International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 28 Issue 9 – OCTOBER 2021.

FUZZY LOGIC-BASED CONTROLLER FRAMEWORK TO CONTROL A MOBILE ROBOT OVER THE BEHAVIOR OF 'VIEWPOINT-ACTION' UNDETERMINED ENVIRONMENTS

K.Sasi Kumar(sasi30in@gmail.com[#1]
Neha Prabhakar Rajas((neharajas1722@gmail.com)[*2]

***Abstract*— Effective robot activity in a true situation is a test which requires thought of a few issues. Genuine conditions are dynamic, in this way earlier data can't be depended upon. Robots must depend on ecological information acquired through detecting, or a blend of earlier information and detecting. With no accessible earlier data, a robot's information on the earth is restricted to the scope of its sensors. On the off chance that an article draws near inside scope of a robot's sensors, the robot must be capable to respond rapidly enough to stay away from contact with the item.**

I. INTRODUCTION

A strategy for preparing natural data rapidly what's more, proficiently, and afterward responding to the new data, is basic for self-ruling robot activity. Making a scientific model of the robot's connection with its condition is troublesome, if certainly feasible, to accomplish. Customary control frameworks are not proficient when there is an absence of exact and complete information on nature Earlier information on a situation is generally fragmented, unsure, and inexact .Too, the controller must have the option to react responsively as occasions are seen. In the 1980's, a move in mechanical autonomy research happened, in which the accentuation put on gathering and handling information to shape a worldwide world model pushed toward an immediate planning of sensor contributions to control activities. To accomplish this immediate planning capacity, Brooks proposed deteriorating robot usefulness into basic conduct units, with the goal that the robot controller is capable to deal with numerous errands simultaneously, for example, target chasing, deterrent evasion, and crisis moves. Numerous specialists have since planned mechanical frameworks utilizing Creeks' conduct based methodology. Thong chai proposed a fuzzy control framework for a portable robot outfitted with sonar sensors. Rules and enrollment capacities for snag shirking, divider following, and objective looking for were characterized. The robot had the option to effectively maintain a strategic distance from hindrances, be that as it may the direct speed did not depend on the transparency of the condition, thusly the time expected to move from point A to point B was not ideal. Ramirez structured a fuzzy control framework to ascertain both precise and straight speed for a portable robot. Seven ultrasonic sensors were utilized to see the earth and guide the sensor information to a safe direction. Results indicated that when deterrents drew nearer, speed changes were enormous and unexpected. Smoother speed changes were accomplished by Chee , with a controller consolidating more than 100 fuzzy standards. Chee proposed a two layer fuzzy framework, where the main layer incorporates the sensor readings and yields both ways freedom esteems. These qualities are joined with an objective heading variable and at that point contribution to the second layer of the controller, from which a straight speed and turning rate are yield.

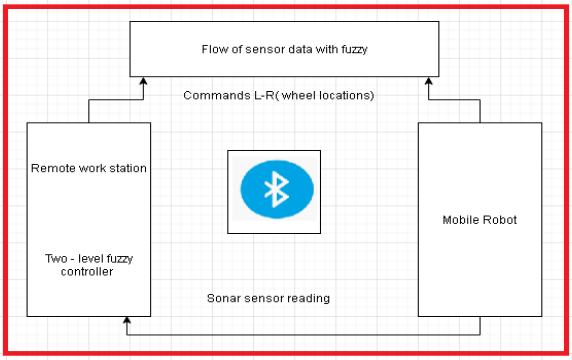

Figure1: Flow of sensor data and control commands

Numerous scientists have since structured automated frameworks utilizing Creeks' conduct based methodology. Thongchai proposed a fuzzy control framework for a portable robot furnished with sonar sensors. Rules and enrollment capacities for impediment evasion, divider following, and objective looking for were characterized. The robot had the option to effectively dodge snags, be that as it may the direct speed did not depend on the receptiveness of the condition, along these lines the time expected to move from point A to point B was not ideal. Ramirez structured a fuzzy control framework to compute both rakish and direct speed for a versatile robot. Seven ultrasonic sensors were utilized to see the earth and guide the sensor information to a safe direction. Results indicated that when obstructions drew nearer, speed changes were extremely huge and abrupt. Smoother speed changes were accomplished by Chee , with a controller joining more than 100 fuzzy principles. Chee proposeda two layer fuzzy framework, where the principal layer coordinates the sensor readings and yields both ways leeway esteems. These qualities are joined with an objective heading variable and at that point contribution to the second layer of the controller, from which a straight speed and turning rate are yield.

