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An Analysis of Path Planning for Autonomous Motorized Robots

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***Abstract:** Mobile robots are widely used in many industrial fields. Research on path planning for mobile robots is one of the most important aspects of mobile robots research. Path planning for a mobile robot is to find a collision-free route, through the robot's environment with obstacles, from a specified start location to the desired goal destination while satisfying certain optimization criteria. Determination of a collision free path for a robot between start and goal positions through obstacles cluttered in a workspace is central to the design of an autonomous robot path planning. This paper presents a comprehensive study on state of art mobile robot path planning techniques focusing on algorithms that optimize the path in the obstacle abundant environment. Simulation scenarios are performed in the perspective of single and multi-robot path planning and the experimental results show the best performing path planning technique in the corresponding scenario. This paper intends to give assistance in the better understanding of the path planning techniques and also guide researchers to formulate novel techniques for better path planning in both single and multi-robot environments.*

***Keywords:** Path Planning, Traditional Method, Soft Computing, Autonomous Mobile Robot.*

1. INTRODUCTION

A mobile robot is a various control system which is capable of locomotion with a broad set of applications. Autonomous Mobile robots [1] are capable to move around in the environment but are not fixed to one location. It is used in various applications like danger seeker, target finder, exploration, and security patrol along with various fields of agriculture, medical, mining, space mission, industries, military, and education. The mobile robot agents are used to interact with an environment. The basic requirement in motion planning of mobile robot includes path exploration, localization, and obstacle avoidance. The planning of path in the autonomous mobile robot is more complex while operating in a dynamic or unstructured environment, but it is easy in a static environment when compared to it. Some robots are allowed to go where the humans cannot survive to collect the information of the particular location.

Many research activities have been proposed in the field of the mobile robot under challenging conditions for the past few decades to reach the target. An autonomous mobile robot has to be intelligent by gaining the information about the environment, adapting to changing the environment and make a decision without any human interaction [106]. The navigation is the ability of the autonomous mobile robot to plan its path in real-time and to navigate safely from one location 'A' to another location 'B'. This is achieved using some techniques. The robot motion planning is the basic method to select whether the implementation can be performed either in the static or dynamic environment.

The motion planning algorithm in the mobile robot is decided to use three basic approaches like Grid based Algorithm, Sampling based Algorithm and Potential based Algorithm. In Grid based algorithm, the low-dimensional problem can be solved and compute the shape. The Potential field algorithm allows the mobile robot to attract towards the goal position, but fall prey to local minima.

The Sampling based Algorithm avoids the local minima and considered as the state of the art in a high dimensional space. The mobile robots are applicable to various fields like Agriculture, material factories, transport, transport, warehouse, office buildings, and indoor and outdoor security patrols, site cleanup, underwater application and military applications. The current research in new robotics areas is Humanoid Robotics, Human-Robot Interaction, and some specialization.

The Humanoid Robots [2] interacts with human tools, environments for experimental purpose and sensor plays a major role in robotics paradigm. The current research declared in 2050, the team of soccer robot shall win against the winner of the most recent world cup. DARPA announced major trend is to make a robot to do things in the future as a human can do. Kelly and Stentz [107] have developed a mobile robot for both indoor and outdoor environment and integrated into field system, these projects transferred to the NASA and to DoD applications.

There are many types of mobile robot navigation like Manual Remote, Guarded tele-op, Line Following car, Autonomously guided robot and Autonomously randomized robot. The Manual remote robots, like iRobot PackBot and ARI-50, are totally under the control of the driver or any other wireless computer. The guarded tele-op has the ability to avoid obstacles by the sensor and the Line Following car might follow the line painted on the floor or ceiling or travel along the electric wire placed on a ground. The Autonomous guided the robot to travel from source to destination by gathering some prior knowledge about the environment and the communication occurs via sensor technology. These robots are the part of a wireless network which can be operated from any location either from building to building or in a single room. The robot has an ability to travel in any critical environment by avoiding obstacles by selecting a randomized path from a number of solutions. The autonomous mobile robot can be navigated in the indoor and outdoor environment for reaching a goal with the help of a human interaction or automatic controller to actually perform a physical task and also enters into the region where the human cannot intervene.

The path planning is important for the autonomous mobile robot to find the shortest path or optimal path between two end points. The robot could not find the shortest path always sometimes deals with the optimal solution by considering the number of turnings, number of breakages when required. The process of finding the shortest path not only applicable in Network Routing, video games and also suitable for robots for finding a destination in particular time. Before entering into path planning stage the map is preloaded in a mobile robot to aware of its location, so it is capable of avoiding obstacles. This survey paper provides a snapshot of attitude and behavior of path planning in an autonomous mobile robot in various environments. It also provides a few ideas for further implementation in bringing new solutions with perfect decision making for future generation.

2. ROBOT PATH PLANNING TECHNIQUES

Path planning or Motion planning is the process of cracking down the desired movement work into separate motion that satisfies movement and possibly optimizes various aspects of the movement. The path planning on a mobile robot is very complex and even more complicated if the robot needs to find a target function like shortest path, minimization of energy, less time and also involves in solving mazes. The mobile robot also comes across many obstacles avoidance problems which are outstandingly important and involves in achieving a target in a static and dynamic location by avoiding or detecting obstacles. The motion planning consists of many approaches, but usually involves only two approaches for finding the task. The first approach is represented as Global Path Planning and the second approach is Local Path Planning. These two approaches are briefly discussed in the following sections.

2.1 Global Path Planning

A Global Path Planning [3] is the complete description of a goal and static space of the obstacles are predefined or the complete information about an environment in advance. A prior knowledge of the location allows the robot to find the best path to reach its target by avoiding collision with obstacles. Here, the obstacles are static or predefined and the path is well known to an autonomous mobile robot and the path planning is applicable to both indoor and outdoor environments. It usually generates a low-resolution and high level path from location A to B, in the environment, by avoiding obstacles and accomplishes effective navigation.
A comprehensive map, grid, and cells are preloaded into the robot and the navigational algorithm determines the optimal path before the robot starts its motion. Though the complete description of the environment is available in prior, the global path planning is a highly complex problem and it is solved using a Genetic Algorithm in a large scale Grid Maps [4]. The global path planning problem can also be solved using Exact or Meta-heuristic [5] search methods that explore the search space because it can often find good solutions with less computational approach rather than any other iterative or a traditional method. The exact method has advantages of completeness and the execution time increases with the size of the problem. The Global applied to a large scale grid maps and also combine with algorithms like A*, D*and Dijkstra's Algorithm for finding a less cost and shortest path from source to destination in a topology by dividing an environment into several grids. The comparison between Exact and Meta-heuristic search method is mentioned in [108].

2.2 Local Path Planning

A Local Path Planning (LPP) [6] is preferred where the environmental description is incomplete and also in a dynamic environment for real time scenarios. It generates a fresh path by overwriting the original Global Path Planning in response to a geographical change in the environment. In a Local Path Planning, the path or obstacles are not known in advance so the robot has to sense the environment before it decides to move and generate a trajectory planning towards the destination. If the obstacle is found, the autonomous mobile robot deviates from its current path and search for a new path towards the target location in the environment. The artificial potential field is one of the simple LPP technique which operates based on the attraction and repulsion potential. In this technique, the mobile robot is repelled on identifying an obstacle in the path and attracted towards the intended goal position.

A Local Path Planner structure [6] for the robot is implemented using the Row-Wised and Column-Wised movement of the robot. In row-wised movement, the mobile robot is allowed to move row by row from the start point to an end point, i.e. the robot moves in a horizontal line where the path will meet only once. Similarly, in Column-wised movement, the robot is allowed to move column by column to the destination from the source (i.e.) the target is achieved in a space in the vertical line format. The encoding technique is also applied to solve the path planning problems which consists of four variables like Path-Location, Path-Direction, Path-Flag, and Path-Switch.

3. ROBOT PATH PLANNING MODELS

The Path Planning involves two broad approaches, namely traditional or conventional method and Soft Computing method. The traditional method does not enforce intelligence into the path planning and it includes Graph Searching Techniques, Artificial Potential Field, cell decomposition method, Vector Field method, Road Map method. The soft computing methods introduce intelligence into the path planning and contain Genetic Algorithm, Ant colony Optimization, Swarm algorithm, neural networks, and Fuzzy logic. The Bio-Inspired Algorithm [7] is also applied in finding a path at mobile robot where the process of finding a solution is compared with any one of the characters of biological systems. Either the action of mobile robots in finding a path or avoiding the obstacle can be derived from the intelligence of an animal or bird behavior. In Bug algorithm, a sensor is used to detect an obstacle and to minimize the outer perimeter of an obstacle usage without the need of a map and response to the output based on a sensory contact. The path planning has been demonstrated using different types of Bug Algorithms like Bug1 [8], Bug2 [8] and Distbug [8].

