Fully Autonomous Drug and Food Delivery Robot for Hospital and Patient Care Logistic Management based on Artificial Intelligence

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Abstract.

We developed a fully autonomous drug and food delivery robot for hospital and patient care logistic management based on an artificial intelligence. This robot will act as an intermediary in delivering food, medicine, and medical supplies among the departments themselves or departments and patients, which will be controlled via a very intuitive software that enables navigation technology with intelligent coordinate systems by simulating the use area as a map to control the movement of the robot. The intelligent coordinate navigation technology for this robot will be integrated with a depth camera, and a LIDAR sensor operating on an robot operating system melodic for Simultaneous Localization and Mapping allowing robots to recognize objects or people in the environment. The robot achieves the maximum traveling speed of 0.2 m/s and can operate for 2 hrs with a fully charged battery.

Keywords. Logistics in hospital, autonomous robot, SLAM, LiDAR, depth camera, ROS, RealSense.

1. INTRODUCTION

The hospital is an organization with a complex internal management system. Therefore, it needs high accuracy and high precision in managing information, devices, materials, or medical products including drug, medical supplies, medical equipment, food, and patients. These materials and medical products are the last mile in hospital logistics that could help determine the life and death of each patient. The flow of information among these responsible areas in this last mile is fractured and unorganized resulting in very poor resource and supply management which could be very costly.

The drug and medical management system are one of the most important systems in the hospital which can demonstrate the potential of communication management and coordination of various departments related to medical and medical supplies in the hospital. To achieve maximum efficacy, accuracy, completeness, and timeliness on time which these activities show the performance, safety, reliability Including the availability of medical services in the hospital. Because the delivery system needs to be done through the medical personnel of different departments, which means it may cause delays and errors from the steps, wastes the time and human resources, as well as increasing unnecessary workloads for hospital staffs. For this reason, the automation system began to support the increasing number of patients and to ensure the smooth operation of medical units.

At present, various automatic robots are used in hospitals. With the expectation that the robots will replace the hospital personnel in complicated, redundant tasks and require high accuracy. There are advantages in reducing the cost of hiring non-essential personnel. To shorten the working time to reduce errors and increase the efficiency of work. Including in the field of treatment to increase the ability to support patients who need treatment which is likely to increase from the number of elderlies in the future.

The purpose of a fully autonomous drug and food delivery robot for hospital and patient care logistics management based on artificial intelligence is to reduce the unnecessary workload of hospital personnel. The robot allows the person to focus on working with patient care to their full potentials The use of robots will help increase patients' security, reduce the risk of errors, reduce time and costs in terms of hiring personnel for unnecessary long-term workloads. Furthermore, it can help in reducing the amount of waste generated by the tracking system, forwarding, and reporting in the old document formats including more efficiency in easy in following up and traceable medicines and medical supplies in case that the medical product has a problem or needs to be recalled. There, we aimed to develop a delivery robot that can achieved the aforementioned tasks at an affordable price point with great versatility and utility.

BACKGROUND

1.1. Logistics in a hospital

Patient safety is very important for medical care, with each step of the procedure being at risk for errors. The hospital is an organization that has medical products such as medicines and medical supplies, medical equipment, etc., which are important resources that affect the lives of patients receiving medical care. However, the material flow of people and the information in the hospital is complicated causing each department in the hospital to not yet be able to connect to the data between each other effectively. As a result, the system does not have data to track and trace medicines and medical supplies in the case that a medical product has a problem or requires product recall.

Logistics is a flow science. Stock and Lambert define this flow in 3 ways:

1. Product / Service Flow is a flow in the form of Physical Movement.
2. Information Flow is the flow of information for communication such as product needed, cost, etc.
3. Financial Flow such as goods or services must be paid in exchange for goods and the resulting flow focuses mainly on the product or service with the aim of how to flow the most effective,

Therefore, to meet this efficiency, the logistics system is built based on 13 activities as shown in Figure 1 [1].

Figure 1 The basis of 13 activities in the logistics system

1.2. SLAM – Simultaneous Localization and Mapping

SLAM is a process to create maps of the environment as robots are moving and identifying their locations at the same time, with no information about the environment before. SLAM is very important for robots that need instant interaction [2].

