Development of a Collaborative System Between A Drone and A Home Service Robot for Enhanced Operational Efficiency

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Abstract

This research proposes a system that coordinates a home service robot with a drone to improve task efficiency. As an experiment, we conduct a search and pick-up task that integrates the home service robot and the drone. The drone's front camera and YOLOv8 are used to detect objects and send information to the robots.

Keywords: Drones, Home service robots, YOLOv8

1. Introduction

Home service robots are robot that operate in human living spaces. Such as households and stores to reduce human workload. Home service robots are equipped with RGB-D cameras, LiDAR sensors, robotic arms, and a mobile vehicle which enable them to perform tasks such as housework. Although the performances of home service robots are improving daily, however challenges remain when deploying them in home environments. These problems include the inability to detect distant or dead space objects in large rooms, as well as the failure to recognize individuals behind the robot, potentially resulting in collisions.

Drones are small flying robots. In this research, we focus on drones capable of unmanned flight and environmental recognition. Drones can move quickly and, when mounted with cameras, can watch wide areas at high speed. Compared to home service robots, drones can rapidly gather information and cover blind spots with ease. Moreover, by flying at heights above human stature, drones can reduce the risk of collisions with people. While highly useful for home operations, drones lack the power of home service robots, making tasks such as accurately lifting objects extremely difficult.

Fig. 1 shows how the drone acquires information about objects in the room, while Fig. 2 shows the method used by the home service robot. In this research, we use Toyota's Human Support Robot (HSR) as the home service robot. As shown in Fig. 1, the drone can get information about objects in the room by flying above them and capturing images. In contrast, home service robots must rotate 360° to gather information about its surroundings. Thus, drones are more efficient in get information about the environment.

Furthermore, compared to surveillance cameras, drones have the advantage of mobility, which eliminates blind spots commonly associated with stationary surveillance cameras. Surveillance cameras incur various costs, including the initial installation of comprehensive camera systems, maintenance, and upgrades [1]. In contrast, drones require significantly fewer units due to their mobility, resulting in lower costs for installation, maintenance, and system upgrades. Additionally, installing surveillance cameras raises complex concerns regarding privacy and individual autonomy. Even in public spaces, the awareness of being constantly monitored can instill feelings of vulnerability and self-censorship, which, if extended to the home, could have detrimental psychological effects [2]. However, drones are easily movable, allowing their operation to be quickly stopped or relocated if they cause psychological discomfort. This flexibility helps reduce the mental burden associated with their use.

This research proposes a system in which the home service robot and the drone collaborate to accomplish tasks more efficiently.

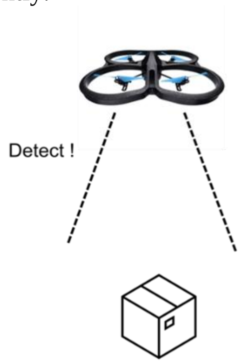

Fig. 1. Method for the Drone to Get Information About Objects

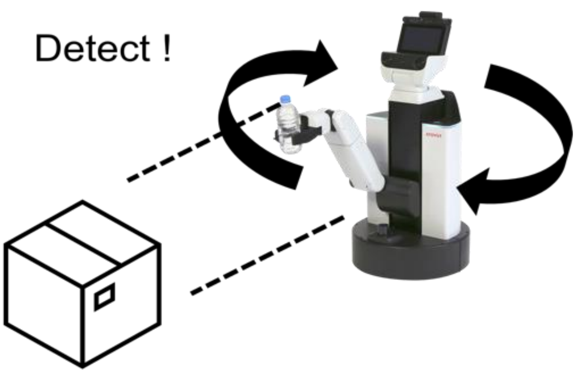

Fig. 2. Method for the Home Service Robots to Get Information About Objects

2. Pre-Experiment

Comparison of movement time between drone and home service robot.

2.1. *Experiment Methods*

As shown in Fig. 3, both the drone and the home service robot are moved along the bold arrows. And We measured the time of movement within the room.

