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## A Review on Motion Planning and Obstacle Avoidance Approaches in Dynamic Environments

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### Abstract

Path planning with obstacles avoidance in dynamic environments is a crucial issue in robotics. Numerous approaches have been suggested for the navigation of mobile robots with moving obstacles. In this paper, about 80 articles have been reviewed and briefly described to offer an outline of the research progress in motion planning of mobile robot approaches in dynamic environments for the last five years. The benefits and drawbacks of each article are also explained. These papers are classified based on their issues into ten groups which are: smooth path, safety, path length, run time, accuracy, stability, less computation cost, control, efficiency, and future prediction (uncertainties). Finally, some challenging topics are presented based on the papers mentioned.

**Keywords:** Robot navigation; Dynamic motion planning; Obstacle avoidance

### Introduction

Robots are currently replacing human in different activities in various sectors, which vary from typical robots for industrial applications to self-directed robots for difficult tasks, for instance space exploration [1]. Robotic motion planning is a promising study issue in the field of robotics [2]. Robot path planning is to create a collision-free route from a starting point to a goal point in an environment while achieving shortest route, collision free and low run time [3].

Based on the data acquired from the environment, there are two types of motion planning approaches, namely global path planning and local path planning. If the environment is well known, it is identified as global path planning, and the motion planning serving in unknown environment is identified as local path planning. It is also categorized as off-line or static and on-line or dynamic motion planning according to the behavior of obstacles. If the route is a predefined decision in the case of stationary obstacles, then the motion planning is called offline decision making or static motion planning. On the other hand, if the decision is made by the robots when the obstacles are not static (moving obstacles), the circumstances are recognized as on-line or dynamic motion planning [4].

Path planning can be widely categorized in two main methods: classical and heuristic. The classic approaches suffer from numerous disadvantages, such as a high time complication in high dimensions, and catching in local minima, which render them ineffective in practice [5]. Consequently, the application of the heuristic approaches was extended due to their achievement in addressing problems such as computational complexity, exploration and local minima [6].

The purpose of this paper is to provide a review of motion planning algorithms for dynamic environments used in mobile robots. This article offers an outline of the research progress in motion planning of a mobile robot for online environments for the last five years. Commonly used conventional and evolutionary techniques of motion planning in dynamic environments of mobile robots have been addressed. The advantages and disadvantages of each approach are also briefly described. Additional scope and challenges that included in evolving computationally efficient motion planning procedures are also known.

### Related Work on Dynamic Path Planning

Given the whole information of surroundings in which a robot is situated, the globally optimal or near-optimal route can be established by using optimization techniques; whereas the local planner uses sensory information, and when previously unidentified and unaccounted obstacles are detected, makes on-line re-planning to avoid the recently revealed obstacles [7]. A huge number of researches on path planning in dynamic environments for mobile robots have been conducted. Consequently, we introduce several of these works and mention the most significant works of each one. As we reviewed about 80 papers, we categorized these articles according to their respective issues:

#### Smooth path

Faisal et al. [8] have executed the obstacle avoidance behavior and the Wheeled Mobile Robot (WMR) is steered to its goal via fuzzy logic control method. It gave smooth paths, flexibility, self-organization, and cost savings. However, it is not accurate for rapid dynamic movement of WMR. An improved obstacle avoidance and route correction mechanism is suggested by Shih [9] to escape obstacles and correct the route. It makes the robot navigate through three hindrances smoothly and correct the walking route in the same period. Besides that, it uses a little cost device which can have a similar performance as a costly device, but the surroundings do not guarantee best performance each time, particularly when an obstacle may interfere with the ultrasonic sensor's revealing capability, and the slipperiness of the ground could also curb the robots walking capability.