In this article, ultrasonic sensors and fuzzy control are utilized to help in the route of a remote, independent robot (Figure. 1). The robot must go through an impediment filled condition with the goal for it to accomplish its objective position. The robot should, arranged by need,

1) Reach the objective without impact,
2) take an immediate course to the objective,
3) Minimize travel time by shifting speed

To achieve these objectives, a two-phase fuzzy controller for an independent robot has been executed. The primary stage of the controllerascertains the rate at which the robot ought to turn, in view of the sonar sensor readings. We present a variable called free space, which is aproportion of the receptiveness of the prompt condition. A direct speed is determined in light of the free space esteem and the recently determined turning rate. A sum of thirty-nine principles are utilized in the controller plan. Free space-subordinate conduct edge levels just as weighted sensor esteems are likewise thought of in the plan.

II. BACKGROUND

The mobile Robot:

The robot utilized in our investigations is Dr. Robot's Wi-Robot DRK 8000. A low-level controller on the robot handles sensor information, movement orders, and interchanges. Significant level control of the robot is prepared on a remote workstation. Sensor information and control orders are sent between the robot furthermore, remote workstation utilizing Bluetooth remote innovation (Figure. 1). The front of the robot is outfitted with five equally separated ultrasonic sensors in a semi-circle arrangement (Figure. 3). Every sonar sensor can precisely quantify separations to objects in the 5-110 cm extend. To explore, the Wi-Robot utilizes its two wheel differential drive framework situated at the robot's geometric focus.

Differential movement:

The Wi-Robot uses a differential drive component for development. This drive framework comprises of two wheels mounted on a typical hub and fueled by independent engines. The direction of the robot can be constrained by differing the speed of each engine. The general speed of each wheel decides the point about which the robot will pivot about. This point is known as the immediate focal point of arch (ICC). The kinematic conditions of a robot working with a differential drive framework are given as

$$x = cos\theta\,(v_l + v_r)/2 = cos\theta v,$$
$$y = sin\theta\,(v_l + v_r)/2 = sin\theta v,$$
$$\theta = (v_l - v_r)/(2c_r) = w, \qquad (1)$$

where vl is the left wheel speed, vr is the correct wheel speed, v is the translational speed, x˙ is the x-hub speed, y˙ is the y-hub speed, θ˙ is the edge between the x-hub and the robot's going, cr is the separation between each wheel area and the midpoint of the hub, and w is the angular rate at which the robot pivots about the ICC.Angular and linear velocity can be mentioned as

$$u = \begin{bmatrix} v \\ w \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & \frac{1}{2} \\ \frac{1}{2c_r} & -\frac{1}{2c_r} \end{bmatrix} \begin{bmatrix} v_l \\ v_r \end{bmatrix}, \qquad (2)$$

where u is speed. When vl = −vr and the separation to the ICC is 0, the robot will turn set up. This capacity makes differential drive exceptionally alluring when route in confined situations is basic. When vl = vr, the separation to the ICC is limitless and the robot will go in a straight line. For every other estimation of vl and vr, the robot will travel in a bended direction about the ICC.

Robots utilizing differential drive are helpless to erroneous direction issues even with little blunder speeds. Too, a couple of casters are important to keep up the robot's balance. The materialness of this drive framework is constrained to research center conditions with smooth floors, on the grounds that the castors can't slide over unpleasant surfaces without making the robot experience huge vibrational unsettling influences.

