Implementation of Robot Operating System in Smart Garbage Bin Robot with Obstacle Avoidance System

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Abstract—Hygiene problem is a no solution problem in Malaysia due to the littering of the citizens. To solve the problem, the government has increased the garbage bin in the public space to encourage the citizens to throw rubbish in the garbage bin. However, the task of collecting the garbage will become difficult due to a large number of garbage bins. Thus, autonomous garbage bin that has the mobility to transport itself from one location to another should be the trend in future. In this paper, we proposed for developing an intelligent garbage bin robot utilizing robot operating system (ROS) for autonomous garbage retrieval. Using the robot operating system, the microcontroller was allowed to control the robot for running capacity detection, global positioning, garbage delivery and obstacle avoidance at the same time. The results shows that the robot was able to operate its bearing adjustment through motor control when confronting an obstacle.

Index Terms—Autonomous Garbage Bin; Robot Operating System; Obstacle Avoidance

I. Introduction

Nowadays, garbage bin has become a standard facility in public space such as shopping mall, theme park, zoo and others. This is because the prosperity of business has made a lot of products waste which includes plastic bag, product's cover, tissues and bottles that citizens do not know how to handle. For convenient, citizens usually will just put it anywhere and they believe the cleaners will handle it. Due to this culture, around 60 per cent of the Malaysian population still ignoring the existing garbage bin although some have been adequately provided for them [1]. Some of them even throw the garbage to the lake or sea because since they think it is the best way to settle the garbage. Annually, more than 14 billion pounds of improperly disposed garbage ends up getting into the world's ocean [2]. Moreover, independent burning of garbage for disposal added to the cause of environmental pollution.

To avoid any illegal disposal of garbage, the number of garbage bin at public spaces must have great coverage of the city. However, it may increase the cost of collecting the garbage from a large number of garbage bins. Thus, autonomous is the key to solve the problem stated. An autonomous garbage bin which will retrieve the garbage automatically to the waste disposal center will be the trend in future. The automation of the garbage bin loading is necessary since it actually not a difficult or complex job which has to be relied by a human.

The case study of this project is focused on the automation of the garbage bin. This system is developed to reduce workload purposes by detecting the capacity of the garbage bin and deliver the filled garbage bin to the garbage disposal centre. This will reduce the burden of the cleaner at an open public location, hence improve the efficiency of cleaning. In general, accomplish the improvement of environmental hygiene of open public space in Malaysia.

In general, the issues regrading the waste management can simplified into three main issues.

- Waste management cost is too expensive for increasing the coverage of garbage bin.
- Unmanned management of garbage bin at night due to garbage collector duty only on working hours.
- Waste management crews are exposed to health risk to exposure to hazardous pathogens or hazards resides in the garbage.

This paper proposed a design a smart garbage bin that can move on wheels to improve the the condition and providing automation in garbage collection. The system for smart garbage bin is developed to recognize its location, detect capacity of garbage bin and transport without collision.

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II. LITERATURE REVIEW

The Smart Garbage Bin is an innovation for automation of garbage bin that has the capabilities which include capacity detection, mobility, obstacle avoidance and global positioning without being tied directly to any real-time commands or controls by any humans operators.In this chapter, there will be a discussion on the concept used in this project and the description of the existing system with comparison among them.

A. Autonomous Robot with ROS

Autonomous Robot is a robot with the ability to make its own decisions. An autonomous robot is expected to perceive its environment, generate decisions based on how it was programmed to and actuate a movement or manipulation within that operating environment [3]. Robot Operating System (ROS) is an open-source, meta-operating system for a robot that acts as an operating system for provide services including hardware abstraction, low-level device control, implementation of commonly-used functionality, message-passing between processes, and package management.

