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An Asus_xtion_pro based indoor MAPPING using a Raspberry Pi with Turtlebot Robot

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Abstract— **The developers of path planning algorithm and localization have significantly improved the usability of the robot those days. By using software such as a Gmapping, the robot will be able to create a map of the surrounding area. This research utilizes the 3D sensor Asus xtion pro to create an indoor map using SLAM and create 3D models for surrounding objects with a Turtlebot robot, The first case, we used the Turtlebot to generate an indoor map of the robotic lab room using the Gmapping ROS packet. The second case, we used the robot to create 3D models for the surrounding objects in the room. We used the raspberry pi 3 as a replacement of the laptop that use to control the Turtlebot. The same implementation of the first and the second tasks have been repeated to compare the performance. The raspberry pi accomplishes the given tasks successfully; however, there is some delay due to the different on the CPU power. Finally, the low cost proposed solution is capable of running ROS based SLAM algorithm and using the point on cloud to create 3D models. In addition, the use of raspberry pie allows the robot save considerable amount of power in contrast with the use of a normal laptop.**

Keywords— Raspberry Pi;* Asus Xtion pro; *mapping; 3D; Turtlebot II; ROS; Robotics.

I. INTRODUCTION

Nowadays, the mobile robots become more popular that perceives a great improvement in technology. However, many obstacles prevent the robots to be used widely in our daily activity, such as robot cost and hardware and software performance in operating tasks, such as mapping, localization and path planning. The mapping is the area of robotics research, which focus on giving the robot's ability to learn about the surrounding area and it is essential for mobile robots in order to be able to perform the localization and the path planning [1] [3]. Therefore, creating a virtual environment in the surrounding area of the robot that could be used as a map would be vital, which is used for Path Planning that could be useful in operations like military, search and rescue and smart cities and so forth.

Sending the robot into rough missions and exploring unknown places that could be dangerous for human to explore means that the robot itself will be in danger, therefore, the cost of the robot that could perform such an operation will be a vital factor [1]. Thus, decreasing the cost of the hardware and the software for the robot is desirable. Mapping an Indoor environment will require a laser scan, a mobile robot base and compute unit with wireless communication. So, robot the depth information gathered by the **Asus Xtion pro 3D sensor** as stated in various implementations [3]. For instance, creating a map, make a 3D model for indoor environment. Localizing and mapping within indoor environments is actually vital for remote controlled robots. There are several approaches for the mapping that has been researched, counting utilizing laser scanners, 3D vision and wireless strength, [3] [8].

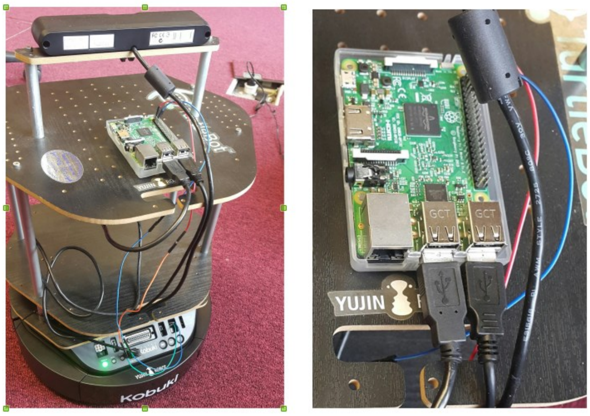

Fig 1. Utilizing a Raspberry Pi as a main computer unit for Turtlebot II

The objective of this paper is that to integrate the Raspberry Pi 3 with the Turtlebot II robot, which normally comes up with a laptop. As shown in Fig 1, in order to establish a cost effective robot platform, which could create a map for a new environment by utilizing low cost equipment while maintaining the performance in accomplish the tasks. In addition, reduce the power consumption for the robot platform.

This paper is structured as follows. Section II discusses the system specification. Then, section III information about the SLAM procedure. Section IV demonstrates information on the experimental setup and the obtained results. Finally, Section VI covers a conclusion and future work.

