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Robot Navigation and Path Planning Techniques Challenges: A Review

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***Abstract*—Robotics is the current blooming technology in tl world with tremendous applicatons in different fields. Autonomous robot which work without human administrator. Localization, motion control and path planning are the key process for the navigation of autonomous robots. The various algorithms based on these parameter are studied for robot navigation in given environments.**

***Index Terms*—Autonomous, Navigation, Path planning, localization, motion control and Search algorithms.**

I. Introduction

Robotics is the technology that bargains with the plan, development, activity and utilization of robots, just as computer framework for their control, feedback criticism and data handling. Robotics is a latest emerging technology which will greatly effect the society in future. Now day's different type of robots are being developed and are put to different applications and uses [1].

Self-learning robots, which work without human guidance, are required in automation field. Now a day's, a number of robots work in different sectors like houses, offices, hospitals and industries which effect human life greatly [2]. For a mobile robot to navigate in given environment, basically, focuses on two tasks viz localization and navigation. In this context, localization refers the position of robot in its frame of reference. Moreover, robot navigation refers to robot movement with obstacle avoidance in the given environment. The problem with navigation is to find secure path when there is dynamism in the given environment [3].

A. Robot Navigation

Navigation is the ability of robots to generate an optimal path, to find desired location by avoiding obstacles and conserve energy [4]. Robots are machines which mimic human activities through sensors for input, actuators for decision making and effectors for output. To build up every part can be tested, sensors must almost certainly recognizes things like pictures and sounds precisely. Effectors must be flexible and quick enough to do what they require them to do. Control framework needs to settle on everyone of the important choice to get the sensors and effectors co-operate. The architecture of navigation environment is as presented in Fig.1: [5].

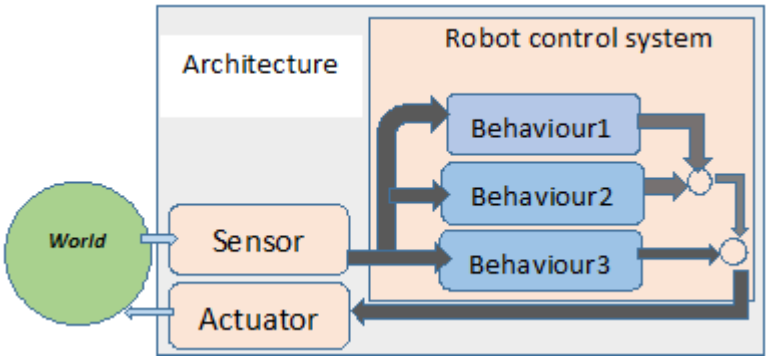

Fig. 1. Robot Navigation

The capacity to explore in obscure environment is significant in people. For example, if we human want to cross a road, if there is no vehicle we cross the road safely. But if there is movement of vehicle on the road we focus on the vehicle coming toward us, then we wait and notice the approximate time to reach there. Then we decide wether to cross the road or not. In order to mimic human, so the robot has ability to navigate in dynamic environment without collision [6]. For mobile robot to navigate in the dynamic environment, where there are number of vehicle and human is challenging task because of complex structure of given environment. To overcome the problem of path planning, various algorithm based on deterministic, non-deterministic algorithm and neural network are developed [2]. Researcher try to predict the motion of moving obstacles and human being. Presently, robots are able to recognizes the objects at some distance and change their path. Navigation in unknown environmentis presented through position and orientation [7]. In future, robots move successfully from start to goal by avoiding dynamic obstacles in the path. Now Robot can take their own decision without human operator. In robotics, navigation is the ability of robot to find its path while moving from source to goal successfully. Navigation is based on three basic questions which are as: Where am I ?. This states the mapping probem of the unknown environment. Where am i going? This staes the localization problem. What is the best way to get there?. This states the path planning problem which are as shown in Fig.2: [8].

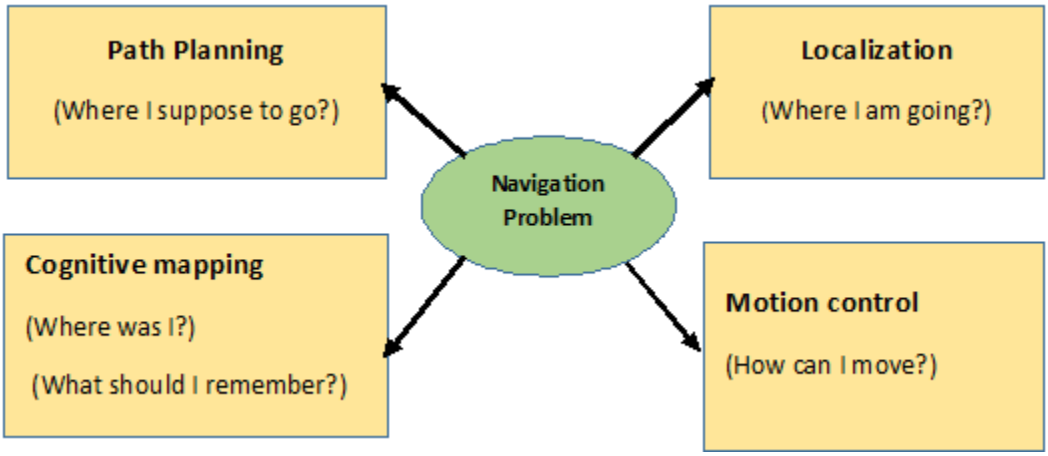

Fig. 2. Navigation problem

II. Literature Survey

The author of the paper mainly focused on the following problems in robot navigation: (i) Optimal Path planning (ii) Collision prevention (iii) Search algorithms