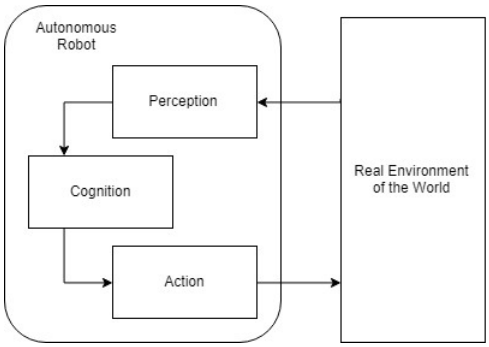

Fig. 2.1: A design for an Autonomous Robot

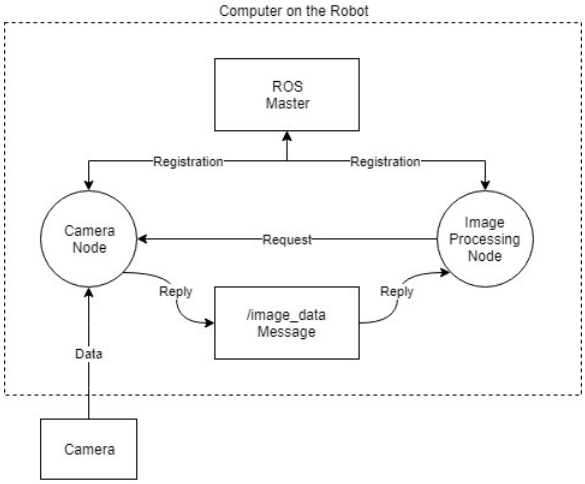

Fig. 2.2: Example of ROS Structure

B. Ultrasonic Acts as Capacity Measurement Sensor

Ultrasonic waves is a type of media that human used to measure distance. The sensor head emits and receives the ultrasonic wave reflected back from the target to estimate the distance between the ultrasonic sensor and the target. The distance is calculating by the time between the emission and reception with the specific formulae. Since the speed of ultrasonic wave is fixed which is 340 m/s, the distance can be found by multiply the speed with the time between emits and receives and hence divide by two (since include the time for the wave to return). Hence, the level of the capacity can be measure by using ultrasonic sensor to detect the distance between the cover of the container and the surface of the contents [6].

C. Autonomous Vehicle

Autonomous vehicle has the ability to guide itself without human conduction. It use various kinds of technologies which including Global Position Sensor (GPS) to help with navigation, sensors and other equipment to avoid collisions and augmented reality to recognize the situation of the road. Automobile collision avoidance systems are developed under the principle of reducing the severity of any accident. Variety of sensors including images were utilized for detection of unavoidable obstructions in front of a moving vehicle and for generating support to the driver for undertaking any corrective actions [7].

D. Existing System

1) Smart Garbage Alert System based on Internet of Things [8]: A smart alert system was programmed to determine the fullness of a garbage bin and providing indicator for immediate response to empty the bin through a municipal web server. By equipped the ultrasonic sensor and Arduino UNO on the bin, the level of garbage filled is displayed and a notification will be sent directly to the municipal web server. Once the garbage collector has emptied the in, the crew needs to place the Radio Frequency Identification (RFID) Tag on the garbage bin. RFID is provides verification technology based on the capacity level on the garbage bin and provide the current status of the bin for making sure that the clearance process was conducted.

2) Garbage Collection Robot on the Beach using Wireless Communications [10]: It is a mobility robot with electric energy supply from seal acid battery supported by solar cells. The robot can be given the command by using Bluetooth via computer. The robot is equipped with active Internet Protocol camera that transmits feedback data by displaying a real-time current situation. This robot is capable to provide efficient and environmentally friendly operation.

III. MATERIAL AND METHOD

The garbage bin robot is a differential wheeled configuration design that was developed based on a customized chassis. Two DC worm gear motors are used for actuating the movement of the robot. Three ultrasonic sensors were used to identify obstacles around the robot movement path. A DC motor drive is used to control the speed of the motors. The main controller board is a Raspberry Pi 3 Model B+, Under this operating system, the ROS Kinetic version is installed.

A. System Architecture

The overall system architecture of this research is shown in Figure 3.1. There are two major applications that operates within the proposed device, which is the obstacle avoidance system and the motor control system. The obstacle avoidance system will perceive the surrounding environment through the three ultrasonic sensors continuously. Hence, these data will further be processed under the obstacle avoidance algorithm, with which the processed information will be handed over to the motor control system for triggering the DC motors to operates to the desired direction. The motor control system was programmed to move the robot after the trigger in forward direction, left or right direction depending on the obstacle detected.

