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An Adaptive Approach for Mobile Robot Path Planning Using Optimized Artificial Potential Field Method

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Abstract: Robot path planning is an imperative fragment in enlargement of the autonomous systems. Abundant stratagems have been proposed in literature concerning mobile robots but the trajectory planning for manipulators is substantially more challenging meanwhile all-inclusive structure can move & produce accidents with the adjoining obstacles. APF (Artificial Potential Field) technique is extensively used for the mobile robots path planning due to its sophisticated mathematical analysis & minimalism. Nonetheless, this method has some characteristic shortcomings in the path planning. This paper benevolences newfangled effectual method for the autonomous mobile robot path planning in the comprehensive known surroundings. We are primarily considering an artificial potential field process with the amended layers of design after that gain coefficient of repulsion are optimized through proposed the genetic algorithm by considering repulsion coefficient as our objective function, as we know that force of repulsion plays an important role in the path planning. A more efficient technique used here is backtracking model. In this manner, we have to save trace of running algorithm to select the shortest path. A novel total potential concept is also proposed which consider effect of obstacles near target & conception of the velocity based force calculation is also derived in the case of movable obstacles or target. Simulation results show that this technique has a better, accurate & optimized results than other common approaches such as bug & artificial potential field.

Keywords: Articial potential field, Robot path planning, Mobile Robot, Genetic Algorithm, Search Optimization, Backtracking, Potential Learning.

I. INTRODUCTION

Autonomous navigation & obstacle avoidance for the mobile robots is widely recognized as fundamental research issue & is of interest to numerous researchers. An artificial potential field technique being computationally inexpensive is one of most popular methods used to navigate mobile robots in the dynamic environment. It was introduced by Khatib [5]. In last few decades, the robotic scientists have investigated on the service mobile robots which could be able to operate within the human-robot coexistent environments to perform different complex works, like transportation of the heavy objects, surveillance, rescue, & guiding people in exhibitions & museums. The autonomous mobile robot path planning or navigation is one of most significant applications for the robot control systems & has attracted remarkable attention from the number of researchers. The path planning is aimed at enabling robots with capabilities of automatically deciding & executing a sequence of the collision-free & safety motions in order to achieve certain tasks in given environment. As described in numerous interesting researches, 2 significance features that distinguish these algorithms are whether environment is known or unknown & whether it is static or dynamic.

The known environments are those in which all info about obstacles & targets are known priori, the motion of robot is designed from given information. Examples of the successful path planning algorithms in this know environment include the sub-goal network [1], cell decomposition [2], A* [3] & D* algorithm [4], the traditional artificial potential field [5], & many others [6-8]. In the unknown environments, robot doesn't have any previous knowledge about environment or only the partial information is available. Therefore, the robot must plan a path based on few available information or the local sensing information. In recent years, the lots of researchers have achieved significant investigation results in such critical environment, for instance, the genetic algorithm [9, 10], simulated annealing [11], the ant colony optimization [12], & others algorithms [13, 14].

Most of approaches mentioned have improved repulsive potential function to overcome these difficulties. But traditional attractive function is still used. So repulsive function becomes complex while attractive is much easier. This paper presents new efficient method for autonomous mobile robot path planning in the complete known environments. We are originally considering an artificial potential field technique with improved layers of the design after that gain coefficient of repulsion are optimized through proposed the genetic algorithm by considering repulsion coefficient as our objective function, as we know that force of repulsion plays an significant role in the path planning. A more efficient technique used

here is backtracking paradigm. In this technique, we have to save trace of running algorithm (i.e. the traditional APF). The different generation performed by genetic algorithm, establish a set of the feasible paths. In every generation, we save path that has shortest length, then we drawback to previous generation to compare it with the best path of each one. Every time we find path shorter than current, we switch to found one else we keep current path.
At last we achieve research by shortest path over all generation performed by adapted genetic algorithm. A novel total potential concept is also proposed which consider effect of the obstacles near target & concept of the velocity based force calculation is also derived in case of the movable obstacles or target. The edifying steps of paper are as follow: Section II present background & review of problem area. A systematic procedure for the APF technique is point out in section III. Section IV contains details of important points from proposed work. At last, results & conclusion are presented in the Section V & VI.

II. BACKGROUND AND RELATED WORK

There have been numerous research studies over past few years regarding the global path planning for the mobile robots, applying different kinds of algorithms & methods, with strong emphasis on metaheuristic approaches of solving grid based path planning, which have demonstrated great range of the applications in artificial intelligence.