The work presented in [9] is focused on to find the shortest path from start to goal without any collision. In addition, obstacles of different size and shape are considered. For this purpose, a mathematical model is proposed. Moreover, the main algorithm is divided into three sub-functions. (i) Sub-function of path length: if there is no obstacle present in the given environment this sub-function calculates the diagonal distance between source and goal.

$$Fun = \sum_{i=1}^{n} [pi, pi + 1] \tag{1}$$

(ii) Sub-function of path clearance: if there are some obstacle present in the path then path length will be different. Then obstacle avoidance function is to be used. (iii) Sub-function for smoothness: This function is used to find the smoothness of given environment and calculates the smoothness. Curve angle and turning points are recovered through Beziers curve method. MOBOTISM software is used for simulation in 2D environment.

In [10], multi-mode control technique is used for collision free robot navigation. An adaptive and flexible algorithm is used in this paper, that deals with stability and smoothness. Moreover, the given algorithm combines the two approaches one is planning and other is re-planning. The first one is based on potential field, and the second is based on reactive learning based on limit cycle principle. On combining two approaches, collision free path is generated from source to goal within minimum time. Further, trajectory is generated by robot when an unexpected obstacle is observed. There is problem in localization and also its efficiency can be tested through other techniques. In future, it could also be tested for multi-robot system.

The robot navigation is challenging task in open environment. The author explain in [11] neural network based model is trained to control the robot movement in populated environment. This model has number of hidden layers, and respond fastly. By applying this model robot navigate successfully in open environment, where both static and dynamic obstacles are present.

An autonomous robot, is able explore keenly anyplace using sensor-actuator control techniques. The utilizations of the autonomous mobile robot in numerous fields like industries, space, transportation, and other social divisions are developing. The mobile robot performs numerous jobs like protecting activity, watching, distance measurements, planetary investigation, and material dealing with, and so forth. In this way, an autonomous mobile robot is required that could travel independently in different static and dynamic conditions. A few systems have been connected by the different specialists for mobile robot route and collision avoidance [2].

A Simulink model demonstrating for robot route in obscure condition has been proposed and actualized in [12]. Laser scan algorithm based on standard deviation is used. The robot comes out of the repetitive path and successfully reverses its angular velocity when the same obstacle is found on the next iteration of the path. The re-appearances of obstacles are effectively perceived and maintained a strategic distance from. Also, obstacle recognition feature is used to break repititive loop. The robot successfully detect and avoid obstacles present in the path.

In [13] a simple navigation approach based on odometry and global positioning system is given. Kalmar filter is used for data handling which help to measure noise in the sensor. This approach is applicable to indoor environment like offices, industrial sectors and home. Robot can work only in 2D environment. Real time path planning has been done.

A MATLAB-Simulink model was developed for robot navigation in unknown environment with obstacle avoidance. Two type of controllers are used that is pure pursuit controller, which is used to generate angular velocities for movement of robot and fuzzy controller is based on mamdani-type FIS. It is used for trainning data and input output mapping. The

collected data from mamdani FIS is provided to Adaptive neuro fuzzy system to obtain sugeno fuzzy inference system. By this model robot is capable to navigate successfully in unknown enivironment [6].

In [14] the authour proposed that supervised robot manages path in known conditions. The navigation task is subdivided into two sections, where first one deals with supervisor system. This system performs global navigation in the given environment. A virtual map of the environment was created and set a mark at different points. Then robot is guided to reach the marked location. Mobile robot achieves only local navigation. However, mobile robot was unable to cross the marked point because of real size of robots. In such conditions, supervisory system are used to achieve global navigation. colored petri-nets are used for calculation of optimal path, point detection and vector mark estimation. The proposed approach is also applicable for multi-robotic system.Where in [15] BUG1 algorithm is proposed, which is motion planner. This algorithm use petri net model here. The proposed approach make use of sensors, to capture the information of nearest obstacle, while moving toward goal [16]. It is based on local path planning and has limited environmental information.

Navigation in unique or obscure condition is a test for self-governing vehicles due to the restricted scope of sensors and non precise maps. In their proposed work , researchers break down the main problem into three conditions on basis of desired path. They are 'known space', 'free space', and 'obscure space'. For the dynamic condition, we determine a calculation to address the false obstacles in the path, when a customary path planning is trapped. For the obscure condition, they determine novel calculations and contrast them and then established methodologies under free space condition. Finally, they use Monte Carlo technique to assess the execution of these algorithms. Experimental results shows the conditions based on calculation which are superior to the others [17].

