Development Application of Indoor Logistics Transportation using Autonomous Mobile Robot

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Abstract
In this paper, we develop an application for autonomous mobile robot to be able to transport the logistics for certain indoor environment. This application could help industrial factory to move internal logistics from one manufacturing process room to another room. In this approach, development system real-time localization in artificial certain environment. By getting user input, autonomous mobile is able to move from initial room to stop room. Using wall following and navigation algorithm in certain indoor environment, such as home industry, logistics transportation, etc, the autonomous mobile robot is able to mapping in real-time by collecting sensor data from environment. We represent mapping algorithm based on the environment condition for logistics transformation.

Keywords: Autonomous Mobile Robot, transportation, logistics, navigation, localization

INTRODUCTION
In industry mobile robot are used as autonomous transport system to make logistics process more flexible and efficient. This turns out that mobile robot system in this kind of applications are guided and controlled by supervisory system and are still far away to act autonomously as intelligent mobile robot system. There are numerous research about autonomous mobile robot implemented in industrial logistics transportation such as real-time indoor mapping for mobile robot [1], indoor localization for mobile robot using RFID [2], etc. Demanding a solution for logistics transportation problem, we need autonomous system that can help the logistics distribution and transportation to make current system process efficiently and effectively. An autonomous mobile robot for logistics transportation is good solution for this problem. The autonomous mobile robot will be able to navigate autonomously form one position to another position. This subsystem is involved in logistics system required for flow operation and manufacturing process development.

There are various approach to make autonomous mobile robot to be able to navigate and localization autonomously. In [1], they develop real time indoor mapping for mobile robot with limited sensing, even though, they use only short range sensor such as bumper and/ or wall sensor that enable wall-following. The method that is developed by them is using odometry data from robot’s wall-following trajectory, together with reading from bumpers and wall sensor. They success to build map that is set of line segmentation that represent the wall outlines. On the other method [2], they conduct the new method to make mobile robot be able to navigate and localize autonomously based on passive RFID. By using read-time of IC tags method, they success to reduce the localization error of an RFID navigation system. The system that they build is able to estimate robot’ location and orientation more accurate without external sensor.

In [3], they develop new platform of autonomous mobile robot that can use in education and research of logistics. In area of discrete manufacturing use AGVs (automated guided vehicles). The mobile robot connect to work places, then be able to distribute the logistics in incoming and delivery zones achieving lean production.

In [6], they represent a localization system developed for estimating pose such as position and orientation of omni-directional wheeled mobile robot operating in indoor structured environment. This system uses a combination of relative and absolute localization method for pose estimation. The odometry serves as the relative localization method providing pose estimates through the integration of measurements obtained form shaft encoders on robot’s drive motors. In the advance approach of autonomous mobile robot for surveillance of indoor environment [7], the mobile robot and multi-functional robot are generally adopted as mean to reduce the environment structuring. They propose s system able to handle autonomously general-purpose tasks and complex surveillance issue simultaneously.

This paper represent about logistics transportation activities and automated internal transportation system widely used at industry, hospital, which can support for logistics transportation information and analyzing. For industry, hospital and indoor situation, the need a high mobility system that can support their system process such as logistics transportation. For example, in industry, there are several process work together in manufacturing process, but from one to another process they need move all logistics from one manufacturing process to another manufacturing process.

In this approach, we define indoor environment to make robot understand about surrounding condition of the environment. Then, our approach allows autonomous robot understand its own environment, so, it can navigate and do localization easily.
by collecting data and information about environment by using sensor information.

**PROPOSED SYSTEM**

Due to application development to give command to an autonomous mobile robot to move from one room to another room, we proposed the certain indoor environment that is implemented to robot localization and navigation in this paper.

![Figure 1. Map of Indoor Environment](image)

This figure is artificial landmark for autonomous mobile robot. Based on the figure, we could define that the red line is door for each room. In the door, there is dark area signing that is a door for room. Based on the figure above, there are four rooms that initialize the position of logistics that autonomous mobile robot will move.