Mohammadi et al. [10] presented an improved A-Star motion

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planning procedure, which discover an obstacle-free path, has an optimal calculation time and smoothness of the last route. The route is smoother than routes which result in other classical procedures. In contrast, other motion planning approaches such as multi-point potential field method for an under-actuated flat-fish type AUV which are developed by Subramanian et al. [11] are potentially incapable to avoid the local minima issue despite it giving a smooth route. The new hierarchical architecture that Team Magician evolved by Boeing [12] gives smart and effective tactical planning, smooth real-time route alterations and obstacle avoidance, while it cannot give the shortest route. A computationally effective path planning procedure is proposed by Choi [13] for autonomous floor vehicles working in semi-structured surroundings with a job identified by waypoints, corridor widths and obstacles to decompose the job path and to smooth the route, but it suffers from limited sensor range. The advantage of a self-reconfigurable steering system which planned for independent robots working in heterogeneous surroundings [14] is to provide extra evidence on the advantages of bearing in mind ROS as a backbone of the robot's control system. However the route followed by the robot has some dissimilarity from the ideal path, caused by diverse factors.

## Safety

The use of the Artificial Potential Field (APF) technique with a Bacterial Evolutionary Procedure (BEA) [15] is to get an improved flexible route planner technique. Although it ensures a safe, optimal and feasible route, it did not consider the direction of obstacles. Sezer and Gokasan stated [16] a novel method called the Follow the Gap Method confirms safety by guiding the robot into the center of the maximum gap as much as possible, while providing the reach of the end point, but it suffers from low velocity, the local minimum at the dead-end scenarios.

A new potential field technique to eliminate largely the needless obstacle avoidance is proposed by Zhang [17] to move to the goal safely and quickly in changing environments. The disadvantage of this algorithm is the collision when the velocity of the hindrance increases since the repulsive force is too minor to escape the moving obstacle. A plain biologically inspired approach has been adopted for the steering of a unicycle-like robot towards a goal while evading collisions with moving obstacles [18]. The proposed algorithm is pretty simple and computationally effective with a safe navigation. Meanwhile, a different method [19] called Escaping Algorithm (EA) uses Kalman filter to forecast the movement of dynamic objects and merge them with potential field method to steer safely in changing environment. However this paper did not have comparison between its method and other same approaches.

Llamazares et al. [20] proposed a three-D extension of the Bayesian Occupancy Filter to resolve the issue of dynamic obstacle avoidance for a mobile platform via the stochastic optimum control framework to calculate routes that are best in terms of safety and energy competence under restrictions. On the other hand this method suffers from the high calculation cost of using AICO in real-time planning implementations. According to Wang [21], a novel collision free steering approach for an electric-powered wheelchair in chaotic dynamic environments is proposed to prevent collisions with dynamic obstacles such as pedestrians or vehicles under the guidance of the suggested procedure and reach the goal. The feature of this procedure is the flexibility and applicability for a huge diversity of environments and it accomplishes the navigation mission with limited information, but it assumes the driving wheels roll without sliding.

A new method proposed by Jaradat [22] which is Q-learning procedure is advanced for solving the mobile robot steering in changing environment issue by limiting the quantity of situations based on a novel definition for the situations space. It is a good algorithm to decrease the size of the Q-table, growing the speed of the navigation procedure. Nevertheless the robot only looks at the current position of the goal. It does not look at the previous positions to guess what the next new position will be. A collision avoidance technique for a mobile robot in changing environments is suggested by Ohki [23] which considers the near-term movement and "personal space" of moving obstacles to evade evacuees in a two dimension plane environment, but this method did not consider the obstruction of the sensors in simulation test at the current moment so, if it applied on a real mobile robot, it is difficult to accurately guess the obstacles "movement. The adjustments of VFH+ and VFH\* (Vector Field Histogram) approaches offer collision-free path in environments with dynamic obstacle [24]. In this method, there is no necessity to re-plan the route or switch between diverse procedures to accomplish collision free avoidance of both stationary and dynamic obstacles. The technique VFH\*TDT handles it at the same time. According to Molinos [25] a novel technique based on well-known Curvature Velocity Method (CVM) and a probabilistic three dimensional occupancies and velocity grid advances to offer a strong and safety self-directed navigation. However, this method tested in indoor environment only.

Non-linear model predictive control (NMPC) is applied by Hsieh [26] to determine realistic trajectories for the WMR to track safely to reach a given target in a known changing environment, but the environment occupied with stationary and dynamic obstacles is predefined. Shan [27] presented an enhanced RRT\* to mixture lane information and evade obstacles to discuss an application state whereby the required route is not similar to an optimal route. In this algorithm, there is still a gap in its effective embodiment in an actual autonomous vehicle. Gori [28] presented Dynamic Force Field Controller (DForC), which is a dependable and efficient framework in the situation of humanoid robotics for real-time arrival and navigation in existence of obstacles. This method appears to be particularly supply with respect to environmental variations permitting a safe navigation process, and creating reliable routes in practically every state. In contrast, a procedure for dynamic unknown environments based on an enhanced ant-based procedure is presented by Zhu [29] which has the drawback that it did not consider the multiple dynamic obstacles occurring simultaneously within Rob's VD despite it has good influence and great real-time performance.