Mapping of the environment is the process in which measurement data that can be measured from the environment. From various sensors that are combined to create a data structure to describe the environment in that area. The localization is a description of the position of the robot or various objects that we are interested in the map which may be predefined or created while specifying the position.

In the operation of the robot specifying locations and creating maps localization and mapping is an important task for robots. Because the robot needs to use map data together with the location data of the robot to plan activities to respond to the environment, such as the movement of the automatic survey robot, rescue robot, robot housekeeper, or even to pick up things, robots also need to know the location of items to be picked up and the position of robot's hand too.

There are many types of maps used to describe the robot environment, using patterns that humans may understand or not, explaining the environment with a large number of points (Point Cloud), explaining environment by arranging content that robots are interested in or describing things surrounded by the relationship structure of the environment is possible (Topology).

1.3. LIDAR - Light Detection and Ranging Data

The working principle of Light Detection and Ranging system is quite simple. It generates a laser pulse train, which sent to the surface/target to measure the time and it takes to return to its source. The actual calculation for measuring how far a returning light photon has traveled to and from an object is calculated by:

$$\text{Distance} = \left(\text{Speed of Light x Time of Flight}\right) / 2. \tag{1}$$

The laser instrument fires rapid pulses of laser light at a surface, some at up to 150,000 pulses per second. A sensor on the instrument measures the amount of time it takes for each pulse to reflect. Light moves at a constant and known speed so the LIDAR instrument can calculate the distance between itself and the target with high accuracy. By repeating this in quick progression the instrument builds up a complex 'map' of the surface it is measuring [2].

1.4. Three-dimension (3D) Depth sensing: Intel Realsense camera

The cameras can calculate the distance between objects, separating objects from the background layers. This gives much better object, facial and gesture recognition than a traditional camera.

Mapping and navigation: A RealSense SLAM uses a fisheye camera, accelerometer, gyroscope, and depth camera to track a system's movement in 6DoF. It also allows a location that was mapped previously to be recognized, which is known as re-localization. Tracking and re-localization allow robots to build and share knowledge about the environment.

Facial recognition/person tracking: identify faces in the camera's range of facial features on an individual face.

Obstacle avoidance: The RealSense camera can help robots identify and autonomously avoid objects. The RealSense camera can calculate the distance between object and separate objects from the background layers behind them [3].

1.5. ROS – Robot Operating system

The Robot Operating System (ROS) is not an actual operating system, but a framework and set of tools that provide the functionality of an operating system on a heterogeneous computer cluster. Its usefulness is not limited to robots, but the majority of tools provided are focused on working with peripheral hardware.

ROS provides functionality for hardware abstraction, device drivers, communication between processes over multiple machines, tools for testing and visualization, and much more.

The key feature of ROS is the way the software is run and the way it communicates, allow to design complex software without knowing how certain hardware works. ROS provides a way to connect a network of processes (nodes) with a central hub. Nodes can be run on multiple devices, and they connect to that hub in various ways as shown in Figure 2.

The main ways of creating the network are providing requestable services or defining publisher/subscriber connections with other nodes. Both methods communicate via specified message types. Some types are provided by the core packages, but message types can be defined by individual packages [4-5].

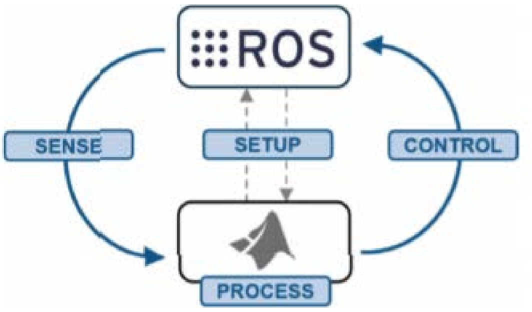

Figure 2 Working principle of ROS

2. METHODS

The work is divided into 3 main parts namely sub-system design, robot design, and software design. Each part is described in detail below.

2.1. Sub-system design

This part separates into 4 sub-system as shown in Figure 3.

