2015 International Conference on Industrial Instrumentation and Control (ICIC)
College of Engineering Pune, India. May 28-30, 2015

A Review on Indoor Human Aware Autonomous Mobile Robot Navigation Through a Dynamic Environment.

Survey of different path planning algorithm and methods.

Mr. Rahul Shivaji Pol, M. Tech.
Life Member of ISTE, IET, NI CLAD
Assistant Professor & VIIT-NI LabVIEW Acad. Coordinator
Department of Electronics and Telecommunication,
Vishwakarma Institute of Information Technology,
Pune -411048, Maharashtra, India
Mob: +91-9657799066, Email : rahul.s.pol@gmail.com
http://www.viit.ac.in
http://www.viit.ac.in/faculty-profile.php?entc-pol

Dr .M. MURUGAN, M.E (E&TC), Ph. D
Life Member of ISTE, IEI, IETE, ISOI, SEMCEI, SSI
Vice-Principal & Professor of E&CE Department,
SRM's Valliammai Engineering College,
SRM Nagar, Katankulathur, CHENNAI- 603 203 (T. Nadu)
Tel: 044-2745 4784/26, FAX:2745 1504
Mob: +91-909 453 7070, Email : dr.murugan.m@gmail.com
http://www.valliammai.co.in

***Abstract* : Practical realistic environment for path and continuous motion planning problems normally consist of numerous working areas such as in indoor application consist of number of bedrooms, hallways, multiple doorways with many static and dynamic obstacle in between. Disintegration of such environment into small areas, or regions shows impact on the quality of adaptive path planning in dynamic environment. Many algorithms are developed for solving problems involving narrow passages and multiple regions with optimal solution. Autonomous mobile robot system must have sense of balance of its potential, steadfastness and sturdiness issue with task and the final goals while generating and executing an adaptive as well as effective strategy with optimal solution. Navigation algorithms approaching to a certain maturity in the field of autonomous mobile robot, so most of research is now focused more advance task like adaptive path planning and navigation through dynamic environments. Adaptive path planning and navigation needs to set learning rate, rules for classifying spaces and defining proposed library parameters. The aim of this survey is to informing the progress of human sentient manipulation planner.**

Keyword — Autonomous mobile robot navigation, navigation through dynamic environment, adaptive path planning, human machine interaction, human aware navigation.

Literature survey:

Autonomous mobile robots now a day performs numerals task with amazing speed, accuracy with safety. The application of various algorithm from soft computing techniques, image processing, control system, wireless sensor network, biologically inspired algorithm, statistical method and classical methods defines great results in autonomous mobile robot path planning and navigation through dynamic human aware environment. The objective of this survey paper is to inform over the past and current research trends with their results in this field. The aim of all these algorithms and method is to achieve optimal path with less number of computation and greater human safety for the projected environment. This paper present overview of various methods that have developed for path planning and navigation through dynamic human aware environment.

Soft computing is a model cognitive behavior of human mind which is foundation of conceptual intelligence in robots. Soft computing algorithms are tolerant of imprecision, uncertainty, partial truth and approximation. Many researchers efficiently utilize Softcomputing techniques for defining strategies for path planning and navigation e.g. Neural Network (NN), artificial immune system (AIS) Machine Learning (ML) Fuzzy Logic (FL), Evolutionary Computation (EC) - based on the origin of the species such as Genetic Algorithm, Swarm Intelligence, Ant Colony Optimizations.

I.I Fuzzy Logic :

Fuzzy logic control is characterized by the use of linguistic rules to manipulate and implement human knowledge in control system so as to handle the uncertainty present in the environment. Foudil abdessemed developed behavior based control architecture in which each each local navigation task is analyzed in terms of primitive behaviours. He also used combination of fuzzy rules and stereo vision system for carrying out hazard free navigation[1]. Emna Ayari [2] designed system with two fuzzy controllers: the heading controller and the speed controller. The fuzzy logic body (inference) produces necessary rules for the robot to achieve a known goal with an intelligent decision. Experimental results using the above method to navigate in uncertain and dynamic environments have shown that the robot can successfully achieve its goal without collision.