Based on the Fig. 1. above, we have decided the certain environment to autonomous mobile robot. The mobile robot will be able to navigate autonomously based on two method those are wall following algorithm and sensory data. Those two methods develop to increase the accuracy of navigation and localization for autonomous mobile robot.

![Figure 2. Block Diagram System.](image)

This figure describe about how the proposed system works. Exactly, there are two side of system those are smartphone system and mobile robot system. Algorithm will be constructed in smartphone and sensor data will be collected from mobile robot.

Based on the Fig. 2 above, this is a diagram block system for our autonomous mobile robot. In this diagram, we can see that there is wireless communication between mobile phone and autonomous mobile robot. As we can know that in android smartphone, we develop navigation and localization algorithm. This navigation and localization algorithm is working when it gets sensor information from mobile robot. Sensor information is transmitted from mobile robot in real-time communication via Bluetooth connection.

Autonomous mobile robot algorithm for making robot move autonomously is navigation and localization algorithm. In navigation algorithm [4], we develop navigation algorithm based on wall following method. Wall following provides a simplification of 2-D navigation problems by providing a reference by which these problem are reduced to 1-D.

For localization algorithm [5], we develop localization algorithm by using sensory data information. This sensory data information uses to decide where mobile robot is. There are various methods that have been developed by researchers to develop localization algorithm based on sensory information such as [10] localization by ultrasonic sensory information, [11] localization by sensor data fusion. Based on [5], there are seven categories for positioning system those are odometry, inertial navigation, magnetic compass, active beacon, global positioning system, landmark navigation, and model matching. Those kinds of approach for localization algorithm used in autonomous mobile robot. In this approach we develop localization algorithm based in magnetics compass information. Because of using certain environment, we could process sensory information and then decide where the mobile robot is.

![Figure 3. Layout of Android Applications.](image)

This is a layout of application for autonomous mobile robot. In this application, we can observe value of each sensor that we use for navigation and localization. Then, this layout also show room number of which is robot localize in real-time.
Based on android application above, user could monitor sensory data information, room number of localization, started and stopped mode of autonomous mobile robot. This Application will inform about room position of robot and then user be able to stop mobile robot localization mode when exploring each room started from initial room as a destination room.

In this approach, an autonomous mobile robot explore the certain landmark by using two main algorithm those are navigation algorithm and localization algorithm. Those kinds of algorithm are developed by collecting information from sensor. And data from sensor will be processed to determine where the robot is and what the robot does. Data which is gotten from mobile robot sensor is being processed in real time for helping robot to decide navigation mode such as right wall following mode or left wall following mode and localization mode such as room number 1, 2, 3, or 4.

There are numerous approaches for navigation and localization algorithm in an autonomous mobile robot. Based on [8], this paper represent an autonomous mobile robot wall following is using only bearing information measured by a single ultrasonic transducer. They propose a simple wall following algorithm where the robot moves perpendicular to direction to the nearest reflection point. In [9], this paper present an obstacle detection algorithm based on consecutive and cooperative range sensor scanning schemes. An autonomous mobile robot scans the surrounding using a range sensor that can rotate 360 degree. The robot is able to build an environment using nodes of two adjacent walls. In this approach, we develop an autonomous mobile robot in artificial landmark by using navigation algorithm based on infrared sensor and localization algorithm based light sensor and magnetics sensor.

**Navigation Algorithm:**

In this navigation algorithm, our approach is based on wall following that makes mobile robot be able to navigate from one room to another room. Wall following algorithm is parted into two main wall following those are right-side wall following and left-side wall following.

**Figure 4.** Location of Infrared Sensor on Autonomous Mobile Robot for Navigation Mode.

Based on the sensor configuration on Fig. 4, we develop navigation algorithm using wall following algorithm those are right-side wall following and left-side wall following. Both of wall following which are right-side wall following and left-side wall following schema will be used to make robot navigate on artificial landmark.

