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A Novel Robot Navigation Technique Based on Signal Strength

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ABSTRACT

Since many applications cannot be handed by human beings due to safety issues, repeated machine commands and adverse situations, robotics has emerged as a promising technology. Robots can be broadly classified into two types namely; fixed robot and mobile robot. Mobile robot may prove a breakthrough and is a future of robots. But there are some challenges in mobility of mobile robots such as ad-hoc networks, path finding, navigation etc. Path navigation is an important factor for mobile robots. A precise navigation technique is necessary so that a robot can reach at destination point exactly. Many navigation techniques are have been developed that require vision system, number of sensor nodes etc. This paper presents a novel navigation technique for robots, in which the robot navigates its path using received signal strength that is available from a transmitterlocated at a distant destination point. As the signal strength decreases with increasing distance, hence this concept can be used as an efficient technique for robot to find shortest path automatically. The architecture involves two antennas mounted on the robot and these antennas received signal from the destination point. On the basis of received signal strength the robot navigates its path. The accuracy of this navigation technique is very high because the robots find its path using received signal strength. This algorithm is cost effective and easy to setup as compared to other navigation techniques.

Keywords: antenna, fuzzy logic, mobile robots,navigation,received signal strength and sensor nodes.

1. INTRODUCTION

Robotics is the science and technology of robots including their design, manufacturing and applications. It is a combination of electronics, mechanical, software and so many other fields. A robot offers specific benefits to worker and industry like safety issue, repeatability and accuracy etc. There are two types of robot: fixed robot and mobile robot. Fixed robots are used in industries and place wherever there is a need of repetitive task, whereas mobile robots have the capability to move around in their environment. The challenging problem in mobile robot is path planning and navigation. In mobile robot,navigation technique play very important role. If a robot's navigation technique is not accurate and precise than it will not be able to reach at its destination point [4]. Therefore it is very important that navigation technique is accurate and precise. Today there are many navigation techniques and these are suitable for robot according to their work environment. The main types of robot navigation techniques are: dead reckoning [1], landmark based [6], vision based [3] and behavior based techniques [2].

A navigation technique for robot has been proposed by authors in where a robot finds its path on the basis of received signal strength. A novel technique where signal strength has been used for navigation has been described in this paper.

The main idea behind this work is received signal strength. The robot finds its path on the basis of received signal strength. The strength of the signal decreases with increasing distance and this forms the property to find the destination point. In this technology a transmitter at a destination which the destination point transmit RF signal that decreases with increasing distance and the robot finds its path on the basis of

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this received signal strength. Then to achieve this twobidirectionalantennas have been mounted on the robot. The two antennas receive signal and then measure the strength of signal it received. Then signal strength module differentiates this signal. After this outputs of this circuit is given to fuzzy logic controller and then the output of the fuzzy logic controller is send a decision signal to robot. Now the robot follows path according to the control signal it received from fuzzy logic controller and this process is continueduntil the robot reaches its destination point. This is the first attempt to use received signal strength for mobile robot navigation. This technique is a non-vision based technique for mobile robot navigation, but it is need for some cases. This technique is used for any types of signal, but the receiving antennas mounted on robot are according to the signal type.

1.1. Signal Strength Node/Tags

Signal strength node (SSN) is trans-receiver which transmits and receive signal [7]. These continuously transmit signal till it receive a signal from robot. When it receives signal from robot it stop transmitting its signal. SSN are placed in workspace where robot moves or doesit work. For this SSN, a trans-receiver is mounted on robot. Two antennas mounted on robot receive signal from SSN and measure the signal strength of received signal. Robot finds its path using purposed navigation technique and Robot continuously measure signal strength of signal till it reaches near to SSN. For this, signal strength is measured near the SSN and it is stored in robot and robot is continuously measure signal strength of signal it receive from SSN and compare this signal strength value with stored value in robot. When measure signal strength value is equal to saved value, than robot reached near to SSN and then robot sends a signal to SSN and SSN is switched off. Then other node (if present in workspace) is ON and robot continuously follow the same procedure till it is not reaches at destination point.

