MOBILE ROBOT PATH PLANNING AND TRAJECTORY TRACKING USING ARTIFICIAL POTENTIAL FIELD METHOD

Jitender kumar[1*], Vishal Shankar Srivastava[1]

[1]*Department of Mechanical Engineering, GL Bajaj Institute of Technology, Greater Noida, UP, India*

ABSTRACT

The application of mobile robots for industrial automation plays an important role in the field of robotic research. The path planning and optimization in various environments is a challenging job among the scientists and engineers since last three decades. There are various methods have been developed for efficient and safe navigation of mobile robots to cater in different situations. Fuzzy logic, Genetic algorithms, artificial potential field etc. have been widely used in mobile robot path planning. This Literature review will discusses the mobile robot navigation using artificial potential field (APF) method which is good for simplicity and real time path planning problems in the workspace and local minima problems solution. The study can be further advanced to dynamic environment problems.

Keywords – Attractive, potential, Mobile robot, Local minima, path planning, Repulsive potential

I. INTRODUCTION

After industrial automation robots have been used so much to increase the productivity and to remove human limitation. Specifically mobile robots have been widely used there. Because they are capable to move in planned path. After that research has been going on for path planning methods which can give optimize path and flexibility also. Many methods have been introduced i.e. artificial potential field method, fuzzy logic, genetic algorithm etc. Their application not only limited to industries but in real time gaming, science laboratories etc. But artificial potential field method has been widely used due to its mathematical ability and less time taking method. Automation techniques are applied widely in many fields like industrial plants, factories and offices. The main purpose of automation is both to save time and manpower and to improve the service quality. Hospitals are ideal candidates for automation of transportation, as many items are transported daily from one location to another by trained people. The heavy load of transportation tasks requires a significant amount of manpower, and common tasks are mainly concerning transportation of trash, food, laundry, beds, samples, medical equipment, office supplies, mail etc. This is not only waste of the trained personnel's expertise but also a monotonous and tedious work. Automation is a key aspect for increasing efficiency and saving both time and manpower. The main purpose of an automatic technology is to reduce the need of human transportation tasks and replace them with robotic technology where the transportation task is suitable. A mobile robot that can perform transportation tasks could therefore relieve hospital personnel of this time consuming, secondary task and free their time for the more critical primary duties the solution will require an automation system consisting of a mobile robot there is able to transport the different hospital equipment from one place to another. The robot must be suitable for hospital environment where human traffic will not interfere with the system and not lead to potentially collisions with people or interior. The system must therefore be able to deal with changes in its surrounding environments such as people and other obstacles. One technology that has been successfully implemented in many industrial applications to move materials around a manufacturing facility of a warehouse is Automatic Guided Vehicle AGV. An AGV is a mobile robot which means the robot is not fixed to one physical location. The benefit of robotic technology and the increasing knowledge from the research and the experience in industrial environments, result in introducing solutions to transportation of goods in places like hospitals. There exist several examples on utilizing robotic technology in hospitals. One of the earliest service robot projects is the Help Mate robot capable of navigating hallways and riding elevators to deliver payloads to programmable destinations throughout a hospital. TUG is another commercially available robot, which is able to transport attached wagons by tugging them. These examples indicate an increasing interest for such robotic systems. Artificial potential fields is a method that originally mimics the behavior of magnetic fields where points of interest attract, and obstacles repel a mobile object that moves in the resulting field. To get to the goal, the object and its way to it by, at each point in time, choosing the steepest possible attractive direction for its next move. As the technique was developed to support decision making in robot navigation, in general it does not need to calculate the potentials in all possible positions of the field. Instead, it typically filters out a number of look ahead positions (that can be reached by the mobile robot), and probes the potentials in these positions, given the positions of other objects of interest. Since there are only the distances and possibly the directions of the attracting or repelling charges in relation to the positions probed that are of interest, there is no need to calculate the potentials of the intermediate positions. A robot should be designed and controlled to navigate and traverse without colliding to the obstacles located around itself which may be static or dynamic.Artificial potential fields (APF) is a reactive approach in which trajectories are not planned explicitly. In- stead, agent's interactions with its environment are superposed or emerged to make the robot flexibly cope with the changing environment. Although the idea behind using APF in path planning seems easy, problems such as local minima and oscillatory movements make it difficult to find a path connecting two-end positions. But many solutions have been given by researchers for solving local minima problems. Today the problem of multi robot path planning also have focus. The goal of defining a basic motion planning is to isolate some central issues and analysis them in depth before considering additional difficulties. The general motion planning is complex task and there will be a number of simplifying assumptions. The potential field method treats the robot like a particle moving in a field under the influence of an artificial potential field whose local variations are expected to respect the structure of the C-free. The robot then moves in the direction indicated by the potential field. The goal acts as an attractive force on the robot also obstacles form a repulsive force directing the robot away from obstacles. The correct combination of repulsive and attractive forces moves robot from the initial position to the goal position while avoiding obstacles. If new obstacles appear during robot motion the potential field needs to be updated in order to integrate this new information. The drawback of the potential field method is that there is a tendency that the robot might get trapped in local minima which is not the goal position. This can happen when the forces associated with the potentials evaluates to zero and therefore the robot does not move. This happens in the situations where the attractive force towards the goal and the repulsive force are equal. As a result the robot is trapped in local minima and in practice the robot oscillates close to the local minima. This means that there is no guarantee that potential field method will find a path to goal position. The fundamental idea behind potential field approaches is to treat the target position as a attractive well, where the minimum is at the target; and to treat obstacles as high potential hill that create a repulsive force. The overall potential is the sum of these two types of potentials and can be written as:

$$UTotal\ (q) = UAtt\ (q) + URep\ (q)$$

Where Utotal (q) denote the total artificial potential field; U att(q) denote the attractive potential field; and U rep(q)is the repulsive potential field. All of them are function of position q only; where q = trans[x, y] in two dimensional workspace and q =trans [x, ,y z] in a three dimensional workspace. With this idea in mind, if the robot is design to follow the negative gradient in the total potential field, it will finally converge to the target position since that is the lowest point in the potential field. Negative gradient of this function will give overall force.

II LITERATURE REVIEW

O. Khatib (1986) [1] have first implemented APF for real time obstacle avoidance and presented a unique real time obstacle avoidance approach for manipulators and mobile robots base on the artificial potential field concept. In this approach, collision avoidance, traditionally considered a high level planning problem can be effectively distributed between different levels of control, allowing real-time robot operations in a complex environment and proposed low level control with a path that will enable the robot to accomplish the assigned task free from any risk of collision. But the complexity of tasks that can be achieved with this collision avoidance approach is limited. In a cluttered environment, local minima can occur in the resultant potential field. This can lead to a stable positioning of the robot before reaching its goal.Charles W. Warren (1989) [2] described a path planning technique for robotic manipulators and mobile robots in the presence of stationary obstacles. The planning consists of applying potential fields around C-Space obstacles and using this field to select a safe path for the robot to follow. The advantage of using potential fields in path planning is that they offer a relatively fast and effective way to solve for safe paths around obstacles. In the method used to accomplish path planning presented here, a trial path is chosen and then modified under the influence of the potential field until an appropriate path is found. By considering the entire path, the problem of being trapped in a local minimum is greatly reduced, allowing the method to be used for global planning. It limited only by the computational power of the robot's planner. For most fixed base and simple mobile robot planning problems, this technique offers a fast, effective solution to global planning problems.Hsuan Chang (1996) [3] presented a new technique to reduce or eliminate the need for random walks while improving performance. Random walk like techniques have been used to help potential field based motion planning techniques to escape from local minimum configurations. However the associated cost can be large for some applications which require smoothing to take out the incoherent motion steps that are discovered through the random walks. It is especially effective for constrained path planning because the potential field inside a constraint volume provides a good general direction, while the new technique presents and efficient perturbation technique to replace traditional random walk mechanisms in guiding a search along this general direction.Min Gyu Park and Min Cheol Lee (2003) [4] given a new concept using a virtual obstacle to escape local minima that occur in local path planning. A virtual obstacle is located around local minima to repel an object from local minima, have also proposed the discrete modelling method for the modelling of arbitrary shaped objects used in this approach. This modelling method is adaptable for real-time path planning because it's reliable and provides lower complexity.A. Poty. et al. (2004) [5] given method for motion planning of mobile robots in a dynamic environment. In path planning design, potential fields can introduce force constraints to ensure curvature continuity of trajectories and thus facilitate path tracking design. The parametric thrift of fractional potentials permits smooth variations of the potential in function of the distance to obstacles. In the approach used, the fractional order of differentiation is the risk coefficient associated to obstacles. As the environment is often dynamic, we extend this method to dynamic obstacles. In this paper the Ge and Cui method is used to take into account the obstacles movement. Two methods have been merged for dynamic motion planning for mobile robots. The Ge and Cui method defines attractive and repulsive potentials by taking into account position and velocity of the robot with respect to obstacles.Concerning the second method, the fractional potential has permitted to characterize each obstacle of the environment. Thus, the danger zone and the danger itself will be all the more significant around the obstacles as the risk coefficient (the fractional order) associated with the obstacles will be important. Computer simulation has been done and the robot successfully avoids obstacles and reaches the target.M.H. Mabrouk and M.R. Mclnnes (2008) [6] proposed a new, extended artificial potential field method, which uses dynamic internal agent states. The internal states are modeled as a dynamical system of coupled first order differential equations that manipulate the potential field in which the agent is situated. The internal state dynamics are forced by the interaction of the agent with the external environment. Local equilibria in the potential field are then manipulated by the internal states and transformed from stable equilibria to unstable equilibria, allowing escape from local minima in the potential field. This new methodology successfully solves reactive path planning problems, such as a complex maze with multiple local minima, which cannot be solved using conventional static potential fields. The investigation of agent-based systems begins with a definition of the term agent, “An agent is a system that tries to fulfill a set of goals in a complex, dynamic environment such that it can sense the environment through its sensors and act upon the environment using its actuators". A