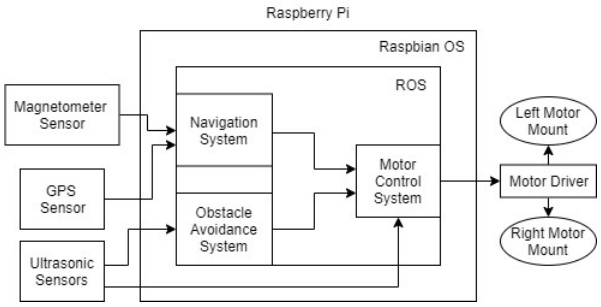

Fig. 3.1: Block diagram of system architecture

B. ROS Installation on Raspberry Pi

The Windows system and Raspberry Pi are connected to the same WI-FI device. The IP Address of the Raspberry Pi is checked through the admin pages of the WI-FI device by specific link (Example: 192.168.1.1). The Raspberry Pi is communicated through a Secure Shell (SSH) software, PuTTY in a Windows system.

C. Application Software

The programming language used for the software development is Python. As in Figure 3.2, the program will detect whether the garbage bin is filled first. Once it full, the program starts move the robot by determine whether the bearing is correct and adjust it if not. When the bearing corrected, start move the robot with obstacle avoidance system; when distance in front is less than 60 cm, detect the right distance and left distance, choose the longer distance side to turn. This program run until the robot reach the destination.

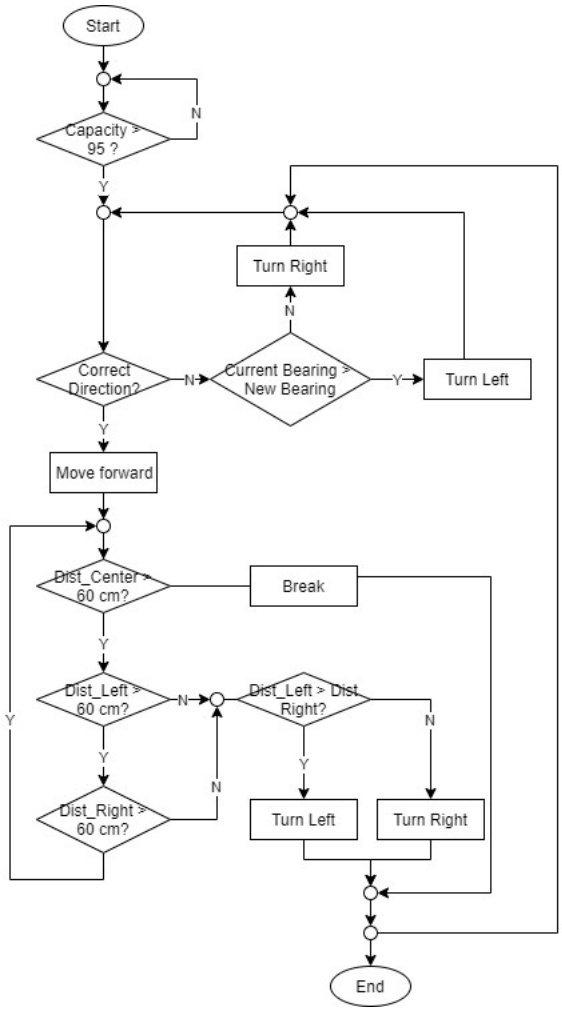

Fig. 3.2: Robot Application flow-chart

In Figure 3.3, the GPS node consists of a program that is used to retrieve the GPS message from the GPS sensor, hence publish the message for subscription by Navigation Node for allocate the location of the robot.

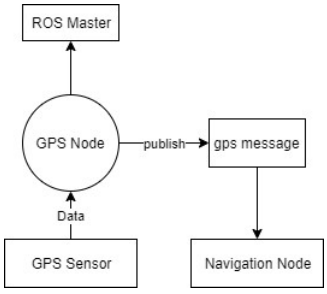

Fig. 3.3: GPS block diagram

In Figure 3.4, the magnetometer node consists of a program that is used to retrieve the magnetometer message from the magnetometer sensor, hence publish the message for

subscription by Navigation Node for recognize the bearing of the robot.