III. CHARACTERISTIC –BASED FRAMEWORK:

The conventional way to deal with independent robot control is in light of a sense-plan-act conspire in which a model of the world is first worked from the tactile information. An arrangement of activity is then settled on and completed. The trouble in accomplishing a total and precise model of the world filled research which moved toward the issue from an alternate perspective. Creeks spearheaded the subsumption engineering which depends on starting practices when fitting sensors fire. The prevailing conduct can be controlled by utilizing an organized discretion conspire. Lower level practices can be briefly stifled by more significant level practices, albeit all practices are really running in equal. When the sensor conditions not, at this point trigger a more significant level conduct to act, a lower level conduct is permitted to continue control.

Sonar sensing:Sonar sensors are light, vigorous, modest, and are currently in across the board use for route in unstructured conditions, map-building, target-following, and snag shirking. Because of the low precise goal of sonar separation estimations, exact geometric data of the earth is hard to get.

Be that as it may, receptive robot practices don't require a mind boggling portrayal of the earth. The control activity can be resolved dependent on an impression of the encompassing region's impediments as opposed to a geometric model of the earth. Ease sonar sensors are valuable when we have to know roughly the distance away the robot is from an impediment, however not when we have to know the specific separation between the robot and deterrent. Sensor data is regularly deficient and off base. Too, a logical model of the earth is only very seldom accessible. Numerous analysts, for example, havediscovered that fuzzy controllers function admirably for these sorts of conditions because of their high level of vigor and proficient activity.

Fuzzy control:
Zadeh proposed a technique for displaying human thinking utilizing fuzzy sets. Fuzzy rationale handles surmised data in a precise manner. It tends to be thought of as an expansion of Boolean rationale which takes into consideration the preparation of fractional truth esteems between totally obvious and totally forged.
Fuzzy logic is perfect for demonstrating complex frameworks where just a vague model exists. Fuzzy participation capacities evaluate the degree to which a characteristic is uncertain. Fuzzy rationale controllers have been utilized to manage the vulnerability and uncertainty of the data that a robot gets, and have been appeared to function admirably with sonar sensors. Various creators have actualized fuzzy control utilizing sonar sensors with no different methods for detecting the earth. Fuzzy rationale includes three steps: fuzzification, fuzzy inferencing, and defuzzification.

1) Fuzzification:
During the time spent fuzzification, no data is lost. It is basically changed to an alternate structure, from a genuine incentive to a level of participation. In fuzzy rationale frameworks, the capacity to speak to an enormous number of fresh rationale esteems by utilizing few fuzzy qualities is ground-breaking. The participation capacities characterized on the information factors are applied to decide the level of truth of the genuine qualities. Each information esteem should be changed over into a structure where the guidelines can work on.

2) Fuzzy interface:
All information sources got by the framework are assessed utilizing IF THEN standards that decide their reality values. Fractional coordinating of the information is utilized to interject an answer. Every fuzzy outcome acquired by the deduction are joined into a solitary end. A wide range of strategies exist to locate the most proper end. For our robot control framework, the MAX-MIN strategy for determination was utilized, in which the most extreme fuzzy estimation of the induction ends was utilized as the last end.

3) Defuzzification:
After the standards have been handled, the prescribed activity should be changed over from an inner portrayal to an exact yield esteem. This progression is fundamental on the grounds that the controllers of physical
frameworks require discrete signs. Numerous strategies for defuzzification exist. We utilize the focal point of gravity str ategy appeared in Fig. 2, which is given as

$$U = \frac{\int_{min}^{max} u\mu(u)\,du}{\int_{min}^{max} \mu(u)\,du}, \qquad (3)$$

Here above shows U is the crisp output value, u is the representative of crisp value and $\mu(u)$ is the given grade of the membership at u.

IV. RESEARCH

Design of the controller:The research center robot has been arranged with five sonar sensors in a semi-hover setup, as appeared in Fig. 3.