II. System specification

This approach was planned to offer an affordable operational indoor mapping system that can be used over the network, particularly in environments that could be considered as a danger for human. Even though, there are several existing systems that are able to do the mapping and planning task indoor, however, our solution becomes very handy when the risk of losing the robot is very high.

A. Robot Operating System (ROS)

It is an open source platform that provides a number of packages and software that provides the robot functions [9]. In addition, it controls the commutation between the robots and the controller, where each device becomes a node within the ROS environment. The robot sensor data that are called topics, all the communications are managed by a master node, which is responsible of the interconnection protocol between the nodes, by using the sensors and the actuator as topics that would be available to subscribe or to publish, as the fig 2 shows. The messages contain various kinds of data such as video and Odometry data that's transferred between the nodes [6].

ROS support manly Linux Operating system such as Ubuntu and Debian, however, ROS hydro works with several in some of other OS such as, android, windows and so on. ROS provides a support for a wide range of hardware, sensor and actuator. It defines the hardware architecture as well as a low level of control to manage the linked devices, regardless if this was a robot or an individual sensor linked to a computer or smartphone.

The time between the ROS nodes is a key factor in the mapping process, which need to be constantly synchronized between the nodes (robots and computers). Whereas the sensor data and the control command move between the nodes that need to be coordinated, ROS use software called Chrony to manage the Network Time Protocol (NTP) [1].

ROS has flexibility to work with ready algorithms that can be utilized for improving the robots performing complex tasks. SLAM is an example that used for robot mapping and navigation [3].

In order to run the ROS packages, at least one ROS master should be active in the network as fig 1 shows, the simple ROS connection system that allows the ROS node to send and receive messages from other nodes. Once the node has been registered on the master the message could be sent directly between the nodes [6].

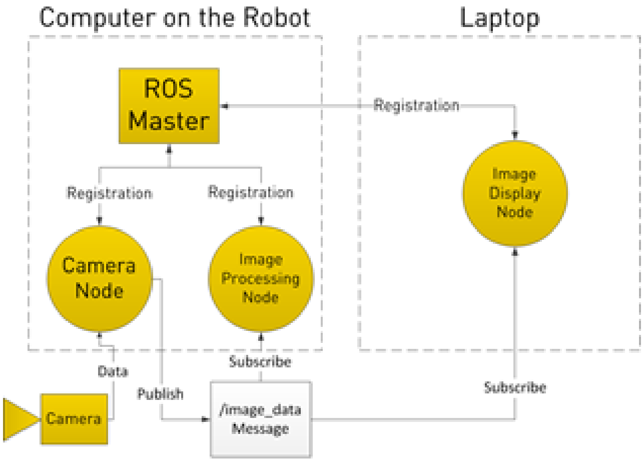

Fig 2. The ROS system [6].

Since 2010, ROS have developed and grow to be the main robot software manager for number of robots, now the latest version named ROS Lunar, However, in this study, we used ROS Indigo, because of the Turtlebot II have been supported with all essential libraries.

B. Turtlebot II

Turtlebot II is a development of the initial Turtlebot, which is an open hardware developed by Willow Garage [5] and the robotic platform runs on a base of motorized wheel. The Odometry can be obtained by using a single sensor called Asus xtion pro sensor that mounted on the robot. In order to produce 3D images and depth image information.

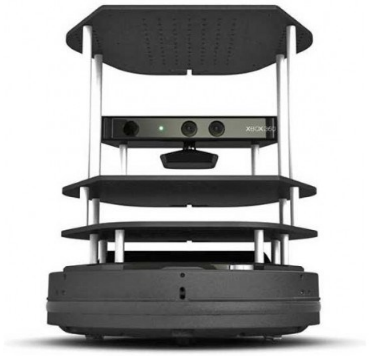

Figure. 3. The Turtlebot 2 robots.

