Path Following of Autonomous Mobile Robot with Distance Measurement using RFID Tags

Conference Paper · September 2019

DOI: 10.1109/ISMCR47492.2019.8955666

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***Abstract*—The path following mobile robot is implemented around the world which are mainly related with localization, mapping and transportation. Still now in maximum sector or complex, the mobilization and transportation system in industrial area or an institute building are operated manually. Because of these reasons the Autonomous Mobile Robot (AMR) system is used to overcome the manual systems. Path following mobile robot is an example of this system. In this paper, we proposed a robot movement strategy to follow the path built by the low-cost passive Radio Frequency IDentification (RFID) tags which not even needs any power source. The main focus of this paper is to track the Read Only (RO) tags *without the help of directional antenna* to follow the path.**

***Keywords*—Path following by RFID readers, RFID tag tracking, Path following by mobile robots.**

I. Introduction

In this current decade the use of RFID systems [1]–[4] are one of the important technology which is also very helpful for future technology like Internet of Things (IoT). Here we use automated transportation system as a small part of IoT applications. RFID based mobile robot [5], [6] gives tracking information at the time of path following [7]–[10]. The RFID system uses mobile robot for self-localization and mapping, found in many article. In our previous work [11], we have considered there a model which includes passive RFID tags for designing a path. Each robot uses the procedure MOVE() to follow the path which is designed by plotting passive RFID tags sequentially. That proposed passive RFID based tracking system is robust and cost effective than conventional image processing techniques for path following by mobile robots. In that proposed method, the *Write-Once-Read-Many* (WORM) tags are suitable which are more costly than RO tags. In spite of that disadvantage, WORM tags are used because at the time of plotting tags to design the path, tag id can be modified according to the sequence of tags along the path. We have also proposed a simple but realistic error model. With that proposed algorithm, the robot uses a simple and robust arithmetic computation and it always reaches the destination as close as the distance no more than instrumental error *Formula* in distance measurements.

In this work, we replace the WORM tags with RO tags and do not use the directional antenna. Both the technique will reduce the cost of the system. But its make the movement strategy more complicated. But it is useful in emergency situation (directional antenna failure or not available).

II. System model

In this section, we describe the system structure and description of the functionality of system parts by providing a prototype model of the real system. This prototype model is applicable in indoor or outdoor environments. The description of the system as follows:

A. Advantages of RFID Systems

Major advantages of using RFID as an auto-ID system are the following:
1) RFID readers do not require a line of sight to access data from the RFID tags.
2) RFID systems can read data over varied range from few centimetres to few hundred meters.
3) RFID readers can interrogate, and make RFID tags readings much faster.
4) RFID systems can read and write different sizes of data from / to the tag, based on the type of tag.
5) RFID systems can read tags in harsh environments, without any human interference.
6) RFID systems have longer life the any other system.

B. RFID Tags

An RFID transponder, or tag, consists of a chip and an antenna. A chip can store a unique serial number or other information based on the tags type of memory. The tags type of memory can be read-only, read-write, or write-once and read-many. Read-only tags are much cheaper to produce and are used in most current applications. Read-write tags are useful when information needs to be updated. The antenna is used to transmit information from the chip to the reader, and the larger the antenna the longer the read range. The RFID tag can be easily attached with an object for identification, and it can be detected by movable or stationary readers using radio waves.

C. Hardware model

RFID reader need to installed under the mobile robot in such a way the robot can move smoothly in any direction.

In case of autonomous wheel robot [12], [13] there are lots research has done to maintain the movement strategy of robot [14].

D. Mobile robot

The mobile robot can move any direction according to the command which has two control wheel.

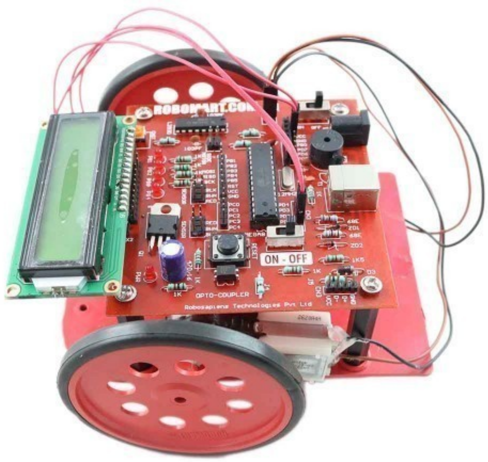

Fig. 1. Model of Mobile Robot [15]

E. Limitation of the model

In this work, we consider RO tags assuming all tags read properly without failure. In RFID system there are many chances that occurring false reading, such as sometimes it show tags in range but it would not and vise-verse. we also assume at one always fall into the sensing range of robot. Therefore, the distance between two consecutive tags always less than sensing range of robot. This paper does not define how to handle this problem, we are still in progress to solve the problem.