The proposed work shows a methodology based on the A*-Algorithm. To produce time ideal path for a robot based on deburring procedure of inner forms. Other than the streamlining of the deburring procedure, by using uncommon deburring instruments with legitimate parameters the robots direction between the individual focuses must be enhanced. The technique permits a quick and enhanced path getting ready for inexperienced robot developers. Further research exercises will concentrate on extensive parts [18].

The authour explain in [19] that both local and global navigation was done. The first one is baed on reinforcement learning while later one is on the basis of topological map. Essentially, the proposed architecture must expected to achieve a path for mobile robot which is flexible in such conditions, Where human traffic with alot of people. In order to get capacities, with respect to altering dynamic obstacles in such circumstances, a test framework replicating veritable universes is required for learning. Then a map of environment which is fit for robot learning is created first. This test framework is had common sense involvement in amusement of two-dimensional shape, and it could achieve learning in shorter time than existing test frameworks. Next, a learning system reliant on DDQN(Deep Q-network) was proposed for local navigation. A number of test and examinations were performed to show reasonability of the proposed structure. The robot navigates in public place with complete obstacle avoidance.

Navigation is a sort of program which provides graphical representation or direction from source to destination. Autonomous robot are mobile robot which work without human operator and move from one place to another with speed and precision. Robot navigation can be done through different method. The proposed paper is based on common algorithm that is go-to-objective, obstacle avoidance, following divider and way arranging. Obstacle are sensed through sonar range sensor and localization is done through encoders. Simulation is done in the environment where obstacle of different shapes are present in unknown environment [8].

The simulation and implementation of a vision based mobile robot navigation was accomplished to determines the viability and the effectiveness of using optical flow based algorithms in self govrned robot navigation. VRML 97 was used to create the virtual world for simulation. Simulink model was used to implement the algorithm and calculates the optical flow. The video stream captured through a virtual camera as seen by the robots was used to calculate the optical flow to determine the direction and the speed of the robot for the next step. A mathematical model was used to solve the problem analytically in [20]. The main drawback of this work is that robot was unable to see both sides. Also didn't capture the images near his wheel. In future it could be done through video streaming.

In [11] examination, an enhanced hybrid administrator is proposed, for taking care of path planning issues using hereditary calculations (GA) in static condition. GA has been broadly connected in path enhancement issue which comprises in finding a legitimate and attainable path between source and goal, while keeping away from obstacles. For example,(i) reduce path length, (ii) The path should be beyond from the obstacles and so forth. A few researchers have given new methodologies utilized GA to create an ideal path. Existing crossover operator can create infeasible paths. The majority of these techniques don't consider the variable length chromosomes. The proposed operator offers possible path with complete obstacle avoidance. A new fitness function is proposed for taking into consideration of saftey and optimum path length. To validate the proposed technique, it can be tested to various environments.

In [21], study shows the drawbacks of existing path planning techniques in unknown environment. They mainly focused on path planning. In dynamic environment, there may be chances of collision in unknown dynamic environment is more. Moreover, because of complex structure of environment there is chances of non optimality. The study focuses on: (i) To build up a predictive method, where both static and dynamic obstacles are present. Moreover, also have no idea about their speed are being avoided successfully. Also find a secure path to navigates from source to goal location. (ii) To design a

decision making process by using predictive method to acess the information about velocity vectors of moving obstacles in the environment with help of sensors. Moreover, information about location, shape and size is also collected with the help of rangefinder sensors. Results show that the proposed technique displays high optimality, high strength, low running time, and zero error rates. The error rate is zero for all test issues. The normal way length for all test conditions is 16.51 with a standard deviation of 0.49, which gives a normal optimality rate of 89.79 percent.

In [22] explain the navigation of robot in uncertain environment, where moving obstacles are also present in the environment. The proposed paper is based on firefly algorithm. Attaction of two firefly is based on brightness. Fuzzy controllers are used to explore environment efficiently in minimum time stamp. With the help of controllers moving obstacles easily get recognized. This algorithm is efficient over other algorithms. It reduces search times and robot easily navigate in given environment. Distance can be calculated through Eucladian distance.

The proposed work in [23] is based on pure pursuit algorithm, the probabilistic guides (PRM) in robot route. The guide of the robot's condition is created as inhabitancy lattice. In the inhabitancy environment map, the probabilistic guides are acquired. An ideal way from begin to end area of the robot route is acquired from probabilistic guides. Test work is conveyed out on reproduced Turtlebot robot in Gazebo test system. MATLAB is used as programming language. Likewise, the 'Automated System Toolbox' of the MATLAB is used to program the robot route process. The confinement of this work is that it is appropriate to the condition with static obstacles. For future research work, there is a degree to broaden this work for the dynamic condition with moving objects.