There are several features associated with this robot, such as low cost, wheel encoders, a gyroscope that is integrated, big batteries, sensors on the bump, cliff sensors as well as wheel drop sensors are some of the other features of this robot. It possesses an impressive speed of about 50cm/s, and is powered by a lithium battery, which also powers the Asus xtion pro sensor connected to it.

C. Raspberry Pi

A single board computer has most of the computer components built-in a small board. The Raspberry pi uses an ARM processor 1.2 GHz for the raspberry pi 3 [4], which is used during in this research. The raspberry pi 3 runs on Ubuntu 16.04 Mate Operating System that has been installed in a 32 GB Micro SD card. Moreover, ROS has been installed with its basic packages. The raspberry pi 3 connects to the Turtlebot base and the Asus xtion pro Sensor via USB cables, the Asus xtion pro is mounted on the middle of the robot; the raspberry pi is responsible for collecting the sensor's data namely:

1. Depth image received from the Asus xtion pro sensor.
2. Images and video stream received from the Asus xtion pro.
3. Odometry information received from the robot.

On a the raspberry pi 3 that had ROS installed on it, we give a description of the application or the handlers that are running on it:

1. The Turtlebot handler, also referred to as the hardware driver would be main driver that is used in the connection of the various components that are found within the Turtlebot, and this connection is done by the use of a USB cable.
2. The OpenNI handler is the driver that is used in the connection of the Asus xtion pro to the raspberry pi 3, therefore, as to be able to collect video data, in-depth information or even streaming audio files.

3. The Depth_to_laserscan application refers to the application that has the ability to every bit of the Asus xtion pros depth information into what is considered the depth information, which occurs, in a horizontal line of sight. It also exploits the use of laser scan data, which is later used within the application that is the main area for detecting and the building of the grid map.
4. The Gmapping application is referred to as the main ROS application that has been tasked with the processing of all the information within Odmetry or laser scan data, in order to build a grid map on the map sever [11].

D. *Master PC*

This personal computer runs on the Ubuntu 16.04 operating system and ROS desktop installed on it, which comes with number software that make it possible to view the maps, allow one to view the maps as well as be able to view the video streams by the use of the following components:

1. This is the main application that should run on the ROS master node the ROS core Application when it comes to the communication with the ROS master node, in order to be able to access all of the nodes that are available in the ROS environment. This makes it as the main database where all of the nodes are listed as well as the path to access them.
2. The application that is applied to the connection of the ROS ecosystem and the sending of the control commands to the Robot to be able to control its movements is known as the Tele-operating application. Its operation id guided by the use of a keyboard or a joystick that is connected to the corresponding PC.
3. The 3D visualizer that is used for displaying both sensor data and state information from the ROS is what is referred to such as the RVIZ. This is software developed by ROS community works as a visualizer [7]. It is used to view the robot model, video streaming, 3D model and the created map. In addition, the software is able to deal directly with robot sensor topics, such as infrared distance measurements, camera data, and sonar data amongst others as in figure 3.
4. The Map server refers to the application that is used in the saving of the grid maps that have been currently built into a local file within the workstation.

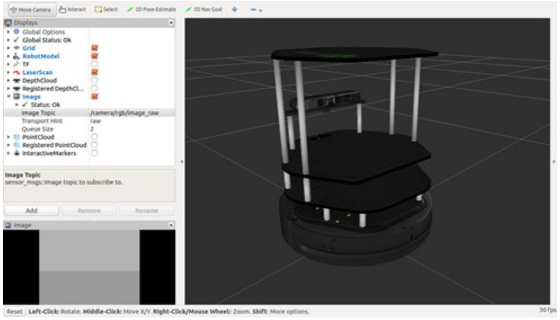

Image Topic /camera/rgb/image_raw
Transport Hint raw
Queue Size 2

Image Topic
sensor_msgs::Image topic to subscribe to.

Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel: Zoom. Shift: More options.

Fig 3. The RVIZ visualizer.