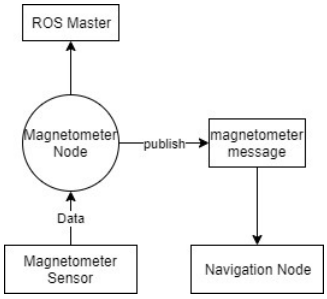

Fig. 3.4: Magnetometer block diagram

In Figure 3.5, the navigation node consists of a program that subscribe GPS message and magnetometer message from GPS node and magnetometer node respectively for calculating the route for the robot to reach the destination.

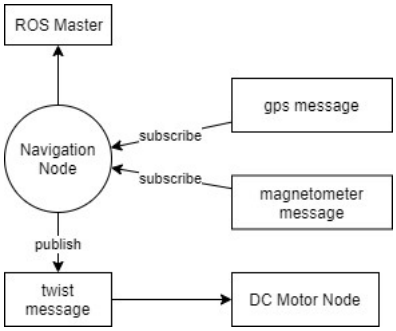

Fig. 3.5: Navigation block diagram

In Figure 3.6, the ultrasonic node continuously receives data from the ultrasonic sensors and the data received is converted into centimetre to indicate the distance detected in the current moment. Hence, the distance detected are published as distance left, distance right, distance centre and distance capacity messages which subscribed by the obstacle avoidance node and DC motor node.

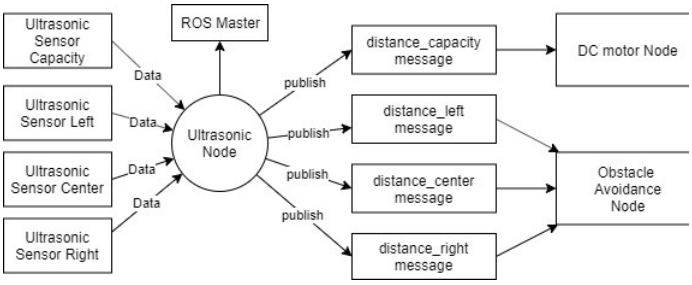

Fig. 3.6: Ultrasonic sensor block diagram

Based on Figure 3.7, subscription of the data from the obstacle avoidance node is constructed to compare the distance of left, centre and right of the robot. This node will always subscribe to the ultrasonic node for deciding whether the robot should go left or right during obstacle appear in front.Hence, the node will publish the obstacle avoid message which subscribed by the DC motor node.

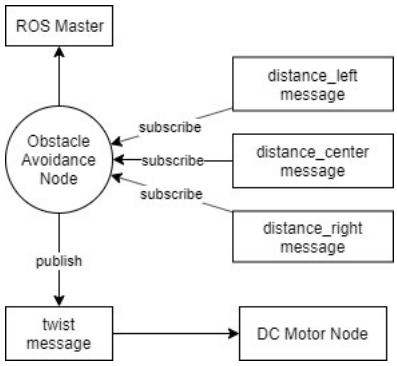

Fig. 3.7: Obstacle Avoidance block diagram

In Figure 3.8, the DC motor node consists of a program that is used to control the movement of the robot. This node will subscribe to the obstacle avoid message and navigation message continuously from the obstacle avoid node and navigation node.

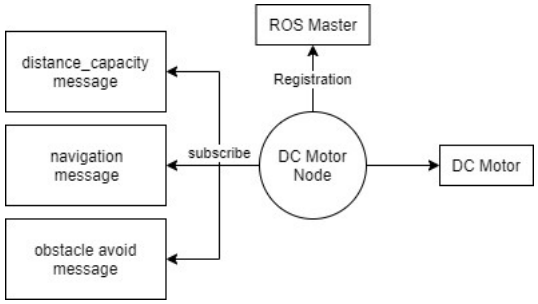

Fig. 3.8: Dc Motor block diagram

IV. Result and Discussion

A fully automatic garbage bin that can operate on its own to reduce the workload for waste management. The garbage bin must have the ability to detect whether the garbage bin is full or not. The garbage bin must have the ability that move to the specific location by receiving the longitude and latitude from the global positioning system. The garbage bin must have the ability to detect the obstacle in front and avoid the collision.

A. ROS Graph

The ROS graph provides a visualization graph for the ROS computation graph which used to visualize the communication between different nodes. Each of the nodes initializes a specific topic to communicate with the specific node.