The author proposed in [24] that laser scan executed for concurrent localization and mapping in robot navigation. Two calculations are displayed to achieve the laser examination using typical dispersion change. The first calculation was proposed to gather and store the laser examined data acquired from the robot scan. The second calculation is to perform scan matching and map building. By using the information of good output matches, a neural network is prepared and tried. It has been seen that a portion of the experimental results, it has been seen that a portion of the output experimental outcomes, forgotten from the NDT, are not of good quality. A neural system is effectively prepared to assess the robot present for a given infomation comprising past pose of the robot and the general pose of the robot to the present, in spite of the fact that, the neural network system requires the similarity of the requests of information yield. Furthermore, the quantity of neurons in the hidden layers is issue explicit.

In [25], described that to built up a straightforward calculation for robot navigation using bumper event. This calculation is actualized on Turtlebot (a robot demonstrate) in the Gazebo test system and on a genuine Turtlebot robot. The guard and state fields of robot's are considered for the diverse direction speeds. The trial results are appeared mat plots using Robot Operating System (robot working framework) device 'rqt'. The usage of the new calculation demonstrates that the obstacle avoidance assignment can be taken care of by using the Turtlebot. The Turtle-bot effectively recovers from the crashes and pursues the new speed directions. On the off chance that self-ruling path in obscure condition, this calculation is valuable at the point when different sensors for obstacle evasion are not harmed or evacuated to limit the multifaceted nature. The principle of the proposed calculation is that this calculation does not prompt a crash free route. In this manner, alternate sensors of robot like laser what's more, camera may get need over sensors for crash free path.

Mechanical technology look into a development, since most recent three decades. The presented research work in [26] mainly focused on optimization and path planning algorithm. The proposed algorithm is suitable for both static and dynamic environment. The path planning techniques of mobile robots can be sorted as Classical Methods and Heuristic Methods. Further subcategorized as (i) Analytical Methods, (ii) Enumerative Methods, (iii) Evolutionary Methods and (iV) Meta-Heuristic Methods. The proposed algorithm is based on free segments and turning points in static and known environment. This algorithm also works when there is more than one obstacles present in the path. In addition, to this also find shortest path while navigating from source to goal [27].

III. Path planning

Path planning is an important primitive for autonomous mobile robot to find the optimal path between source and goal. Optimal path is a path that reduces the translation and rotation, while navigating from source to goal. Moreover the obstacles present in the given environment are being avoided. It requires a map of environment and location with respect to map [28]. Path planning mainly based on two techniques: (i) Local path planning and (ii) Global path planning. Local navigation is based on high resolution and sensors are used to find ranges. In local method, no prior information is available and also the map of environment is not predefined. It works for the dynamic environment [29]. In global navigation is based on low resolution, where prior information is available and map of environment is predefined. It is adequate only for static environment. Both approaches has inefficiencies, so by combining the two to get suitable results. Robot path planning problem can be classify as (i)Classical approach and (ii) Heuristic approach. That can furthur divided into different categories mention below in fig:3 [30].

A. Classical Approach

The classical method is furthur sub-divided into: (i) Cell decomposition method (ii) Potential field method and (iii) Goal oriented method.

(i) Cell decomposition method:

In this method is used to find free space and occupied space between geometric area and the region divided into

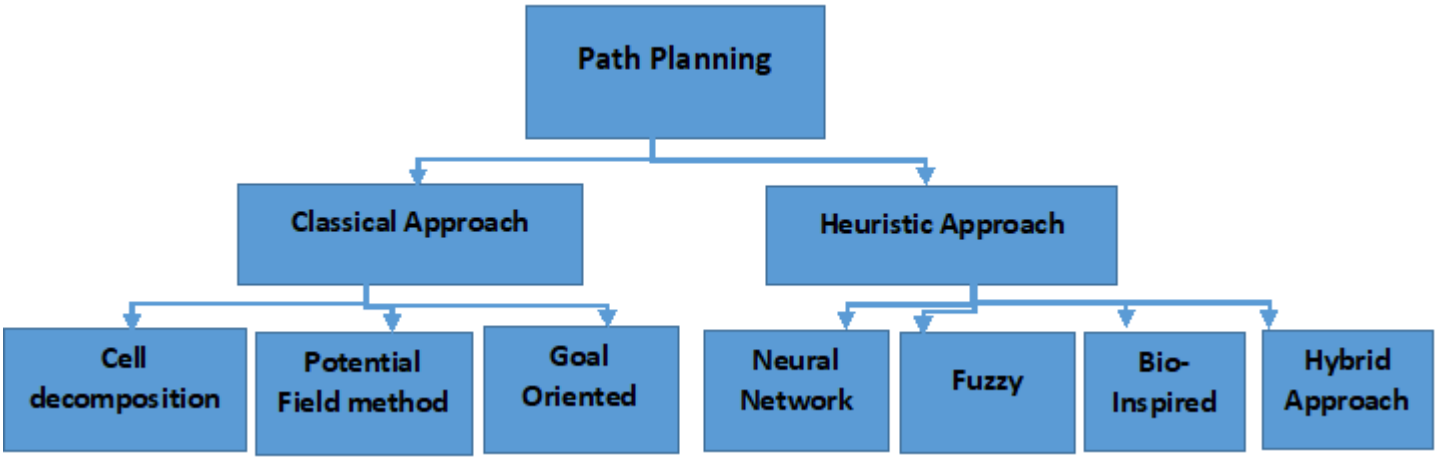

Fig. 3. classification of path planning algorithm

small region known as cell. The objective of this algorithm is to reach the goal safely. In proposed path planning technique the robot reach to goal by avoiding obstacles present in the path. The basic path planning algorithm based on cell decomposition as following steps [26]:

1. Segregate F into fundamental, related territories called "cells".
2. Besides, make sense of which opens cells are adjoining and build up an "accessibility graph".
3. Thirdly, find the cells wherein the hidden and target setups untruth and output for a route in the accessibility graph to join the fundamental and target cell.
4. At last, from the gathering of cells found with a suitable calculation, figure a path inside each cell, for instance, experiencing a progression of divider following developments or by the midpoints of as far as possible and improvements along straight lines. Cell decomposition is categoried as Exact cell Decomposition, if structure of environment has assigned cell border as function and there is lossless decomposition. Approximate cell decomposition, when the border assignment is approximate and there is loss of information. Probablastic cell decomposition, which is similar to approximate but have no physical meaning.

(ii) Potential field method:

In this method repulsive and attractive forces are assign to target and obstacles. An attractive field is generated which moves inward to goal. In each time stamp a different potential field is generated across the free space. Also, calculate potential field at different position of robot and force induced by the field is also calculated. So, by induced force the robot moves and successfully avoid the obstacles. The obstacles produces repulsive field around it. the force moves the robot away from the obstacles. When obstacle are detected nearby, new approach of potential field repulsion is applied. Attractive/Repulsive potential field is given by:

$$U(q) = U_{att}(q) + U_{rep}(q) \tag{2}$$

where U(att) is attractive potential field moves toward target and U(rep) is repulsive potential field to avoid obstacles.

$$U_{att} = 1/2\delta.P^{m}.(q, q_{target}) \tag{3}$$

$$U_{rep} = 1/2\alpha(1/P(q, q_{obs}) - 1/P_0)^2 P^{n}(q, q_{target}) \tag{4}$$

where delta is scaling factor.

(iii) Goal oriented method:

In this method, sonar range sensor are used for path planning and robot configuration. Obstacles are avoided while moving toward target [8]. It is based on the method where map of environment is predefined.

B. Heuristic approach

Heuristic approach is furthur sub-divided into (i) Neural network (ii) fuzzy logic (iii) Bio-inspired and Hybrid approach.

(i) Neural network approach:

This approach is used for path planning and obstacle avoidance. It has number of hidden layers and works in populated environment [11]. It avoids the obstacles present in the path irrespective of their size [31]. A neural network based model is trainned to control the robot navigation in such open environment. And also check the performance of neural network in different environment. Neural network broadly use to implement motion planning in auto guided robot. Path planning can be done by Principle component analysis (PCA) and multiple perceptron learning (MPL) algorithms. A new technique known as dynamic wave expansion (DWENN) proposed by Lebedev et al. It work in the environment where no prior information is availableThe major limitation of NN is that it consume more time as compare to other techniques. Moreover, it always not provide efficient results [30].

(ii) Fuzzy logic:

Fuzzy logic was proposed by Lotfi zadeh in 1965. The idea

behind fuzzy logic is to represent human thinking which is not represented in crisp logic. It is based on IF-THEN fuzzy rules and based on membership fuctions. For example, to measure the height like very small, short, tall and very tall. To implement this problem is divided into simpler sub-tasks [6]. Fuzzy controllers are used for input output mapping. These controllers are also used for obstacle avoidance [5].

(iii) Bio- Inspired algorithms:

Algorithms based on biological behaviour are known as bio-mementic approach.The proposed mementic algorithm is based on global path planning. Mementic algorithm is a collaboration of genetic algorithm for path planning and path improvement. The study in [32] proposed a bio-inspired algorithm for local navigation. In proposed work has successively achieve the goal.The robot has to find next location, to reach the objective irrespective of time and distance travelled. These are furthur categorized as Genetic algorithms, particle swarm optimization algorithms and Ant colony optimization algorithm.Every one of these aforementioned techniques has its own points of interest and detriments.The problem is examined in both static and dynamic environments [33]. Algorithm is tested in different simulated and real world. In [34] is based on multi- objective of path planning. It is based on Learnable evolutionary algorithm, which determines the correct direction by using machine learning and also, find the fitness function. Various operators are used to find the optimal path, that is length, saftey and smoothness. Robot avoid obstacles and also find optimal path by using this algorithms.