1.2. Signal Strength

Signal strength is the magnitude of the electric field and it spreads with increasing distance. Then the signal strength is decreases with increasing distance. The antenna transmit signal, than strength of signal is decreases with increasing distance. In between transmitting antenna and receiving antenna, signal strength is high at transmitting antenna and minimum at receiving antenna. Then this signal strength is increases when receiving antenna moves towards transmitting antenna. This property is used for robot path navigation. It is an efficient technique and use for all types of signal because signal strength of all signals is decreases with increasing distance. The biggest advantage of this technique is that, there is no effect of signal loss or error on robot's movement. The robot's movement depends upon difference of signal strength of both antennas. Generally signal received by an antenna is

$$T = Rx + \text{gain} - \text{loss}$$

Where, T = signal received by antenna, Rx = signal transmitted by antenna, so signal received by first antenna is,

$$T1 = Rx1 + \text{gain} - \text{loss}$$

Similarly, signal received by second antenna is

$$T2 = Rx2 + \text{gain} - \text{loss}$$

The receives signal difference of both antennas is

$$T = T1 - T2$$

$$T = Rx1 - Rx2$$

So, the error is automatically cancelled. The loss of signal of both antennas is same because, both antennas received same signal and error is very small due to distance between two antennas.

2. PROPOSED WORK

Architecture of system consists of signal strength module, control unit and fuzzy logic controller. In this purposed work number of signal strength nodes is placed in work place. All these sensor nodes are controlled by a control unit. Control unit activates all signal strength nodes. Control unit activate sensor nodes which are need to robot to reach at its destination point. Control unit is pre-programed with an ordered list of signal sensor nodes which are placed in path of robot when it navigates a particular path. Let robot goes to form one place to other. Then control unit activate all the nodes which are placed in path of robot and ON the node which is near to robot. Let nodes in path of robot are a, b, c, and d. Then control unit activate all the nodes and ON nearest node a. All the nodes not transmit signal simultaneously. First node ‘a’ transmits signal strength and robot finds its path using this navigation technique and another antenna which are placed on the robot continuously measure the signal strength of node ‘a’.

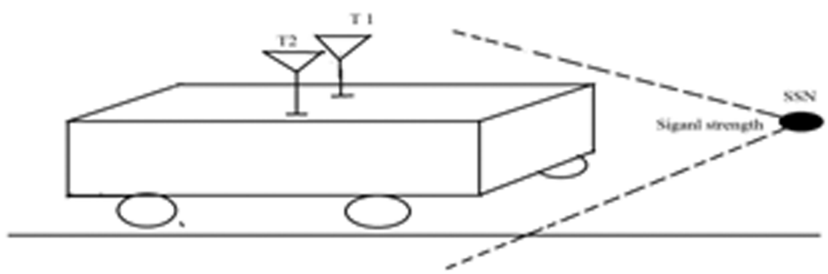


Figure 1: Robot Architecture Where T1 and T2 are antennas

When signal strength of node ‘a’ is similar to value which is programmed in robot than antenna transmit a signal and node ‘a’ received this signal and stop transmit signal or deactivate and also this signal is received by control unit and it ON nearest node ‘b’. then robot follow its path using signal strength received by signal strength node ‘b’ and reach at node ‘b’. Then similarly robot goes to node ‘c’ and after that goes to node‘d’. In this technique robot continuously measures the signal strength from signal strength node or destination point and find its path on the basis of this received signal strength. A general idea of this technique is depicted in Fig 1.1 in which robot follow a straight path. In which a signal strength node is placed in front of robot and it transmit signal continuously. Than robot follow their path on the bases of this received signal strength and measure a straight path. The other detail of this navigation technique is explained below.