single agent may be fully autonomous, but its abilities may be limited according to resource and physical constraints. On the other hand, swarms of self-organizing agents that exchange information may have a greater functionality than the individual members. The method allows a swarm of agents to escape from, and manoeuvre around, a local minimum in the potential field to reach a goal.Dhananjay Bodhale et al. (2009) [7] focused on development of algorithms with the integration of path planning by potential field method and Monte Carlo localization method for navigation, obstacle avoidance, and localization of the mobile robot in a dynamic environment like in manufacturing industry. The path planning algorithms has divided into two sub modules, one is global path planning which uses visibility graph with A* search method and another is local path planning which uses potential field method to avoid the obstacles. The image processing is used to get the working environment information from the global camera. The robot control program uses MCL algorithms with gradient path planning for continuous localization. User-friendly path planning software PMADE V 2.0 is developed. PMADE v 2.0 is used for image processing, path planning, simulation of robot navigation, real robot manual control and real robot automatic control for navigation in dynamic environment from position data of the simulator.Sung-hwan Kim (2010) [8] proposes a multi-robot support APF by defining new potential functions: SWARM or SPREAD. This APF uses priority selection scheme between multi robots and calculates a new potential functions based on priority, and then solves local minimum problem in multi robot APF which is a traditional problem of APF. Therefore this paper enables distributed path planning in multi-robot with real-time using suggested APF. All of these works are verified its effectiveness with simulation using Player/Stage simulator.Jia-Heng Zhou and Huei-Yung Lin (2013) [9] proposed a system to cope with the problem of autonomous mobile robot navigation. It is able to perform path planning and localize the robot in the real world environment. The path planning is first carried out using the known map, and the laser range scanner is then used to localize the robot based on the ICP registration technique.During the robot motion, the potential field is taken into account for obstacle avoidance. For the path planning, the visibility graph is established based on the current position of the robot. The Dijkstra algorithm is then used to find the shortest path to the goal position. Self-localization and path planning are two important issues for autonomous mobile robot navigation. For theautonomous motion, the robot should have the ability to localize its current position, perform the path planning for the future movement, and move to the next position as expected, proposed a navigation system to deal with the problem of robot motion in the known environment using the laser range scanner. First we build the visibility graph and find the shortest path by Dijkstra algorithm, then localize the robot by registering the laser scanning data and the visibility mode based on the

ICP algorithm. Finally, the potential field is incorporated to decide the robot motion for the next step. Experimental results in the real world environment have shown the feasibility if this work.Guanghui Li et al. (2012) [10] presented an improved artificial potential field based regression search (Improved APF-based RS) method which can obtain a global sub-optimal/optimal path efficiently without local minima and oscillations in complete known environment information. They redefine potential functions to eliminate non- reachable and local minima problems, and utilize virtual local target for robot to escape oscillations. Due to the planned path by improved APF is not the shortest/approximate shortest trajectory, we develop a regression search (RS) method to optimize the planned path. The optimization path is calculated by connecting the sequential points which produced by improved APF. Amount of simulations demonstrate that the improved APF method very easily escape from local minima and oscillatory movements. Moreover, the simulation results confirm that our proposed path planning approach could always calculate a more global optimal/near optimal, collision-free and safety path to its destination compare with general APF. That proves our mproved APF-based RS method very feasibility and efficiency to solve path planning which is a NP-hard problem for autonomous mobile robot. Path planning problem is one of the most important robotic problems for autonomous mobile robot to accomplish given tasks. An improved artificial potential field based regression search method was proposed to obtain a global optimal/suboptimal path without local minima and oscillations incomplete known environment information. Virtual local target and repulsive force disappearance method are utilized to eliminate local minimum caused by traditional APF when attractive force and repulsive force in collinear but opposite direction. Oscillations problem is resolved by tangential line of circle when robot moves nearby the vertex of polygonal obstacles and circular obstacle. Due to the computed path by improved APF is not the shortest trajectory, we developed a regression search method to optimize the planned path, and proved that a safely, shorten and collision free path for autonomous mobile path could be produced by amount of simulations. That proved their improved APF-based RS method is very feasibility and efficiency to solve path planning.Hossein Adeli et al. (2012) [11] proposed a new algorithm for solving the path planning problem of mobile robots. The algorithm is based on Artificial Potential Field (APF) methods that have been widely used for path planning related problems for more than two decades. While keeping the simplicity of traditional APF methods, our algorithm is built upon new potential functions based on the distances from obstacles, destination point and start point.