E. *The Network:*

The network architecture that used in the experiment demonstrated on Fig 4, the robot connected to the master node via a local wireless-G network with a bandwidth of 54 Mbit/s in Wi-Fi connection [2]. In order to configure ROS environment over our network, we provide the master node PC and the raspberry pi with IP addresses as well as the hostname that are considered very important for the ROS communication system.

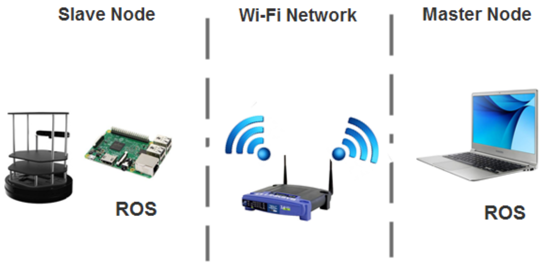

Fig 4. Workflow for the mapping process

In order to make the Raspberry Pi mobile there is the need to connect it to a wireless network, which uses a router that connects it to the main master node. This connection is kept intact as long as the router is able to reach the Raspberry Pi.

The other important factor when it comes to a network would be latency. Given the operation of the robot is done on a remote base, the failure for it to receive the right commands and on time might mean that the robot could be faced with obstacles since there is the possibility of the control commands reaching the Raspberry Pi late. Latencies of up to 200ms are typically found to be acceptable.

III. Simultaneous Localization and Mapping

The simultaneous localization and the mapping (SLAM) within the Robots entails complex computational problems that are focused on dealing with building a map of an unknown environment, which is able to track down the location of the robot in the same map [3].

Normally, the depth information that is normally received through the 3D sensor, in our case the Asus question pro sensor is converted into a laser 12-format data on real time basis, which is deemed as the initial data that is needed by the entire process. Thus, as to be able to begin the generation of the first local grid map as well as the first pose of the robot, where the middle of the map gives the provision for the initial location of the robot. An algorithm for the Gmapping process that is considered main begins its generation of the local grid maps at a very opportune moment within a limited region.

Having a grid map that's been built previously, this is considered a continuous process eve at times when the robot is immobile since even at such times, the laser scans that are received from the Asus xtion pro that produces 30 depth images per second.

There is always a scan that matches the 14, 15 algorithm against the local grid map, which generates a set of what is referred to as the sampling points within an interval that is around the reported pose. The weight of the particle is normally calculated through the application of these points in the next interval.

In instances where the scans are not able to match for reason, there is the substitution of the Odometry information as the main tool that estimates the pose of the robot. This normally leads to the same issues being inconsistent during the building of the map, as has been discussed in the observable part of the under the Experimental results section.

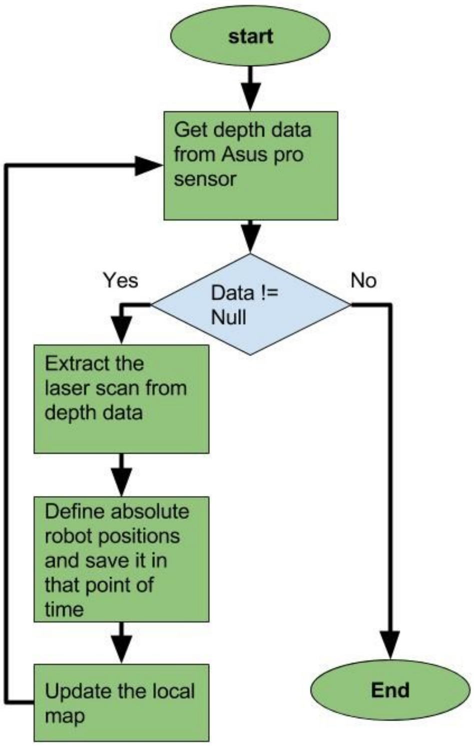
start
Get depth data from Asus pro sensor
Yes
Data != Null
No
Extract the laser scan from depth data
Define absolute robot positions and save it in that point of time
Update the local map
End

Fig 4. Workflow for the mapping process

IV. Experiments

We use the development system to run some experimental tests within our lab and compare the result with the same system that use laptop instated of the raspberry pi 3.

