Towards Autonomous Robot Application and Human Pose Detection for Elders Monitoring

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***Abstract*—Some elders prefer to stay at home compared to a nursing home. They can be assisted by several technologies such as a robot, smart home, and smartwatch for their safety and comfort. When an elder has an abnormal vital sign or abnormal pose, a notification email can be sent to the caregiver, and a mobile robot can move autonomously toward the elder. This paper describes the experimental results of the navigation of an autonomous mobile robot, the human pose detection by a camera, and the heart rate reading by a smartwatch. The integration concept of those subsystems for elders monitoring, utilizing MQTT protocol, is also explained.**

Keywords—autonomous robot navigation, human pose detection, integrated system, internet of things

I. Introduction

Recently, some older people preferred to stay in their own homes rather than nursing homes. However, it might not be safe for them to live alone, as they need continuous monitoring to ensure their safety, physical health, and comfort. They also need to communicate with others regularly to maintain good mental health.

Some technologies might be able to help them live independently. A smart home could benefit them as it improves the safety and comfort aspects of the elders. Various sensors (such as temperature, humidity, light, etc.) could be embedded in the house so the elders feel more comfortable. Whenever there are dangerous situations (such as a gas leak, smoke, fire, intruders, etc.), the house system can notify the owner via the internet.

Wearable devices also could assist the elders in monitoring their health. Apple Watch, for example, can detect (and track) vital signs such as heart rate, blood oxygen, and respiratory rate. Some vendors also create robots to clean the floor autonomously, and patrol around the house to ensure the house's security. A telepresence robot mainly is made to help people communicate with others remotely via the internet.

Despite those useful technologies, most of them work independently, so it will be difficult (if not impossible) to exchange data between those different systems. Imagine this scenario: if a smartwatch detects a low heart rate for an older person, the smart house system should notify his family member. The robot should then move autonomously toward the elder (so the family member can talk directly to the elder). This scenario is impossible to be realized if there is no integration between those subsystems.

This research is focused on autonomous robot implementation to supervise an elder by incorporating data from other subsystems (such as a smartwatch and a smart house system).

II. Literature Review

Some work has been done to detect human presence and posture, which will be helpful in a system that assists elders. Benezeth et al. [1] proposed a vision-based method to detect and track humans. Firstly, they detect the change using a background model at different levels. Later they performed moving object tracking, and lastly, they classified the activity using multiple classifiers. As camera usage might cause privacy issues for elders, Waga et al. [2] used an infrared array sensor to estimate the state of the elders by using the temperature detected by the sensor.

Other researchers use a combination of laser scanner and vision/infrared information to detect humans [3]. This work includes the prediction of the moving trajectory of humans. Machine learning approaches, such as PCA, LSTM, and SVM, are also utilized to recognize human pose [4].

A robot is also used to help elders in their daily life. Koceska et al. [5] designed a low-cost telemedicine robot that can navigate to a particular goal, move its arm to pick up an object, and facilitate communication between elderly patients and their caregivers. Isabet et al. [6] perform experiments using a social telepresence robot to reduce loneliness and isolation among elders at-home care.

Although previous work has been successful, the robot and other smart detection mechanisms work independently, so each does not benefit from accessing other system data. Our research goal is to integrate those different systems so we can monitor and assist elders better.

III. Methodology

A. System Diagram

Our system consists of three subsystems: an autonomous telepresence robot, a smart home, and a smartwatch. They exchange the data by utilizing the MQTT protocol, which is lightweight and suitable for the internet of things applications. An MQTT broker is provided to handle the

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communication between MQTT clients. The diagram can be seen in Figure 1.

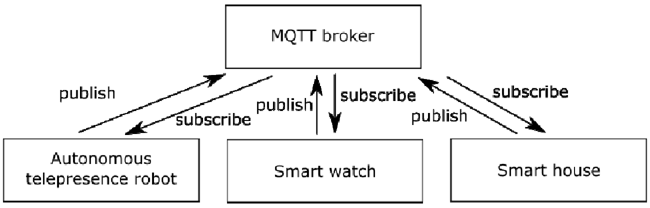

Fig. 1. The diagram of our elders' monitoring system

The smart house has various sensors and actuators, as reported in our previous work [7]. However, in this paper, we only use the camera as the vision sensor to detect the pose and location of the elders.

B. System mechanism

Our system mechanism is relatively simple. If there are abnormalities detected by the smartwatch (the abnormal heart rate) or the camera (the abnormal pose), our system will send an email notification to the registered caregiver. The elder's location is also will be sent to the robot. Then the robot will move autonomously to the given goal location. Once it has arrived there, the caregiver can initiate communication with the elder via the telepresence robot. As there are several cameras in the robot, the caregiver can also inspect the elder's condition so he can decide the following action correctly. This mechanism is shown in Figure 2.

