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User Tracking of an Educational Robot with Android Operating System Based Robot Platform

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Abstract – For an education purpose between an education robot and user, the robot needs to identify the location of the user and follow the user when the user stays or moves. In this work, a distance measurement scheme between a robot and user using ultrasound sensors and RF modules is introduced. Also, algorithms following the moving user with certain distance are addressed and those applications to the developed robot were implemented, showing the results including distance measurement and user-following. The robot control system is totally based on Android system, which makes the robot operation convenient and compact.

Keywords – Educational Robot, Tracking, Ultrasonic sensors, Android operating system

1. Introduction

Recent research reports address that a robot can train kids so that they solve some tasks and think creatively [1-2]. Furthermore, education using a robot gives them self-experience which is a crucial element for being a leader in future. With this point of view, a robot plays an important role in an education market[3]. However, the education robot mostly faces with young kids, which requires the robot to have many functions and handle limited data, which makes the robot development difficult.

With introduction of URC (Ubiquitous Robotic Companion) technology, communication with user at any place and any time is available nowadays[4]. The URC technology can be applied to an education robot for children. Without installing high power processor on the robot, many contents in need can be easily delivered from servers[5]. One way of adopting the URC technology with ease is an Android OS (Operating System). The Android OS is an open source and numerous device drivers such as smart phone camera, Wifi, microphone, and display are developed in public, making robot development easy and cheap[6].

In this work, a tracking algorithm and its implementation for an education robot equipped with Android OS is introduced. From the frame of sensors for location identification, numerous researches using a camera or laser finder have been reported [7-10]. At the environment with many obstacles, the tracking with camera or laser finder sometimes ends in failure due to increasing uncertainty, requiring additional cameras or finders for the rear detection or side detection. High cost for installing those sensors on the educational robot limits the robot to expanding to commercial robots. This work focuses on this issue, utilizing low cost sensors and mounting minimum numbers of sensors on the robot, developing the robot capable of identifying and tracking wherever the user locates.

2. Robot Mechanism

The developed robot is equipped with four ultrasensors and one PSD (Position Sensitive Device) sensor for identifying marker which is put on the user, and avoiding obstacles. The sensor locations are displayed in Fig. 1.

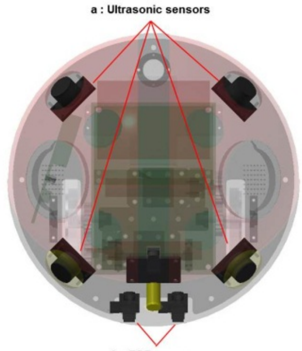

Fig. 1. Sensors layout

The robot actuators are composed of two wheels and one ball caster as shown in Fig. 2. The wheel is coated with Teflon to increase friction on the floor, being connected with two DC motors.

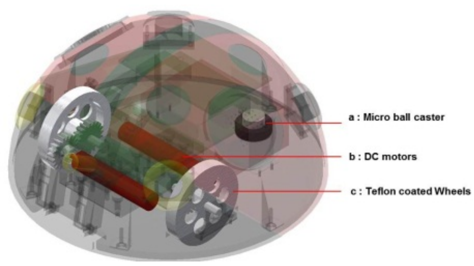

Fig. 2. Driving module of Robot

On the aspect of control and program, the robot has four boards as seen in Fig. 3. Those are a voice recognition and analysis board, Android flatform board, microcessor and motor control board, and a board for communication among boards and interface with external devices.

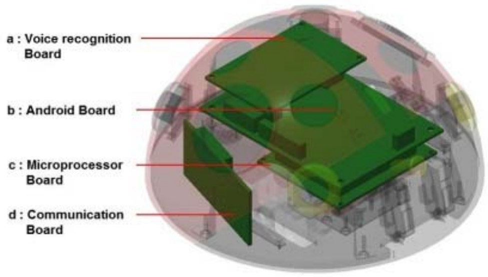

Fig. 3. Boards layout for the robot

As seen in Fig. 4, a camera for image data transfer and high sensitive microphone for receiving user's voice, and a speaker for sound data output are equipped on the robot. The camera is designed to be able to tilt accodring to the user's pose.

Fig. 4. Components arrangement in the robot

Table 1 depicts geometrical specifications of the developed robot. As seen from Table 1, the robot is light and compact enough to carry.

Table 1 Specification

Size (W x D x H)	200 x 200 x 100 (mm)
Weight	1.5kg

3. User location identification

3.1 Sensors arrangement

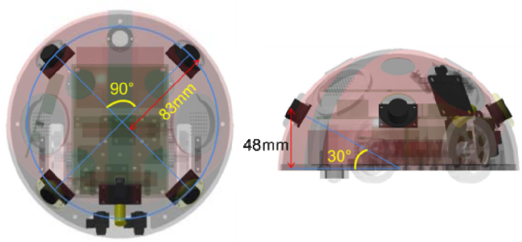

Fig. 5. Ultrasonic Sensors

As stated before, four receiving ultrasound sensors are mounted, being arranged 90° apart each at 83 cm from the body center (Fig. 5). The sensors can cover 180° range frontward, and detection distance ranges from 0.1 to 5m. For a wireless transfer, a ZigBee module is equipped. On the other hand, for a signal transmission, an ultrasound sensor is placed at the marker which is usually put on user side in the form of name tag, which has also a wireless RF module.