Large part of the autonomous mobile robot path planning is pertaining to scheduling & routing, & is well-known to be the NP-hard (NP-complete) problem. The path planning algorithms are classified as classic & heuristic approaches [15]. The classic algorithms aim to estimate an optimal solution if one exists, or prove that there is no possible path. Though, most of the classic approaches are based on free configuration space (Cspace) concept. In addition to their lack of adaptively & robustness, thus conventional methods are not suitable for the dynamic environments since utilizing sequential search algorithm to generate the single solution which may become infeasible when environment changes, a novel solution has to be generated from scratch. Expect for, greater dimension of free C-space, more complex & computationally expensive path planning problem will be. Instead, the heuristic algorithms attempt to find the search for a good quality solution in the short time. However the heuristic algorithms may fail to find good solution for the difficulty problem, deadlock & oscillation happen easily.
The APF technique can be implemented quickly & provide excellent results in the real-time. However, APF method has numerous inherent drawbacks as follows:

- Trap situations due to the local minima;
- Oscillations in presence of obstacles;
- Goals Nonreachable with the Obstacles Nearby (GNRON);
- Modeling inaccurately for the obstacles with complex shape.

To overcome these disadvantages, numerous improved algorithms based the potential field are presented. The Artificial Potential Field (APF) is firstly introduced by Khatib [5]. Potential function can be defined over the free Cspace as sum of attractive potential pulls robot toward goal configuration, & the repulsive potential pushes robot away from obstacles. The APF has often represented good quality to achieve a fast & reactive response to the dynamic environment. However, this technique has been widely demonstrated that it suffer from an unavoidable drawbacks which are very likely for the robot to get trapped into the local minimum & oscillations. Paper [16] describes the hybrid approach, which integrates priori knowledge of environment with the local perceptions in order to execute assigned tasks efficiently & safely. The results indicate that this technique guarantees the robot can not ever be trapped in deadlocks even when operating within partially unknown dynamic environment. In spite of its good properties, navigation system designated in this paper has typical disadvantage that is the system is relying on the local perceptions & navigation strategies. Another improved the APF is proposed in [17] utilizing quantum particle swarm optimization for the rapid global searching & realizing the optimal path planning. They employ the quantum particle swarm optimization to modify parameters of the APF for adapting different environment & the dynamic obstacles. To address local minima problem in traditional APF, a technique composed of the robot regression & potential field filling is proposed [18-19]. The similar approaches propose in [20-21], before calculating resultant force that is put on an object in potential field, they build links among the closed obstacles to optimize planed solution. Other types of improved artificial potential fields are inspected, such as in [22], they introduce relative distance between robot & target into repulsive force function & modify repulsion direction to ensure global minimum is at the position of target. Paper [23] researches learning reactive & the planning rules into mobile robot path planning. The main distribution of [24-25] is that apply the virtual local target to guide the robot escapes local minimum.
While all mentioned above APF & its improved approaches still suffer from numerous drawbacks, like the high time complexity in the high dimensions that result in these approaches could deal with the real-time path planning, & some methods don't completely solve the local minima & oscillation which makes them inefficient in practice. Moreover, path under previously approaches is not optimal/near-optimal, but only feasible for robot to adapt given environment. In other words, robot move along planed path will consume more energy & costs. As described in this paper, a efficient improved the APF technique which can obtain the global optimal/near-optimal path without the local minima & oscillations in the complete known environment information

III. PROPOSED ARTIFICIAL POTENTIAL FIELD

Basic idea of APF technique assumes that robot as point moves in an abstract artificial force field. Artificial field in

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environment is composed of the attractive field of target & repulsive field of obstacles. Attractive field is produce by target & direct to target point, while the repulsive field is synthesis repulsive field of the different obstacles & the direction of synthesis repulsive field is away from the obstacles. Consequently, the potential function (1) is APF of robot which is defined as resultant of attractive field & repulsive field. The robot controls its movement toward the target point along direction of APF. Under the technique of APF, robot could find the collision-free path by searching route along the decline direction of the potential function. The coordinate of robot is $q = (x, y)^T$, thus APF is defined as

$$U(q) = U_{att}(q) + U_{rep}(q) \quad (1)$$

Where $U(q)$ is the artificial potential field. $U_{att}(q)$ is attractive field. $U_{rep}(q)$ is repulsive field. Negative gradient of the APF is defined as artificial force which is steepest descent direction for guiding the robot to the target point. Attractive force is negative gradient of the attractive field, & repulsive force is negative gradient of the repulsive field. Thus, artificial force of robot is:

$$F(q) = -\nabla U_{att}(q) - \nabla U_{rep}(q) = F_{att}(q) + F_{rep}(q) \quad (2)$$

Where $F(q)$ is artificial force. $F_{att}(q)$ is the attractive force. $F_{rep}(q)$ is repulsive force.
Attractive field between the robot & target is constructed to pull robot to goal area. The attractive field created by goal is given by

$$U_{att}(q) = \frac{1}{2}k\left(q - q_g\right)^2 = \frac{1}{2}k\rho_{goal}^2(q) \quad (3)$$