A. Case 1: Create a MAP for the lab

In this test, we created MAP uses Gmapping ROS software to the University of Huddersfield robotic lab as it shown in Fig 6 the generated map floor layout for the lab. The robot moves around the room and scan it by using an Asus question pro. The scan had been done while the robot is moving at a speed of 25cm/s forward, which is considered an average speed given the Turtlebot robot, is capable of an ultimate speed of 50cm/s.

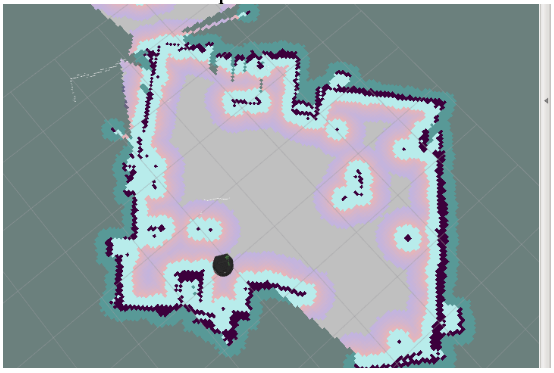

Fig 6. Map for a University of Huddersfield robotic lab using Raspberry pi.

The Asus xtion pro has the ability to provide in-depth information by the use of an IR beam that is reflected from the facing wall against the robot, there was no realization of any power that had been consumed the raspberry Pi 3.

In contrast, we repeated the same experiment with using the laptop instead of the raspberry pi 3. As shown in Fig 7 the map was more clear in comparison to the map in Fig6.

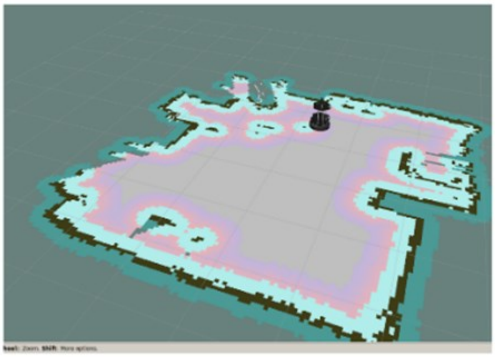

Fig 7. Map for a University of Huddersfield robotic lab using the laptop.

B. Case 2: Create a 3D model for the Objects

On of the processing that use intensive processing power is that creating a 3D model for the environment using a point cloud, which use the depth image data collected by Asus xtion pro sensor. In this test we benchmark the network and processing performance for the raspberry pi in contrast to the laptop as shown in Fig 8.

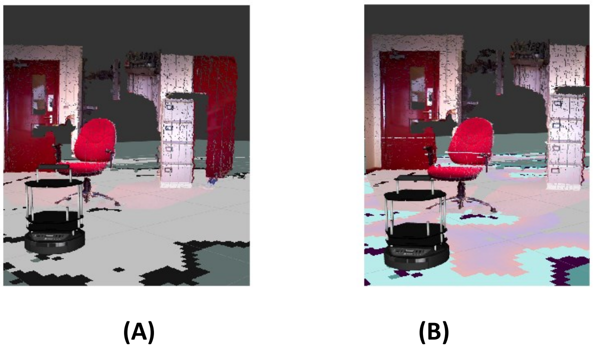

Fig 8. A) 3D model generated by Turtlebot with laptop B) 3D model generated by Turtlebot with raspberry pi 3.

Based on the observation from Fig 8 The quality of the 3D model that generated by the raspberry pi was very close to the one that generated by the laptop.