3.1 Conventional Methods

The traditional method solution is deterministic and it needs an exact input data for accurate path planning of a robot. It is tolerant of imprecision, uncertainty, provides a partial truth and approximate solution for a problem when a mobile robot allows to take a decision while travelling. The operations are performed in a sequential manner by using a binary or crisp system. Researchers have proposed many search techniques under this method in order to find a comprehensive solution from source to destination in the search space. Each algorithm shows a separate result with the subset of solutions in static or dynamic environments.

3.1.1 Graph Searching Technique

The graph searching technique is the simplest method for finding a path using a mobile robot. It is a well-defined, very efficient method with less complexity in identifying a path. After the environment is constructed; the path is connected by line for robot travels, which is safer for target achieving. It will continue until finding a better optimal solution from one node to another node. If the robot reaches the particular location, it is further allowed to proceed to the successor location and this can be implemented using a Depth First Search [9] or Breadth First Search [10].

In [11], Singh et al proposed an "Optimized path planning algorithm" which gives best new path compared to Dijikstra's algorithm [12] from a single source to destination. This proposed algorithm contains four steps. The first step deals with object growing and produces an actual space for mobile navigation. The second step produces a complete graph by connecting all the edges of obstacles by an autonomous mobile robot and it is better than a meadow map technique. The third step allows the Dijikstra's algorithm to find a path from source and destination and final step allows the optimized algorithm to find the optimal solution with less cost and energy.

In [13], Robotin et al explained about D* Algorithm (by Anthony Stentz, 1995) [14] where the robot navigation takes place in an unknown environment to given goal parameters. When the robot knows about the obstacles position it finds the optimal path from source to destination. If any unknown obstacles interrupt, it adds a new location in the map and preplans the other best path from the current location to goal destination. The authors explained the path cost estimation of the robot, by considering a *start* '*S'* and *goal* '*G*' node in a graph. The heuristic function used for the estimation of the cost of robot path is,

$$f(A,M)=h(A)+g(A,M) \quad (1)$$

where,

- f(A, M) is the estimated cost of the robot path
- M is the current state of the robot
- *g (A, M) is* the cost of robot position from *M* to *A*
- *h(A)* is the sum of estimated cost from *A* to the *goal* node

In fig 1, the movement of the mobile robot from one start node to the goal node through the number of obstacles ha been shown and the total cost of the path plan can be estimated using the equation given in Eq. (1).

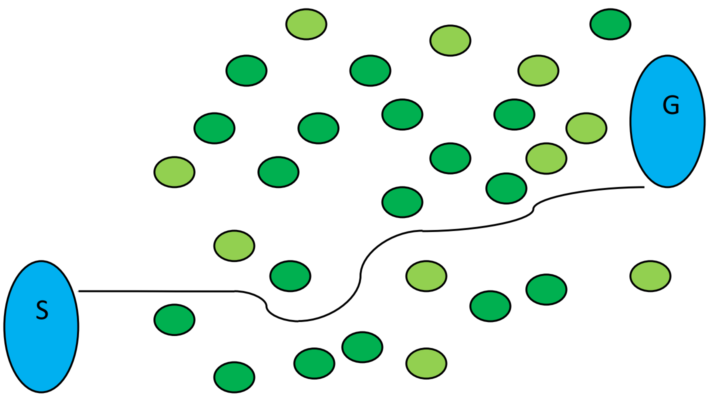


Fig 1. Optimal Path From Start Node 'S' to Goal Node 'G' by Mobile Robot

3.1.2 Artificial Potential Field

The Artificial Potential Field (APF) technique is a nature inspired using the combination of positive and negative charge. It is a reactive approach designed to traverse in a path without colliding with the obstacles located around itself or either in a static or dynamic environment. In this method, two forces play a major role in achieving the optimal path plan from a particular source of the goal. A mobile robot moves towards the goal with the help of an attractive force which proceeds with the negative charge. If the robot moves towards the obstacle it is pushed back with the help of a repulsive force by the positive charge. It is achieved in a robot by reducing down the potential using gradient descend method to reach a destination while avoiding the obstacles. Then the potential field is calculated from the robot position and then calculates the induced force from the field. This method suffers from Local minima problem and high complexity due to its bi-operational path model.

In this method, the local minima may occur when all the vector field from obstacles and the goal point cancel to each other, so the path never to reach the goal. The local minima problem can be overcome by backtracking from the original position, by doing some random movements from the current location, or use any one of the Bug Algorithm (using Point Bug Algorithm) [15] for obstacle avoidance. This local minima problem can also be solved using some Soft Computing Techniques as discussed in Section 4. Hossein et al [4] explained about path planning for a mobile robot using APF in which the workspace for a mobile robot is divided into rectangular cells of grids where each cell is obtained as an obstacle or non-obstacle. Then they evaluated the potential function for each cell based on the distance estimated from the source, obstacles, and destination by an autonomous mobile robot. This evaluated value is used to find the optimum solution from all the possible paths. The authors assumed two-dimensional workspace with 50*50 cells and a robot made to fit in one cell where another cell is either empty or occupied with an obstacle. The formula for calculating the potential function for every empty cell is defined as follows:

$$P_{Total}(C) = P_{Start}(C) + P_{End}(C) - P_{Obs}(C) \quad (2)$$

Each parameter is calculated with separate *distance function D* is used to calculate a distance of cell from start, end and closest obstacles. The path from start node and goal node is calculated using a midpoint M. The Midpoint varies according to the position of obstacles like M1, M2….Mn.

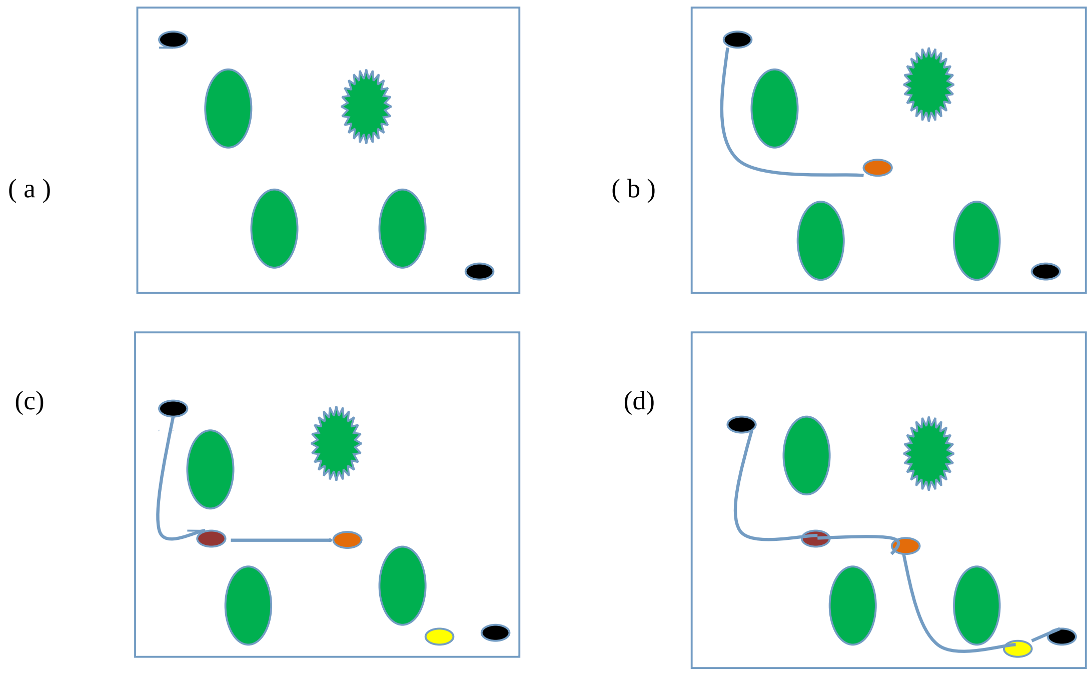


Fig 2. Formulation of the Collision Free Path Using Artificial Potential field.

In the figure,

(a) represent the obstacles in the path.
(b) represent midpoint M2.
(c) is the midpoint M1 from start node to the previous midpoint M2.
(d) is the midpoint between M2 and Goal node.

By connecting all the Midpoints it forms a smoother path if the obstacles increase the process of finding a midpoint iteratively increases until reaching collision free path. In the paper, the authors also calculate time and space complexity for finding the path. The APF is the basic method for path planning for mobile robot and proposed strategies for reaching a goal by using a formula for repulsive force and attractive force in [17]. In the work, authors showed APF suffers from the issues like Local minima and high complexity while travelling on the path.

3.1.3 Vector Field method

A Vector Field (VF) method is a fast, reliable and computationally efficient method when travelling through the path which is densely populated obstacles. In this method, obstacles are represented using a histogram grid. The histogram is a well suited for inaccurate sensor data with three major components, namely Cartesian Histogram grid, Polar Histogram and Candidate Valley.