Where: k is a positive coefficient for the APF. $q_g = \left(x_g, y_g\right)^T$ is location vector of target. $\rho_{goal}(q) = ||q - q_g||$ is the Euclidean distance from location of robot to position of target. The attractive force on robot is calculated as negative gradient of the attractive potential field & takes the following form:

$$F_{att}(q) = -\nabla U_{att}(q) = -\frac{1}{2}k\rho_{goal}^2(q) = -k(q - q_g) \quad (4)$$

$F_{att}(q)$ is a vector directed toward q_g with the magnitude linearly related to distance from q to q_g. The components of $F_{att}(q)$ are minus directional derivatives of attractive potential along the x & y directions. Therefore, when attractive potential takes effect, components can be written as:

$$F_{att-x}(q) = -k(x - x_g) \;\&\; F_{att-y}(q) = -k\left(y - y_g\right) \quad (5)$$

Where $F_{att-x}(q)$ is attractive force on the x direction. $F_{att-y}(q)$ is attractive force on the y direction. The robot should be repelled from obstacles, but when robot is far from the obstacles, author don't want obstacles to affect robot's motion. We uses function (6) as the repulsive potential field.

$$U_{rep}(q) = \begin{cases} 0 & , \rho(q) \geq \rho_0 \\ \frac{1}{2}\eta\left(\frac{1}{\rho(q)} - \frac{1}{\rho_0}\right)^2 & , \rho(q) \leq \rho_0 \end{cases} \quad (6)$$

Where η is positive scaling factor. Let $q_c = (x_c - y_c)$ be unique configuration in an obstacle closest to q . $\rho(q) = ||q - q_c||$ is shortest distance between robot & obstacle. ρ_0 is the largest impact distance of the single obstacle. There is no impact for robot when distance between robot & obstacle is greater than ρ_0 . Similarly to attractive force, repulsive force is the negative gradient of the repulsive potential function, as follows:

$$F_{rep}(q) = -\nabla U_{rep}(q) = \begin{cases} 0 & , \rho(q) \geq \rho_0 \\ \eta\left(\frac{1}{\rho(q)} - \frac{1}{\rho_0}\right)\left(\frac{1}{\rho^2(q)}\right)\nabla\rho(q) & , \rho(q) \leq \rho_0 \end{cases} \quad (7)$$

$$F_{rep}(q) = -\nabla U_{rep}(q) = \begin{cases} 0 & , \rho(q) \geq \rho_0 \\ \eta\left(\frac{1}{\rho(q)} - \frac{1}{\rho_0}\right)\left(\frac{1}{\rho^2(q)}\right)\frac{q - q_c}{||q - q_c||} & , \rho(q) \leq \rho_0 \end{cases} \quad (8)$$

$F_{rep-x}(q)$ and $F_{rep-y}(q)$ are Cartesian components of the repulsive force F_{rep}. When repulsive potential acting on robot takes effect, components can be written as:

$$F_{rep-x}(q) = \begin{cases} 0 & , \rho(q) \geq \rho_0 \\ \eta\left(\frac{1}{\rho(q)} - \frac{1}{\rho_0}\right)\left(\frac{1}{\rho^2(q)}\right)\frac{x - x_c}{||q - q_c||} & , \rho(q) \leq \rho_0 \end{cases} \quad (9)$$

$$F_{rep-y}(q) = \begin{cases} 0 & , \rho(q) \geq \rho_0 \\ \eta\left(\frac{1}{\rho(q)} - \frac{1}{\rho_0}\right)\left(\frac{1}{\rho^2(q)}\right)\frac{y - y_c}{||q - q_c||} & , \rho(q) \leq \rho_0 \end{cases} \quad (10)$$

While there are numerous obstacles in environment, the total repulsive potential field is sum of all obstacles' repulsive potential field. Total potential field can be expressed as function (11).

$$U(q) = U_{att}(q) + \sum_{i=1}^{n} U_{rep}(q) \quad (11)$$

Where: n is number of the obstacles. The total artificial force is:

$$F(q) = F_{att}(q) + \sum_{i=1}^{n} F_{rep}(q) \quad (12)$$

Although the traditional APF technique can plan smooth path effectively, it has fatal problems. When attractive force & repulsive force is equal or almost equal & collinear but on opposite direction in process of moving to target, potential force of robot is zero, then it will cause robot to be trapped in the local minima and oscillations. And when position of target is very close to obstacles, the robot could not reach the target. According principle of the artificial potential field, path planning technique for the mobile robot based on the artificial field can be divided into 3 parts to design.

A. Design of the behavior control layer
Behavior control layer is the more complicated & more decisive than basic control layer. Its existence decided that robot avoid barrier intelligent are possible, & it is very significant calculate layer. Its main mission is to let robot judge the distance information collected by ultrasonic sensor whether should carry on evade barrier or not, also give corner's size & the turning.