<table>
<thead>
<tr>
<th>Right Side Wall Following Algorithm State Condition</th>
<th>Schema</th>
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<tbody>
<tr>
<td><strong>State 1</strong></td>
<td><img src="image1" alt="State 1" /></td>
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<tr>
<td><strong>State 2</strong></td>
<td><img src="image2" alt="State 2" /></td>
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<tr>
<td><strong>State 3</strong></td>
<td><img src="image3" alt="State 3" /></td>
</tr>
<tr>
<td><strong>State 4</strong></td>
<td><img src="image4" alt="State 4" /></td>
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</table>

**Figure 5.** Right-side Wall Following Algorithm Schema.

Based on the figure above, this mobile robot is equipped by six infrared sensor. This six infrared sensor will help robot navigate around artificial landmark.
This is right side wall following algorithm for make robot be able to navigate on landmark by follow right side wall of artificial landmark.

![Figure 6. Right-side Wall Following Flowchart.](image)

Based on this flowchart diagram, we could observe condition when autonomous mobile robot navigate from one room to another room and follow right-side wall.

Based on the Fig. 5. This is right wall following schema used in this navigation algorithm. The algorithm for right side wall following is developed for making robot be able to navigate by following its right own side. There are five state defined for making robot follow right-side wall. In condition, IR Sensor 1, IR Sensor 2, or IR Sensor 3 have value, not zero. Robot will move left forward. In condition, IR Sensor 3 is greater than IR Sensor 1. The state will check value of IR Sensor 3 and IR Sensor 2. If IR Sensor 3 is greater than limit value of IR Sensor 3, Robot will move right back. And if IR Sensor 2 is greater than limit value of IR Sensor 2, Robot will move back. In this case, we define limit value of IR Sensor is a half of maximum range of IR Sensor. In condition, IR Sensor 1, IR Sensor 2 or IR Sensor 3 value is still zero, Robot will move forward. In condition, IR Sensor 4 is zero, Robot will move right forward. In this case, we propose very sharp right forward because robot will change its direction. For making sure that robot still hold right side wall. In condition, IR Sensor 1 or IR Sensor 2 or IR Sensor 3 is not zero and Robot places in the corner. In this condition, Robot will move left forward. As the result of algorithm, we could observe from right-side wall following algorithm on Fig. 6. For left-side wall following, this use same paradigm. So that, left-side wall following algorithm will produce same movement as right-side wall following algorithm.

In wall following algorithm, we keep autonomous mobile robot near the wall by using IR Sensor comparison mechanism. Based on algorithm above, we make PID controller by comparing those IR Sensors values which are IR Sensor 1, IR Sensor 2, and IR Sensor 3 for deciding whether robot is going to move forward, left forward, right forward, left back, right back, and back, and, IR Sensor 4 and IR Sensor 5 for deciding whether robot places on right side or left side. This algorithm make robot move robustness on left-side of wall and right-side of wall.

Localization Algorithm:

Localization algorithm that we build is using light sensor and magnetics filed sensor. Light sensor will give information about whether mobile robot is entering the door or going out the door. On 3-axis magnetics sensor, we could formulate a value from this x-y-z for obtaining direction of robot on the earth coordinate. On this case, we formulate a value of x-axis and y-axis for deciding which direction of robot orient. In 3-axis magnetics filed sensor, we are able to measure magnetic field for each axis direction. For obtaining a compass direction, we could get from magnetics value of x-axis and y-axis. By this following formulation to measure robot direction in artificial landmark, the magnetic field around 3D magnetic position sensor can be reduced to three vectors. Based on Fig.6, we could result an analysis that shows why it is able to use a single sensor with two sensor elements (pixels) a known distance apart can be used with a mathematical ATAN2 function in firmware to detect value of magnetic field sensor in the presence of stray fields.

\[
\text{Compass Direction Value (x – y region)} = \tan^{-1} \left( \frac{\text{Magnetic Filed–Y}}{\text{Magnetic Field–X}} \right) \quad (1)
\]

Based on the 3-axis magnetic field on each direction, we could get compass direction value calculated from Eq. 1. The purpose of using two argument instead of one is to gather information on the sign of the inputs in order to return the appropriate quadrant of the computed angle.