The Cartesian Histogram Grid: The robot ranger sensor is used to construct a Two- dimensional Histogram Grid and which is further reduced to a One-Dimensional Histogram called as Polar Histogram. The sector with less polar densities below the threshold is considered as a candidate Histogram. As an enhancement of VF method, the VFH* has been proposed in [18] that explicitly deal with a local path planning by not ensuring with global optimal. The VFH* algorithm verifies the command produced based on the heuristic objective function using A* algorithm.

In [19], Jianjun et al proposed an improved VFH for path planning of real-time robot when the environment is unknown and dynamic. The ratio parameter for the area to be covered has been proposed by considering the size of the robot and obstacles [20]. The authors also used the Fuzzy Logic module to effectively avoid the obstacles in the dynamic environment. The proposed technique rectifies the accumulated error, need of large grid space for storage and also overcomes the local minima problem. The area of an obstacle in the robot perception space is calculated using the following equation.

$$P_i=\alpha_i(x^2-y_i^2)/2 \quad (3)$$

Where,

- P_i is the projected area
- α_i is the subtended angle of a robot in i^{th} obstacle
- y_i is the shortest distance between the robot center and i^{th} position of the obstacle.

The association of the function is used as a Fuzzyfication method of input and center of gravity is represented as a Defuzzyfication of output. In this work, the result evaluation has performed, using Mobotism software, under two different scenarios, namely Experiment under Destination Unreachable state and the Experiment under Dynamic Environment. Similarly, the process of avoiding obstacles by the mobile robot has been tested in the USARSim [21-23] environment using the real time path planning method called Vector Field Histogram.

3.1.4 Road Map Method

A Road Map (RM) method [26] is used in a mobile robot to solve the problem of determining the optimal path plan from one location to another location. The working of RM method has been segregated into two phases, namely constructional phase, and a query phase. In the constructional phase, the path graph is built from the source to destination along with the obstacles. In query phase, only the source and the destination location are provided and information about the obstacles or any interruption in the middle are not specified. The mobile robot chooses the best suitable and easiest path among n-number of possible paths using algorithms like Dijkstra shortest path. The Road Map method can be further divided into two approaches for path planning, VORONOI Diagram, and Visibility Graph.

3.1.4.1 VORONOI Graph

Voronoi Diagram (VD) is a sensor based motion planning algorithm and it can be applied specifically to the static environment. It is the process of capturing a path from the initial location to the final location without any collision by maintaining the gap between the obstacle and mobile robot as high as possible. Among the available path $\{p_1, p_2 \ldots\ldots p_n\}$, the robot finds a best suitable path which is interconnected by the edges provided ample free space is available between them. In [24], the effectiveness of the Voronoi diagram is justified for path planning in collision- free network and for building trajectory maps [25]. The authors used a Fortune's algorithm [26] for the computation of VDs to identify the optimal path between the source and destination points in the environment.

In [26], the authors have constructed Voronoi based Roadmaps for robot path planning for various purposed using the different optimization methods such as Path Planning for unmanned vehicles using Ant Colony Optimization (ACO) on a Dynamic Voronoi Diagram, Roadmap based Path Planning Using the Steiner Points [27] and Voronoi Diagram for a Clearance-Based Shortest Path, Real Path Planning based on Genetic Algorithm and Voronoi Diagrams and Motion Planning for mobile robot Navigation using combine Quad-Tree Decomposition [28] and Voronoi Diagrams.

In [29], Martínez et al. compared the performance of the VD with respect to the the Potential Field technique based on the simulation results obtained using path planning using mobile robot. Authors used Delaunay triangulation [30] method to determine the midpoints along with VD to avoid the road or path that blocks the mobile robot while navigating. In [31], the authors implemented Voronoi diagram to extract the obstacle free path in the robot nagavigation environment using the Fast Marching Method. The proposed method combines sensor and also map based operations in order to provide a reliable motion plan to the robot.

3.1.4.2 Visibility Graph

In a robot motion planning, a Visibility Graph (VG) is an inter-visible location for the set of points (nodes) in the searchspace. Each node represents a particular location and each edge represents a visibility between them. In this method, the path of a mobile robot is closer to the obstacle when compared to the VORONOI Graph method. The VG technique performs the path planning by formulating Hamiltonian Cycle [32] using the combination of the position of the source, the destination and the obstacles vertices in the graph. The VG technique takes the graph as the input and forms a polygon of paths around the obstacles between the source and destination nodes.

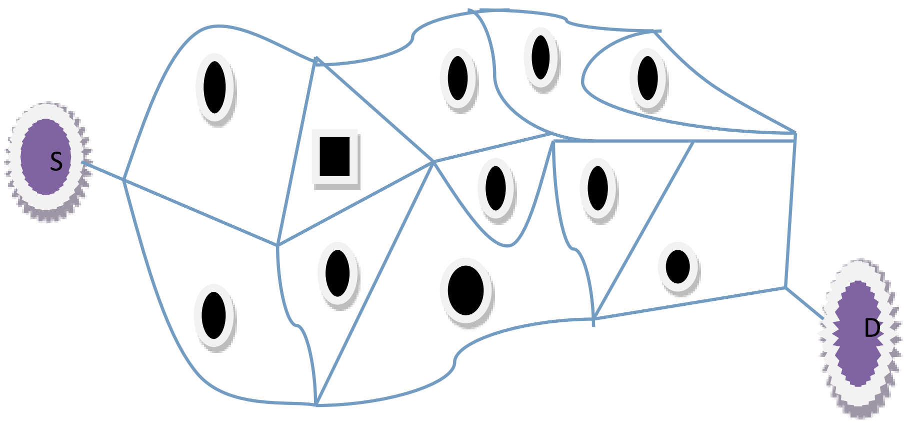


Fig 3. The Visibility Graph Formulation Between the Final Goal Vertex 'D' From the Source Vertex 'S'

In [33], authors used VG to generate a series of intermediate approach which allows the mobile robot to reach the final position by avoiding local minima. Authors The problems in a mobile robot like velocity constraints, kinematic constraints, and non-holomonic constraints are considered for finding the best optimal solution. In [34], Kaluder et al. proposed the modified VG using Asano's Algorithm [35] in which CGAL library is used for implementation to achieve the low complexity in path formulation.

In [36], authors used Polygon Aggregation in addition to the VG to reduce the path computuation time in the obstacle abundant search environment. The search-based, sampling-based or combinatorial Planning is the approaches commonly used in Path Planning. In [37], a modified visibility graph is used to reduce computation time based on a combinatorial planning in mobile robot when several obstacles in an environment. In [38], a minimal metric obstacle avoidance path is achieved using a visibility graph through the communication between the obstacles based on the ray shooting technique.

3.2 Soft Computing Methods

The term Soft computing was coined by Lotfi A. Zadeh in 1981 [39] which is the process of solving the complex problems whose solutions are unpredictable, uncertain with large search space. This provides an approach to derive a near-optimal solution rather than obtaining an exact optimal solution.

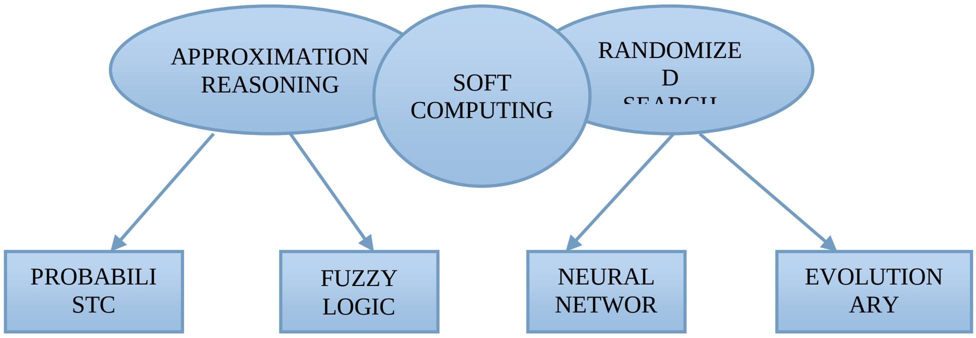


Fig 4. Varieties of Soft Computing Methods in Robot Path Planning

It is used when the user doesn't have enough information about the problem search space in which the optimal solution resides. It is a tolerant of imprecision, lower cost, partial truth and have high machine intelligent quotient that enables the system to act with Artifical Intelligence. Soft computing resembles the biological processes rather than a conventional method. Even though the path planning in the robot is performed using this soft computing, which is less complex and easy to predicate a solution rather a hard computing. The enhanced knowledge representation, flexible knowledge accession, including learning from human experts. The soft computing allows performing parallel computation and deals with ambiguous and noisy information. These advantages are implemented in robotics for path planning along with an optimal solution. The soft computing techniques involve Genetic Algorithm [40-40A], Fuzzy Logic [41], Neural network [42], Swarm optimization [43] and Ant Colony Optimization [44].