Another approach focus on safety can be found [30]. A hybrid planning method comprising of global planning and local planning is proposed by adopting the improved ACO to design the global route and rolling window to evade the local collision. Nevertheless, it only discusses motion planning in which the obstacle's moving route is known. A fuzzy control procedure for both obstacle avoidance and motion planning has been applied in test so that it permits the mobile robot seek target, avoid obstacles, and preserve heading [31]. The disadvantage of this paper is it did not consider the velocity vector of obstacles. The same disadvantage can be found [32] in which the application of an adaptive Neuro-Fuzzy inference system (ANFIS) to route generation and obstacle avoidance of a self-directed mobile robot in an unknown stationary and changing environment is presented.

## Path length

Goel and Singh [33] proposed an enhanced algorithm for motion planning using Artificial Bee Colony Algorithm to discover collision

free shortest route in changing environment. This algorithm suffers from discarding the physical dimensions of mobile robot. A novel algorithm of choosing the closest or the most dangerous obstacle and evading collision with it is presented by Savkin [34] to decide the most dangerous obstacle how to deal with obstacles that are unseen or out of sensing range, how to handle locations with two or more dangerous obstacles simultaneously. However, Hossain proposed [35] a novel procedure based on Bacterial Foraging Optimization (BFO) method is advanced to determine the shortest reasonable route to travel from any current location to the goal position in an unidentified environment with dynamic obstacles. However this algorithm did not take into account the direction of robot and obstacles.

A new method for robot navigation in changing environments, denoted as visibility binary tree procedure, is introduced Rashid [36], but it does not reach the accomplishment of VisBug and TangentBug procedures. According to Raja [37], an effective on-line motion planning procedure for mobile robots in dynamic surroundings has been advanced which merge a mathematical model for collision-avoidance and evolutionary PSO method to design an optimal collision-free route achieving both kinematic and dynamic restrictions of robot. This algorithm does not need any discrete recovery mode method to evade from trap locations. In Narayanan [38] states that anytime designer is established which builds off Safe Interval Path Planning (SIPP), which is a quick A\* variant for planning in changing environments which use intervals as an alternative of time-steps to signify the time dimension of the issue. Although it can give safe routes for the next fifteen seconds of implementation within 0.05 seconds, it does not take into account a physical robot.

Lin and Yang [39] improved RRT algorithm by using a new two dimension-span resampling technique and a pruning method based on a b-spline function to decrease route distance and calculation time. However, when the robot passed between two hindrances, router planning did not consider the safe boundary, and the suggested method did not consider any discrepancy between the real and assumptive obstacle locations. An optimization method is presented for multiple paths generation using simulated niche based particle swarm optimization for changing online motion planning, optimization of the paths and evidenced to be an effective method for giving short, safe, and feasible paths in dynamic restrictions [40]. To generate a reasonable collision free route from the initial position to the target position when the mobile robot is stuck in an acute U or V shaped obstacle or the mobile robot comes across dynamic obstacles, Genetic Algorithm (GA) based Dynamic Path Planning Algorithm (DPPA) is suggested by Yun [41] to eliminate the unnecessary route ways to decrease the entire travelled distance. Nevertheless, it did not take into account the physics constraint.

A novel method is presented by Purian [42] by using fuzzy logic to discover the shortest route in unidentified, dynamic environments with numerous difficulties. In this method, the robot considered as a point. Lafta et al. [43] construct a system which able to accomplish tasks without human interference in chaotic unknown environments. The main advantage of this controller is it permits robot to evade obstacles and reach target with shortest distance, but it did not consider the velocity vector of hindrances.