2.1. Control Unit

Control unit activates and deactivates the signal strength nodes. It is programed and has all the information about the number of nodes is present in the workplace where robot works. When robot goes from one point to another point in workplace, then it activate all the nodes coming in the path of robot and then ON the signal strength node which is near from the robot. When a signal strength node is ON then it starts to transmit the signal and robot receives this signal. Then measure signal strength of this signal and on the basis of this received signal strength reach near to this signal strength node. Another antenna also put on the robot which continuously measure the signal strength and compare this signal strength value with reference value stored in the programme. This referenced value is manually calculated and it is signal strength value near to the signal strength node. This value is same for all the signal strength nodes. So when antenna’s signal strength value is same as referenced value then this antenna sends a signal and this signal is received by this signal strength node. Then this signal strength node stops to transmit the signal and then the control unit deactivate this node and ON other node which is near to the robot. This process is continue till the robot reach at their destination point.

2.2. Signal Strength Module

This module consists of antennas and differentiator. When robot follows its path it continuous measures the signal strength which it receives from the signal strength node. Let robot's two antennas T1 and T2 receive signal from L1 and L2 respectively from signal strength node or destination point. Then this signal strength received by two antennas is send to differentiator. This differentiator has two inputs Q1 and Q2. Then subtract these two inputs Q1 and Q2. The output is ΔQ, which is equal to

$$\Delta Q = Q2 - Q1$$

ΔQ gave the information to robot, in which direction it move. If the ΔQ is positive then signal strength is lies in left side of the robot and if ΔQ is negative then signal strength node is lies in right side of the robot. If ΔQ is equal to zero then signal strength node is in front of robot. ΔQ becomes input for the fuzzy logic controller.

2.3. Fuzzy Logic Controller

In this purposed work researcher used one input and one output fuzzy logic controller [11]. Input of this FLC is output of differentiator which is ΔQ. The output of FLC is depends upon ΔQ, as shown in Fig. 1.2. The main aim of FLC is to give movement to robot. ΔQ is received signal strength difference of the signal received by two antennas T1 and T2 which are mounted on robot.

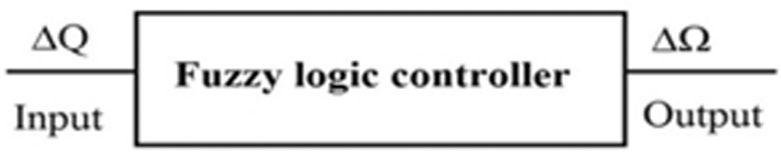


Figure 2: Fuzzy logic controller

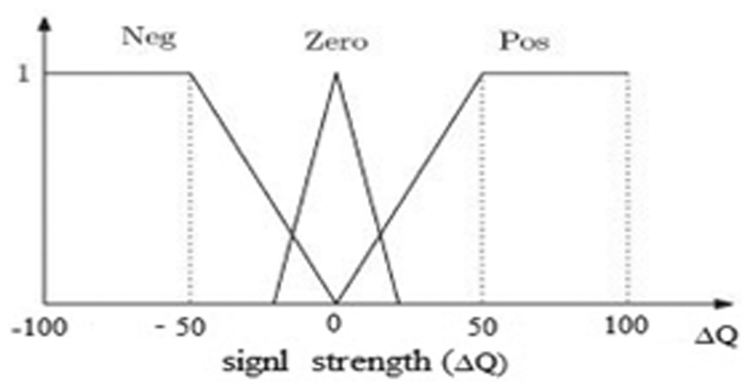
FLC used this signal strength to turn up its direction. Let the output (robot turn) of FLC is $\Delta\Omega$. Than $\Delta\Omega$ is equal to

$$\Delta\Omega = \text{FLC } \Delta Q \text{ (depend upon value of } \Delta Q)$$

The fuzzification and de-fuzzyfication membership function are used as trapezoidal and linear triangular form, shown in Fig. 1.3 and if than statement is used to calculate robot's direction or movement. The fuzzy rules used in this technique are:

$$\text{If } \Delta Q = \text{-VE than } \Delta\Omega = \text{CCW}$$
$$\text{If } \Delta Q = \text{+VE than } \Delta\Omega = \text{CW}$$
$$\text{If } \Delta Q = \text{Zero than } \Delta\Omega = \text{Zero}$$