Emna Ayari [2] presented a multi-agent simulation model of robot's behavior in dynamic and uncertain environment. Emna Ayari mention Potential Fields Approach, Vector Field Histogram, Dynamic Window, curvature velocit, Nearness Diagram, fuzzy logic approach. The main drawback of these strategies is that the robot gets into an infinite loop or a local minimum. To face this limit, many methods like memory state method, minimum risk approach, virtual wall method are

proposed. However these strategies do not take into account the dynamic nature of the environment and the uncertainty of perception, which means that the robot can be driven into dangerous or blocking situations. Hence, other approaches applied in dynamic environments are proposed with the idea of combining the reactive techniques with global planning methods[5]. These approaches need a priori complete information about the environment. Some other approaches appeared to combine the reactivity and the anticipation. These approaches need a movement planning that requires an important computation time to find the most appropriate way. But in a dynamic and uncertain environment, often the path cannot be executed if there is an unexpected change in the environment[6].

While dealing with environmental uncertainty, the Bayesian inference has been mostly used particularly in localization and mapping,[3] but it is very sluggish and complex (NP-Complex). Since, the fuzzy logic control (FLC) has been experimented by several researchers to treat the problem of immediate navigation and obstacle avoidance. FLC has the ability to treat uncertain and imprecise information using simple linguistic rules[4]. FLC offers the possibility of combining many behaviors and it is also faster than Bayesian networks. Although fuzzy logic techniques may simplify navigation problems in indecisive environments, there are situations where a fuzzy logic approach fails in taking appropriate action[4][7].

Fuzzy logic offers a formal method demonstrating and realizing uses a human specialists heuristic knowledge and perception-base accomplishments. The mobile robots navigation mostly used Fuzzy logic and fuzzy languages in their path planning algorithms. In this method the complete problem is divided into small and simpler task and each action composed of a group of fuzzy logic rule statement planned at achieving a clear defined set of objectives.

I.II Wireless Sensor Network and RFID: (Ref 8 to 18)

Navigation is a significant problem in mobile robotics, ubiquitous computing, and Ubiquitous Robotic Companion. So many solutions about mobile robot navigation have been proposed. The radio based navigation system are proven well efficient[8][9]. WSN nodes are incorporated to generate potential field through combining information collected from different nodes for an indoor mobile robot[10][11]. The radio signal strength intensities (RSSI) combined with camshaft algorithm based method (servo mounted camera) for safely navigate the robot. The said system allow the robot to estimate the human's distance and relative angle with robot. Passive RFID based mobile robot navigation is presented[12][13]. The RFID tags were read and then recorded so as to estimate location, position of the robot for navigating to end goal.

Osman Mudthir Elfadil[13] designed and tested WSN hybrid sensor network which makes possible to not only reduce the cost of the system, but also improve adaptability to dynamic environments. In [14], the transition probabilities named utilities, which are calculated at each sensor node for navigating a mobile robot, were utilized. These utilities were used in order to compute the optimal direction for the robot to travel towards the goal. A distributed algorithm is presented for guiding mobile robots across a sensor network along the safest path, away from danger detected by the sensors in [15], [16]. An artificial potential field or a credit field is set up to guide the robot to its destination along the safest path. In [17], surrounding sensor nodes with ultrasonic GPS modules provide a mobile robot with measured distance values respectively. Using the localization technique based on these values, the dead reckoning error of the robot can be compensated while the robot is navigating to the goal.

Some algorithms combining mobile robots with static sensor networks are proposed and maps are not needed. But in [17], error range is relatively large because distance measurement depends on RF RSS (Received Signal Strength) holding poor distance resolution. And in [18], the cost of the system is high because additional devices such as GPS module and digital compass are used.

I.III Genetic Algorithm (GA):

Genetic algorithm are very popular meta-heuristic techniques for generating optimized result. In this method population of candidate solution is evolved to search better solution based on natural selection. In GA an initial set of population which are the possible solution to the problem are generated randomly and then fitness value of each solution is calculated by applying the objective function of the problem. Then the more fit solution are selected and genetic operation mutation and crossover are applied to them to generate a new population of more fit candidates. This process is repeated till the maximum number of iteration are reached or satisfactory fitness value is achieved. This method is adopted by various researcher for generating and analyzing well optimized result for different application.