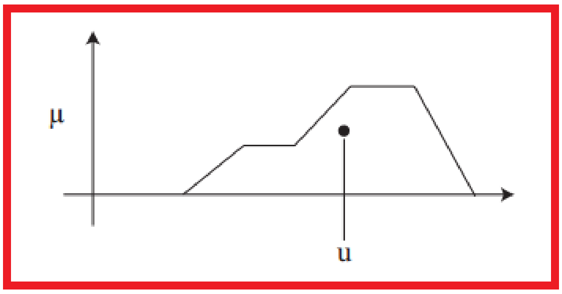

Figure2: defuzzification of solution set: center of gravity method

The sensors have a filtering scope of roughly 45 degrees also, are exact for separations somewhere in the range of 5 and 110 cm. These values were resolved exactly from our perceptions in the lab, and fused into our reproduction. Normally, the more noteworthy the quantity of sensors, the more prominent the quantity of derivation rules required. So as to diminish the number of rules, we just utilize the lower of the two qualities for the left and left focus sonar, and the lower of the two qualities for the privilege and right focus sonar. In the event that the middle sonar sensor perusing is not exactly both of the left or right qualities, its worth is allocated to the lower of the left and right controller inputs; else, it is overlooked.

Fig. 3 shows the conduct engineering of the proposed controller. The three characterized practices are obstruction evasion, target chasing, and crisis stop. In our usage, target looking for conduct is dynamic if there are no close by impediments that could represent a danger to the article. At the point when an object shows up before the robot, the deterrent evasion conduct will stifle the objective looking for conduct until the object is no longer in the robot's prompt region. The establishment of our work is a two-phase fuzzy controller that yields both precise and straight speed, as appeared in fig. 4. At the point when the obstruction shirking conduct is dynamic, the least of both the left and right-side sensors are sent to the primary phase of the fuzzy controller, and a rakish speed is yield. The rakish speed is then taken care of into the second phase of the controller, alongside another variable, freespace, which is a proportion of the transparency of the prompt condition. The freespace variable is a weighted normal of all current sensor readings. Fusing this worth gives the controller with the capacity to adjust to the transparency of the encompassing region, and accordingly permits the robot to move at a speed appropriate for the current conditions. The yield of the second phase of the controller is straight speed, which when joined with the yield from the primary stage, is adequate data to figure the left and right wheel speeds. In an application where speed of activity is fundamental, however in which there are additionally firmly contracted zones where sharp turns are required, it is important to control the straight speed of the robot.

To decide if the robot should start hindrance shirking conduct

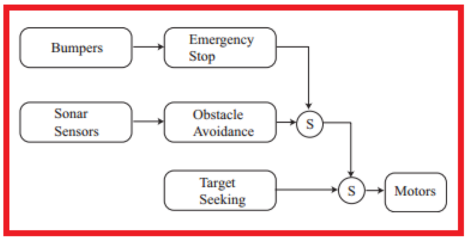

Figure3: Behavior control scheme

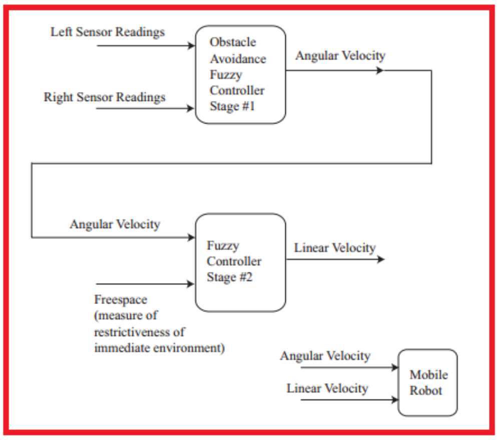

Figure4: Two-Stage fuzzy controller

separation limit esteems have been characterized for every sensor. On the off chance that an item is distinguished inside any of these limit locales, the robot quickly stifles the target looking for conduct and endeavors to move out of range of the snag. Fig. 5 shows that we have given the middle sensor the best limit esteem, trailed by the left/right focus sensors. The robot is continually pushing ahead, in this way the front sensors give the best sign of a looming crash. The more prominent limit go for the inside sensors gives the robot more opportunity to alter course and keep away from a impact.

At the point when the objective looking for conduct is dynamic, the separation to the objective just as azimuth to the objective are sent to the first phase of the fuzzy controller, and precise speed is yield. During objective chasing, the supposition that is made that the robot knows the specific directions of the objective and is ready to precisely limit itself, for example immaculate dead-retribution. In actuality, because of wheel slip and different elements, odometry mistakes will gather until the robot is lost or until, for instance, an object of realized directions is situated by a dream framework, from which the right robot directions can be determined. In the recreation, the robot separation to the objective just as edge to target are determined at a recurrence of 20 Hz.