### Run time

Velocity obstacles techniques used for dynamic collision prevention are enhanced by considering distance and period before collision [44]. It overwhelms conservative approach of robot's movement of collision

avoidance; accomplish rapid motion towards the target when robot avoids collision with dynamic obstacles. However, this algorithm can be implemented to avoid circular obstacles only. A novel approach for resolving mobile robot tracking in dynamic environments, based on the heuristic characteristic of an optimized ant colony with fuzzy logic procedure is presented by Purian [45] to optimize smoothness, time and length of the route and lastly improves elements of fuzzy rules table, but the table which is considered as heuristics information in choosing of ants is set by hand to accelerate the convergence of the algorithm.

A Subgoal-Guided Force Field technique, which significantly develops the performance of the Force Field technique is proposed by Jin-xue [46] for real-time path planning and collision prevention in partially known and dynamic environments. It gave quicker planning procedures and a broader range of implementations, but the wheel sliding and extra degrees of freedom because of a robot's interior structure, are disregarded. Abiyev [47] suggested methods are essentially based on potential field technique, vector field histogram and A\* approaches to direct of a robot in any orientation towards the target, and to distinguish its exact position in the environment. It has proficiently found the desired and near best solutions in short period, on the other hand it does not consider a physical robot.

Matveev [48] planned a sliding mode-based approach for steering of a unicycle-like robot to the goal through a changing environment chaotic with dynamic and deforming hindrances. This strategy gave quicker navigation and it performs better than VOA. Meanwhile, due to the decreased speed, the robot accompanies the dynamic obstacle for an extended time, which involves the robot in a lengthy side maneuver. A novel dynamic obstacle avoidance method for non-holonomic mobile robots in changing environments is presented by Hashim [49] to confirm the mobile robot is capable to gain the period lost through obstacle avoidance and reach the last position at the specified period. This approach is useful for task-based implementations such as patrolling a huge area and robot soccer, which require the mobile robot to be at the specified position at the specified period with desired direction. However, the dynamic obstacle is supposed to follow its route exactly and does not diverge from its originally planned route.

A novel method of global motion planning for a robot navigating in an environment chaotic with obstacles which have random shape, size and position is designed by Raja [50]. It is applicable to stationary, partially moving in addition to dynamic environments comprising obstacles. The advantage of this technique is decreasing start to end route distance and calculation time of the processor, but the environment is global (location and speed of obstacle are known). According to Hsu [51] a global complete coverage path planning (CCPP) procedure with the ability of presenting least working period, least energy consumption, mixed process modes and obstacle escaping for static or dynamic objects. It contributes a benefit of reducing the period or energy consumption with the hindrance avoidance, but there is no slipping on the right and left wheel. Zheng [52] states a novel technique of motion planning method to steering robot soccer in changing environment based on ant colony procedure is presented to design the greatest path. It makes the convergence constancy superior and makes the speed quicker.

### Accuracy

To achieve accuracy, a method for robot navigation that merges a global method strategy with a local reactive hindrance avoidance method is designed by Hacene [53] so as to direct the robot towards the goal through the use of the "gap vector".



It permits the robot to design its route in a chaotic environment and to keep its route as near as possible to the desired path (DP) while avoiding hindrances. Nevertheless, the back sensors are omitted in planning the robot since the robot seldom uses the back sensors because it generally travels forward. In contrast, the suggested method by Alsaab [54] extracts the collision cones of circular and non-circular obstacles by the use of a laser sensor, where the hindrance size and the period to collision are measured to weigh the speeds of the robot. It created a collision cone more precise and generated by the circle fitting approaches and allows the mobile robot to effectively pass a narrow gap despite it being able to avoid obstacles which had diverse capability to evade other obstacles.

Montiel et al. [55] planned a scheme of fuzzy controllers for a differential mobile robot which was advanced to steer in outdoors surroundings over a predetermined path from position A to position B without human interference. It is useful for minimizing the accumulated mistake that rises with the interval when an odometer system is used, but it did not consider the velocity vector of obstacles. There is an advanced framework for long-term track guess and strong collision avoidance of pedestrians and other moving agents in real-time, even when these agents display formerly unseen behaviors or variations in intent [56]. It is capable to learn new conduct patterns online and rapidly discover and respond to change-points and advance guess accuracy relative to current methods.