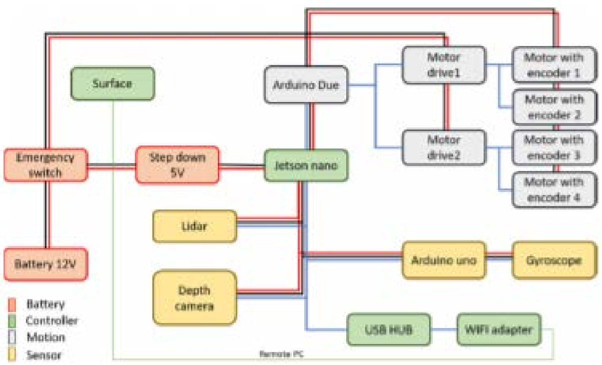

Figure 3 Hardware system diagram

Our delivery robot needs a 12-volt 30-Ah batteries split them into 2 outputs. The first one goes to drive 2 motor. The second one is used as an input to step voltage down to 5 volts for supplying to the a Nvidia Jetson (version Jetson nano) used to control robot's four sub-systems. Those are:

1. Battery sub-systems: this part consists of a step down 5 volts, an emergency switch, and a 12-volt Lithium-ion battery.
2. Controller sub-systems: this part used a Jetson nano as a microcontroller to control the robot, software, and hardware. The Microsoft Surface pro 5 computer (Model: Surface Pro) was used to enter commands and to display information about the robot.
3. Motion sub-systems: the motion of the robot consists of 2 driving motors, 4 motors, and 4 wheels.
4. . Sensor sub-systems: A Lidar and a depth camera (3D sensing sensor) for image processing are utilized to avoid obstacles in real-time.

In motion sub-system part, we used both a Lidar and a depth camera as 3D sensing elements. The depth camera will be used to acquire 3D images and process them in high resolution 3D images. However, it has a short operating scan range (0.1-10 meters). The lidar will acquire images in series of 2D planes and will process them into 3D images with low resolution due to its long operating scan range (0.12-18 meters). The chosen Lidar and depth camera are a RPLidarA2 and an Intel RealSense D435 for positioning and map creation, respectively. By combining both sensing elements, the overall system will achieve a higher resolution wither moderately long operating scan-range. The specifications of both sensors are listed on Table 1 and Table 2.

Table 1 Depth camera specifications.

Depth camera operational specifications: the Intel RealSense D435	
Operating Range (Min-Max)	0.1 m – 10 m
Depth Resolution and FPS	1280 x 720 @ 90fps
Depth Field of View	82.5 x 58

Table 2 Lidar specifications.

Lidar operational specification: RPLidarA2	
Distance range	0.12-18 m
Angular range	0-360 deg
Distance resolution	<1% Dis.range
Angular resolution	0.9 deg
Sample duration	0.25 ms
Sample Freq.	2000-4000-8000 Hz
Scan rate	10 Hz
Weight	190 g
Height	41 mm
Width	76 mm

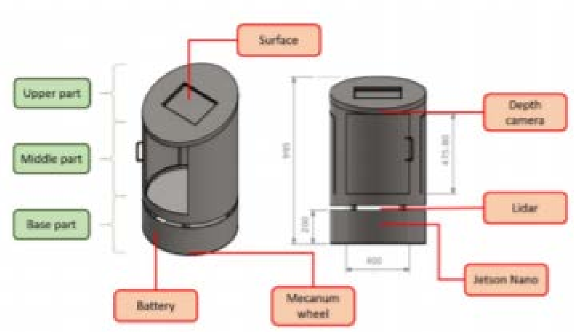

Figure 4 All components in the 3D model

2.2. Robot design

Our delivery robot shell was designed with the Solidworks 2018 program which has the following characteristics:

- Base part: the robot shell has a cylindrical shape with a diameter of 606 millimeters and its backside height of 995 millimeters. It has 4 wheels controlled by 4 motors and 2 dual-motor driving boards. The bottom compartment of the base contains a robot's microcontroller system and other electronics circuit boards. The top compartment contains a circularshape slot for Lidar laser scanning for a mapping process.

- Middle part: this part is a storage area for food, drug, or any medical supplies. This part adds an additional height of about 500 millimeters from the base part. This part is allocated for both a space shelf installation and a mounted weight sensor to check overall load limits. The front area above the door is for a depth camera installation for both a distance measurement and as a 3D scene scanner.