F. Steering technique

Generally two DC geared motors are used for driving. Those two motors are responsible for driving the robot backward and forward as well as steering in any required direction. A free running wheel is set in front of the robot. The robots steering mechanism is designed in such a way so that it can perform right (correct) turns. The complete steering process is listed in the TABLE I.

No	Command	Wheel 1	Wheel 2
1	Forward	Forward	Forward
2	Right	Forward	Backward
3	Left	Backward	Forward
4	Stop	Stop	Stop
5	Back	Backward	Backward

TABLE I
DIFFERENT COMMANDS AND CORRESPONDING WHEEL MOVEMENTS [16]

III. PATH FOLLOWING

Like our previous work, the mobile robot start from a position where at least one tag must be readable and distance between two tags is less than the radius of the reader.

A. Calculate position using co-ordinate geometry

Let the position of A, B and C are (x_1, y_1), (x_2, y_2), and (x_3, y_3) respectively. Also by RSSI Technology, the distance of A, B and C can be computed from the tag. Let the distances are d_1, d_2, d_3 respectively. Let the position of the tag is (x, y). Then, $(x - x_1)^2 + (y - y_1)^2 = d_1^2$
So,

$$x^2 + y^2 - 2xx_1 - 2yy_1 + x_1^2 + y_1^2 = d_1^2 \quad (1)$$

Similarly,

$$x^2 + y^2 - 2xx_1 - 2yy_1 + x_1^2 + y_1^2 = d_1^2 \quad (2)$$

and

$$x^2 + y^2 - 2xx_1 - 2yy_1 + x_1^2 + y_1^2 = d_1^2 \quad (3)$$

Subtracting 2 from 1, we get

$$2x(x_2 - x_1) + 2y(y_2 - y_1) = d_1^2 - d_2^2 + x_2^2 + y_2^2 - x_1^2 - y_1^2 \quad (4)$$

Subtracting 3 from 2, we get

$$2x(x_3 - x_2) + 2y(y_3 - y_2) = d_2^2 - d_3^2 + x_3^2 + y_3^2 - x_2^2 - y_2^2 \quad (5)$$

Multiplying 4 by $(x_3 - x_2)$,

$$\begin{aligned} 2x(x_2 - x_1)(x_3 - x_2) + 2y(y_2 - y_1)(x_3 - x_2) \\ = (d_1^2 - d_2^2 + x_2^2 + y_2^2 - x_1^2 - y_1^2)(x_3 - x_2) \end{aligned} \quad (6)$$

Multiplying 5 by $(x_2 - x_1)$,

$$\begin{aligned} 2x(x_3 - x_2)(x_2 - x_1) + 2y(y_3 - y_2)(x_2 - x_1) \\ = (d_2^2 - d_3^2 + x_3^2 + y_3^2 - x_2^2 - y_2^2)(x_2 - x_1) \end{aligned} \quad (7)$$

Subtracting 7 from 6,
$2y\{(y_2 - y_1)(x_3 - x_2) - (y_3 - y_2)(x_2 - x_1)\} =$
$(d_1^2 - d_2^2 + x_2^2 + y_2^2 - x_1^2 - y_1^2)(x_3 - x_2) - (d_2^2 - d_3^2 + x_3^2 + y_3^2 - x_2^2 - y_2^2)(x_2 - x_1)$

Therefore,

$$y = \frac{(d_1^2 - d_2^2 + x_2^2 + y_2^2 - x_1^2 - y_1^2)(x_3 - x_2) - (d_2^2 - d_3^2 + x_3^2 + y_3^2 - x_2^2 - y_2^2)(x_2 - x_1)}{2\{(y_2 - y_1)(x_3 - x_2) - (y_3 - y_2)(x_2 - x_1)\}}$$

Here $(y_2 - y_1)(x_3 - x_2) - (y_3 - y_2)(x_2 - x_1) \neq 0$, as the points A, B, C are not co-linear, implies slopes of AB and BC are not equal. Similarly,

$$x = \frac{(d_1^2 - d_2^2 + x_2^2 + y_2^2 - x_1^2 - y_1^2)(y_3 - y_2) - (d_2^2 - d_3^2 + x_3^2 + y_3^2 - x_2^2 - y_2^2)(y_2 - y_1)}{2\{(x_2 - x_1)(y_3 - y_2) - (x_3 - x_2)(y_2 - y_1)\}}$$

B. Algorithm and movement strategy

On the basis of the equation we define a very simple algorithm to present the mobile robot movement strategy. Using this algorithm the robot able to move by tracking one by one tag and reach it destination without any problem. Error modeling can be done in future.