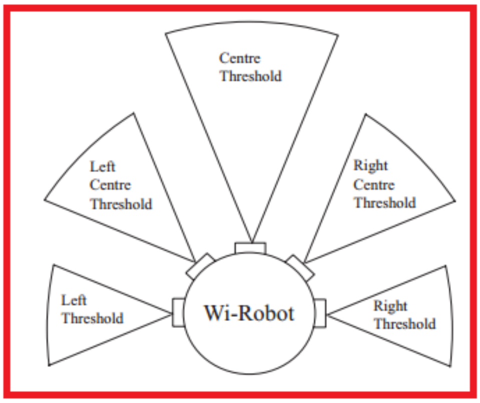

Figure5: behavior threshold levels

In the structure of the controller, fuzzy sets were first characterized for each semantic variable. The precise speed rules for deterrent evasion are appeared in Table I, and straight speed rules are appeared in Table II. Three triangular enrollment capacities for each information (left and right) are utilized in the impediment shirking controller: close, center, and far. The triangular bend is a component of a vector, x, and depends on three scalar boundaries a, b, and c, as given by

$$f(x,a,b,c) = \max\left(\min\left(\frac{x-a}{b-a},\frac{c-x}{c-b}\right),0\right). \quad (4)$$

The feet of the triangle are assigned by a and c, and the top by b. Five enrollment capacities are utilized for rakish speed: positive enormous (LP), positive little (PS), zero (Z), negative little (SN), and negative enormous (NL). Five participation capacities are utilized for direct speed: exceptionally moderate (Versus), slow (S), medium (M), quick (F), and extremely quick (VF). Fig. 6 shows the participation functions with obstacle ignorance linear and angular velocity.

Table1: Obstacle avoidance rule for angular velocity

Rule #	Left	Right	Angular Velocity
1	Close	Close	Z
2	Close	Middle	PS
3	Close	Far	PL
4	Middle	Close	NS

5	Middle	Middle	Z
6	Middle	Far	PS
7	Far	Close	NL
8	Far	Middle	NS

V. EXPERIMENTAL AND SIMULATED RESULTS

Numerous researchers have utilized recreation to test their robotic calculations, anyway due to the differences in simulations

and reality, the recreation results might be of little worth. Mechanical calculations should at last be powerful enough for real world use. For improved strength, sensible aggravations for example, clamor and sensor reflections ought to be remembered for the reenactment to all the more precisely model the earth. In any case, the usage of these unsettling influences can be troublesome may in any case not produce exact outcomes, due to the complexities of nature. In spite of these issues, reproductions are broadly utilized by analysts in controller plan, particularly when hundreds or thousands of test tests are necessary
To test the robot controller, reproduction was performed utilizing Sim Robot Toolbox for Mat lab, and research center trials were led utilizing Dr. Robot's Wi-Robot DRK 8000. Changes were made to the test system's drive framework to precisely display our research facility robot. As communicated before, our objective was to plan a robot controller that empowers the robot to effectively arrive at the

Rule #	Angular Velocity	Average Proximity	Linear Velocity
1	NL	Close	VS
2	NS	Close	S
3	Z	Close	M
4	PS	Close	S
5	PL	Close	VS
6	NL	Middle	S
7	NS	Middle	M
8	Z	Middle	F
9	PS	Middle	M
10	PL	Middle	S
11	NL	Far	VF
12	NS	Far	VF
13	Z	Far	VF
14	PS	Far	VF
15	PL	Far	VF

objective in The briefest time, by means of an immediate course. Fig. 7 and 8 show the way of the reproduced robot during two effective preliminaries of the two-phase controller. To completely test the robot's capacity, an all the more testing condition is required. Fig. 9 shows a domain containing enormous hindrances containing wide holes for a robot to explore between, medium-sized snags with littler holes, and furthermore little snags firmly separated together. To satisfy our exhibition objectives, the robot ought to preferably move rapidly through the open territories and gradually through the firmly limited regions, while taking the briefest conceivable course.
In our tests, the robot was just ready to arrive at the second arrangement of impediments (Fig. 9). To improve the exhibition of the controller, boundaries of the enrollment capacities were physically altered. While agreeable execution was accomplished, the robot couldn't explore through the medium-sized paths. Despite the fact that the robot's speed.
Wasincredibly decreased when moving toward a firmly bound region (due to the free space boundary), the hindrance evasion conduct would smother the objective looking for conduct and power the robot to pivot. To address this issue, the conduct edge level for every sensor was changed in an exertion to discover ideal exchanging limits. Too, these conduct edges were additionally made free space-subordinate. In this manner in a fully open zone, the limit level was set to an a lot higher incentive than in an intently limited region.