(a) Genetic algorithms

To overcome these drawback, meta-heuristic strategies have been considered in this wide field of research. Genetic algorithm is a technique based on natural genetics and is based on operators like crossover, mutation and natural selection. This technique was proposed in 1975 by Professor J.Holland from Michigan University. Hereditary calculation is to copy the possibility of the survival of the fittest, it recreates the methodology saw in a trademark structure where the stronger has ability to survive and endure while the weakest tends to pass on or die. Another population is created by using operators. In each generation of genetic algorithm, path improvement is applied. The smoothness function is calculated through path length and smoothness function. This shows better results as compare to other algorithms [35]. The popualtion is a sequence of strings known as chromosomes. The chromosomes are selected based on fitness function, which define target capacity and pure pursuit issue. The three operator works iteratively untill a termination condition is applied. Various methods has been created in path planning, for moving robots around the world. It can also work for multi-robotics system. In [31], the author explains the robot navigation in populated environment. Where both static and dynamic obstacles are present irrespective of their size and shape.

(b) Particle swarm optimization Technique

Particle Swarm Optimization (PSO) is a population based investigation technique. This technique is widely used in artificial intelligence. The nature of this algorithm is based on movement of flock of birds in search of food. PSO perform arbitrary populace and use target capacity to produce particles. Intially particles are randomly generated to form population. The particles travel in search space and each time update their location. To evaluate the velocity by using fitness function, which is based on real numbers. The velocity can be calculated as:

$$ParPos_j^{i+1} = ParPos_j^{i+1} + ParVel_j^{i+1} \tag{5}$$

$$ParVel_j^{i+1} = ParVelo_j^{i+1} + c_1 r_1 (Posbest_j^i - ParPos_j^i) + c_2 r_2 (gbest^i - ParPos_j^i) \tag{6}$$

$$ParVel_j^{i+1} = ParVelo_j^{i+1} + c_1 r_1 (ParPos_j^i - Posworst_j^i) + c_2 r_2 (ParPos^i - gworstj^i) \tag{7}$$

Where: c1 and c2 are balancing factors and r1 and r2 are random number between 0 or 1 gbest is the best position of swarm. In any case, the fundamental shortcoming emerges from the point that, analytical method are multiplex for elusive applications. While the enumerative techniques are concerned by the degree of the search space. Moreover, when search space is complex in path planning procedure, numerous transformative strategies have been appeared to be ineffectual. The path planning and obstacle avoidance is done through Particle Swarm Optimization.

(c) Ant colony optimization technique (ACO):

ACO is data clustering algorithm based on natural ant colony method. This technique is suitable where source and goal are predefined. The communication between the ants through pheromones deposited on the path. So, that they find the shortest path between food sources and their hole. This technique is based on multi-goal path planning problem in the presence of obstacles. This technique is based on following algorithm:

1. Create ants.
2. Iterate for each ant until whole task is completed.
3. Place pheromone on visited sites.
4. Daemon actions
5. vanishing pheromone

These techniques are used for path planning and obstacle avoidance [35] [33] [34].

(iv) Hybrid approach:

It is combination of more than two approaches for better results or to improve the limitations of existing systems. For example in nature inspired algorithm, genetic algorithms, expert system, fuzzy logic and neural network are combined for better performance [36]. Global path planning and obstacles are avoided successfully.The aim of the proposed work in [36] is to develop a hybrid system by combining neural network, fuzzy logic, genetic algorithim and expert system. The hybrid system was able to deal with vehicle in unknown environment by using hybrid intelligent system. This approach generate a path from source to goal by avoiding obstacles present in tne path. It provides better results.Where in [37] hybrid approach is baesd on global path planning and obstacle avoidance. It

uses Distance tranformation technique for path planning and Gilebert-Johnson-Keerthi approach for obstacle avoidance. In [38] path planning can be done through hybrid approach by using wireless sensor network. It is based on multirobotic system. It make use of known environment map for path planning. In [5] a hybrid approach that particularly deals with navigation of robot in partially unknown environment. Two approaches are combined here. The hybrid approach is combination of trajectory tracking and reactive navigation. Robot navigates in efficient time and has ability to deals with unknown environment. Fuzzy controllers are used for input and output mapping.