- Upper part: this part adds an additional height of approximately 150 millimeters with an oblique cut from the middle part. It is a part of the display screen and was cut obliquely for visibility. The Microsoft Surface pro 5 computer was used to both inputting commands and displaying robot information.

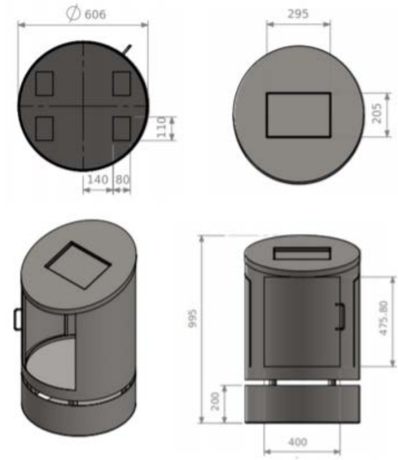

Figure 5 Our delivery robot design: bottom view (top left), top view (top right), side view (bottom left), and front view (bottom right).

2.3. Software design

The Jetson nano operating system was installed with the Ubuntu 18.04 and the ROS melodic for controlling the robot. Figure 6 shows the ROS diagram. An arduino due (Microcontroller AT91SAM3X8E) was employed to both read the encoder value from the motors and to control their speeds by varying pulse frequencies. Then, we used command from rosserial packages to communicate with the motor controller while the ROS was used to control the motor via a keyboard. Integration of both a Lidar with a depth camera were used for a gmapping node and a navigation node, respectively. A 3-axis accelerometer/Gyro module (MPU 6050) we employed for a gyroscopic function for the base controller. Finally, the base controller was calibrated with all acquired data to be ready for an operation.

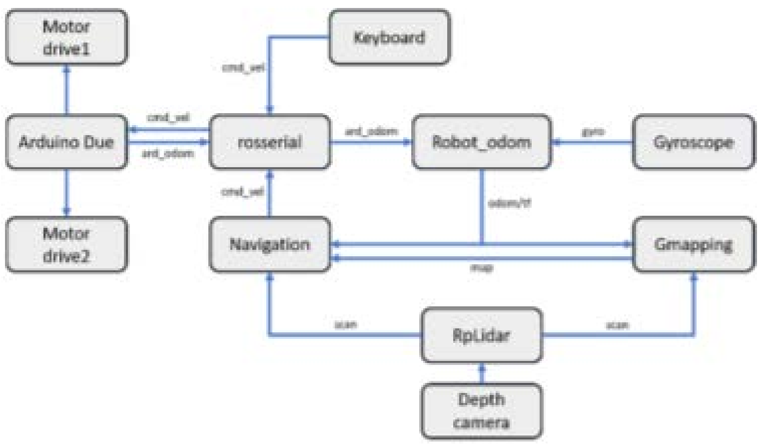

Figure 6 ROS diagram

3. RESULT

3.1. Aluminum Robot Frame

The robot frame is shown in Figure 7 consisting 3 main compartments as mentioned in previous section. The robot is designed to support the maximum load of 30 kgs.

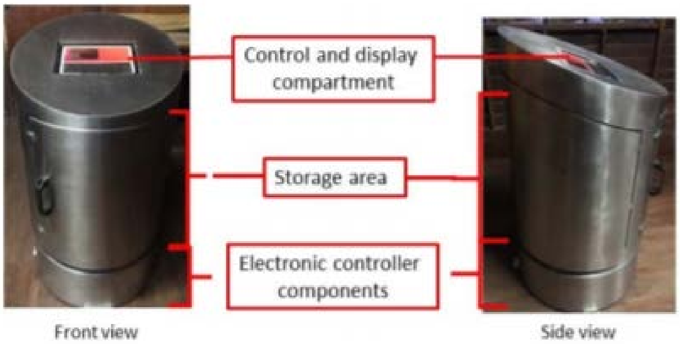

Figure 7 An aluminium robot frame

3.2. The interface of depth camera: Intel RealSense D435

The RealSense camera run on the Ubuntu 18.04 operating system was connected via a USB port. Then, the camera processing software controlled the RealSense Viewer program can display video streams in 3 types including a red-green-blue (RGB) video stream, an infrared (IR) video stream, and a depth video stream. The software combined all imaging data namely left RGB camera, right RGB camera, and an infrared camera to improve both depth resolution and image accuracy. Figure 8 shows the RealSense Viewer software interface with images acquired from the aforementioned cameras.