B. Design of basal control layer
The basal control layer can be definite as basic behavior layer, the mission of which is looking for target point, & insure the robot can arrive target smoothly. Under circumstance that assurance destination position already, in order to attain above- mentioned purpose, calculator must carry the gravitation pole on target point, to lead robot move.

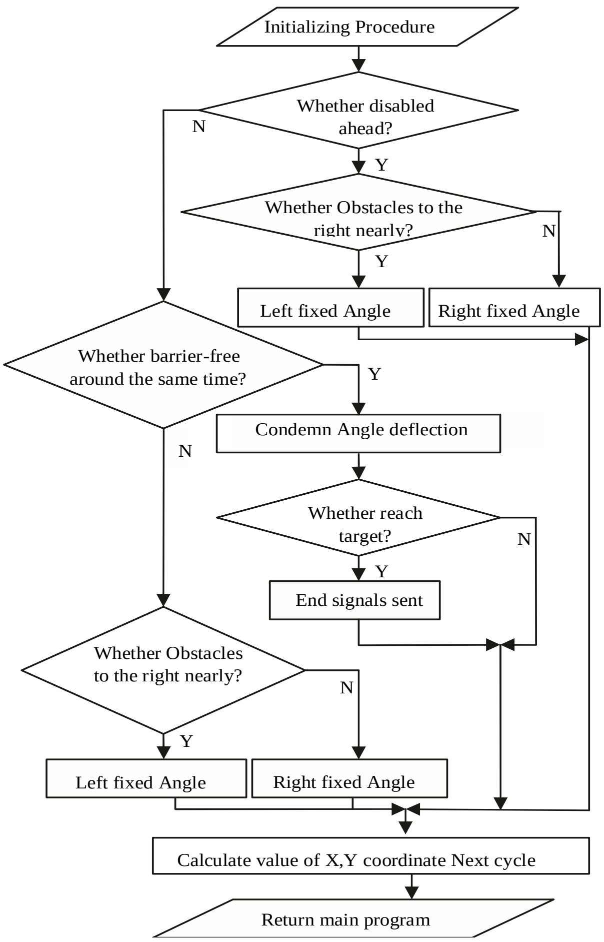

Figure 1. The overall flow of path planning procedures program

C. Design of the coordinate calculatingly layer
The design project of coordinate calculatingly layer, main adopt dummy coordinate method, it can definite robot's opposite barrier & the target's concrete position visually to insure robot avoiding the barrier in time & arrive the target point smoothly.

IV. SECTIONS OF PROPOSED WORK

The general procedure of the proposed path planning stretagy is achieved in 3 stages: pre-processing, processing & decision. The system model or the block diagram for proposed work by proposed design Layers of the APF with backtracking under influence of mobility & aim to control effect of repulsion which is further optimized using the genetic algorithm is shown in figure below:

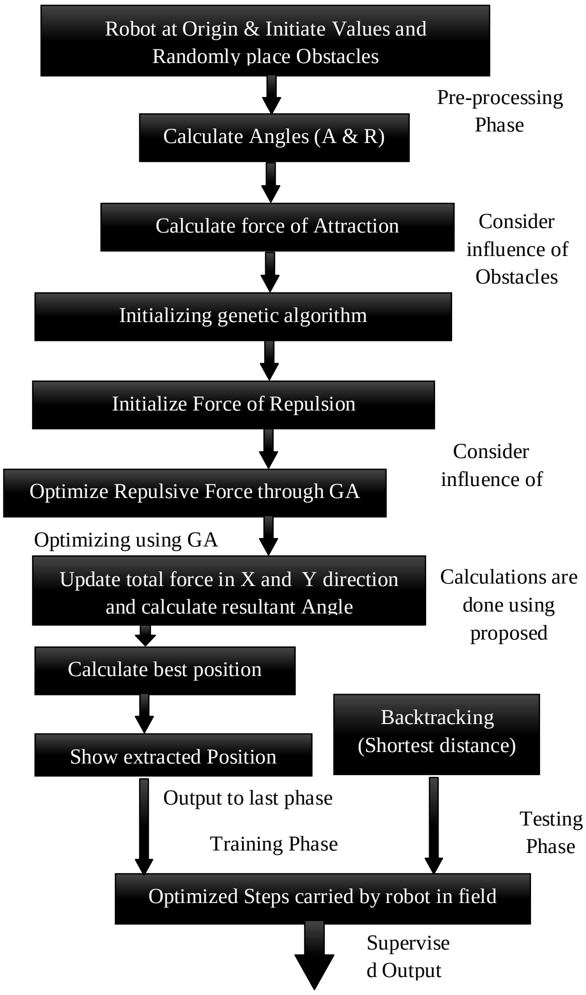

Figure 2. System model for the proposed work.