Robot's movement depend upon the value of ΔQ. If ΔQ is –VE then robot move counter clock wise direction and it means the destination point is left side of the robot. Then robot turns CCW till ΔQ is equal



(a)

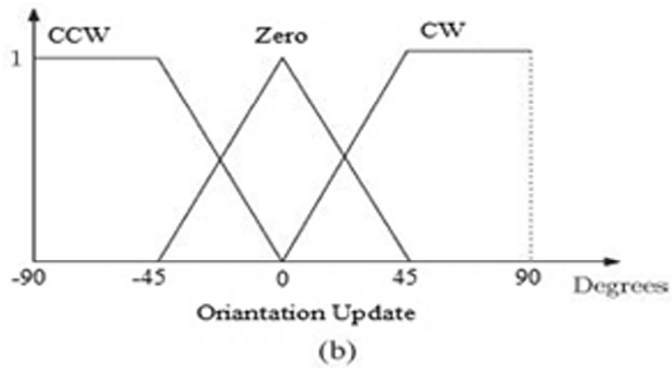


Figure 1.3: FLC's membership functions. (a) Input membership functions. (b) Output membership functions (not to scale) [15]

to zero and move forward till ΔQ is equal to zero. If the ΔQ is +VE then robot moves clock wise direction and it means the destination point is right side of the robot. Then robot turns CCW tillΔQ is equal to zero and move forward till ΔQ is equal to zero. When ΔQ is equal to zero than robot forward direction and it means the destination point is placed in front of robot. Robot move forward till ΔQ is equal to zero.

2.4. Navigation Algorithm

Navigation algorithm is needed for robot to reach at its destination point. It combines the efforts of signalstrength module and FLC. The flowchart of navigation algorithm is drawn in Fig. 1.4.

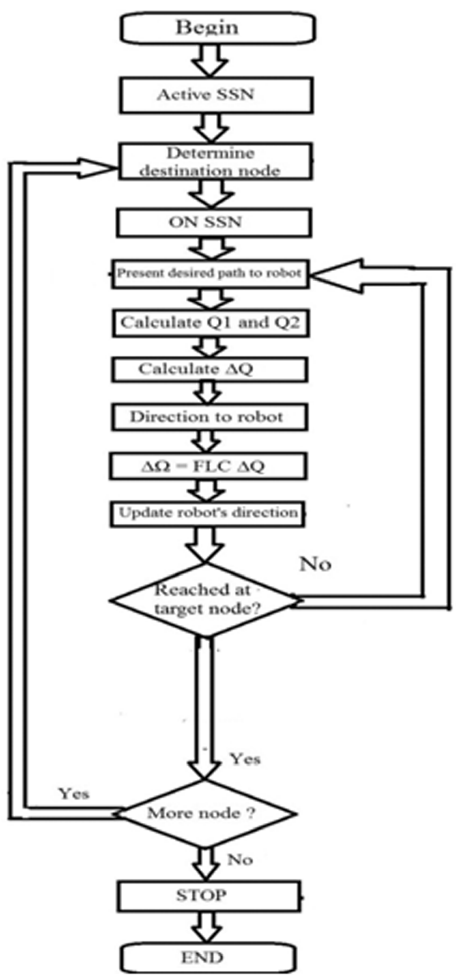


Figure 1.4: Navigation algorithm

The detail of algorithm is given below:

(1) Robot is programmed with entire detail of signal strength nodes in path of robot.

(2) Control unit active all the SSN in path of robot and ON SSN nearest to robot and then this SSN transmit signal continuously.

(3) Then antennas mounted on robot receives signal from this SSN and calculate signal strength difference of this signal received by both antennas (ΔQ).

(4) Then ΔQ is passed to FLC and FLC calculates in which direction robot will turn (Robot move desired direction till ΔΩ is not equal to zero and When ΔΩ is equal to zero than it move forward till ΔΩ not equal to zero).