III CONCLUSION

- The basic robot path planning shows that artificial potential field method good for path planning and can do smooth path planning in lesser time.
- Many research advance in APF limited to single mobile robot. There is not so much research of multi-robot path planning by artificial potential field method.

- Robot path planning of random obstacles shows that number of steps given to robot affects robot navigation accuracy and time speed coordination. With lesser number of steps it can deviate from the fin point.
- By changing obstacles and its robot path planning power shows that it is highly analytical method and flexible also.
- Robot path planning of random obstacles shows that number of steps given to robot affects robot navigation accuracy and time speed coordination. With lesser number of steps it can deviate from the final point.
- Voronoi diagrams that divides the workspace into cells only good for static obstacles. And artificial potential field method is comparatively better than this.
- The convergence of APF shows that it choose optimize path for particular value.
- In most of the research papers authors presented different methods to solve local minima problem but still it is the most interesting topic of APF. Because there is solution needed for local minima in complex environment.
- Many research advance in APF limited to single mobile robot. There is not so much research of multi-robot path planning by artificial potential field method.
- Robot path planning can be lead to 3 dimensional inclined obstacles and can propose techniques for better object recognition.
- In dynamic environment this method can be tested and make flexible for different workspace.
- For avoiding local minima and multi robot path planning still our proposed method needs several modification because robots can make intersect point and can lead to damage themselves.
- Many research advance in APF limited to single mobile robot. There is not so much research of multi-robot path planning by artificial potential field method.

REFERENCES

[1] Khatib.O, Real-Time Obstacle Avoidance For Manipulators And Mobile Robots, *Vol. 2, 1986 pp. 500 – 505*

[2] Charles W. Warren, Global Path Planning Using Artificial Potential Fields ,*Pp. 316 - 321 vol.1*

[3] A New Technique To Handle Local Minimum For Imperfect Potential Field Based Motion Planning, Hsuan Chang 1996 *Pp. 108 – 112, vol.1*

[4] A New Technique to Escape Local Minimum in Artificial Potential Field Based Path Planning, Min Gyu Park and Min Cheol Lee KSME International Journal, *Vol. 17 No. 12, pp. 1876~ 1885, 2003*

[5] Dynamic Path Planning For Mobile Robots Using Fractional Potential Field, A. POTY. P. MELCHIOR and A. OUSTALOUP 2004 *Pp. 557 – 561*

[6] Solving the potential field local minimum problem using internal agent states, M.H. Mabrouk , C.R. McInnes,*Volume 56, Issue 12, 31 December 2008, Pages 1050–1060*

[7] Path Planning for a Mobile Robot in a Dynamic Environment, Dhananjay Bodhale, Nitin Afzulpurkar Member IEEE and Nguyen Truong Thanh 2009 *Pp. 71 – 76*

[8] New Potential Functions for Multi robot path planning : SWARM or SPREAD, Sung-hwan Kim *2010 Pp. 557 – 561*

[9] A Self-Localization and Path Planning Technique for Mobile Robot Navigation, Jia-Heng Zhou and Huei-Yung Lin 2011 *Pp.694 – 699*

[10] An Efficient Improved Artificial Potential Field Based Regression Search Method for Robot Path Planning, Guanghui Li, Atsushi Yamashita and Hajime Asama 2012 *1227 – 1232*

[11] Path Planning for Mobile Robots using Iterative Artificial Potential Field Method, Hossein Adeli, M.H.N. Tabrizi, Alborz Mazloomian, Ehsan Hajipour and Mehran Jahed IJCSI International Journal of Computer Science Issues, *Vol. 8, Issue 4, No 2, July 2011*