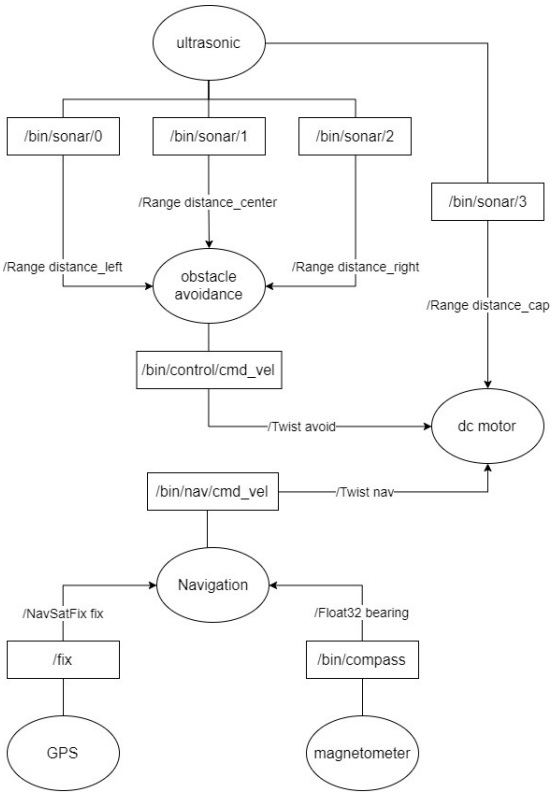

Fig. 4.1: ROS graph

Figure 4.1 shows the ROS graph for communication between nodes. The topics *bin/sonar/0* to *bin/sonar/3* are initialized by ultrasonic node and subscribed by obstacle avoidance node and dc motor node to detect the obstacle distance and the capacity of garbage bin respectively. After that, the topic *bin/control/cmd vel* is initialized by obstacle avoidance and subscribed by dc motor node to avoid collision. At the same time dc motor node subscribed the topic */bin/nav/cmd vel* initialized by navigation node to navigate the garbage bin robot to the destination. The topic *fix* initialized by GPS node and topic *bin/compass* initialized by magnetometer are subscribed by navigation node to generate navigation message.

B. Execution of ROS Nodes

ROS Nodes playing the role in communicate each other for an application in a ROS system. By running the command *roscore*, the collection of nodes and programs that are prerequisites of a ROS system will be activated. It must be launched to start up:

- a ROS Master
- a ROS Parameter Server
- a rosout logging node

To start up the communication between ROS nodes, all the systems above must standby. It can be terminated with keyboard interrupt to shut down the ROS system. Before running a *roscore*, the path of ROS must be source to enable the ROS commands and build into the workspace:

$ cd ros catkin ws $ source /opt/ros/kinetic/setup.bash

$ source /devel/setup.bash

```
pi@raspberrypi:~ $ cd ros_catkin_ws
pi@raspberrypi:~/ros_catkin_ws $ source devel/setup.bash
```

Fig. 4.2: Source of ROS setup bash file

```
pi@raspberrypi:~/ros_catkin_ws $ roscore
... logging to /home/pi/.ros/log/1e19d602-149a-11ea-a231-b827eb197c4f/roslaunch-
raspberrypi-3932.log
Checking log directory for disk usage. This may take awhile.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

started roslaunch server http://raspberrypi:33213/
ros_comm version 1.12.14


SUMMARY
========

PARAMETERS
 * /rosdistro: kinetic
 * /rosversion: 1.12.14

NODES

auto-starting new master
process[master]: started with pid [3942]
ROS_MASTER_URI=http://raspberrypi:11311/

setting /run_id to 1e19d602-149a-11ea-a231-b827eb197c4f
process[rosout-1]: started with pid [3955]
started core service [/rosout]
```

Fig. 4.3: Execution of *roscore*

C. Execution of Application Nodes

After the *roscore* launched, the application's programs can be run by using *rosrun* command. In a ROS system, the program is called as a node. In an execution of the application, all nodes must be run since most of them required to communicate with another node to send and receive a message at that instance. Hence, all the features of the application can be executed. The application starts with the communication between ultrasonic node and dc motor node. The ultrasonic node was always sending the capacity detection message to the dc motor node for judgement of movement. Once the dc motor received a "filled" message from ultrasonic node, it starts subscribes from obstacle avoidance node and navigation node even though both of them are executed since running the commands.