(5) Then robot move forward and check it is reached at target node or not. Another antenna is mounted on the robot continuous measure the signal strength of this node and compare this signal strength value with reference value (reference value is manually measure by programmer near the robot). When both values are equal, then robot reached at target node and if reference value is more than measured value then it does not reach at target node. Robot follows path from step (2).

(6) If robot reached at target node then it sends a signal to control unit and control unit deactivate this SSN node (when a SSN is deactivate then it is again not activated or ON) and ON other nearest SSN, if it is present in workplace. If there is other node present in workplace then control unit ON this node and it starts to transmit signal. Then robot follows its path using this navigation technique. If there is no node in workplace then robot reach at destination point.

3. SIMULATION WORK

The simulation of navigation algorithm is performed on MATLAB. For this number of targets are assign at a particular point according to the work environment of robot. The targets are assigning as an angle. Then robot identifies these targets using proposed algorithm.

For simulation of proposed navigation technique, analyse this technique on different number of targets. The position of these targets is defined on the basis of degree on MATLAB simulation to analyse number of tags. Targetscan be analysed using MATLAB simulation as follows:

3.1. Three Targets

Researcher analyses three targets in robot working environment. Three targets are defined in robot working environment at 60, -10 and -40 degree. Then first target at 60 degree is activated by control unit and

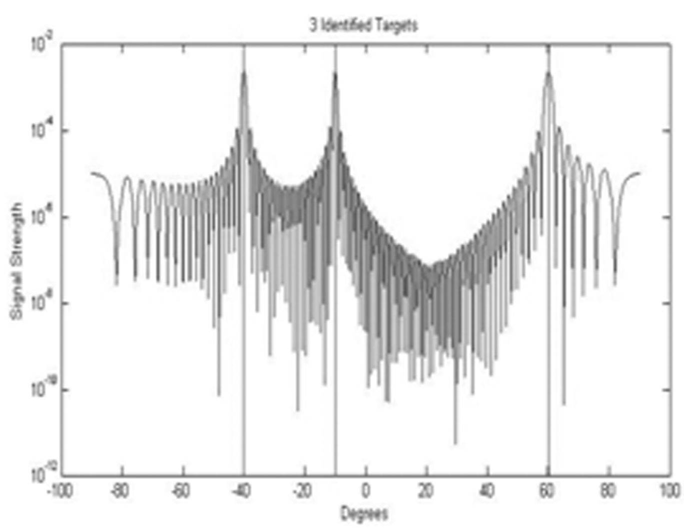


Figure 1.5: identified three targets at 60, -10 and -40 degrees

transmits signal continuously and this transmitted signal is received by robot. Then on the basis of received signal strength the target is identified by robot. As we can see in Fig. 1.5, this target is identified by robot at 60.13 degree instead of 60 degree. At 60.13 degree the signal strength is highest and then robot identifies this target at 60.13 degree and robot identifies one target at this point. Then control unit deactivate first target and activate second target which is present at -10 degree. Then this target at -10 degree is transmits signal continuously and this transmitted signal is received by robot.

Then on the basis of received signal strength the target is identified by robot. As we can see in Fig. 1.5, this target is identified by robot at -9.98 degree instead of -10 degree. Because at -9.98 degree the signal strength is highest so robot identifies this target at -9.98 degree and robot identifies second target at this point.

After thatcontrol unit deactivates second target and activate third target which is defined at position -40 degree. Then similarly as in case of last two targets, robot identifies this target at -39.97 degree. As we can see in Fig. 4, the signal strength is highest at this point and robots identify third targets. So, robot identifies three targets which are assigns in robot working environment which is shown in Fig. 1.5.

Then robot identify these targets at 60.13, -9.98 and -39.97 degree instead 60, -10 and -40 degree.

Table 1.1
Average accuracy and error of targets at 60, -10 and -40 degrees

S. No.	*Target (Degree)*	*Target Identify (Degree)*	*Accuracy (%)*	*Error (%)*
1	60	60.13	99.78	0.22
2	-10	-9.98	99.80	0.20
3	-40	-39.97	99.92	0.08
Average			99.83	0.17

The accuracy to find these targets is 99.78%, 99.80% and 99.92% and the error to identify these three targets is 0.22%, 0.20 and 0.08%, shown in Table 1.1. The average error to finds these two targets are 0.17%.