### Stability

To reach the stability, a multi-robot scheme (MRS) by Benzerrouk [57] must reach and preserve a particular formation in dynamic surroundings using mostly the limit-cycle principle and a penalty function to get linear and angular robots speeds. It promises the stability (using Lyapunov function) and the safety of the MRS, also the toughness and the efficiency. However, this method did not consider the kinematic restrictions of the robot while creating the convergence toward the control set-points. Tamilselvi et al. [58] proposed a technique which constructs the test bed with Fire Bird V Mobile Robot for future improvement of a smart wheelchair for old people aid in the indoor environment for calculating the distance between obstacles. The procedure's stability, rapidity, and minor storage footprint make it common for real-time collision discovery.

### Less computation cost

Masehian and Katebi [59] introduced a novel easy tool for online hindrance avoidance called Directive Circle (DC) for creating collision-free routes for differential-drive wheeled mobile robots following a moving goal amidst changing and stationary obstacles. It can be applied very simply in real-time with fewer computations than the VO technique and without suffering from great amount of obstacles. However, the robot does not guess the obstacles expected tracks, and reacts to their movements based on their existing velocity and location. On the other hand, Miao [7], improved SA method is advanced for robot motion planning in changing environments with both stationary and moving obstacles to enhance performance in both robot route solution and processing period. It gave the best or near-best robot route solution, and made its real-time and on-line applications possible, but the dimension of the robot is ignored.

A bio-inspired smart method is suggested by Choi [60] to path planning for decentralized mobile objects in changing environments to preserve a safe space between one another, and travel towards their respective targets. It discovers impending neighbors, decreases

the calculation overheads and removes redundant robot travels. On the other hand, the navigation parameters of the suggested method are practical, determined using trial and error, and there is still an absence of effectual analytic guideline to plan the parameters. Vechet [61] proposed a hybrid method which incorporates three techniques: potential fields, rule based motion planner and Voronoi diagrams is suggested to take the greatest of all mentioned techniques to generate reliable steering system with extreme emphasis on safety. The mixture of all three procedures decreases the calculation cost and raises the strength of navigation, but this approach is not optimum in its performance but in the strength and with regard to the safety of both the robot and surrounding moving persons.

### Control

To achieve control, Mallik [62] offered a control procedure based on collision cone method to prevent collision with static and dynamic obstacle in addition to irregular obstacle. It has an easy and simply executable obstacle avoidance control procedure following the virtual leader in a changing environment. However, stability analysis of the suggested control procedure is under examination. In contrast, Franzè and Lucia [63] advanced a new separate-time receding horizon control (RHC) approach based on set-theoretic notions to assurance control performance and calculation load savings under restriction contentment and disturbances impact weakening necessities. The proposed method deals with serious obstacle scenarios that are not simply worked by dynamic motion planning units, but the obstacle positions on the working space are known.

The improvement and application of neural control schemes in mobile robots in hindrance avoidance in real time by using ultrasonic sensors with difficult approaches of decision-making in improvement (Matlab and Processing) are designed by Medina-Santiago [64]. It displays a great solution to the issue of navigation of vehicles, their capability to learn nonlinear associations between the input values and sensor values output. Meanwhile, an online planning procedure is suggested by Lopez [65] for unknown changing environments that concentrate on accessibility and on the use of objects motions to reach a given goal. This algorithm is capable to discover a route through moving platforms to touch a goal situated on a surface which is never directly reachable, but does not consider steering in physical domains with physical objects.

### Efficiency

Wu and Feng [66] created a local route using obstacle-movement estimation and a rolling window for dynamic route planning to partially alter the global route. It achieves both global and local hindrance-avoidance through motion, cooperative with an optimum route, which proves the viability and effectiveness of the technique. The disadvantage of this approach is the limited zone and that there is a certain quantity of stationary obstacles and one moving obstacle. The fuzzy logic method by Faisal [67] is used with four modules so as to direct an autonomous mobile robot in formless, changing and unidentified environment to reach the destination and hindrance avoidance performances between four modules and swapping the control between modules. The proposed technique is effective and strong under moving obstacle scenarios. However, due to the use of numerous sensors to sense the surroundings, we do not have any knowledge on the real time process, and because of absence of simulation and testing, we cannot appraise to what extent that this system is voluble.