1. Proposed Optimization of Traditional Artificial Potential Field

Recent advances in robotics & the machine intelligence have led to application of modern heuristics, like the Genetic Algorithm (GA), to solve path-planning problem. Numerous successful attempts have been reported. In the proposed work we are first who are using the genetic algorithm optimization for **optimization of gain coefficients of repulsion** in order to extract the best results from traditional method.

Genetic algorithm is the part of evolutionary computing, which is rapidly growing area of the artificial intelligence. In genetic algorithm, a population of strings (i.e. called chromosomes or genotype of the genome), which encode

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candidate solutions (i.e. called individuals, creatures, or phenotypes) to optimization problem, is evolved toward the better solutions.

Traditionally, the solutions are represented in binary as strings of 0s & 1s, but other encodings are also possible. The evolution usually starts from population of randomly produced individuals & happens in generations. In each generation, fitness of every individual in population is evaluated, the multiple individuals are stochastically selected from current population (i.e. based on their fitness), & modified (recombined & possibly randomly mutated) to form new population. The new population is then used in next iteration of algorithm. Commonly, the algorithm terminates when either maximum number of the generations has been produced, or satisfactory fitness level has been reached for population. If the algorithm has terminated due to the maximum number of the generations, the satisfactory solution may or may not have been reached.

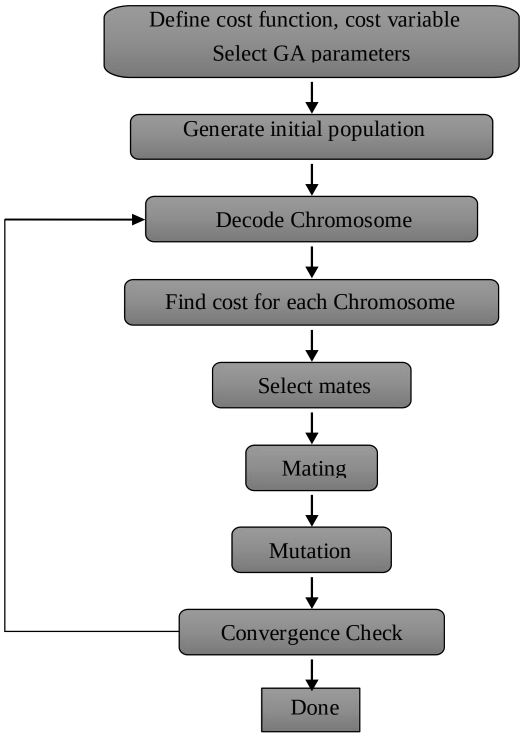

Figure 3. The overall flow of the genetic algorithm optimization

According to simulation result of the previous work, GA successfully detected near optimal feasible travelling path for the mobile robot. The population that converges with solution path is the ending generation of GA run on these data.

2. Proposed Backtracking Concept

A more efficient technique uses backtracking paradigm. In this technique, we have to save trace of running algorithm (i.e. traditional APF). The different generation performed by genetic algorithm (section 4.1, optimization phase), establish set of the feasible paths. In every generation, we save path that has shortest length, then we disadvantage to previous generation to compare it with the best path of each one. Every time we find path shorter than current, we switch to the found one else we keep current path. At last we achieve research by shortest path over all generation performed by adapted genetic algorithm. This path is the solution of optimization developed on the path planning problem of surveyor robot that moves according described potential function.

3. The New Total Potential Concept

The attractive potential is source of the robot motion to the goal. The traditional attractive potential function is given as following

$$U_{att}(q) = k_a \rho^{m_1}(q, q_{goal}) \qquad (13)$$

Where $\rho(q, q_{goal})$ is distance from goal to the robot. k_a & m_1 are positive constant values. The total potential field is sum of attractive potential and the repulsive potential as

$$U_{tot}(q) = U_{att}(q) + U_{rep}(q) \qquad (14)$$

The nearer the distance from robot to the goal is, the weaker attractive potential is. However, nearer the distance from the robot to obstacle is, the stronger the repulsive potential is. If goal is very close to an obstacle, robot may not reach the goal position. When robot methods its goal, it methods the obstacle as well. The robot may suffer strong repulsive force & a weak attractive force when robot locates at the goal position nearby.