The history of Soft Computing starts from the Neural network (McCulloch, 1943) +Fuzzy Logic (Zadeh, 1965) +Evolutionary Computation (Recenberg, 1960). It is a Multidisciplinary field, in Artificial Intelligence for the construction of new generation which is also called as Computational Intelligence. In simple word, the role model of Soft computing is a *Human Brain*
It is a Mirror of a Human Being intelligence. It is characterized by the inexact solution usage to computationally-harder tasks such as the solution of NP-complete Problems where an exact solution cannot be acquired in Polynomial Time.

3.2.1 Fuzzy Logic

Fuzzy logic is widely used in controlling mobile robots. The fuzzy logic deals with neither completely true nor completely false, it represents a partial solution when a perfect solution cannot be predicted and used to solve when pattern recognition problems arise in robotic tasks with more robust. The fuzzy logic converts the human natural language into machine understanding control strategies. Here the controlling operations of a mobile robot can be performed in terms of rules when moving from one location to another and descend the loss of information between the environment experts. In mobile robot fuzzy logic is used to track a visual object by representing a color in a particular destination with the help of a sensor.

The fuzzy logic is designed to solve any problem with the machine in the same way as human does with expected time. The user must design knowledge base logic for controlling a mobile robot with a set of rules and the mobile robot produce an output based on that knowledge along with the turning ability. The fuzzy instructions could able to handle more control devices in mobile robot rather than traditional methods with the same amount of memory. This fuzzy logic allows the robot to move forward, backward, turn right, move left with the set of rules by sensing the input.

A fuzzy logic system is very difficult to implement initially, because of vague in memory, but it is easy to extend the work for future enhancement with many rules. The rules are implemented parallel in hardware and software. The fuzzy controller is the definite controller of the autonomous mobile robot which controls the robot to move in a path to reach a goal and if moves far away from path allow the robot to choose an alternate path from the current position by avoiding collisions. The advantage is Fuzzy logic sometimes produce better result rather than a human can produce in a short period of time. It is well suited for implementing a solution in the complex autonomous mobile system, but it is difficult for the simple control system.

In [45], the fuzzy logic system is used to control the angular velocity of left and right wheels for a path planning in an unknown environment using a mobile robot. The input and output variables are determined using variables. The input is measured from the obstacles to the sensor and the measure of the angle between the robot and goal. The output is calculated from the velocities of right and left wheels variables. Here they mentioned eight conditions for the detection of obstacles, left and the right wheel is operated using fuzzy control rules. The performance of a fuzzy logic system shows better performance with 24 control rules compared with the existing conventional fuzzy logic where it reaches a goal using 49 control rules.

In [46], the linear and angular velocity of a mobile robot is computed using a fuzzy logic system. The first behavior is to target an input, the second behavior is to calculate the distance from the robot and obstacles and third fusion is to combine previous two behaviors, this process continues until reaching a goal position using a fuzzy logic controller involves in searching an obstacle and path planning. The mobile robot is designed to reach a position in a less time, moving wheels in all directions and it is calculated using the kinematic formula as follows: Where B and A is the linear and Angular velocity of a mobile robot from the sensor to the obstacles and θ is the angle between the direction of the robot and target position. The mobile robot involves in three control approaches for finding a goal.

They are Goal Searching Behavior (GSB), Obstacle Avoidance Behavior (OAB) and Fusion weight behavior (FWB). GSB composed of two fuzzy controller behavior, the first controller computes the linear distance and the second controller receives the angle between mobile robot and target position

$$\begin{cases} \dfrac{dy}{dt} = B\cos\theta \\ \dfrac{dy}{dt} = B\sin\theta \\ \dfrac{d\theta}{dt} = A \end{cases}$$

OAB allows the mobile robot logic controller to move freely in an environment without any obstacle collision. FWB is the combination of above two behaviors and represents the activation degree of each behavior and graph is simulated for those approaches.

In [47], mobile robot involves in path planning from source to destination and moving operations like turn left, right, forward and reverse are performed using a fuzzy controller. The two types of fuzzy inference system are Mamdani [48-49] type and Sugeno type [50] which could be implemented in fuzzy logic toolbox. These two types are useful for thinking as a human and allow the mobile robot to move parallel to obstacles. The result is simulated using MATLAB.

3.2.2 Neural Networks

Neural Network is an Artificial Intelligence Techniques that mimics the operations and performance of the human brain. It deals with learning, optimization, identifying and tolerable. It is composed of a large number of neurons which has the tendency for storing, working simultaneously, decision making and solve the problem. The process of reaching a goal occurs by neurons using graph topology. In autonomous mobile robot neural network is used to avoid time consuming calculations. The neural network allows the robot to collect the information about the environment continuously and work without any collision.

If any information is not preloaded in memory of mobile robot the neural network allows the robot to accept the new information and provide an adequate response. Before completing a task neural network must be trained properly to produce an output with a set of functions. The training in robots can be achieved using learning process which can be either a supervised learning or unsupervised learning. The supervised learning means the input to the mobile robot is assumed to be at the beginning and output only at the end of the process because of obstacle problems in the middle of the path. In Unsupervised learning, most input and output observations are produced only at the end of the task. Like training in sports, the neural network also needs a coach, what it should be produced as a response? Here the error is determined and the position of mobile robots is propagated throughout the network. At each neuron, the weight of the error position and threshold values are mentioned. So while moving in a path, the error in the network it is further reduced with the help of the neuron.

In [51], a planetary mobile system for path planning in the autonomous robot is based on Artificial Neural Network. The three consecutive layers of input, hidden and output are considered here [refer Fig: 5]. The input layer contains two neurons for detecting the obstacles of different size fed by a mobile robot. A hidden contains read the input and forward the signals to a robot with the help of three neurons. The output layer which performs the mechanical operations of a mobile robot in various environments. The mobile robot involves in finding a path without any human interaction only with the help of neural networks. The artificial neural network is supervised using a Back-Propagation Algorithm [52] [52A]. These algorithms are proposed for calculating error signal and gaining an accurate result. The neural network is implemented using MS C#.Net 2008.

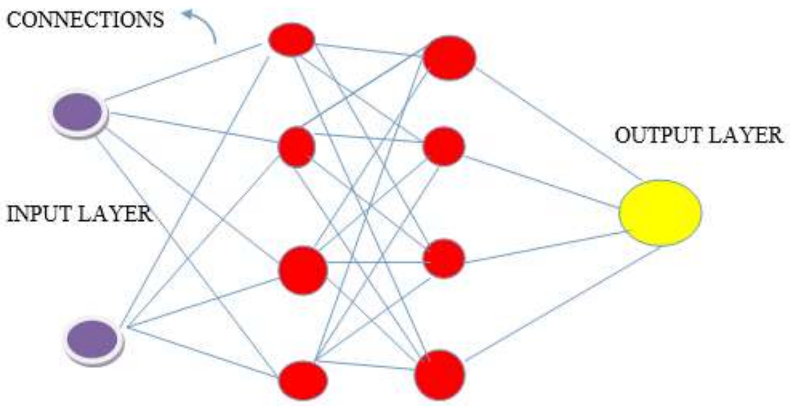


Fig 5. Overview of Layers in Neural Networks Technique

In [53], powerful assignment of mathematical problem is a neural network. The navigation of mobile robots is operated using two recurrent neural networks for avoiding obstacles in the path planning assignment. The localization algorithm [54] is proposed along with neural network for predicting the mobile robot position regarding the goal. In [55], the artificial neural network path planning algorithm is proposed to erase a traditional neural network in order to reach a goal in a dynamic environment. The robot is designed with neuron which coincides with configuration space representation, has a more positive activity for attracting towards the goal and avoids collisions by making to move away from the obstacles.

In [56], Kohonen-type Concurrent Self -Organizing Map (CSOM) [57] is used to find a correct direction among the number of paths using a neural network. In mobile robot, camera is mounted on the top to retrieve the information about the surroundings. The path of a mobile robot is classified into three classes like right, left and straight where the movement of a mobile robot is calculated and fed into SOM module.

3.2.3 Swarm Optimization

Swarm Optimization is used to reduce a total path planning time while avoiding obstacles during travel. Initially, swarm robotics are developed to allow a group of mobile robots to reach a common goal. In order to solve a more complex problem, the optimization concept has been introduced to reach a goal by overcoming a critical situation. Recently these techniques have applied to an autonomous mobile robot application for solving a problem like estimation of unknown parameters, machine learning task, job-scheduling, less response while moving from one location to another location. The motion planning of a robot contains many obstacles in the path in work space produce an optimal solution which is more effective than other techniques. This algorithm allows the robot not to lose its ground path truth and how to move around safely and effectively by making a decision within a reasonable computational cost. The output of swarm optimization is ten times faster than fuzzy logic.