Algorithm 1: Movement strategy

$Move(TagID, x_1, y_1, Ang)$
$d_1 = GetDist(TagID)$
$MoveFD(m)$
$x_2 = x_1 + mCos(Ang)$
$y_2 = y_1 + mSin(Ang)$
$Ang = Ang + 45$
$d_2 = GetDist(TagID)$
$Rotate(45)$
$MoveFD(m)$
$x_3 = x_2 + mCos(Ang)$
$y_3 = y_2 + mSin(Ang)$
$d_3 = GetDist(TagID)$
$Find(x, y) using(x_1, y_1, x_2, y_2, x_3, y_3)$
$Ang = Cos^{-1}[(d_3^2 + m^2 - d_2^2)/(2md_3)]$
$Rotate(Ang)$
$MoveFD(d_3)$

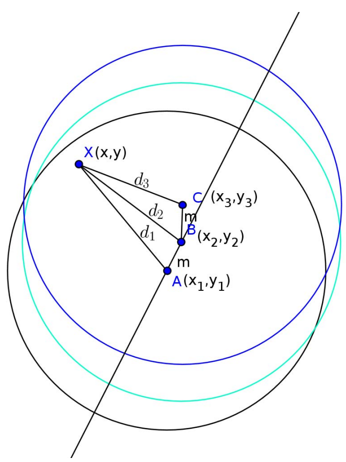

Fig. 2. Tracking of Tag

In the Fig. 2 shows that the mobile robot is initially at the known position A, and the distance between robot and target tag is d_1 which is measured by RSSI technique [17]. Then robot moves by m unit to reach at the position B where distance with tag is d_2. Then it turn left or right with θ degree (Here, $\theta = 45°$). After that, the robot moves again by m unit to reach at the position C now the distance with tag d_3. Now, we have three position $A(x_1, y_1)$, $B(x_2, y_2)$ and $C(x_3, y_3)$ and distance of tag from this three position d_1, d_2 and d_3. With these three position and three distance we can get position of tag and angle (where $Ang = Cos^{-1}[(d_3^2 + m^2 - d_2^2)/(2md_3)]$) with current position of robot. Then robot rotate angle and move d_3 distance and mark the tag visited then find the new one. This way the robot complete its journey to reach ultimate destination.

IV. Simulations

We have performed the simulation of the algorithm in programming language python in Fig. 3, and we have observed that in four different random instances of the same input, i.e., in this case,
Number of RFID tags = 10,
sensing range R = 500,
robot movement distance m = R/10 = 50.

Eventually finishes within a distance of R/10 from the position of final RFID tag, by sequentially tracking the position of consecutive RFID tags.

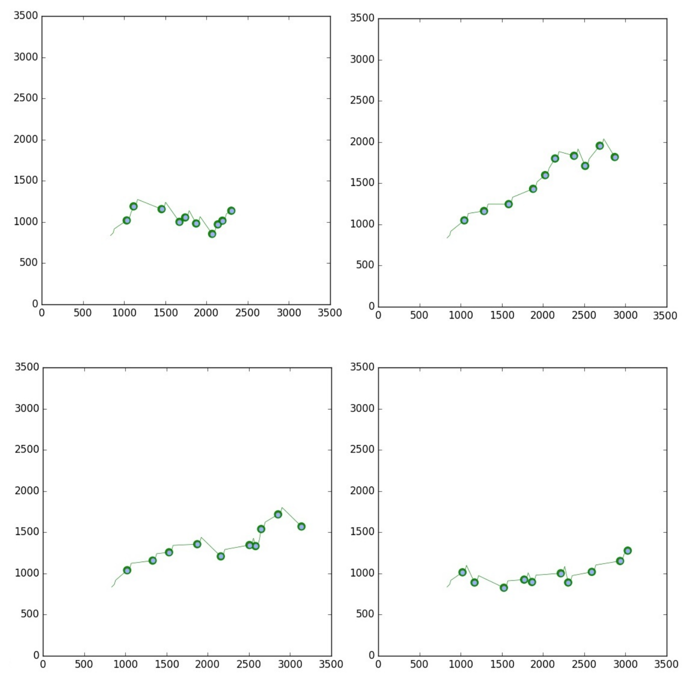

Fig. 3. The movement path of mobile robot

V. Performance Analysis

After analysis of simulations, we have seen the work performance is not good as our previous work but if the directional antenna is failed or not available then the work performance is better where other system might be stopped.

A. Comparison

With compare with our previous work we have found the result in below TABLE II.

Parameters	Previous Method	Current Method
Cost	relatively high	low
Processing Time	less	relatively more
Movement	less	relatively more
Reading failure chance	more	almost negative
Size of the tag	relatively big	small
Antenna	directional	non-directional

TABLE II
PREVIOUS WORK VERSES CURRENT WORK

VI. CONCLUSION AND FUTURE WORKS

In this paper, We present the path following autonomous mobile robot to follow the path build by passive RO tags. AMR is more safety, easy to handle and more helpful to control remotely.

This paper is only deals with single robot. In future we will work with multiple mobile robots where shortest path finding, collision avoidance and optimize technique will be novel challenges. Also provide the ability to obstacle avoidance by adding extra sensor to run in road where cars or buses are present.

ACKNOWLEDGMENT

The first and second authors would like to thank University Grants Commission (UGC) for giving them a formal support and Jadavpur University for giving formal platform to carry their research works.

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