![Figure 6. Three-axis magnetic field sensor.](image)
In this figure, we could observe a value of magnetics field in each direction that is x-axis, y-axis, and z-axis.

After getting value of compass direction calculated on (1), we could develop the localization algorithm. This refers to flowchart of localization algorithm on Fig. 6. Firstly, robot, placed in one of four rooms, will be able to know which navigation algorithm will be use before beginning to explore the maze. There are two navigation algorithm used for exploring maze those are right-side wall following and left-side wall following. By using IR Sensor, robot will know which wall is near to robot. If wall is near to robot on left side, then robot will do left-side wall following algorithm. On the other hand, if robot is near to wall on right side, then robot will do right-side wall following algorithm.

While robot pass through dark side, it will be mark as robot going out the room. Then using compass direction calculated from magnetic field on (1), we are able to know which room robot places. If robot directs to south, it means that robot is in room number 1. If robot directs to west, it means that robot is in room number 2. If robot directs to north, it means that robot is in room number 3. If robot directs to east, it means that robot is in room number 4.

And after exploring maze and second passing through dark place, robot is entering the room. In this position, robot will process which room robot enters by using compass direction. If robot directs to south, it means that robot enters room number 3. If robot directs to west, it means that robot enters room number 4. If robot directs to north, it means that robot enters room number 1. If robot directs to east, it means that robot enters room number 2. Reading a compass direction in real time will make robot be able to localize where robot go out and enter each room.

PERFORMANCE EVALUATION

Figure 8. Path Exploring by Right-Side Wall Following.

In this figure, we could result while robot explore maze and then do navigation and localization at same time.

To verify our approach algorithm for logistics transportation using an autonomous mobile robot, the experiment are researched on artificial landmark consisted of four rooms and then each room connected by alley. Each door are marked by dark place on top of the door location. According to compass direction, an artificial landmark are defined as four direction.
In this research, we have presented a real-time navigation and transportation process from one step to another step. This algorithm prove that robot are able to explore each room. Started on room number 1, robot is going to move to room number 4 as next room. After exploring room number 4, robot is going to move to room number 3. And this room number 3 is define as new location. Next room is room number 2 as last defined room in this artificial landmark. While robot is moving in artificial landmark, robot read IR Sensor and magnets sensor real time to decide action of robot.

CONCLUSION

A kind of an autonomous mobile indoor robot system for logistic transportation is developed. IR Sensor, CDS light sensor, and magnetic sensor are used as the perceptual system which can perceive the surrounding environment around robot. Defining an artificial landmark as simulation for logistics transportation process from one step to another step. This process are define on four room those are room number 1, room number 2, room number 3, and room number 3.

In this research, we have presented a real-time navigation and localization for an autonomous mobile robot in artificial landmark. This approach uses two sensor those are IR sensor and magnetic field sensor. IR sensor is used for developing navigation algorithm. This navigation algorithm make robot able to explore all of side of artificial landmark. Based on the artificial landmark and robot mapping ability, we develop two kind of navigation algorithm those are right-side wall following algorithm and left-side wall following algorithm. Those two kind of navigation algorithm, right-side wall following and left-side wall following algorithm, are able to make robot explore each part of artificial landmark. This mean that robot is passing through each rooms those are room number 1, room number 2, room number 3, and room number 4.

In localization algorithm, this research used magnetic field and CDS light sensor to estimate robot position while doing navigation. CDS light sensor is as mark for whether robot is entering room or going out room. On localization algorithm proposed, we have derived how magnetic field sensor could be formulated for deciding robot orientation on artificial landmark called compass direction. Compass direction check robot orientation while robot enter and go out each room. Finally, robot is able to localize its position in real time navigation and localization algorithm.

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REFERENCES