The technique proposed by Bis [68] is based on an occupancy grid

that has been used to evade static and moving obstacles. A search area permits the robot to evade moving obstacles and travel efficiently to a target using uncertain sensor data, but this technique supposes that the vehicle is holonomic and it would not be appropriate to design long and difficult paths. Behavior-based hierarchical fuzzy logic controller to resolve the robot steering and priority-based performance control is suggested by Dongshu et al. [69] so as to realize the non-collision motion of mobile robots in changing unidentified circumstance. This algorithm can direct the mobile robot in changing unknown environments effectively, but it does not consider the speed of obstacle. A dynamic path planning method for a self-directed vehicle steered without GPS and unmanned operation in unidentified surroundings is presented by Zhao [70]. The Smart Pioneer displayed worthy performances in changing path planning. However, the control of the vehicle's body came to be unsteady when the vehicle velocity was higher, so that it had to be halted and repaired.

Vignesh et al. [71] constructed a 2-D grid based map using the integration of wave-front procedure and A\* search procedure for a given situation of the environment using effectual motion planning approaches to reach the given destination while evading obstacles and maintaining its best size. The suggested algorithm worked well with efficiency of at least 80 percent, but the robot as offered is in its simple form and numerous extensions is probable.

### Future prediction (Uncertainties)

According to Shoushtary [72] a novel hybrid procedure extracted from honey bee mating optimization (HBMO) procedure (for robot navigating distance reducing) and tabu list method (for hindrance avoidance) for team robot scheme. It has a better behavior than ACO and PSO procedure, but all the robots have a similar velocity for every run. A partially closed-loop receding horizon control procedure is offered by Du Toit [73] where the resolution incorporates estimation, prediction, and planning while also accounting for chance restrictions that rise from uncertain sites of the robot and obstacles. It is capable to cope with the growing system uncertainty in the expectation component of the changing, uncertain surroundings solution, as the predicted future data decrease the uncertainty that is related with future belief situations.

An indoor housework robot coverage route is planned by Liang [74] to evade obstacles based on performance fuzzy controller under changing environment. Fuzzy control is a valuable tool for coping with the systems which model is time-variable, non-linear, and uncertain. It just defines indoor surroundings. A novel multi-agent distributed hitting escaping procedure is suggested by Knepper [75] to draw stimulus from human walkers to cooperatively evade collisions without preferring one agent over another and to integrate arbitrary tracks as produced by a path planner running on each steering robot as well as expected human tracks. It offers two supportive attributes: (1) sampling bias is reduced since the distribution of routes in the free space is exactly the fundamental sampling distribution inside that area, and (2) the refusal sampling procedure is easy to apply. However, this method may be expensive in heavily chaotic spaces.

According to Lee [76] a three dimension vision-based local hindrance avoidance scheme that based on the view image and fuzzy logic is planned and advanced on a humanoid robot so that it can select avoidance trend and walking movement effectively. These systems do not need the motion planner which has all data regarding the obstacle position and route data in advance. However, the robot is not capable to control walking professionally because of slip and hardware fault

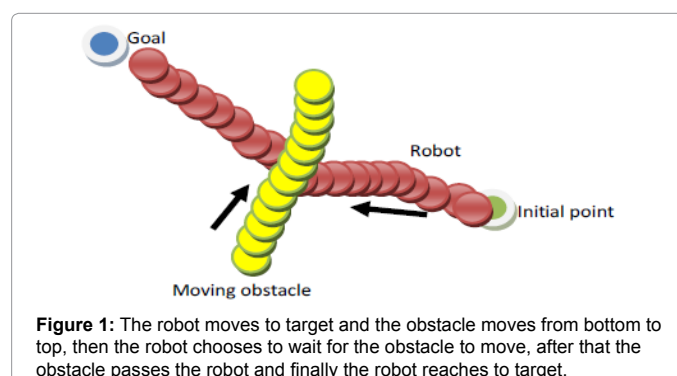
since the robot wants control procedure for steady walking. Mbede et al. [77] joined the benefit of more controllable degrees of freedom offer by Omni-directional mobile robot with the capability of the type-2 fuzzy logic to cope with the high stages uncertainties in unidentified and formless dynamic surroundings. It is appropriated for actual world implementations and on-line stationary and moving obstacle avoidance. Nevertheless, it works in indoor surroundings only, the wheels have no slipping in the orientation of traction force; the interaction forces that are not in the orientation of traction force are ignored and the motor electrical period is constant.