Consequently, robot will be repulsed away rather than reaching goal. This is the problem which was first defined earlier. The problem arises because goal position, which is very close to obstacles, is not global minimum of total potential field. After describing problem, improved repulsive function to eliminating the problem. So attractive function is improved to overcome problem & relieve the burden of repulsive function to some extent in proposed work. A new attractive potential function is presented as follow:

$$U_{att}(q) = k_a \rho^{n_1}(q, q_{goal}) + k_2 \left(\frac{1}{{\rho_0}^{n2}} - \frac{1}{\left(\rho_0 + \rho(q, q_{goal})\right)^{n2}} \right) \qquad (15)$$

Where $k_1 k_2$ & n_1, n_2 are positive constant values. ρ_0 is a positive constant & $\rho_0 < \rho(q_{goal}, q_{obs})$. If $(q, q_{goal}) = 0$, $U_{att}(q) = 0$. If the robot is far from the goal $U_{att}(q)$ approximates $k_1 \rho^{n_1}(q, q_{goal}) + \frac{k_2}{{\rho_0}^{n2}}$ The farther distance from robot to the obstacle is, the stronger attractive potential is. New function keeps the strong attractive potential field at far place. Additionally, the new function decreases attractive potential near goal position evidently. The gradient of attractive potential & the pull near the goal both increase. Therefore, problem can be eliminated using new attractive function. The goal isn't the central of blue

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equipotential. So the goal isn't the global minimum of total potential field. The robot is trapped & can't reach the goal position. As the novel attractive function reductions the potential near the goal position evidently, goal becomes the global minimum & is reached by the robot.

4. The New Total Attractive Potential Concept

In conventional the APF method, local minimum is formed when an attractive force is equal to repulsive force. A simulated obstacle has role of repelling a robot from the local minimum. The simulated obstacle is generated when robot is trapped by the local minimum & then it makes extra force which repels a robot from the local minimum point. To judge whether robot is trapped by the local minimum or not, we defined following criterion.

In the dynamic environment, problem of the mobile robot path planning is to plan & control the robot in an ideal way to track target from initial points, & evade obstacles while moving. In order to simplify analysis, this work does following assumption:

Assumption 1: robot is a particle, & its position q & velocity v are known;
Assumption 2: target robot's position q_{tar} & velocity v_{tar} are known, and $|v_{tar}| < v_{max}$

The trapping point is selected among robot skeleton points, & the inner product of attractive force & the repulsive force has maximum value at this point. The repulsive force at trapping point has maximum component force about opposite direction of attractive force among all skeleton points of robot. Therefore, that the point may has major influence on trapping the robot, & the robot should be far away from this point.

Usually, gravitational field is defined function that is only related distance between robot & target, & target is defined the fixed particle in the space. But when target is moving, the traditional potential field function can't be used in situation. It needs to define new gravitational field function to suit situation.

$$U_{att(q,v)} = \alpha_q \|q_{tar}(t) - q(t)\|^m + \alpha_v \|v_{tar}(t) - v(t)\|^n \quad (16)$$

In this formation of potential, robot can escape from local minima because the trapping point has the higher potential than it's around. An extra potential is applied while a robot is in local minimum area.

V. RESULTS & DISCUSSION

In order to verify validity of the algorithm, this article makes numerous simulations & comparisons for above algorithm. In these simulations, target & obstacles are denoted as particle, with their volume not taken into account. Robot step is fixed at 0.5 in improved the artificial potential field algorithm, expected distance between robot & obstacles is fixed at 2, the adjustable parameter of target point (i.e. gain coefficient of attraction) k is 2, repulsion of adjustable parameters (i.e. gain coefficient of repulsion) m is calculate every time according to field conditions through the genetic algorithm, & obstacles are placed randomly within field area based on the poisson distribution, we did experiments on 7, 10 & 15 obstacles with various cases..

Simulation results based on proposed algorithm in the barrier zone are shown in below figures. Simulation shows that robot move to direction in which can save energy consumption (i.e. shortest distance). The simulation results based on the traditional artificial potential field technique are shown for comparison; simulation shows that the APF fail in such problem in this situation. The simulation results based on an improved artificial potential field technique are shown along with the APF with various number of the obstacles; the simulation shows that APF process is less efficient to catch target in a long time. Simulation results based on the hybrid algorithm of an improved artificial potential field shows that this algorithm has best performance under numerous conditions. Algorithm is verified on the MATLAB 2015a & the robot works in a 15m× 15m 2-dimensional space, assuming that the robot is particle. We can also change field area & further parameters as per experimental requirements.

In following simulations, the paths are found by assuming that robot moves at constant speed, & the virtual force applied to it only determines direction of its motion. The workspace is represented by horizontal plan of 2D. In order to validate effectiveness of improved kind artificially potential field technique, this paper uses MATLAB 8.5.0.197613 to make the simulation experiment. There are numerous obstacles existing in simulation environment, obstacles are given by the artificial setting.