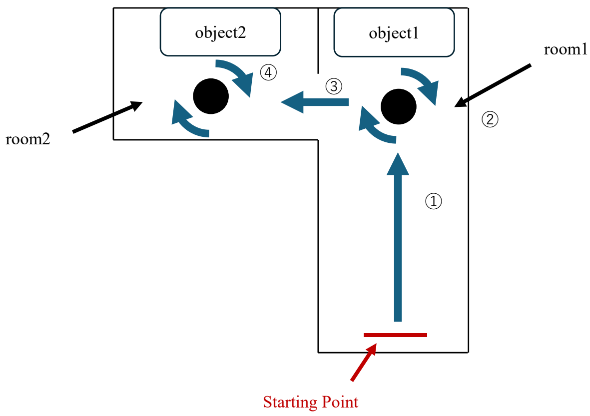

Fig. 3. Environment in Which the Experiment is Performed

2.2. *Results*

The movement time of the drone and the home service robot was measured three times. The results are shown in Table 1. The drone moves more rapidly than the home service robot.

Table1 Results

Times	1	2	3	Average
Drone	00:32.9[s]	00:26.8[s]	00:28.0[s]	00:29.2[s]
HSR	01:07.7[s]	00:54.7[s]	00:52.6[s]	00:58.3[s]

2.3. *Consideration*

As shown in Table 1, the drone was able to move at a significantly higher speed than robots. A significant difference was observed even with just two rooms. There was a time difference of about 30 seconds. Furthermore, it is expected that this difference will increase further when comparing the two in environments with more rooms or larger areas.

3. Related Work

3.1. *Drone*

Fig. 4 one of drones. Drones, which are capable of flight and three-dimensional movement, are used for applications such as image and video capture, as well as pesticide spraying.

Drones can be classified into outdoor drones and indoor drones depending on their operational environment. Tasks expected indoor drones, which are mainly used indoors, include inspection and surveying of buildings, high-speed transportation and assembly of structures, dismantling work at heights on construction sites, and deployment in factory lines utilizing three-dimensional space effectively [3]. Drones are capable of high-speed movement and, since they fly, they do not need to avoid obstacles on the floor. Additionally, by flying at heights above human stature, they can reduce the risk of collisions with people. These features make drones highly compatible with environments such as households, where humans are active, and spaces with complex furniture arrangements.

Fig. 4. Drone

3.2. *Tidy-Up Tasks Using the Home Service Robot*

Tidying up does not only make our lives comfortable but also causes changes in our lifestyle [4].

Tidy up, which involves placing objects in designated locations, contributes to creating a comfortable environment and improving productivity. Furthermore, tidy up consists of two main tasks: an identification task, where the robot identifies the objects to be tidied up within the environment, and a transportation task, where the identified objects are carried to their designated locations.

3.3. *You Only Look Once (YOLO)*

You Only Look Once (YOLO) is a real-time object detection method that achieves high detection accuracy while operating at extremely high speed [5]. The results of object detection using YOLOv8 are shown in Fig. 5. In this research, YOLOv8, among the YOLO 5series, is utilized.

Fig. 5. Object Detection Results by YOLOv8

4. Proposal

We propose a system that connects the robot and the drone, as shown in Fig. 6. The robot and the robot control PC mounted and connected with an Ethernet cable, while the drone and the drone control PC connect with a WiFi. By connecting through both control PC, the robot and the drone are connected. The identification task is handled by the drone, while the transportation task is performed by the robot, enabling efficient progress. We constructed the system as shown in Fig. 6.

The operational flow for performing a tidy-up task using the system is as follows.

(1) The drone transmits images
(2) Perform object detection on the captured images.
(3) Transmit the results to the robot control PC using serial communication.
(4) Operate the home service robot from the robot control PC.