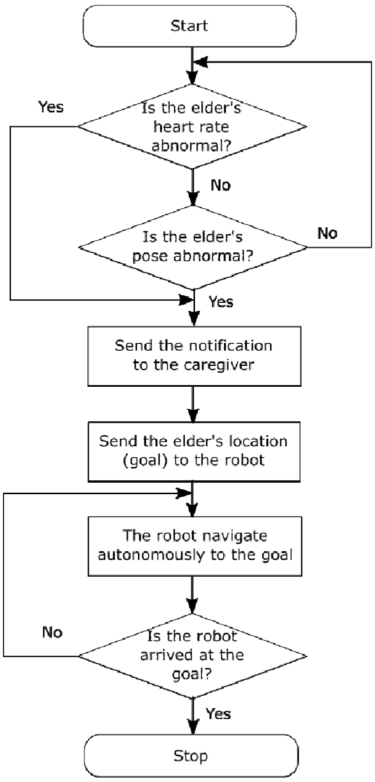

Fig. 2. The flowchart of our system mechanism

C. Telepresence Robot

We use an Ohmni Robot, a telepresence robot made by Ohmni Labs. Initially, this robot could only be manually controlled from anywhere through the internet browser. As we want to add mapping and navigation capabilities to the robot, we add a LIDAR sensor (2D Lidar kit and Versatile Clamp) and an electronic interface (USB extensions hub) to the robot controller. The last part can be added by opening the case of the robot and connecting the board correctly. The opened robot case and the complete robot equipped with a LIDAR sensor are shown in Figure 3.

Fig. 3. The Ohmni Robot is opened and equipped with a LIDAR sensor

We then use ROS (Robot Operating System) to control the robot using the docker that Ohmni Labs provided. The benefits of using ROS are the availability of various existing libraries (including SLAM and Navigation), and it is tightly integrated with the robot simulator such as Gazebo (see Figure 4). This simulator enables us to perform a simulation before applying it to the real robot.

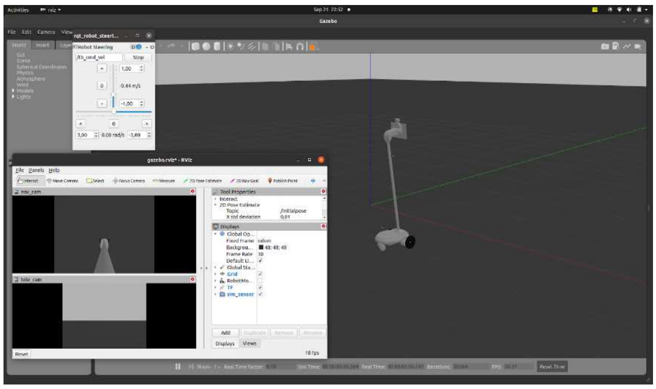

Fig. 4. The Ohmni Robot on the Gazebo simulator

To connect via MQTT protocol, the mqtt_client package in ROS can be used.

D. Smart Home

In our previous paper [7], we installed various sensors (temperature and humidity sensor, light sensor, gas sensor, door status sensor) and actuators (fan, lamps, buzzer) on a real house. The actuator condition can be controlled manually by a web browser or automatically based on the sensor reading. We use NodeRed and MQTT protocol to communicate between sensors, actuators, and the MQTT server. Six Wemos D1 mini are utilized as the IoT controllers.

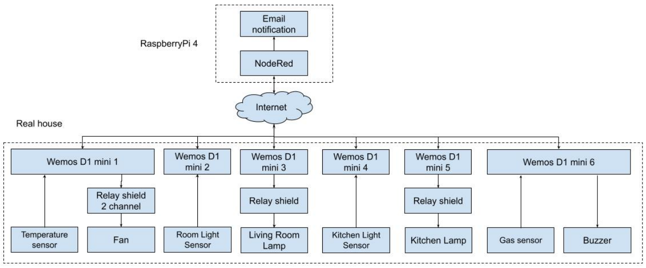

Fig. 5. Block diagram of the smart home [7]

In this paper, we focus on adding a camera as a vision sensor to detect these basic human poses:

- Sit on the bed
- Lay on the bed
- Stand up
- Sit on the floor
- Lay on the floor

We assume that "lay on the floor" pose is abnormal, so when it happens, the system will notify a caregiver, and follow-up action will be taken.