3.2. Four Targets

Researcher analyse four targets in robot working environment. Four targets are defined in robot working environment at 20, 70, -15 and -50 degree. To identify these targets, the first target which is defined at 20 degree is identified by the robot at 20.03 degree instead 20 degrees. This target transmits continuously signal, then robot identify this target on the basis of received signal strength.

As we can see in Fig. 1.6, maximum signal strength is at 20.03 degree, and then robot identified this target at this point. Then robot find second target which is defined at 70 degree is identified by the robot at 70.28

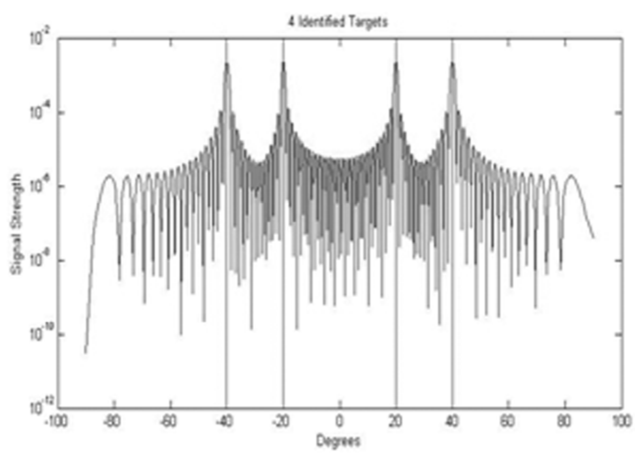


Figure 1.6: Identified four targets at 20, 70, -15 and -50 degrees

degree instead 70 degrees. This target transmits continuously signal, then robot identify this target on the basis of received signal strength. As we can see in Fig. 1.6, maximum signal strength is at 70 degree, and then robot identified this target at this point. Similarly robot identifies other two targets one by one, which is shown in Fig. 1.6. In this experiment, activation and deactivation of all the targets are controlled by a control unit.

Then robot identify these targets at 20.03, 70.28, -14.98 and -50.04 degree instead 20, 70, -15 and -50 degree.

Table 1.2
Average accuracy and error of targets at 20, 70, -15 and -50 degrees

S. No.	*Target (Degree)*	*Target Identify (Degree)*	*Accuracy (%)*	*Error (%)*
1	20	20.03	99.85	0.15
2	70	70.28	99.60	0.40
3	-15	-14.98	99.87	0.13
4	-50	-50.04	99.92	0.08
Average			99.75	0.19

The accuracy to find these targets is 99.85%, 99.60%, 99.870% and 99.92% and the error to identify these two targets is 0.15%, 0.40, 0.13% and 0.08%, as shown in Table 1.2. The average error to finds these four targets are 0.19%

3.3. Five Targets

After analysing four targets, researcher analyses five targets in robot working environment. Five targets are defined in robot working environment at 0, 30, 45, -30 and -45 degree. To identify these targets, the first target which is defined at 0 degree is identifies by the robot at 0.003 degree instead 0 degree. This target transmits continuously signal, then robot identify this target on the basis of received signal strength.

As we can see in Fig. 1.7, maximum signal strength is at 0.003 degree, and then robot identified this target at this point. Then robot find second target which is defined at 30 degree is identifies by the robot at 30.05 degree instead 30 degree. This target transmits continuously signal, then robot identify this target on