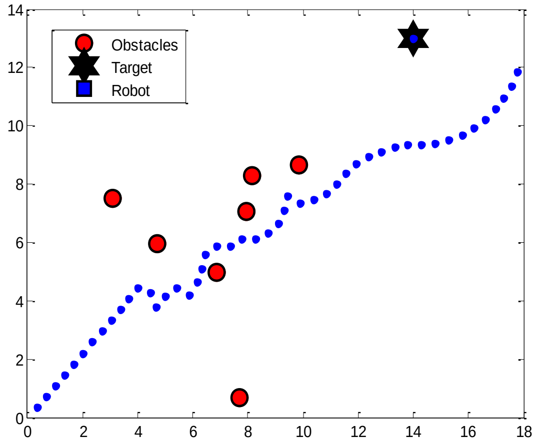

Figure 4. Path planning of the traditional artificial poteintial field method under 7 obstacles.

Through set starting point of capture robot (i.e. blue rectangle), numerous number of obstacles (red circle) & target (black star) & the trajectory, we can verify feasibility of algorithm. The single robot avoiding

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obstacles to capture mobile target in given environment are shown as follows.

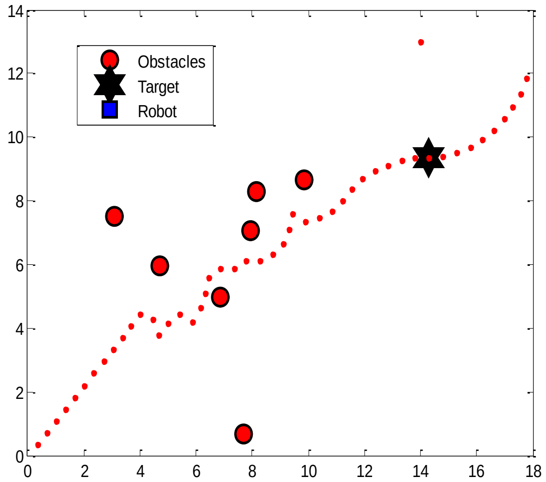

Figure 5. Path planning of the proposed artificial poteintial field method under 7 obstacles.

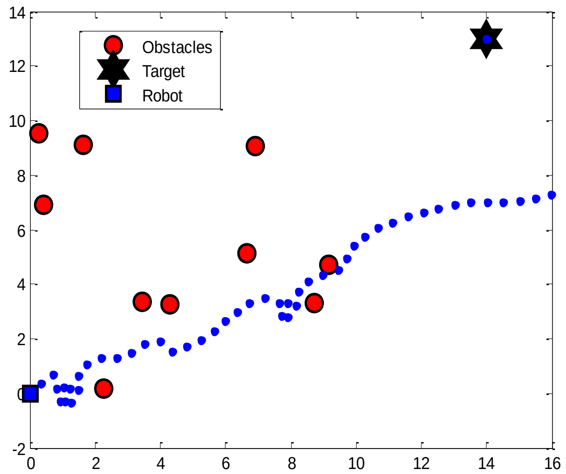

Figure 6. Path planning of the traditional artificial poteintial field method under 10 obstacles.

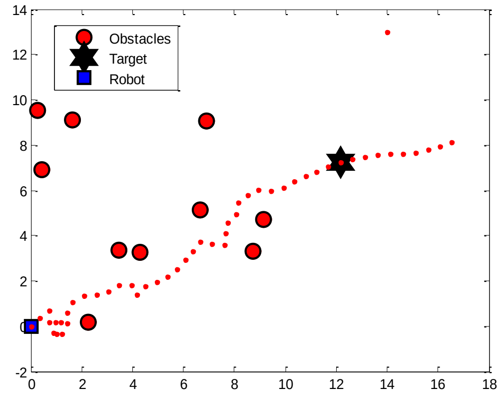

Figure 7. Path planning of the proposed artificial poteintial field method under 10 obstacles.

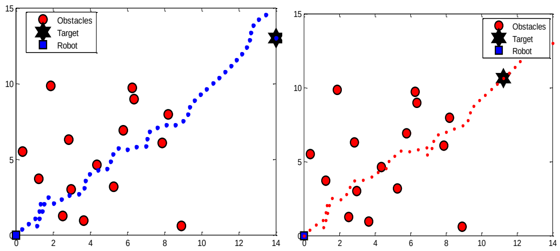

Figure 8. Path planning of the traditional artificial poteintial field method under 15 obstacles.

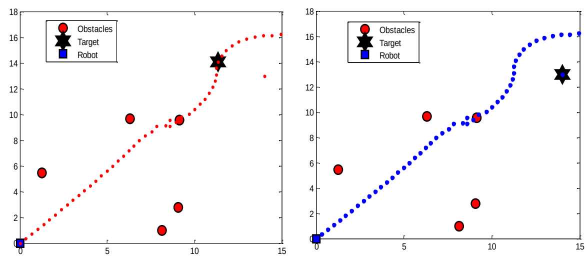

Figure 9. Path planning of the traditional & proposed artificial poteintial field method under 5 obstacles.