We use an efficient deep learning approach to detect those poses, namely YOLOv4-tiny method [8]. YOLO stands for You Only Look Once. Model training will be done on a laptop, while model inferencing is performed on Jetson Nano.

E. Smart Watch

A Samsung Galaxy Watch is utilized to get the heart rate of the elders (see Figure 6). This can be done by implementing this architecture [7], as shown in Figure 7.

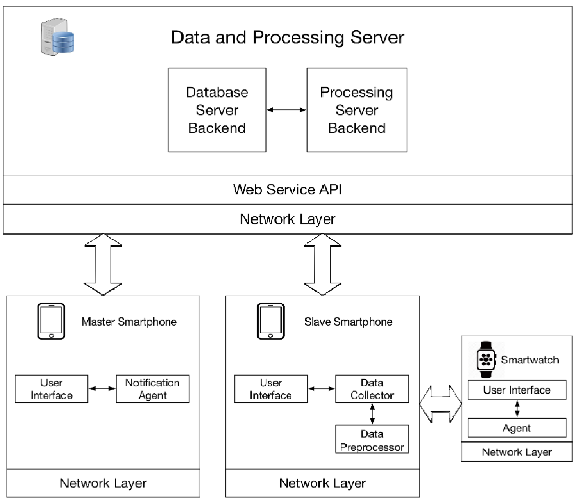

Fig. 6. Mobile sensing platform architecture [7]

IV. Results and Discussions

Several experiments on pose detection, robot control, and heart rate reading are explained here. The further plan to perform data exchange between robot, smart home, and smartwatch is described later.

A. Pose detection using camera experiments

The training was conducted on the author's laptop and took around 80 hours. Each iteration takes 8.69 seconds in the training process, and the training is carried out in up to 10000 iterations. Several .weights files are produced as training. We use the best .weights files for further testing.

The testing is carried out using a Jetson Nano. The selected .weights files, .cfg files for training, and class label files will be loaded by the program that has been developed using the OpenCV DNN library. Programs are executed on the GPU, assisted by CUDA and cuDNN.

We use a standard RGB camera (Logitech C920) located on the upper side of a bedroom. As mentioned before, there are five poses that will be recognized: sit on the bed, lay on the bed, stand up, sit on the floor, and lay on the floor. We categorize "lay on the floor" as an abnormal pose, so further action needs to be taken. The successful pose detections are shown in Figure 7 – 11.

Fig. 7. Detection of "sit on the bed" pose

Fig. 8. Detection of "lay on the bed" pose

Fig. 9. Detection of "stand up" pose

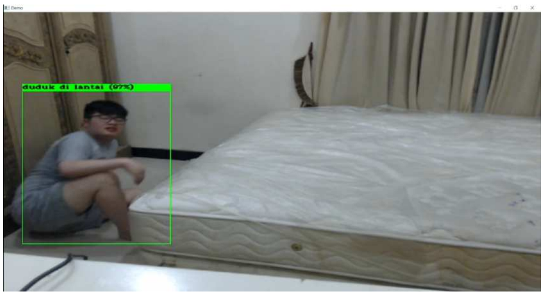

Fig. 10. Detection of "sit on the floor" pose

Fig. 11. Detection of "lay on the floor" pose

The algorithm implementation details are described in our other work [9].

In the future, the usage of multiple cameras will be beneficial to detect human pose in a wider area. Furthermore, the location of humans is also can be estimated. This information might be useful for the robot that needs to visit the elder at the estimated location.

B. *Experiments on the mobile robot*

As mentioned before, some modifications and preparations need to be done so the Ohmni robot can be programmed in the ROS environment and the LIDAR kit can be added on the robot.

The first simple experiment is by performing teleoperation control of the Ohmni robot. The keyboard buttons: W, A, S, and D are used to control the robot (move forward, backward, spin right, and spin left). Figure 12 shows the operation on the terminal, Rviz display, and the robot itself.

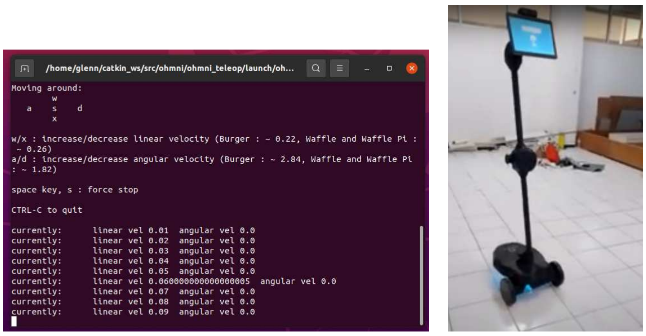

Fig. 12. Teleoperation mode experiment

The LIDAR data is also can be accessed in ROS environment. A simple way to see that LIDAR is working and it detects 2D obstacles around it is by opening the Rviz page (see Figure 13), where the visualization is helpful to show the obstacle detection.