In [58], the swarm robotics concept derived from the nature group of animals and birds. Each autonomous mobile robot combines together forms a swarm. The robot swarm communicates each other using cooperative algorithm key component. The modules are divided into three like information exchange, basic and advance settings. In information exchange module communication occurs via direct communication, communication through an environment and sensing is explained. The swarm robotics optimization modeling is also based on sensor modeling, macroscopic modeling [59], microscopic modeling and swarm intelligence algorithm [60]. The cooperation between robots occurs through locating, physical connections, self-organizing, and self-assembly. The obstacle avoidance and path planning occur using swarm intelligence algorithms like Glowworm Swarm Optimization [61] [61A] and Particle Swarm Optimization inspired search algorithm (PSOISA).

In [62], the optimization problem with proper solution is identified using Particle Swarm Optimization (PSO) [63] [63A]. The process of finding a proper minimum value is discovered in solution space using the PSO search method and evaluation function is calculated for every particle based on position goal of mobile robots in PSO. The new navigation method based on the PSO algorithm consists of three steps: I) To evaluate the fitness of each particle. II) Updates the local, global and best fitness of each particle. III) Update the velocity and position of each mobile robot. The robot is simulated using websites [64] [65] and PSO algorithm, simulated using MATLAB calculates the optimal point. The robot with 16 infrared sensors is used to detect the obstacles within 20 cm radius.

In [66], the collision free path is found by satisfying some criteria like shortest path, security, feasibility, and smoothness. The dynamic multiswarm particle optimization (DMS) [67] is proposed to obtain the better path planning solution with security consultants and result is shown using the Bezier Curve.

The Ferguson curve [68] is used to describe the path in path planning problems. The DMS-PSO algorithm solves the problem of path planning using some functions like punitive function where the security and shortest path is calculated and in objective function, the path length is calculated. Both curves show the better result for DMS-PSO compared to simple PSO.

In [69] problem of path planning in the mobile robot is realized using search space in Particle Swarm Optimization is achieved using model path called Ferguson Splines (FS) [70]. FS is defined by an equation as follows:

$$K\text{: } y(t)=A_0V_1(t)+A_1V_2(t)+A_0'V_3(t)A_0'V_4(t)$$

Where V represents the vectors, A denotes the multinomial functions of Ferguson and it is the parameter for calculating time frequency. The algorithm is compared with Visibility Graph and Potential field due to the local minima problem and found the shortest and smooth best optimal solution path within 30 iterations.

3.2.4 Ant Colony Optimization

Ant Colony Optimization is similar to nature of group ant behavior in finding a food. This represents how ants find a path like that mobile robot involves in identifying a path among several feasible solutions. Each ant communicates each other by dropping a pheromone while travelling in a way. The ant tracks the path by following the pheromone left by the previously travelled ant and reaches the goal. When an ant finds the obstacles in the middle it neglects and finds any alternate path for reaching a goal, likewise, an autonomous mobile robot involves in searching a path when any interruption occurs in the middle. The artificial ant mobile robot involves in finding a path faster by following a previous ant which produces more pheromone in order to find the shortest path.
Likewise, in autonomous navigational mobile robots, each robot communicates with each other using signal strength instead of a pheromone. The mobile robot senses the signal from the previously travelled robot and follows that path for reaching a goal by using a sensor. So the time consuming is reduced and also obstacles are detected as soon as possible. The current research on ACO involves multiple objectives, dynamic modification and stochastic nature of an objective function and constraints.

In [71], the mobile robot path planning on reaching a collision free target point is achieved using an Ant Colony Optimization evolvement Algorithm using the ability of Ant Colony Searching food. By using the user interface the obstacles on the platform can be set by a user in grid platform. Resembles the Ant colony, the nest is represented as Start position and food is denoted as Target point and MEMO is used to store the motion of a mobile robot. The mobile robot moves in a blind alley and each movement is stored in a MEMO for avoiding existing path. Here four types of Obstacle avoidance are implemented using Ant Colony Optimization and also involves lack of stability, low searching ability, premature convergence.

In [72], the Ant Colony Algorithm based on Genetic Algorithm is used to obtain the shortest path in two dimensional grid environment. The robot understands the environment using the corresponding matrix such as 1 for free grid and 0 for obstacle grid. Initially, Information inspiration factor, hope inspiration factor, pheromone intensity, and environment coefficient are required to take a tour of getting a complete path. The compared graph is shown for Genetic Algorithm Ant Colony Optimization which is more effective than normal ACO. In [73], allows the mobile robot to find the optimal path in a dynamic environment using swarm optimization. The ant moves from starting position occupy one of its adjacent positions in four different directions and finally reach the target resembles the mobile robot. The ACO algorithm task is obtained using Pheromone initialization The Pheromone re-initialization like Local and Global initialization occurs when obstacles are added. The grid size of 20X20 is used where the x-axis represents the path length and y-axis points run-time simulation in python.

In [74], for an optimal path generation, the mobile robot path planning in the warehouse by avoiding obstacles utilizes an Ant Colony Optimization. ARPP algorithm for path planning is proposed to take a tour from source to destination and reduce the exploitation of existing solution using global Updating rule and local Updating rule. The number of iterations versus the distance travelled by an ant is calculated using trails. In [75], the set of Artificial ants involves in finding a path by depositing pheromone throughout the search space. The path planning algorithm is Starts from Source point X_s (starting point) to X_g (Goal point). If a robot moves from source to adjacent or new point is denoted as X_n (new paint) and it calculated by summing up current position and step size with dimension angle (Θ) as follows:

$$X_n=X_p+step*\cos(\Theta) \text{ and } X_n=X_p+step*\sin(\Theta)$$

The flag value is set for encountered the obstacles while travelling and if it so moves three steps back. The process of bypassing the obstacles in the navigational robot is achieved, which is far better using an ACO algorithm by overcoming the failures like allocation of tasks over time.

3.2.5 Genetic Algorithm

Genetic Algorithm is a meta-heuristic search algorithm that resembles the performance of natural selection. It belongs to the larger scale of evolutionary algorithms for generating a solution for optimization problems. The genetic algorithm output solution totally depends on the current application performance, which is not decided by using the prior or initial solution. Likewise, in a mobile robot the path is chosen based on the response from the environment by avoiding the obstacles and it is free from collision for reaching a goal. The genetic algorithm is used to avoid a local minima problem and high computational problems. The genetic algorithm also used to solve the degree of freedom and inverse kinematic problem when an object moves without any force. The genetic algorithm's strength enhanced from the search of the solution space via a candidate solution of the population.

In the genetic algorithm, consider the path from the source to the destination, when the robot hits the obstacle the robot moves three steps from the current location and moves towards the goals. The position of a robot varies according to fitness functions of obstacles. The parameters are calculated using an artificial neural network set of solutions. The path from the current obstacle position to the goal is called as an objective solution. If the mobile robot never hit any obstacles and reaches the goal, then it is calculated as a candidate solution. If the objective solution is greater than the candidate solution, then it is not an optimal solution for a mobile robot for travel. Suppose if the candidate solution is lesser than the objective function, it is calculated as best optimal solutions by comparing the parameters. In [76], Boustrophedon Cell Decomposition Method [77] is used in a mobile robot for environmental modeling using Genetic Algorithm. The Genetic Algorithm used to obtain Optimal Coverage allows the mobile robot to reach the target. The effectiveness and relationship between parameters of Genetic Algorithm and search space method are shown using simulation.

In [78], the two layers genetic algorithm is used to obtain an optimal solution based on grid environment. The first layer denotes the Static Obstacles Avoidance and second layer operation deals with dynamic obstacle avoidance. The fitness functions for two layer algorithm is calculated using global optimization searching tool simulation. In [79], it is similar to the previous paper, where grid map is used to denote the mobile robot movement in the environment. The newly proposed genetic operators are obtained in achieving a better optimal solution by avoiding obstacles and it is simulated.

In [80], the process of finding a feasible path in a mobile robot using a genetic algorithm is achieved using a new mutation process called Hill Climbing method [81] avoids premature convergence. The environment is represented using two ways by the way of orderly numbered grid or by coordinate plane. The chromosome in path planning mobile robot represents a candidate solution. The chromosome consists of the start node, end node and the node where the robot travels in a path. The movement or steps in a path are called as chromosome gene. Binary coded string and decimal coded string need less space and memory is used to create chromosome. While generating an initial population each chromosome is checked whether it collides obstacles. The objective function is calculated by summing up the next each node path distance. The direction of a robot is calculated as:

$$\alpha = \tan\text{-}1 \frac{(V_{(i+1)} - V_i)}{(H_{(i+1)} - H_i)}$$

Where $V_{(i+1)}$ and $H_{(i+1)}$ denotes the next step of a mobile robot and V_i and H_i represent the current position of a mobile robot. The new algorithm checks all the nodes instead of selected nodes for finding the optimal path and selects the node according to a fitness value.