TABLE 1. TABULAR VALUES OF THE PATH TRAVELLED BY ROBOT WHILE CONSIDERING 5 OBSTACLES

Steps	X proposed	Y proposed	X traditional	Y traditional
1	0	0	0	0
2	0.340225549	0.366396745	0.340225549	0.366396745
3	0.679722093	0.733469077	0.679722093	0.733469077
4	1.018427908	1.101271158	1.018427908	1.101271158
5	1.356274090	1.469863015	1.356274090	1.469863015
6	1.693183471	1.839311346	1.693183471	1.839311346
7	2.029069346	2.209690448	2.029069346	2.209690448
8	2.363833955	2.581083308	2.363833955	2.581083308
9	2.697366666	2.953582880	2.697366666	2.953582880
10	3.029541787	3.327293582	3.029541787	3.327293582
11	3.360215925	3.702333065	3.360215925	3.702333065
12	3.689224771	4.078834300	3.689224771	4.078834300
13	4.016379161	4.456948046	4.016379161	4.456948046
14	4.341460234	4.836845790	4.341460234	4.836845790
15	4.664213418	5.218723234	4.664213418	5.218723234

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16	4.984340934	5.602804441	4.984340934	5.602804441
17	5.301492365	5.989346767	5.301492365	5.989346767
18	5.615252721	6.378646702	5.615252721	6.378646702
19	5.925127217	6.771046748	5.925127217	6.771046748
20	6.230521742	7.166943432	6.230521742	7.166943432
21	6.530717613	7.566796453	6.530717613	7.566796453
22	6.824838803	7.971138791	6.824838803	7.971138791
23	7.194143571	8.308205533	7.183089333	8.319931792
24	7.551749418	8.657659475	7.535408446	8.674715166
25	7.855189357	9.055056259	7.835830878	9.074397994
26	7.971369747	8.568741425	8.333641187	9.121140860
27	8.466873639	8.635643539	8.572446261	9.560426799
28	8.902519444	8.881026367	8.582021148	9.060518486
29	9.386056704	9.008273051	8.929134162	9.420397015
30	9.835150715	9.228078804	9.231139855	9.818884859][
31	10.07189834	9.668476989	9.691126232	10.01487601
32	10.17349227	10.15804687	9.997842673	10.40974944
33	10.43518827	10.58409288	10.31955290	10.79250592
34	10.72338581	10.99267847	10.59901011	11.20711859
35	10.98457925	11.41903276	10.83217726	11.64942288
36	11.21675111	11.86186030	11.02827042	12.10936578
37	11.40600170	12.32466070	11.171813556	12.58831815
38	11.53197583	12.80853106	11.24383646	13.08310366
39	11.57064955	13.30703316	11.25890558	13.58287653
40	11.63334326	13.80308708	11.36290221	14.07194165
41	11.79401193	14.27656948	11.55118431	14.53513692
42	12.04444462	14.70933208	11.81675916	14.95877591
43	12.37350293	15.08579008	12.15066278	15.33094304
44	12.76779251	15.39325671	12.54235776	15.64170830
45	13.21233138	15.62213484	12.98013622	15.88326577
46	13.69119281	15.76598103	13.45151632	16.05000152
47	14.18810551	15.82145871	13.94362250	16.13849728
48	14.68699799	15.85471967	14.44354185	16.14747744
49	15.17311947	15.97170646	14.93865000	16.21724798
50	14	13	16. 31955290	17. 99267847

This conclude that & also here results shows that, proposed work successfully extends stable region and efficiency of the path planning technique with the lower computational rate & higher values of accuracy.

VI. CONCLUSION & DISCUSSION

The path planning problem is one of most significant robotic problems for the autonomous mobile robot to accomplish given tasks. Shortest/optimal path generation is important for the efficient operation of mobile robot. The recent advances in robotics & the machine intelligence have led to the application of the modern optimization technique such as the Genetic Algorithm (GA), to solve path-planning problem.

In this paper, the GA path-planning method is enhanced with the artificial potential field. The central idea behind this method is the significance of force of the repulsion within robot movement. Additionally we improve result of the applied approaches by backtracking carried out on hidden generation to give shortest path as a solution for optimizing path tracking problem. An improved artificial potential field based technique was proposed to obtain global optimal/suboptimal path without the local minima & oscillations in complete known environment information. Numerous layer based method & influence of the obstacle in angle of attraction & mobility are utilized to enhance path planning & eliminate local minimum caused by the traditional APF when attractive force & repulsive force in the collinear but opposite direction. Due to computed path by an improved APF is not shortest trajectory, we developed new technique to optimize planned path, & proved that safely, shorten & collision-free path for the autonomous mobile path could be produced by amount of simulations.

This proved our improved technique is very feasibility & efficiency to solve the path planning. In future works, we attend to improve smoothness of planning path, utilize improved APF based technique for the dynamic environment, moving the target real time path planning.

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