V. Result

The main outcome of this study is that utilizing a single board computer, such as the raspberry pi with the Turtlebot robot seems to be a successful model to create a low cost robot. In addition, it proved its ability to run such advance robot tasks. The first task was an indoor map for unknown environment, this task was a bit challenging for the raspberry pi, where the generated map had unclear edges for some of the room walls in contrast with the map generated by the laptop that had clear wall edges and objects position.

The mapping process depends on defining the location of the robot according to the last time pose that the was done by the scanner sensor in the previous map, this process can fail for a number of reasons, particularly when the robot start rotating or moving with a high speed, this issue occurs because it needs powerful processing power to process the generated map grid, Therefore, the propose solution will be sensitive for the robot speed and movement. It is suitable to run the SLAM process while moving the robot with slow speed to obtain a clear map as well as to create 3D models.

Looking at the main components for the proposed system, we have the raspberry pi 3, the Turtlebot Robot, the Master PC and the network Modem Wi-Fi.

The systems use a single charging point, where the raspberry pie powered from the kobuki base 5 V socket, in contrast with the original system, where the robot use a laptop that need additional 12 V charger.

Contrast between the power that is consumed by the Raspberry Pi with the power used by a laptop that has an Intel quad core I5 Processor. According to [10] the fact that such a computer requires an average of 48 joules/day as in the figure below means that the laptop consumes about 20 times more than the Raspberry Pi as Fig 9, making it very cheap to maintain.

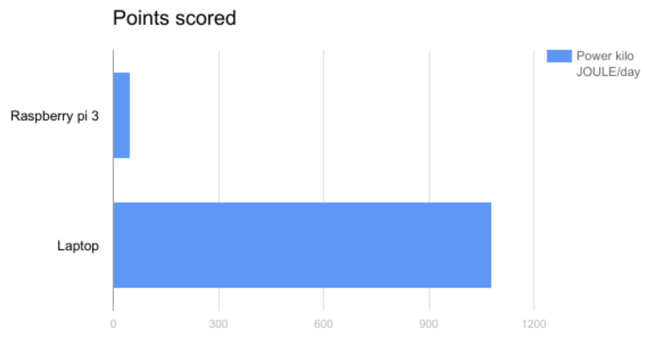

Fig 9. Power consumption in Kilo Joule for both raspberry pi 3 and Laptop Intel I5 Processor

The client node was using a raspberry pi 3 to control the Turtlebot II robot that has ARM processor 1.2 with a 1GB RAM and a 32GB SD card. The Master node used is a PC with I5 processor with a 8 GB RAM and a 500GB hard disk. The Turtlebot robot has been utilized as mentioned earlier.

VI. CONCLUSION

In conclusion, this research provides an affordable solution for utilizing the SLAM algorithm with ROS to generate a 2D indoor MAPs as well as 3D models of the surrounding environment. The use of the raspberry pi 3 proved its usability and compatibility with the Turtlebot II robot. In addition, by using the ROS, which provides most of the desirable robot functionality as a ready to use packages and software. This concept will allow us to develop a cheap robot that doing a complex task, where, the overall cost of the robot is a vital aspect that are used to scan and monitor unknown area, where the risk of losing the robot would be high.

The quality of the depth image that received from the Asus_xtion_pro is accepted to create indoor maps, which can be shared or reused for the motion planning.

The new solution comes with the additional advantage that the use of the power is far less than the normal system. Therefore, it will allow the robot to operate for a longer time. In addition, the robot now require only one charging point.

There are a number of limitations of this project as follows:

- The RAM on the raspberry pi was quite limited; therefore, we created a swappable RAM that uses the some of the SD card storage.
- The robot will require flat land to allow movement
- The performance of the robot with the raspberry pi 3 was slightly less than the same robot with the laptop. In generating a MAP and creates the 3D model.

The future work, the single board computer constantly improving, therefore, the same test case is going to be repeated with an upcoming single board computer with more advance features in terms of processing power and RAM, in order to overcome the current limitation for the developed solution. Using the concept of cloud robotic with this low cost robot is essential to overcome the lack of processing and storage in this design.

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