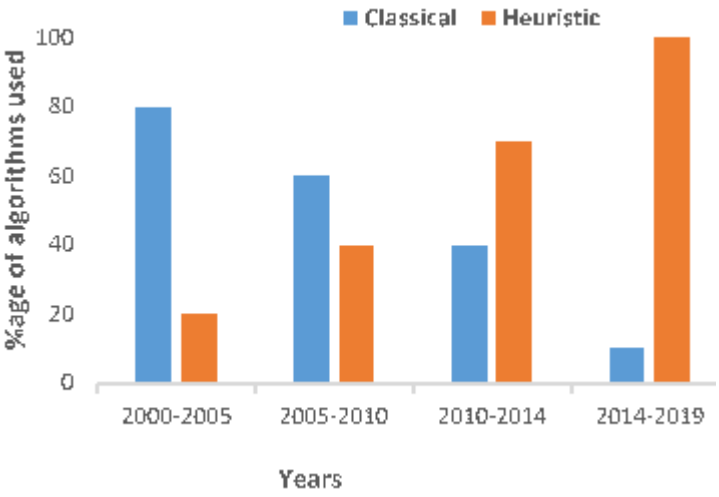

Fig. 4. Application of Classical and Heuristic algorithms

IV. Search Algorithms

Search algorithms are basic unit of robot navigation. While a large number of search algorithms are developed and used in various related fields. A* was the first searching technique to be proposed in 1968 and was pillar to search algorithms. it is combination of breadth first search and depth first search. LPA* algorithm is an improvement over A* [39] [3]. This algorithm is based on two key concept. Presence of two keys makes determination of objective function quite complex. A* Algorithm is used to find suitable path by searching, recognizing and locating the obstacles present in the given environment, and provide collision free path. Configuration space is selected on the basis of robot position with respect to position of obstacle. Configuration mapping is done through geometric mapping and topological mapping. Calculation must be speed up by another method. D* algorithm is used to find optimal path in dynamic environment. A* algorithm is used to find the path for mobile robot. Manhattan distance, octile distance, and Euclidean distance heuristic functions are used to approximate the navigation from a cell to the objective cell. Time taken by the autonomous robot, length of the path secured and the quantity of cells to visit are displayed effectively. The three different heuristic functions were used for implementation of A* algorithm to find path for the Turtlebot robot. It is seen that the directions of the cells on the path created by every one of the heuristic functions don't contrast fundamentally. The time taken by path planning, with various heuristic functions used fundamentally. Among the three, the Euclidean distance, heuristic function creates the most non uniform path planner and also calculate time for the progress of the robot between the source and goal. On the other hand, octile remove heuristic delineates the most uniform result for the worldwide path planner [40] [3]. The proposed work is mainly focused of on path planning. Various algorithms are explaind, tested and compared. The algorithm used here are A*, Focused D*, Basic theta and JPS.Main focus of all these algorithm is on localization and navigation.The performance of all the algorithms is compared. JPS is used to find shortest path, when there is no real time analysis basic theta is used. Moreover, D* and incremental Pi is used for dynamic environment [41].

TABLE I: Analysis of various algorithms

Name of Technique	Name of Author	Year	Navigation Environment	Static obstacle	Dynamic obstacle	Simulation	Real System
Optical flow based algorithm	G.D. Illeperuma et al. [20]	[2011]	Indoor	Yes	No	Yes	No
Hybrid approach	D. Tamilselvi et al. [36]	[2011]	Unknown	Yes	Yes	Yes	Yes
Nature inspired algorithm	J. Freeman et al. [33] [34]	[2011]	indoor	Yes	Yes	Yes	Yes
Planning and replanning	M. Mouad et al. [10]	[2012]	Unknown	Yes	Yes	Yes	Yes
A* algorithm	F. Duchon et al. [3] E. Abelea et al. [18] N. Kumar et al. [40]	[2013] [2016] [2016]	Indoor Unknown Unknown	Yes Yes No	No Yes Yes	Yes Yes Yes	Yes No Yes
V HCTNav path planning algorithm	M. Pala et al. [42]	[2013]	Indoor	Yes	No	Yes	Yes
A*,Basic theta, D* and JPS algorithm	F. Duchin et al. [41]	[2014]	Unknown	Yes	Yes	Yes	Yes
Novel algorithm based on Monte Carlo method	E. Zamora et al. [17]	[2014]	Known and Unknown	No	Yes	Yes	Yes
Laser scan and novel algorithm	R. Deepu et al. [43]	[2014]	Known	Yes	No	Yes	Yes
Fuzzy logic	R. Zhao et al. [5]	[2015]	Unknown	Yes	No	Yes	Yes
Odometry and global positioning system	J. Yernohorsky et.al [13]	[2016]	Indoor	Yes	No	Yes	Yes
Goal oriented algorithm	S. Khan et al. [8]	[2016]	Known	Yes	Yes	Yes	Yes
Pure pursuit algorithm	N. Kumar et al. [23]	[2016]	Known	Yes	No	Yes	No
Path planning using bumper event	N. Kumar et al. [25]	[2016]	Unknown	Yes	Yes	Yes	No
Path planning, collision prevention and search algorithms	D. S. Aggarwal et al. [39]	[2016]	Unknown	Yes	Yes	Yes	Yes
Path planning with sub functions	N. K. Gupta et al. [9]	[2016]	Unknown	No	Yes	Yes	Yes
Evolutionary algorithm	L. da S. Assisi et al. [31]	[2016]	Known	Yes	No	Yes	Yes
Predictive method	F. Kamil et al. [21]	[2017]	Unknown	No	Yes	Yes	Yes
Petri net method	S. Bartkevicius et al. [14]	[2017]	Known	No	Yes	Yes	Yes
Navigation techniques	A. Pandey et al. [2]	[2017]	Unknown	Yes	Yes	Yes	Yes