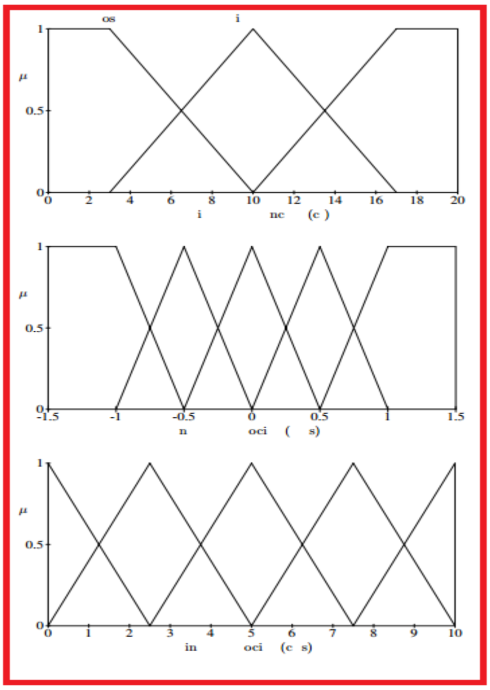

Figure6: member ship functions. Upper One: left/right

distance input(stage1) middle: angular velocity output(stage1), low: linear velocity output(stage2)

To additionally improve the presentation of the controller, one should likewise think about the general significance of the 5 sonar sensors. Instinctively, the front sensor ought to be of most prominent significance, as it is generally demonstrative of a looming impact. The left/right focus sonar sensors would be of next most noteworthy significance, while the left and right sensors would be least significant. The overall significance of every sensor can be joined into the free space boundary by weighting each sensor. It is evident that further tuning of the controller boundaries is important to accomplish our exhibition objectives.

Manual tuning is a complicated and tedious task and not likely to provide us with a feasible solution, So a learning algorithm by default to find the most adjustable control parameters would be highly advantageous.