In [82], path planning in the mobile robot is performed using Adaptive Genetic Algorithm [83] (AGA) by using Crossover and Mutation probabilities for finding an optimal solution by avoiding local minima. From the set of possible solutions, the AGA is used to select an optimal solution in a static environment. The function which leads towards an optimal solution represents a fitness function by avoiding obstacles. The genetic operators like selection, mutation, deletion, insertion, crossover, mobile and improvement operators are used to repair infeasible solution.

The robot speed and accuracy is investigated in each case in path planning and the result is shown which effective compared to simple GA. In [84], the mobile robot is used to find the path planning using a genetic algorithm, the initial population is established using Artificial Potential Field, the fitness function increases the weight of the value and path smoothness. To ensure the individual population collision path newly proposed flip mutation operator is added. The flip mutation occurs when nodes contain obstructions. This algorithm shows a better solution within 20 iterations with a 95 % average success in finding optimal paths with smooth collision free obstacles avoidance is simulated using VC++ compared to traditional Genetic Algorithm.

In [85], the path finding in a mobile robot in a dynamic environment is based on genetic environment, is not applied in the complete space applications only at the point in the problem space. The goal is to find the shortest path from source to destination using GA within an optimal time. The improved Genetic Algorithm is applied in Dynamic Environment and Adaptive Genetic Algorithm in Static Environment. The fitness function is calculated from the distance between the position of the robot where it stops and the destination. If hitting occurs, then three steps back mobile robot moves, then it is calculated as the objective function. The path which never hits then it is called as a candidate solution. If Candidate solution< Objective function, then it is called as a shortest path for a mobile robot. The simulation is performed in MATLAB using 20 random points which is more efficient compared to other algorithm used in mobile robot path planning.

In [86], the genetic algorithm is used for path planning in a mobile robot for local obstacle avoidance in a large problem space by reducing lower convergence speed, time consuming, computationally expensive. The path planning is defined using two specifications like collision free and optimization criteria. This paper divides the autonomous mobile robot operations into Path planning, visual detection of the environment and Control of robot to reach a target. In order to maintain robot movement the task is divided into Row-Wise Movement, where the robot is allowed to move from start to end point in row by row manner and it is allowed to move only in a forward direction and Column-Wise Movement, allows the mobile robot to move from left to right not allowed to move left back. The GA depends on encoding scheme and genetic operators of chromosomes. The chromosome structure holds the whole information about the entire travel of the mobile robot. The proposed work consists of 5 variables like: Path–Location, Path-(Location and Direction for mobile robot), Path-Flag (allows the mobile robot to move next step in a row-wise or column-wise direction), Path –Switch (allows the robot to switch back), Path-Feasibility (allows the mobile robot to find a feasible solution). The simulation is performed using these five tasks and result is shown in MATLAB which is more efficient compared to traditional Genetic Algorithm.

In [87], the path planning mobile robot in a stochastic mobile robot based on Genetic Algorithm. The Variable length representation is used to denote Genetic Algorithm Planner (GAP) [88] to generate an initial population, evaluate population and check for new obstacles and the generic fitness function is used to combine all the objectives of the problem. The vertex graph is used to represent the obstacles in ordered list and chromosome represent the path sequence in the mobile robot. The feasible path is evaluated by considering the length, smoothness, and clearness.

$$E(p)=W_d.dist(p)+W_s.smooth(p)+W_c.clear(p)$$

Where W_d, W_s, W_c is used to represent the cost, dist(p) is the distance between two nodes, smooth(p) is the angle between two nodes and clear(p) is the distance between the current location to all obstacles. The result is simulated using C language and showed the difference in
bestsolution, bestworst, and bestaverage solutions.

3.3. Hybrid Algorithm

The Path planning in an autonomous mobile robot is performed not only by using a single algorithm, it is functioned by combining two or more algorithms, even by combining the traditional method or soft computing algorithms. The traditional algorithm path planning output is dependent upon the position of the starting point, so the input task plays a major role in reaching a target. In soft computing path planning technique, the path of a mobile robot not depends upon the initial point and deals with the multi-dimensional optimization technique. The process of finding a path using an autonomous mobile robot can also be performed by combining any two or more soft computing algorithms also. By combining those algorithms, each experiment shows the different result with more efficiency.

In [88], the random method and hill-climbing method is used to find a solution to a trajectory planning problem. Minimize the time needed to explore a solution and reduce the total cost of mobility. A* algorithm is used to measure the cost from the start position to goal position and path planning prioritized decoupled approaches searches for the time space of a robot in a conflict–free path. The multi-robot path planning algorithm problem is solved and the result is shown by comparing two techniques.

4. PERFORMANCE EVALUATON

The following information shows the performance of a mobile robot in dynamic environments. The tabular column is represented by various factors. The graph is shown for factors mentioned in tabular column phase I and phase II. By watching the graph and tabular column we easily identify the results for required techniques.

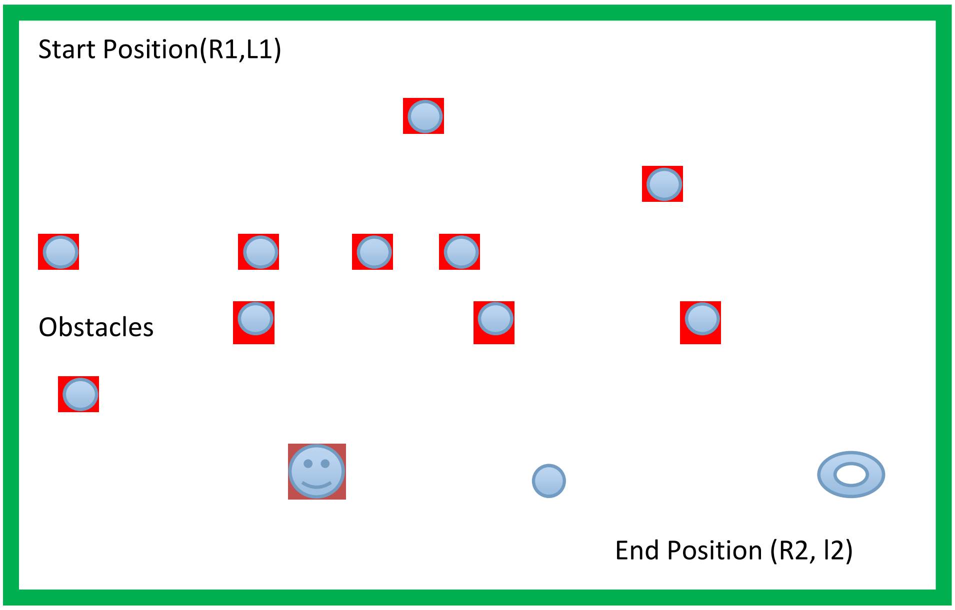
4.1 Experimental Setup

Initially, the location for a mobile robot is set up with n*n cells contains a number of obstacles. The autonomous mobile robot is allowed to move in that environment and the solution of mobile robot varies according to the position of the obstacles when an increase in the count of obstacles. The robot is allowed to move from the right bottom corner (R1, L1) is the starting point of a mobile robot where the values start from (0, 0) to goal point which is placed in the left top corner (R2, L2). The mobile robot is allowed to travel without the prior information about the position of an obstacle or in dynamic environments. The robot is attached to the Infrared Sensor for identifying or avoiding obstacles, each technique is applied in a mobile robot to simulate the different results based on parameters. If the presence of obstacles increases, the number of iterations increases. The robot is allowed to move to move Left, Right, forward and sometimes backward depends upon the position of an obstacle; the sensor is allowed to rotate at an angle of 90° or more than it. The below Table I shows the performance factors involved in the environment.

Table 1: Experimental Setup

Sl.No	Requirments for Performance Factors	Quantity
1	Environmental Size	$n \times n$ cells
2	Autonomous Single Mobile Robot	1
3	Autonomous Group of Robots	5-10
4	Number of obstacles	10-20

The below sample diagram shows the start and end position of a mobile robot with a number of obstacles inside an area. The mobile robot is allowed to take a tour from starting point by passing obstacles or by hitting obstacles.