Continued on next page

TABLE I – *Continued from previous page*

Name of Technique	Name of Author	Year	Navigation Environment	Static obstacle	Dynamic obstacle	Simulation	Real System
Motion planning algorithm based on classical and heuristic approach	M. N. Zafar et al. [26]	[2018]	Unknown	Yes	Yes	Yes	Yes
Firefly algorithm	B.K. Patle et al. [22]	[2018]	Partially Known and fully Unknown	Yes	Yes	Yes	Yes
Standard deviations based algorithm	N. Kumar et al. [12]	[2018]	Unknown	Yes	Yes	Yes	Yes
Fuzzy logic and pure pursuit	N. Kumar et al. [6]	[2018]	Unknown	Yes	Yes	Yes	Yes
Laser scan and neural network	N. Kumar et al. [24]	[2018]	Unknown	Yes	No	Yes	Yes

Various algorithms studied by literature review till now are concluded in above table that is in table 1 on the basis of different parameters. These algorithm are mainly focused on path planning and their navigation environment. All these are based on different structure of environment that is static, dynamic, indoor, outdoor, unknown and known enviroment. Moreover, nature of obstacle is also defined wether it is static or dynamic or either both static and dynamic are present.

V. Challenges

After review of literature, various challenges occour during navigation. Path planning, which is major issue that how robot decided which path is suitable to reach the goal? There is no collision of robot in the navigation environment. In the given environment, a number of static and dynamic obstacles may be present in the path. Avoiding such obstacle and making decision that which path is suitable is a challenging task.

Localization is another issue in robot navigation, that is how to represents itself in the given environment. It defines robot current position and orientation within that environment. In known environment, a map of environment is given to the robot for navigation. This technique is suitable, when there is single robot in static environment. But if there is dynamic environment and for multi-robot system then this is more challenging task.

Mapping is another challenge in navigation that how robot describe where it is currently and what it has to remember to navigate in the environment. And how robot decided in which direction it has to move is suitable in the given environment. To define an optimal objective function for the probabilastic mapping of robot and obstacles present in given environment.

In hybrid approaches, to define the fitness function and also to obtain optimal results. Multiple robot and multiple obstacles present in given environment.

Conclusion

Path planning problem is classified as classical approach and heuristics approach. Classical approaches are used in motion planning and easier to implement. They shows better results in cell decomposition, potential field method and goal oriented method. Classical algorithms requires exact information about their working environment. Moreover, sensors are required for real analysis. On comparing classical method with heuristics methods shows better results, because they are more intelligent and advance [30]. They works in the environment, where no prior information about obstacle and environment is available. The nature of obstacles and navigation environment change constantly. These algorithms achieve best optimal solution by bio-inspired algorithms. Different techniques under heuristic approach are neural network, fuzzy logic and various bio-inspired algorithms. Hybrid approaches like neural network, fuzzy logic, particle swarm optimization and ant colony method provide smoothness functions [6]. Ant colony method and potential field methods provides navigation in dynamic environment but not shows optimal results. All these techniques has some advantages and disadvantages [35] [33] [34]. To overcome the drawbacks of existing systems, we can combine neural network, fuzzy logic,ant colony optimization, swarm optimization and potential field methods for better results. In futur more advance approaches like PRT, PRT* and PRG will be promising approaches for path planning. Most of the work done is based on single robotic system and now, we have to implement multi-robotic system. In this paper various algorithms are studied. The main problem focused is on robot navigation and path planning. we conclude that path planning with complete obstacle avoidance is still major challenge in robot navigation. Most of the work which has been done on single robot. In future, we have to implement multi-robotic system.

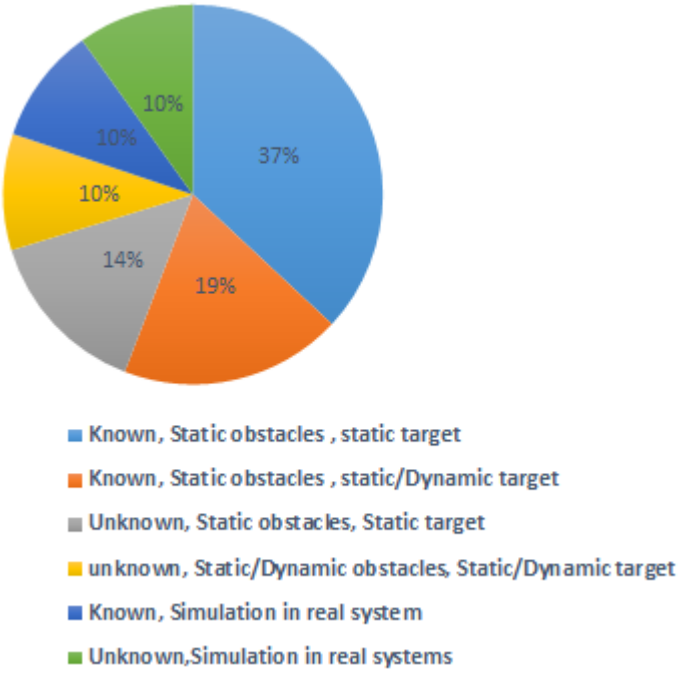

Fig. 5. path planning application from 2000-2018

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