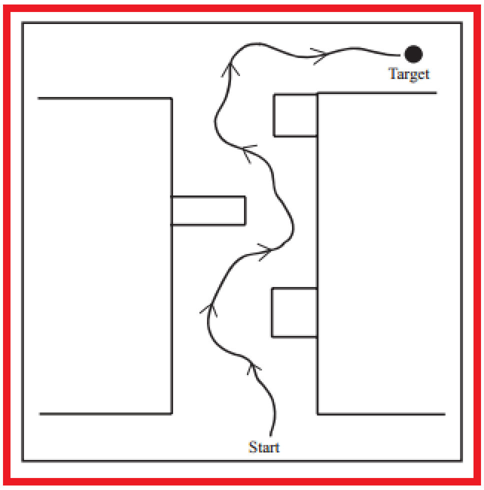

Figure7: Robot navigation through halfway

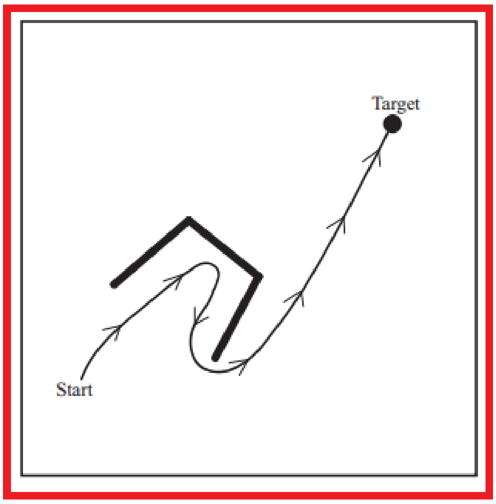

Figure8: robot avoiding obstacles

VI. CONCLUSION

In this article, a two-phase fuzzy controller for a sonar based self-governing robot is proposed. The controller has been both mimicked and tentatively tried. No suspicions were made about the straightforwardness or size of the articles in the earth, and no earlier guide of the earth was accessible to the robot. The structured two-phase fuzzy controller yields both direct and rakish speed. The robot had the option to effectively explore through straightforward test conditions, anyway the robot doesn't perform well in jumbled conditions with paths of different widths. In these kinds of situations, it is essential to go at a fitting straight speed with versatile conduct edge levels.

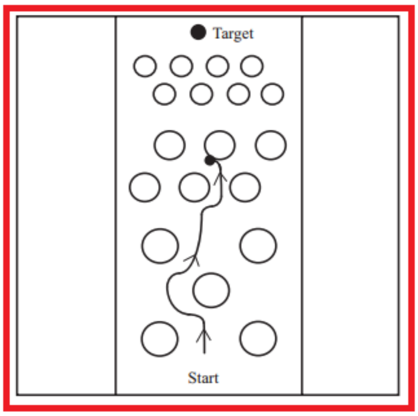

Figure9: robot navigating in cluttered environment

To accomplish better outcomes, extra work is as of now being led to tune the boundaries of the controller's enrollment capacities, sensor loads, and conduct limit esteems, by utilizing a hereditary calculation.

VII. REFERENCES

[1] F. Hoffman, "An overview on soft computing in behavior based robotics," in 10th International Fuzzy Systems Association World Congress, Istanbul, Turkey, June 2003, pp. 544–551.
[2] K. K. A. Saffiotti, E. H. Ruspini, Using fuzzy logic for mobile robot control. Klewer Academic Publisher, 1999.
[3] R. A. Brooks, "A robust layered control system for a mobile robot," IEEE Journal of Robotics and Automation, vol. 2, no. 1, pp. 14–23, March1986.
[4] S. Thongchai, S. Suksakulchai, D. M. Wilkes, and N. Sarkar, "Sonar behavior-based fuzzy control for a mobile robot," in IEEE International Conference on Systems, Man, and Cybernetics, October 2000, pp. 3532–3537.
[5] A. Ramirez-Serrano and M. Boumedine, "Real-time navigation in unknown environments using fuzzy logic and ultrasonic sensing," in IEEE International Symposium on Intelligent Control, Dearborn, MI, September 1996, pp. 26–30.
[6] B.-Y. Chee, S. Y. Lang, and P. W. Tse, "Fuzzy mobile robot navigation and sensor integration," in IEEE International Conference on Fuzzy Systems, vol. 1, New Orleans, LA, September 1996, pp. 7–12.
[7] B. Barshan and B. Aryulu, "Fuzzy clustering and enumeration of target type based on sonar returns," Pattern Recognition, vol. 37, pp. 189– 199, February 2004.

[8] H. Maaref and C. Barret, "Sensor-based navigation of a mobile robot in an indoor environment," Robotics and Autonomous Systems, vol. 38, pp. 1–18, January 2002.

[9] W. L. Xu and S. K. Tso, "Sensor-based fuzzy reactive navigation of a mobile robot through local target switching," in IEEE Transactions on Systems, Man, and Cybernetics, vol. 29, no. 3, August 1999.

[10] T. E. Mora and E. N. Sanchez, "Fuzzy logic-based real-time navigation controller for a mobile robot," in IEEE/RSJ International Conference on Intelligent Robots and Systems, vol. 1, Victoria, B.C., Canada, October 1998, pp.612–17.

[11] L. A. Zadeh, "Fuzzy sets," Information and Control, vol. 8, pp. 338– 353, 1965.

[12] I. Ismail and M. F. Nordin, "Reactive navigation of autonomous guided vehicle using fuzzy logic," in Student Conference on Research and Development, Shah Alam, Malaysia, July 2002, pp. 153–156.

Authored by: K.Sasi Kumar (sasi30in@gmail.com)

Co Author :Neha Prabhakar Rajas
(neharajas1722@gmail.com)