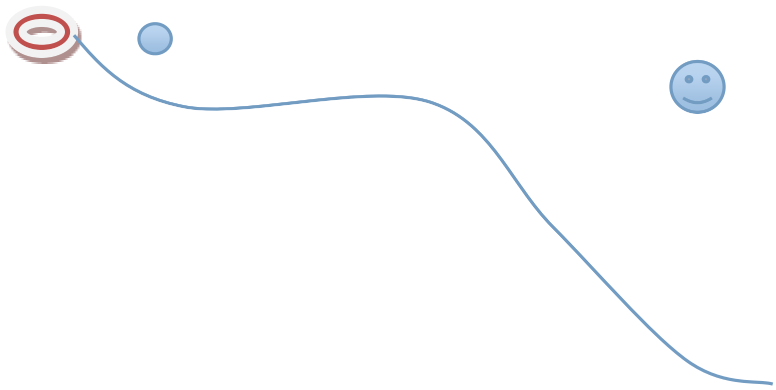


Fig: 6.: Sample 100*100 Environment with a Number of Obstacles by Representing Start Point and End Point

4.2 Experimental Phases

The experimental phases show the result of various parameters for selecting which technique is suitable for navigation by an autonomous mobile robot in a dynamic environment. The experimental Phases is divided into two phases. They are Phase I and Phase II. The Phase I based on Single Robot Phase Analysis and Phase II based on Multi Robot Phase Analysis.

4.2.1 PHASE – I: Sinlge Robot Phase Analysis

The single robot phase analysis shows the value of the various factors involved in conventional and soft computing techniques. The tabular column II mentioned below shows the factors like Shortest Path Distance (SPD), Obstacle Avoidance (OA) and Elapsed Time (ET) represented with various units. The Phase I tabular column II shows the values for each factor measured in

Table II. Performance of Different Path Planning Technique in Phase I of Evaluation

Sl. No	Factors	Conventional Technique					Soft Computing Techniques		
		Artificial Potential Field [89]	Vector Field Histogram [90]	Road Map		Graph Searching Technique [93]	Neural Network [94]	Genetic Algorithm [95]	Fuzzy Logic [96]
				Visibility Graph [91]	Voronoi Diagram [92]				
1	Shortest Path distance (SPD) (m)	35.43	99.45	41.67	40.21	37.22	34.65	**34.11**	35.32
2	Obstacle Avoidance (OA) (mm)	3.5	3.2	3.45	**3.107**	2.73	4	3.99	3.83
3	Elapsed Time (ET) (min)	**3**	9.55	10.78	9.32	10.47	8.21	8.2	8.99

Table III. Performance of Different Path Planning Technique in Phase II of Evaluation

Sl. No	Factors	Conventional Techniques			Soft Computing Techniques			Hybrid Techniques	
		Artificial Potential Field [97]	Road Map		Genetic Algorithm [100]	Swarm Optimization [101]	Ant Colony Optimization [102]	Ant Colony + Genetic Algorithm [103]	Ant Colony + Fuzzy Logic [104]
			Visibility Graph [98]	Voronoi Diagram [99]					
1	Shortest Path Distance (SPD) (m)	39.21	42.34	39.59	36.25	35.51	**34.98**	36.92	37.97
2	Obstacle Avoidance (OA) (mm)	3.36	2.91	**2.87**	3.89	3.91	4.01	4.1	4.07
3	Elapsed Time (ET) (min)	37.54	38.62	38.83	36.69	35.92	**35.027**	36.309	37.1

100 m *100 m square environment. With 10 obstacles in the path. The reference paper cited in Table II can be referred for enhancing separate techniques for each paper. The below sections shows the values used in different factors and comparison between them.

Shortest Path Distance (SPD): The Shortest path between the source and destination is measured in Meters using many approaches represented in Table II. The **Bar Diagram shows the** Genetic Algorithm is suitable for finding the shortest path among many algorithms between source and destination with 34.11m and it is followed by a neural network with 34.65m.The visibility graph finds the path with 41.67m which takes more distance compared to other techniques to reach a destination. This Bar diagram represents Soft Computing Technique is better when compared to Conventional Techniques which is less complicated.

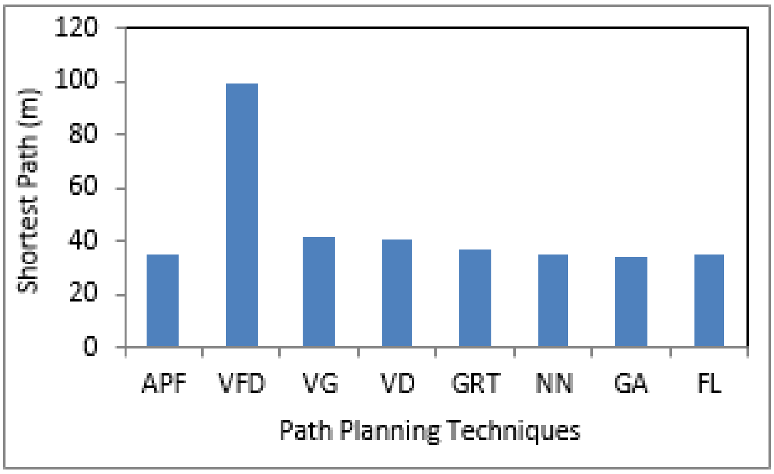


Figure 7: Pictorial Representation of Shortest Path Distance in Single Robot

Obstacle Avoidance (OA): The process of finding obstacles is achieved using techniques mentioned in Table II. The obstacles can be identified by an autonomous mobile robot from current position; the distance between the current position and obstacles is measured in Millimeters. The Table II shows the neural network is better for Identifying an obstacle before 4mm distance from the current position of an obstacle. The vector field Histogram is very slow in identifying obstacles where it finds obstacles before 3.2mm distance from current position; sometimes it may hit the obstacles and travel in a path which is shown in Figure 8. This also represents Soft Computing is better for finding an Obstacles within a short distance when compared to Conventional Techniques.

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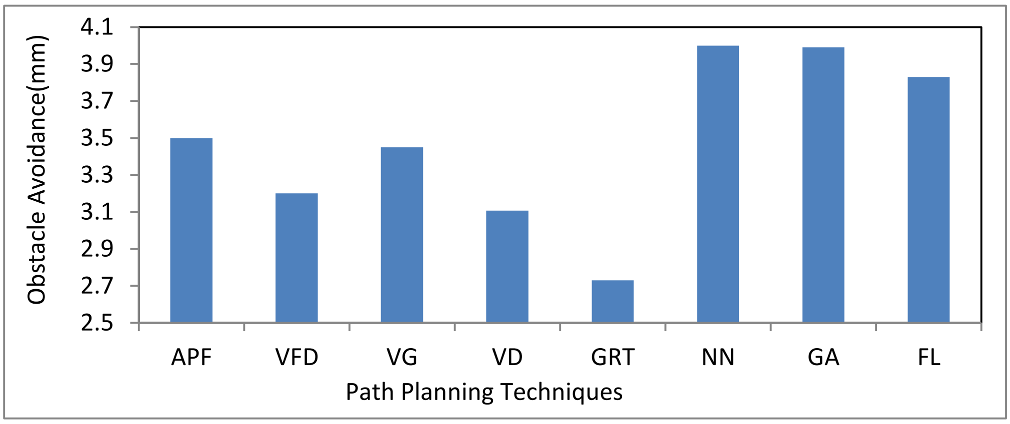

Figure 8.: Pictorial Representation of Obstacle Avoidance in Single Robot

Elapsed Time (ET): The total time taken by the mobile robot is calculated in minutes, from source to destination. The genetic algorithm takes less time for reaching a target within 8.21 minutes where the visibility graph consumes more time for reaching a position with 10.78 minutes and remaining techniques are closer to genetic algorithm elapsed time which is shown in Table II and Figure 9. Here it shows Soft Computing Techniques is far better compared to Conventional Techniques.

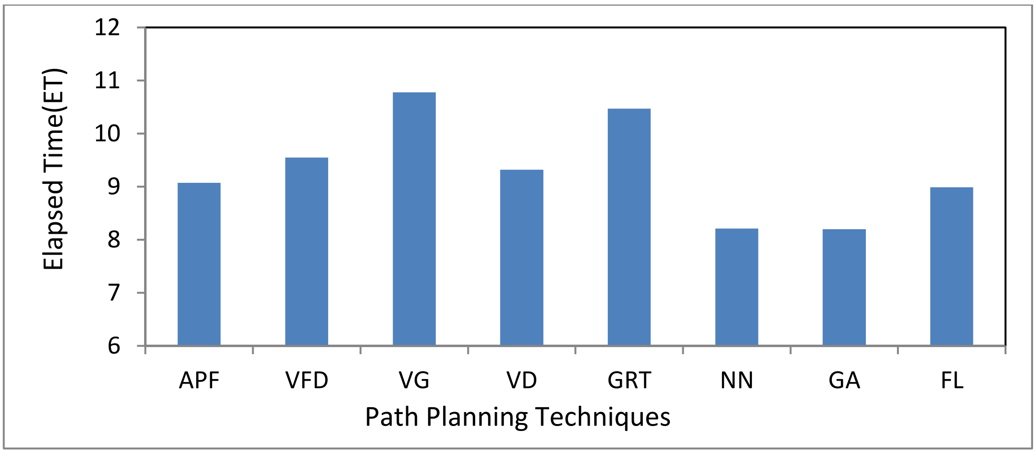

Figure 9: Pictorial Representation of Elapsed Time in Single Robot

6.2.2 PHASE – II: Multi Robot Phase Analysis

The Multi robot phase analysis represents the various factors value involved in conventional, Soft computing techniques and Hybrid techniques. The reference paper factors show value used in a group of the robot for finding a solution by considering the start and end position. The hybrid technique shows the combination of two or more techniques together to produce a result. Like Phase I, Phase II deals with the factors like Shortest Path Distance (SPD), Obstacle Avoidance (OA) Distance, and Number of Robots and Elapsed Time (ET).The reference represented in Table III denotes the technique for each paper which can be enhanced further. Here the solution is identified by considering 5 mobile robots in the 100m*100m secure environment with 10 obstacles in the path. Each factor shows different views for choosing a better algorithm for future enhancement.