Fig. 13. Accessing LIDAR data experiment

After accessing LIDAR data, we can move forward by performing the SLAM algorithm on the Ohmni robot. Gmapping package is triggered here. Here is the picture of the map created by the robot (see Figure 14).

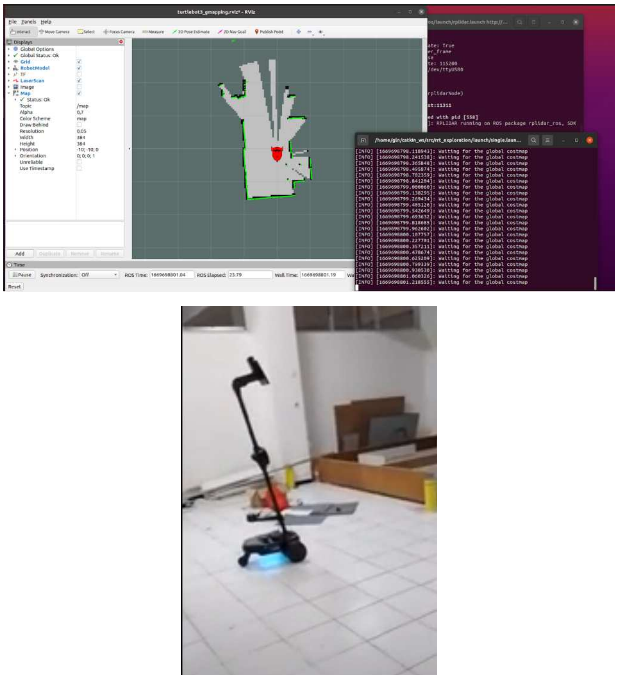

Fig. 14. SLAM experiment

Lastly, an experiment of autonomous navigation for the robot will be done here. The programmer needs to click on the screen (as the coordinate goal). The robot will move to achieve the coordinated goal. See Figures 15 – 16 for more details.

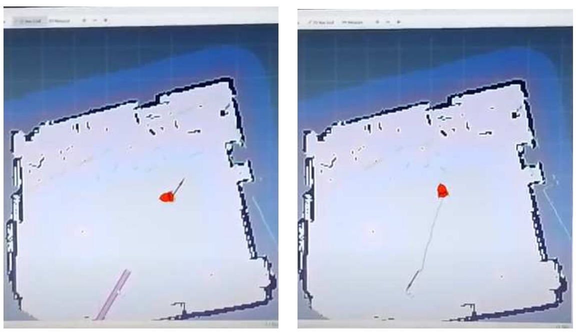

Fig. 15. Navigation experiment on RViz

Fig. 16. Navigation experiment on a real robot

C. Heart rate reading experiment on a smartwatch

The smartwatch collects the heart rate data, and it is sent to the slave smartphone regularly. Figure 17 shows the result of the heart rate reading experiment that we have performed in the past [7].

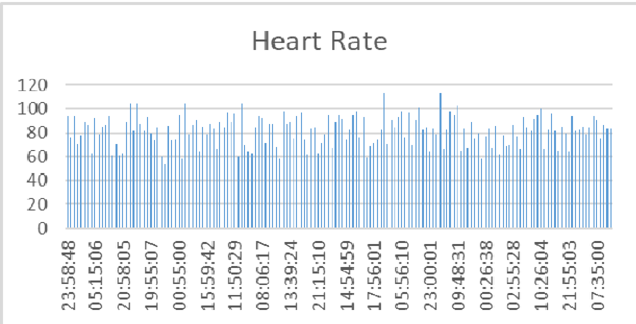

Fig. 17. The heart rate information [7]

D. A further experiment on an integrated system

Further work still needs to be done in integrating the robot, the smart house, and the smartwatch. Data exchange between subsystems needs to be performed by using the MQTT protocol. The complete mechanism, shown in Figure 2, needs to be performed. The elders' location might be estimated using the detection result of multiple RGB cameras and several Ultra Wide Band sensors.

V. Conclusions

Several subsystems can be utilized to assist elders who live independently. Experiments on each subsystem have been performed successfully: autonomous robot navigation, human pose detection, and heart rate reading. The integration concept of those subsystems also has been discussed.

In the future, integration needs to be realized. The mechanism to predict the human location must also be added to complete the elders' monitoring system.

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