each desk is 1.2 meters wide, 0.6 meters long, and 0.7 meters tall, whereas each chair is 0.6 meters wide, 0.6 meters long, and 1.0 meters tall. 24-inch monitors are located on those desks.
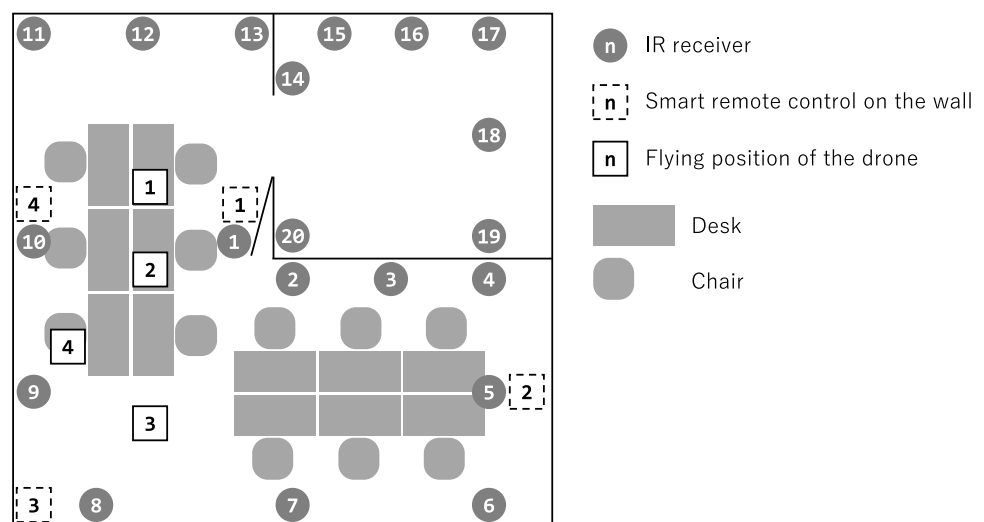

Fig. 2. Experimental environment

For each of the proposed and the conventional (i.e., placed on the wall), we choose four positions of good visibility as possible. We do not choose positions inside the inner room since walls surround them, i.e., they do not have good visibility. Based on a hypothesis that the lower-left area in Fig. 2 makes better success rates, we intensively select the positions from the area. Note that the proposed system can place the drone at nearly the same position as the conventional method; the success rate of the conventional method is considered reproducible by the proposed system. Therefore, for the proposed system, we do not choose from the lower-right area where we select one for the conventional method.

The drone in the proposed system sends infrared signals from 1.7 meters height in the air. The smart remote control in the conventional method also sends signals from 1.7 meters height on the wall. We set the IR receiver, OCR-05W, at 20 positions and measured the success rate. Note that OCR-05W is located on the wall approximately 20 centimeters above the floor. Various household appliances placed directly on the floor have their IR receiver at such a low position e.g., televisions, electric fans, and humidifiers.

Figure 3 shows the result. There is a tendency that the proposed system achieves a higher success rate, while the improvement is limited and the results are different depending on the positions due to various kinds of obstacles such as walls and desks. In particular, placement number 3 of the proposed and conventional that are pretty close positions results in the former being inferior to the latter. The actual difference between them is IR receiver number 12; the proposed system fails, whereas the conventional method succeeds. It is considered that the desks and monitors on them prevent infrared signals of the proposed system while those of conventional may pass through the legs of the desks.

Overall, the experimental result shows that the drone-based smart remote control could widen the coverage of infrared signals compared to a smart remote control placed on the wall. On the other hand, it is difficult to cover the whole room in both ways due to the obstacles. As described in Section 3, we assume that the drone moves automatically to an appropriate position for a target IR receiver when
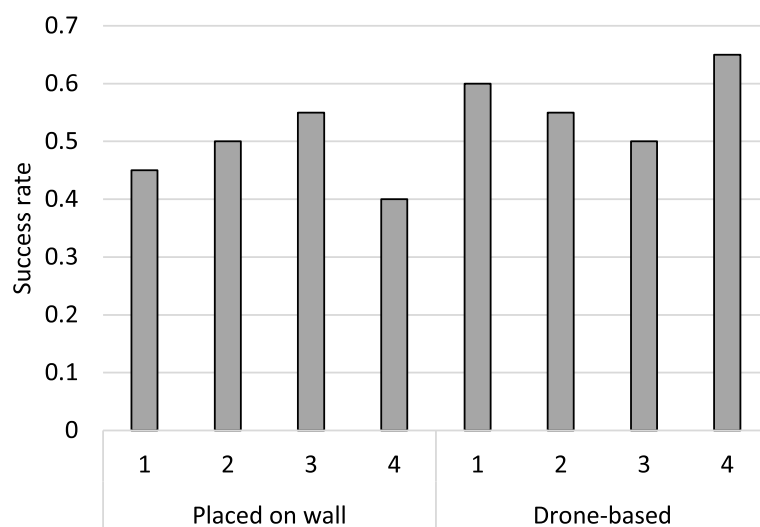

Fig. 3. Success rate for each position

developing a practical system. By this mechanism, the infrared signal reachability is expected to be improved.

Note that the direction of the drone does not affect the result because the infrared signals are sent in a range of 360 degrees. The height of sending signals may influence the result; the higher position potentially lowers the influence of obstacles and brings about a better success rate in both ways. Since infrared signals of RS-WFIREX4 have ranges of up to approximately 30 meters, the increase of distance involved in raising the position is considered not to decrease the success rate. In this experiment, we focus on clarifying the potential effectiveness of the drone-based method, in which the placement of the smart remote control is not limited to the wall, and we experimented with 1.7 meters height. Considering the appropriate height is one of the future works in conjunction with developing the practical movable drone-based smart remote control.

5 Conclusion

In this paper, we proposed a drone-based movable smart remote control. The proposed system integrates a smart remote control with a drone to send infrared signals while avoiding physical obstacles. As a proof of concept, we measured the success rate of controlling household appliances in comparison to a conventional smart remote control, i.e., placed on the wall. Experimental result shows that the proposed system makes infrared signals reach a wider area than the conventional way.

Future work includes developing a practical system with the learning and automatic movement mechanism described in Section 3. To reduce the labor for the initial setting, we plan to introduce a gesture recognition system where a user specifies the direction of a target household appliance by a gesture, and then the drone moves toward that direction. We also plan to confirm the influence of the increased delay time caused by the drone movement.

Acknowledgments