An improved technique of potential function is suggested by Li [78], and artificial neural network (ANN) is also used so as to acquire the data of velocity and locations of the obstacles and target. It discussed how to describe the attractive and repulsive force, and how to expect the velocity of the obstacle and the interval between obstacle and the robot. However, the planned route is not optimal since the size of the robot is limited. A tracking system in an unclear environment concentrating on moving obstacles for a mobile robot is presented by Junratanasiri [79] by designing the velocity, angular velocity and location uncertainties of a hindrance using fuzzy membership functions. A type-2 fuzzy logic scheme is applied to dominate velocity and angular velocity of a robot, but the robot decides to wait for the obstacle and then tracks towards the target and this increases the run time as shown in Figure 1. According to Tang [80] a new reactive obstacle avoidance method is advanced based on the "situated-activity paradigm" and a "divide and conquer" approach which navigate the robot to travel among unidentified obstacles and towards a goal without hitting. This technique minimizes the tasks complexity and improves the reactivity, but it cannot gain the shortest route.

### Results and Discussions

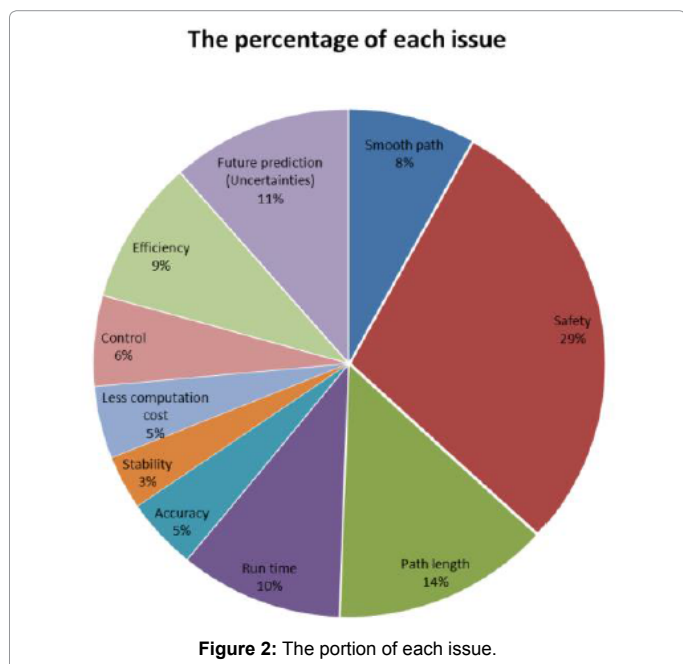
A total of eighty articles were reviewed in this study, covering an adequate depth of works in the dynamic path planning field for the time duration of 2011 to 2015. Table 1 and Figure 2 represent the percentage of each issue and these issues were then compared together. As shown in Figure 1, about 29% of the articles are related to safety and 14% to path length. Meanwhile, about 11% of papers are related to future prediction and 10% to run time. Other percentages are distributed among other issues which are sorted descending as follow: 9% to efficiency, 8% to smooth path, 6% to control, 5% to less computation cost and accuracy, and finally 3% to stability (Table 1). From the percentages mentioned above, it can be seen that the most important issue was safety and the less attention was dedicated to stability.

From the reviewed papers, we can summarize the overall procedure of obstacle avoidance in Figure 3 below:

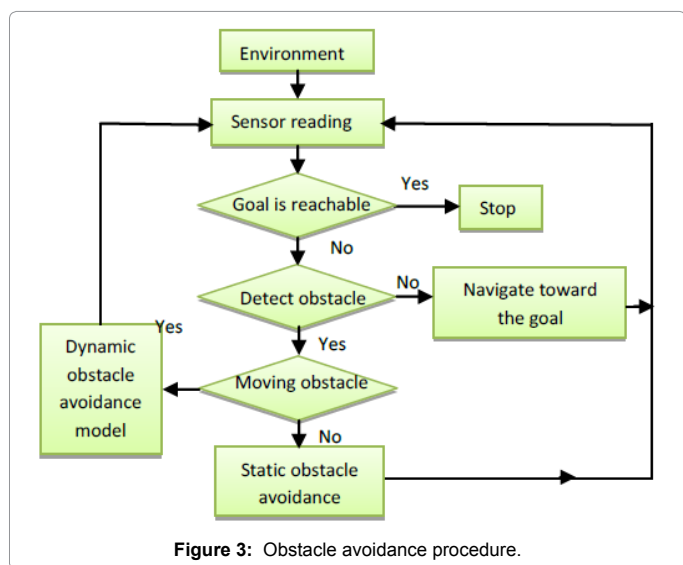


Issues	Last five years%
Safety	29%
Path length	14%
Future prediction	11%
Run time	10%
Efficiency	9%
Smooth path	8%
Control	6%
Less computation cost	5%
Accuracy	5%
Stability	3%
Total	100%

**Table 1:** Dynamic path planning issues.



**Figure 2:** The portion of each issue.



**Figure 3:** Obstacle avoidance procedure.

heuristic approaches have demonstrated to yield better outcomes than pure conventional approaches [4]. Numerous algorithms have been suggested to overcome the difficult nature of NP-hard motion planning issue as efficient functioning of mobile robot is affected by better quality of routes. The literature review shows that there is still scope for developing more efficient on-line motion planning algorithms with moving obstacles that will produce better quality routes by addressing several challenging problems as follows:

1. The most important factor which has a strong effect in dynamic motion planning is the relative velocity. It is defined as the relative velocity vector of the adjacent obstacle forward with regard to the robot.
2. In the approaches mentioned, the authors did not explicitly use this factor as a constraint. Thus, this factor needs to be emphasized in our approach.
3. Some of the above mentioned approaches used the kinematics constrains of a mobile robot, while the other ignored it. It would be considered a benefit for a specific navigation scheme to take some of actual-world factors that affect the plan of mobile robot steering schemes into account, because this makes it easier to transform into a practical application.
4. In a dynamic environment for successful navigation of a mobile robot to the goal, two significant problems should be resolved. The first one is real-time recognition of the moving obstacles. The other is that the shortest and safe path produced dynamically. Consequently, an obstacle avoidance system for mobile robot navigation in dynamic environments and a good path which has faster travelling time need to be designed.
5. Heuristic procedures do not guarantee the discovery of a solution. Thus, to enhance the efficiency of these methods, one of the excellent ways is to integrate some of them together.
6. Because the whole information of a dynamic environment will alter along with the motion of obstacles, the difficulty and uncertainty of the motion planning problem rise significantly in dynamic environments. Hence, an improved technique for a hybrid Meta-heuristic motion planning in an environment with dynamic obstacles is deemed necessary.

Furthermore, multiple optimization goals, multiple robot direction, uncertainty in detecting, forecast, path control, and many others constitute numerous extra challenges in mobile robotics.

## Conclusion

At the present time, improvement in motion planning has been increasingly inspired by new applications in different sectors. The research community presents several techniques for solving the motion planning problem in dynamic environments. This paper discusses many approaches of the motion planning and obstacle avoidance algorithms such as Fuzzy Logic, Velocity Obstacles, Gap Vector, Fitting Circle, Collision Cone, Potential Fields, Follow the Gap, Directive Circle, A\*, Neural Network, Biologically Inspired, Escaping Algorithm, Bayesian Occupancy Filter, Artificial Bee Colony, Ant Colony, Bacterial Foraging, Honey Bee Mating, Rolling Window, Q-Learning, Personal Space, Simulated Annealing, Sub goal-Guided Force Field, Vector Field Histogram, RRT\*, Particle Swarm Optimization, Voronoi Diagrams, Genetic Algorithms and Generalized Complete Coverage. This paper also reflects the research evolution that has occurred in path planning of mobile robots in dynamic environments, containing on-line planning

## Scope and Challenges

In the domain of motion planning in dynamic environments,



for the last five years. In spite of the fact that several efficient techniques have been improved, the multitude of motion planning issues has been steadily growing. These problems involve determination of collision-free route, shortest path, low run time, modeling of changing environment, multiple optimal functions, dynamic constraints, to name but a few. These restrictions craft motion planning issues to be more challenging and require more strong and efficient algorithms.

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