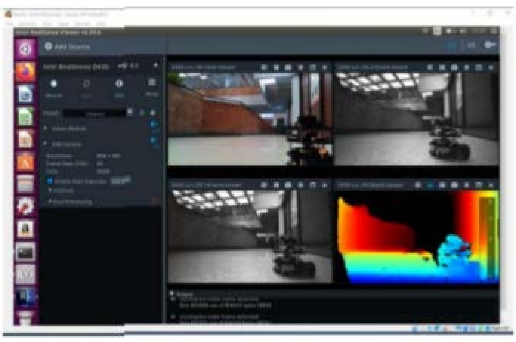

Figure 8 An interface of the RealSense Viewer and displayed images: RGB (top left), IR (top right and bottom left), and depth (bottom right)

3.3. Mapping on ROS visualization (rviz)

To collect mapping data from a Lidar sensor commanded via the ROS, both a slam node and a teleoperation node need to be manually controlled for a mapping process first. Figure 7 shows an example of mapping data file that control and display through the rviz program on the ROS. Therefore, this interface shows environments around the robot, location, a path of the robot, and a target position that the robot will navigate to. This information is applied for the navigation system in next part.

Moreover, the rviz connects to the RealSense camera and displays on the same interface of this program as shown at the bottom left pictures (RGB and IR camera streams) in Figure 9.

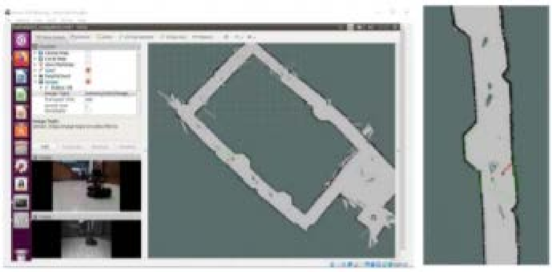

Figure 9 Show the interface environment around the robot

3.4. Navigation system

Navigation node operated on the rviz is a tool of the ROS. This software system communicates with the robot to visualize, detect, and locate the position of the robot. Then, the system will send an exact position to be displayed on the interface program.

To use the navigation system, an operator needs need to first point to a target on the map. Then, the robot will automatically process and create the shortest route to travel to that location.

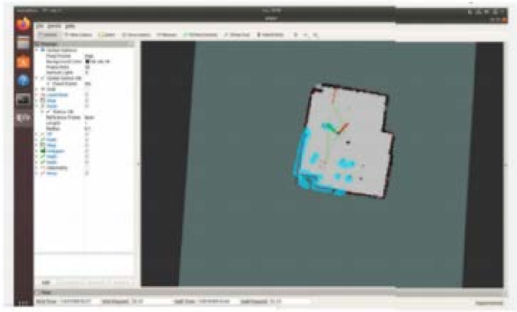

Figure 10 An interface of our navigation program

4. DISCUSSION AND CONCLUSIONS

A fully autonomous drug and food delivery robot has been developed. Mapping generation and shortest path can be automatically generated by utilizing SLAM to specify the location of the robot. Besides, additional navigational maps are derived by various packages of ROS applied on 2D and 3D data obtained from sensing elements to increase the efficiency of the mapping, including the system that can avoid obstacles by itself. The delivery bot can travel at the maximum travel speed of 0.2 m/s for 2 hrs. We anticipate a broad set of robot utility in the transportation of medicines, food, and medical supplies in the hospital, to reduce management problems and reduce unnecessary workloads of medical personal

5. ACKNOWLEDGEMENT

This work is partially supported by grants from the King Mongkut's Institute of Technology Ladkrabang Research Fund, Thailand; the National Research Council of Thailand; the Thailand Science Research and Innovation; the Newton Fund Researcher Links, British Council, UK; the Fraunhofer-Bessel Research Award, Alexander von Humboldt Foundation, Germany.

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