Toolika Arora, Yogita Gigras[19] proposed a genetic algorithm applied to single point instead of whole workspace. Shibata and Fukuda [20] proposed a motion planning strategy for a robot which performs a task of carrying loads on its way. The strategy uses a GA for optimization of the plan and fuzzy logic to evaluate this plan. Lin et al. [21] proposed an evolutionary algorithm for the path planning problem of a mobile robot in an environment which may contain a number of unknown polygonal obstacles. Handley [22] introduced a genetic planner based on genetic programming for the path planning of mobile robots. Shing and Parker [23] presented a GA-based method to produce adaptive, multi-heuristic search strategies for the real-time path planning problem. In a recent work [24], Recently, there has been widespread interest in using genetic algorithms. Compared to traditional search and optimization methods, such as calculus-based and enumerative strategies, the genetic algorithm is a powerful search algorithm based on the mechanism of natural selection and uses operations of reproduction, crossover, and mutation on a population of strings at finding an optimum path in very large workspace.

Genetic algorithm is stochastic search techniques analogous to natural revolution [21]. Potential solutions of a problem are encoded as chromosomes. These chromosomes

form a population. Each individual of the population is evaluated by a fitness function. A selection mechanism based on the fitness function is applied to the population and the individuals strive for survival. The fitter ones have a better chance to be selected and to duplicate offspring by means of genetic transformations, such as crossover and mutation [22] [23] [24]. The process is repeated and the population is evolved generation by generation. After many generations, the population converges to solutions of good quality, and the best individual has good chance to be the optimal or near-optimal solution. Genetic algorithm has already been applied in path planning for mobile robots. A number of results in the literature show the application of GA to robotic path planning. Among the results,

Pu Shi, Yujie Cui [25] a dynamic path planning method based on genetic algorithm for mobile robot under an unknown environment. The real coding, fitness function and specific genetic operators are designed to accelerate the convergence of the algorithm and improve the accuracy of operation. The genetic algorithm used in this paper can achieve satisfying path planning results under an unknown dynamic environment. The simulation results show that the genetic algorithm has strong adaptability of dynamic and unknown environments.

The genetic algorithm always starts with no information of the true solution also it depends entirely on responses from its surroundings and evolution operators i.e. mutation reproduction and crossover to generate at best solution. thus by initiating at several autonomous points and searching in concurrent, the algorithm converging to suboptimal solutions by avoiding local minima. Genetic exploring algorithm is used in producing via-points after discovery the objects by the vision system. The fitness cost of the generated paths is calculated in terms of the protection from the obstructing dynamic obstacle and the space to the target position. Genetic algorithm extensively used in applications of path planning.

Genetic algorithm uses local memory for chromosomes in dynamic area. The technique suffers from a large amount of computation and its performance depends on the configuration of the environment in dynamic situation. The major shortcoming of the genetic algorithm approach in path planning field is that it is not feasible in dynamic environments. This because it operates in a grid map or uses a fixed resolution in the search area also does not control the population variety which causes untimely convergence.

The major drawback of genetic algorithm is due to weakly known fitness functions that generate worst chromosomes blocks instead of the truth that just good chromosome blocks cross-over cannot solve certain optimization problem.

I.IV Artificial immune system (AIS):

Artificial Immune System is an optimization algorithm based on the functioning of the biological immune system. AIS algorithm mimics and exploits the various behaviors of the immune system such as learning, remembering and problem solving. Rajab Challoo & Prashant Rao [26] developed a method for random generation of antibodies to make the system more similar to the actual biological process. authors also introduced generalized architecture for representation of antibodies and antigens in a standard mobile robot using proximity sensors for interaction with the environment. Author found the proposed algorithm was able to explore the unknown environments while learning from past behavior and look for the target. The said algorithm also able to successfully map the traversed path and plot the obstacles based on their type.

The major drawback og artificial immune network technique is that it handle unnoticed low-level alerts that include an disturbance situation, handling possible prerequisite actions and treating disturbance situation changes.

I.V Statistical Method :

Jory Denny and Anshul Agrawal [27] defines three strategies used for region identification are the statistical methods: k-means clustering, PG-means clustering, and Hierarchical cluster-ing. author explore the differences in the regions produced by these three methods in a variety of rigid body and articulated linkage environments. Then, author quantitatively compare the usefulness of the region methods in automated motion planning through the application of the regions within the Unsupervised Adaptive Strategy for Motion Planning (UAS). Author concludes both regions that seem intuitive and non intuitive to the problems solve motion planning problems with increased efficiency and automation. Author also explore planning which generally benefitted from using regions, and the benefit was not tied to the naturalness of the region.