3.2 Distance measurement using ultrasound sensors

In case of the mount of ultrasound sensor on the marker for signal transmission and on the robot for signal reception for measurement of the distance, the time that the sound signal transmits should be acknowledged by the receiver exactly [11]. For this task, a synchronization scheme using the RF signal is employed. The RF signal has 2.4 GHz frequency, which is extremely faster compared with the real ultrasound signal (around 340m/sec), resulting in a good tool for signal synchronization. With this scheme, the marker generates an ultrasound signal and RF signal, measuring the arrival time received at the ultrasound sensors mounted on the robot, calculating the time difference between the transmitter and receiver which determines the distance [12] from the marker and robot. All processes for determining the distance are represented at Fig. 6.

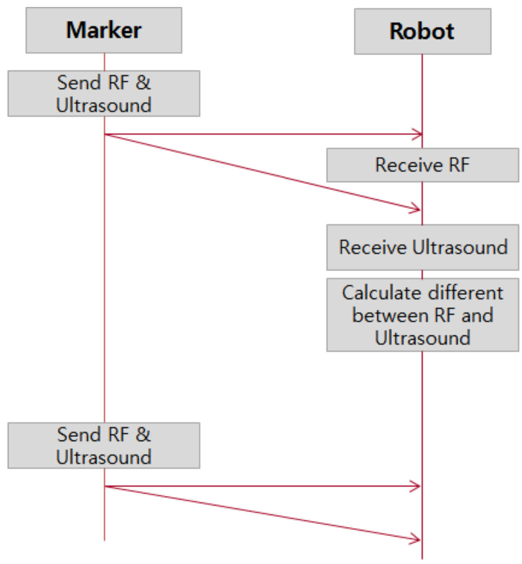

Fig. 6. Distance measuring scheme between marker and robot

3.3 User location determination

To detect the user location from any direction, four ultrasound sensors were employed. Since the sensor covers 180° each, any ultrasound signal could be detected by placing four sensors. With the help of wide range of sensor signal reception, the marker receives signal at least from two sensors. By two signals transmitted earlier the location of the marker is identified. Due to the two ultrasound sensors usually attached from the sides of the robot, the location of the marker can be divided by four sections [7]. However, when the robot locates near obstacles or walls, the sensor signals can be reflected from objects, thus are likely to be received from all four sensors. In this case, the user location identification could face a big hurdle. To solve this situation, only two signals which arrive first at the marker are chosen in determining the distance.

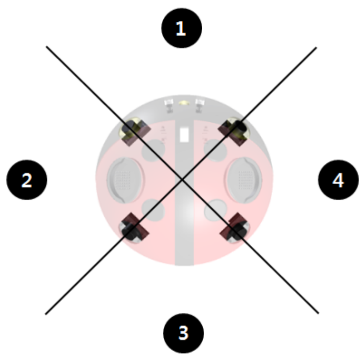

Fig. 7 Section partition for identifying the user location

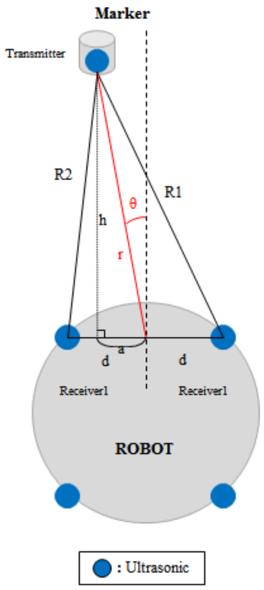

Fig. 8 Distance and angle of the marker

In Fig. 8, the way to obtain the distance and angle to the marker is depicted. When two signals are detected, the distance (r) and angle (θ) to the marker from the center of two sensors can be determined along with the RF synchronization as seen Eq. (1).

$$r = \sqrt{\frac{{R_1}^2 + {R_2}^2 - 2d^2}{2}}$$
$$\theta = sin^{-1}\left(\frac{{R_1}^2 - {R_2}^2}{4\,d\,r}\right) \qquad (1)$$

where R_1, and R_2 are measured distances from the marker and sensors, and d is the half of the distance between two sensors in the horizontal direction, which is set 60 mm in the robot. Because the measurement from four sections is equal, the robot is able to search the marker wherever the marker places from the robot.

4. Experimental results

4.1 Experiment apparatus and conditions

As seen in Fig. 9, the robot was fixed, but the marker changed its location. As the marker moved, the distance and angle between the robot and the marker were measured, and the data was transmitted to PC via a Wifi module.

Fig. 9. Experiment apparatus

4.2 Experimental results of location identification

We set the distance 1m between the robot and marker, changing the angles from 0 to 45^{o} with a set of 5 different angles. Table 2 shows the experimental results. The distance error is around ±30mm for 1m set, which is very small. The angle measurement error is quite larger than the distance, yielding ±2^{o}. The major cause for the errors is from a little incorrect data delivery due to irregular RF signal generation used for signal synchronization.

Table 2 Experimental results

actual distance (mm)	Actual angle (°)	Measured distance (mm)	Measured angle (°)
1000	0	1025.2	1.3
1000	10	1026.8	11.9
1000	20	1027.7	22.0
1000	35	1038.1	37.5
1000	45	1033.7	46.6

4.3 Tracking performance

The tracking performance has been done through experiments, which investigate the robot to follow the moving person whose marker hangs on his neck. The distance between the marker and the robot is kept in the range of 50~80 cm, and the angle is set between ±10^{o}.

Fig. 10 shows the images how the robot follows the moving marker, and the distance is proven to be continuously maintained with certain distance.

Fig. 10 Robot tracking to moving mark

5. Conclusions

An education robot was developed and its hardware and software integration was successfully implemeted. Using ultrasound sensors and PSD sensor, all directional tracking for moving target was accomplished by employing the proposed schemes which determine the distance and angle between the robot and marker. The robot takes an Android OS platform in robot control which makes the robot functional and compact. However, when objects are placed between user and robot some difficulties in identifying and tracking the user arose, which will be developed as a later research topic.

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