Shortest Path Distance (SPD): The shortest path between source and destination is calculated using conventional, soft computing and Hybrid algorithm. The Ant Colony Optimization in Soft Computing techniques finds the shortest path with 34.98 meters where the visibility graph reaches the destination after travelling 42.34 meters.

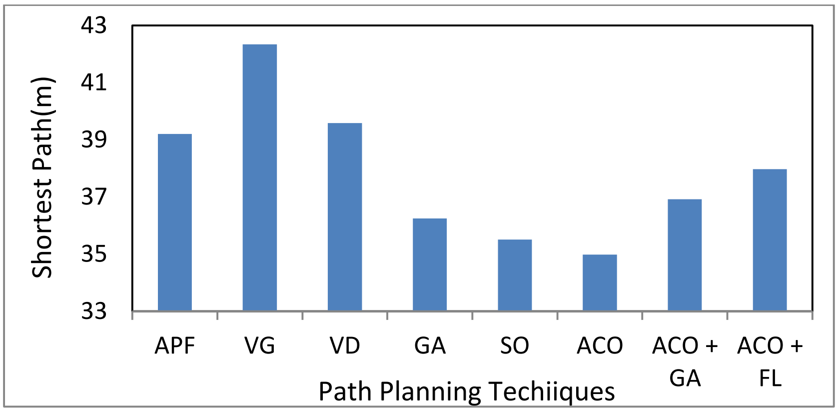

Figure 10: Pictorial Representation of Shortest Path in Mutiple Robots

The Hybrid algorithm also involves in reaching a target where the combination of Genetic algorithm + Ant colony Optimization reaches a destination in 36.92 meters and the combination of Fuzzy Logic + Ant Colony reaches a target position of 37.97 meters, which shows the soft computing techniques is better for finding the shortest path from source to destination which is shown in Figure 10. For Future enhancement, we can use any one of the soft Computing Techniques or Hybrid Algorithm for a better path solution.

Obstacle Avoidance (OA): In obstacle Avoidance factor, ant colony Optimization identifies an Obstacle before 4.01mm from the current position of a mobile robot, where Voronoi Diagram identifies an obstacle while moving closer to obstacles with 2.87mm.The values are mentioned in Table III and the Comparison is shown in Figure 11, Where it shows the distance of a group of mobile robots involves in finding obstacles while traveling from source to destination along required path.

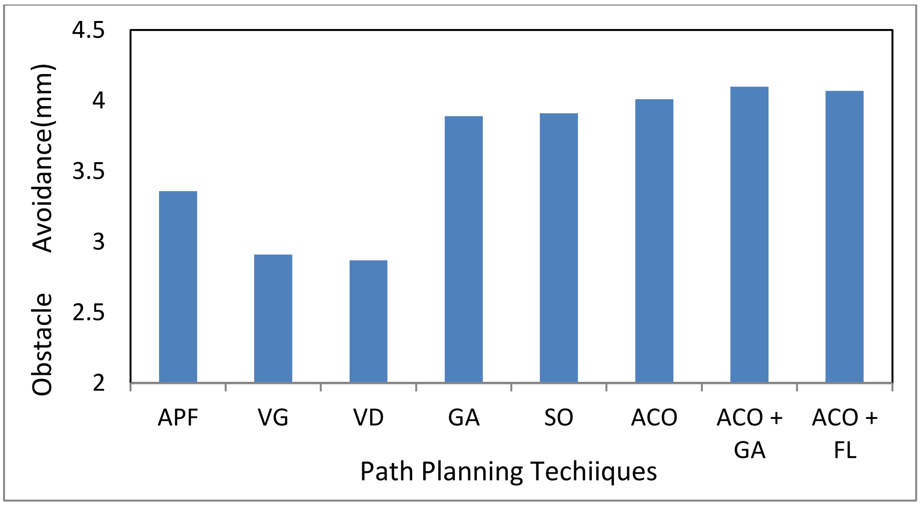

Figure 11: Pictorial Representation of Obstacle Avoidance in Multiple Robot

For a group of mobile robot, Ant Colony Optimization plays a major role in identifying an obstacle with IR sensor where Conventional Technique performance is not much better compared to Soft Computing Technique.

Elapsed Time (ET): The time taken for reaching a target by a group of a mobile robot in Ant Colony Optimization is only 35.027 minutes while Voronoi Diagram takes more time for reaching a destination.

The values are properly mentioned in Table III. The time taken by a hybrid Algorithm is also mentioned, which is more effective compared to Conventional technique, but less Effective compared to Soft Computing Techniques. The Value Comparison of Total time taken in shown in Figure 12.

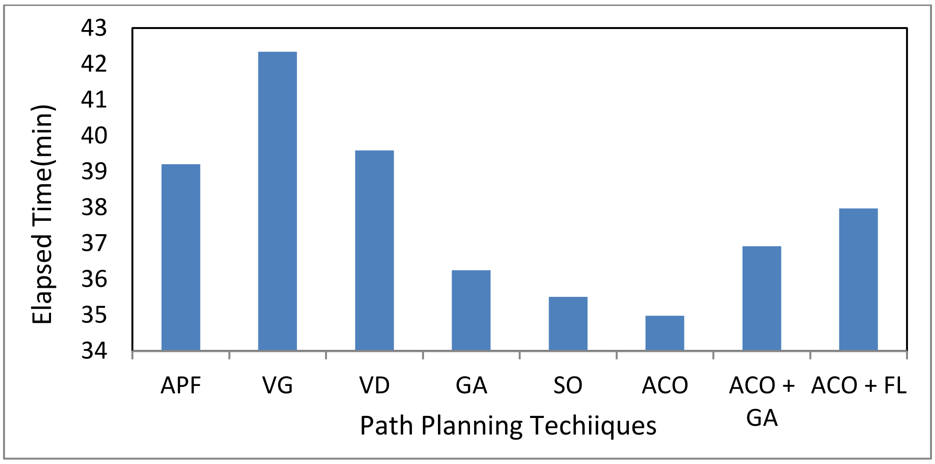

Figure 12:Pictorial Representation of Elapsed Time in Multiple Robot

4. DISCUSSION

To Summarize, the factors involved in Phase I shows better results for path planning in the single autonomous mobile robot. Each Factor is applied for each Algorithm to gain a solution which shows Genetic Algorithm is suitable for finding a Shortest Path Distance which is calculated in meters, for Obstacles Avoidance Neural Network plays a major role which is measured in Millimeters and for measuring a time in Minutes the genetic Algorithm is good for reaching a target in a few minutes compared to other techniques. Thus the required solution shown in Phase I represents Soft Computing is better for Path Planning by an autonomous Single Mobile robot. In Phase II the factors are involved in calculating path planning in Multiple Robots. The Shortest Path Distance factor is applied in Conventional and Soft computing techniques, but better result shown in Ant Colony Optimization which is a soft computing technique. In the process of finding an Obstacles, here also Ant Colony Optimization playing a major role. In the third factor, Ant colony Optimization (ACO) takes less time for reaching a target compared to other techniques. The Hybrid Algorithm is also more effective in finding a better solution like Computing method, but less complex for merging two or more Algorithm.

From the Phase I and Phase II overall view Soft computing Techniques shows better results for finding a shortest path, Obstacle Avoidance and Elapsed time where Conventional Techniques also involve in finding these factors but it shows only less effective results.

5. CONCLUSION

The different path planning algorithm for an autonomous mobile robot has been endured with various techniques. Each technique has its own advantages and disadvantages. Each section shows the different approaches used for Path Planning in Autonomous Mobile Robot in both Static and Dynamic Environment. This work showed complete survey on various mobile robot path planning techniques that can optimize the robot path. Simulation results justify that softcomputing algorithm especially ACO based path planning outperform traditional methods, both in the perspective of single and multi-robot path planning, based on the factors such as shortest path distance, obstacle avoidance, elapsed time and high computational problems. This survey can offer better assistance in the understanding of the path planning techniques and also guide researchers to formulate novel techniques for improved path planning in both single and multi-robot environments.

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