When the dc motor node start communicating with navigation node, the navigation node will received the location message from GPS node which programmed to get signal from satellite. The, it received the bearing message from magnetometer node which programmed as a compass. Then, it will generate movement commands and send to dc motor node for departing. Simultaneously, the obstacle avoidance node subscribing distance messages from ultrasonic node which keep publishing range messages. Afterwards, the obstacle avoidance node will determine whether the obstacle in front of the garbage bin robot. Hence, comparing the distance between the obstacle on left and that on right to calculate where the robot should turn to. This message will be sent to the dc motor node later.

Lastly, the dc motor node will transcript the twist message received from obstacle avoidance node into velocity message which is suitable use for executing the motor mount.

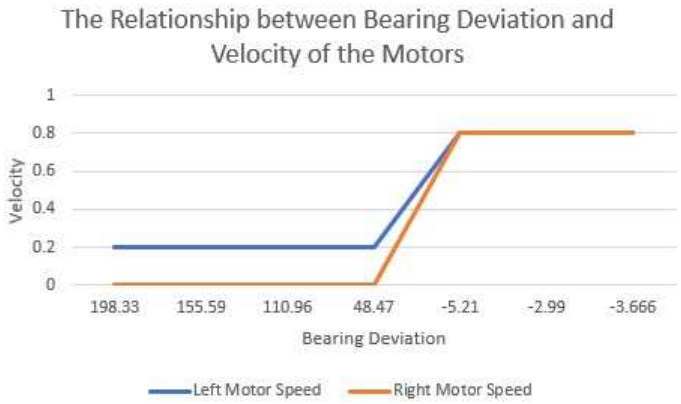

Fig. 4.4: View of Complete Prototype

Fig. 4.5: Navigation System Testing Result

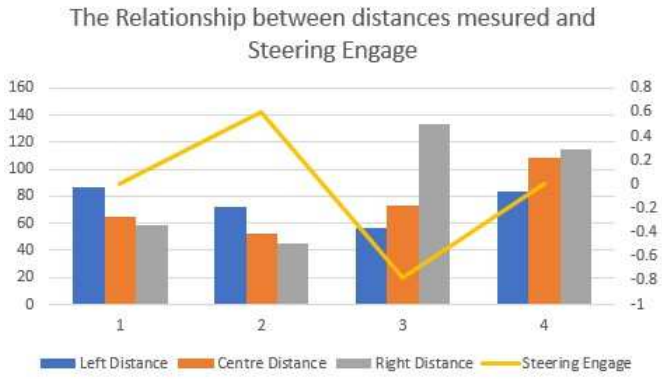

Fig. 4.6: Obstacle Avoidance System Testing Result

Based on the prototype for figure 4.4, a navigation test was conducted where the results can be seen in figure 4.5 and figure 4.6. The output speed of the motor mount can be review from figure 4.5 which is the execution of dc motor node. bearing and velocity relationship can be understood by this figure, where the robot tend to avoid the frontal obstacle through deviating angle by operating the two motors at different speed. Figure 4.6 shows the relation of the three obstacle detection sensors with the steering angle. From this figure, the closer the obstacle is to the robot, a bigger steering engage will be operated.

V. Conclusion

The results of this study indicate that this system will be more efficient than the existing systems discussed. Both of them have the same constraint which is requiring the user notice the status of the garbage bin and then find the bin for proceed next works. This autonomous system presents functions including, capacity detection, mobility, obstacle avoidance and global positioning that can solve the previous existing systems' problems.

This system will improve the efficient of cleaning works of the open public space. The autonomous of the system will reduce the workload of the cleaner such as garbage bin searching, capacity checking and waste loading. It brings convenient to the cleaner so that they could have more time to do others cleaning works.

This system will improve the hygiene level of the open public space. Since the manpower for waste management had been reduce, the increase of garbage bin coverage area is possible now. It can actually solve the littering problem and hence improve the environment hygiene of Malaysia.

VI. Acknowledgment

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