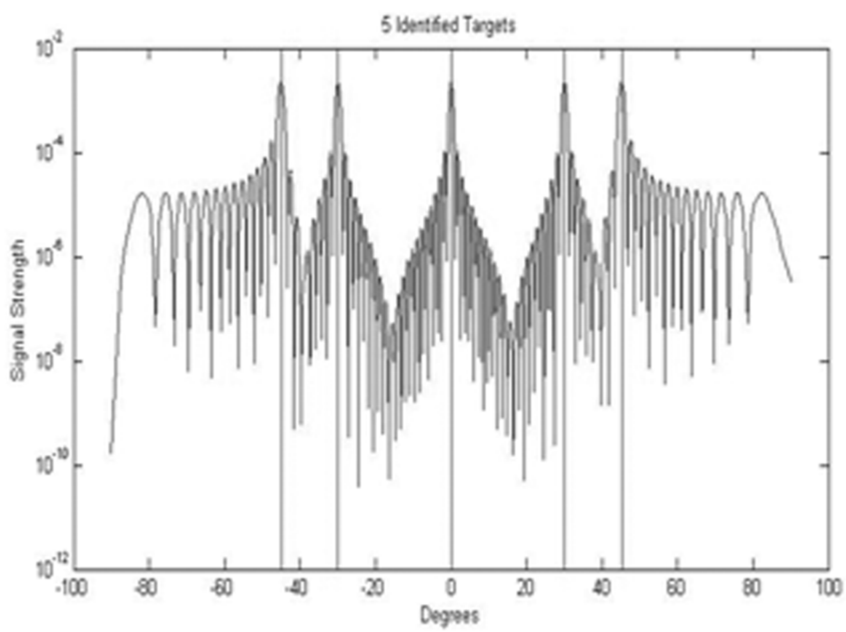


Figure 1.7: Identified five targets at 0, 30, 45, -30 and -45 degrees

the basis of received signal strength. As we can see in Fig.1.7, maximum signal strength is at 30.05 degree, and then robot identified this target at this point.

Similarly robot identifies other three targets one by one, which is shown in Fig.1.7. In this experiment, activation and deactivation of all the targets are controlled by a control unit.

Then robot identify these targets at 0.01, 30.05, 45.14, -29.98 and -45.06 degrees instead 0, 30, 45, -30 and -45 degree. The accuracy to find these targets is 99.70%, 99.83%, 99.69, 99.93% and 99.87% and the error to identify these two targets is 0.30%, 0.17, 0.31%, 0.07% and 0.13%.

Table 1.3
Average accuracy and error of targets at 0, 30, 45, -30 and -45 degrees

S. No.	*Target (Degree)*	*Target Identify (Degree)*	*Accuracy (%)*	*Error (%)*
1	0	0.003	99.97	0.30
2	30	30.05	99.83	0.17
3	45	45.14	99.69	0.31
4	-30	-29.98	99.93	0.07
5	-45	-45.06	99.87	0.13
Average			99.67	0.20

The average error to finds these two targets are 0.20%, shown in Table 1.3.After analysing four and five number of targets, the average error is calculatedly is 0.19% and 0.20% respectively. The average error is 0.195% and accuracy is 99.805%.

4. CONCLUSION

Researcher presents a novel navigation technique for robot using received signal strength. This is a non-vision based navigation technique. In which robot navigate its path on the bases of received signal strength. For this purpose, number of tags is placed in robot work environment. These tags are controlled by a control unit and transmitted continuous signal. This transmitted signal is received by robot and then on the basis of this received signal robot navigates its path. This transmitted signal is received by two antennas which are mounted on robot. The following results were concluded from the analysis of proposed navigation technique and illustrated in the points below:

- The proposed navigation technique is performed by MATLAB simulation and then proposed navigation technique is work successfully in simulation environment. The model used in the simulations is built from real-world based data.
- The average accuracy to navigate robot's path using proposed navigation technique is 99.827%.
- The average error to navigate robot's path using proposed navigation technique is 0.173%.
- In this proposed navigation technique, the error is not increasing with increased number of tags.
- In this technique there is no need to vision based navigation technique. So this is an alternative navigation technique where vision based navigation might not be absolutely necessary.
- Using signal strength for navigation, there is very small error is produced for robot path navigation
- This navigation technique is simple, computationally cost effective, and used in any type of robot architecture.
- To the best of the author's knowledge, this is the first algorithm of its kind where robot navigates its path on bases of received signal strength. This work opens the doors in field of mobile robot navigation where robot navigates its path on the basis of received signal strength.

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