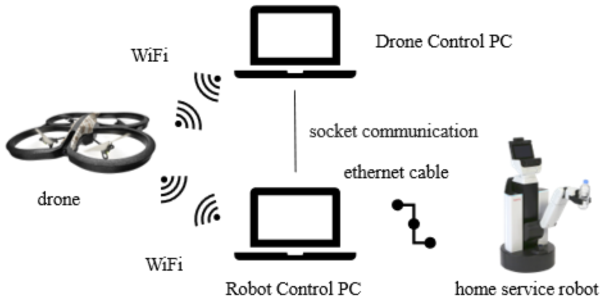

Fig. 6. Propose system

5. Experiment

5.1. *System Operational Experiment*

The drone control PC applies YOLOv8 to the images captured by the drone for object detection. In this experiment, the detection of a mug was conducted. When the drone control PC detects the mug, it sends the message "detect" to the robot control PC via serial communication. Subsequently, the robot control PC commands the robot to move forward.

To verify the operation of the integrated system, the mug was placed in front of the drone, and the movement of the robot was observed, confirming the collaboration between the drone and the robot.

5.1.1. Experiment Methods

As shown in Fig. 7, we confirmed whether the system could detect the mug in the images obtained from the drone and subsequently control the robot's movements accordingly.

Fig. 7. Detect mug

5.1.2. Result

As shown on Fig. 8, Fig. 9, the robot was able to move forward based on the detection results from the drone. This confirms the successful development of the system that integrates the drone and the robot.

Fig. 8. The State Before Movement

Fig. 9. The State After Movement

5.2. *Object Detection with a Drone Camera and Measurement of Latency*

We confirm whether object detection using YOLOv8 is possible through the drone's camera and evaluate the latency.

5.2.1. Experimental Method

The drone and the drone control PC were connected to verify the effectiveness of the proposed algorithm. The experimental setup is shown in Fig. 10. In this experiment, the drone and the drone control PC were placed on a desk and communicated via WiFi. Additionally, the latency was measured using the following method:

(1) A stopwatch was used to display the time.
(2) The drone's camera captured the stopwatch and sent the image to the control PC.
(3) The control PC used YOLOv8 to detect humans and displayed the detection result image.

By observing the stopwatch at each step and comparing the recorded time differences, the latency was measured.

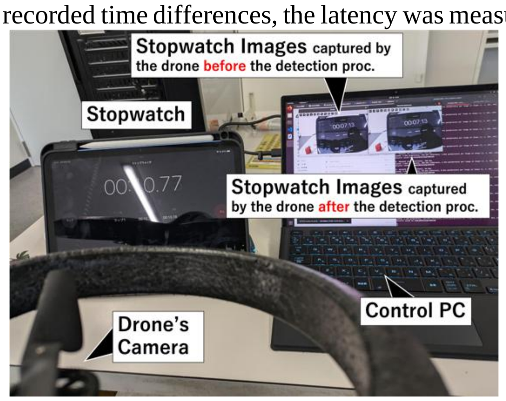

Fig. 10. Experimental Environment

5.2.2. Result

The experimental results are shown in Table 2. From these results, it was confirmed that object detection is possible. Additionally, it was observed that there is a latency of about 3 seconds from the drone capturing an image to sending it to the PC.

Table2 Latency Measurement Results

	The time on the stopwatch	The time displayed on the PC screen	The time after applying YOLOv8
Displayed Time [s]	10.77	7.13	7.13
Delay [s]	N/A	3.64	3.64

6. Discussion

As shown in Table 2, the latency from the time the drone captured an image to its display on the PC screen was about 3 seconds. In contrast, the latency when YOLOv8 was applied—measured from the time the drone-captured image was displayed on the screen—was less than 0.01 seconds. These results indicate a significant information gap between the drone and the PC, which is likely the most significant obstacle when integrating drones with robots in home environments. Furthermore, YOLOv8 demonstrates extremely high processing speed, making it a highly suitable library for real-time applications.

7. Conclusion

In this research, we developed a system that integrates drones with home service robots and demonstrated that drones have advantages over home service robots in certain aspects. However, safety concerns remain regarding the use of drones in home environments. Moving forward, we will focus on developing tasks to enable the safe and effective integration of drones with home service robots for operation in household settings.

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