I.VI Voronoi diagram :

Many researchers used voronoi diagram as efficient tool in their work from last four decade. The generalized voronoi diagram is the set of points where the distance to the two closest objects is the same. Santigo Garrdo and Luis Moreno[28] presented sensor based path planner which results in a fast local or global motion planning also it incorporate the obstacle information. Santigo Garrdo achive motion planning through finding safest areas in environment were extracted by means of a voronoi diagram. Amit Kumar Pandey and Rachid Alami [29] develop a mobile robot navigation system which autonomously extracts the relevant information about the global structure and the local clearance of the environment from the path planning point of view, also dynamically decides upon the selection of the social conventions and other rules, which needs to be included at the time of planning and execution in different sections of the environment, Author also re plan a smooth deviated path by respecting social conventions and other constraints and treats an individual, a group of peoples and a dynamic or previously unknown obstacle differently.

Author uses Voronoi diagram, which has been shown to be useful to author and by others [30], [31], for capturing the skeleton of the environment. Since we are constructing the Voronoi diagram at discrete level of grid cells, we define it as the set of cells in the free space that have at least two different equidistant cells in the occupied space. Fig. shows different

Voronoi cells (green circles) and the red lines connecting them to the corresponding nearest occupied cells. We define the term *'Interesting Cell'* (*IC*) as the Voronoi Cell: (a) which is equidistant from exactly two cells in the occupied space and, (b) both the equidistant points are on the opposite sides on the diameter of the circle centered at that Voronoi cell.

I.VII. ANT Colony Algorithm :

Swarm intelligence is an emerging research area with similar population and evolution characteristics to those of genetic algorithms. However, it differentiates in emphasizing the cooperative behavior among group members. Swarm intelligence is used to solve optimization and cooperative problems among intelligent agents, mainly in computer's networks, mobile robotics [31] and cooperative and/or decentralized control [32][33]. In the context of biologically inspired optimization methods, several models of bacterial chemo taxis algorithm based on pioneered work of Bremermann [34] have been proposed in literature for applications in biology, genetics, communication networks and robotics Literature is rich in boarding's to solve mobile robots trajectory planning in presence of static and/or dynamic obstacles. One of the most popular planning methods is the artificial potential fields . However, this method gives only one trajectory solution that may not be the smaller trajectory in a static environment. The main difficulties in determining the optimum trajectory are due to the fact that analytical methods are extremely complex to be used in real time, and the searching enumerative methods are excessively affected by the size of the searching space.

Traditional ant colony optimization algorithm contains some drawbacks such as requiring a long period to reach to local minimum if the scope of the problem is huge. In usual ant colony optimization algorithm, the pheromone concentrations of total elements are uniformly initialized. Thus solutions are build blindly in the starting of evolution phase also it takes a large time to discover a improved path from a large number of paths.

I.VIII Neural Network:

Neural Network(NN) provides high speed data processing capability of learning [39]. The use of Artificial NN in robotics for its dynamics modeling , kinematics modeling and also in path planning and motion control has enhanced the mobile robot. A *Mobile Robot* is a robot system that is capable of moving within an environment or terrain where it performs the tasks. [38] Using an ANN technique, ample human like decision building feature can be equipped in a robot. This requires the analysis of surroundings to resolve complexity of movement and ensured that the robot is mechanically characterized to carry out motion, with required degree of freedom with electronic has to support the motor used, hence to control the movement. [40] The author discuss a dynamic artificial neural network based mobile robot motion and path planning system. The method is able to navigate a robot car on flat surface among static and moving obstacles, from any starting point to any endpoint. The motion controlling ANN is trained online with an extended back propagation through time algorithm, which uses potential fields for obstacle avoidance. The paths of the immobile obstacles are predicted with other ANNs for better blockage avoidance. The method is presented through the realization of the navigation system of a mobile robot.[41][42] The author uses multi-layer feed forward artificial neural network to construct a path-planning controller by its powerful nonlinear functional estimation. Then the path planning task is simplified to a classified problem which are five state-action mapping association. One reinforcement learning method, Q-learning, is used to gather training samples for the ANN controller. At last the trained controller runs in the simulation background and retrains itself furthermore combining the support signal during the interaction with the environment. Policies based on the Combination of ANN and Q-learning is better than using only one of the two methods. The simulation result also shows that the strategy can find the optimal path than using Q-learning only.

The neural networks consist of extremely concurrent building blocks that illustrate neural networks design principles. These can be used to assemble more complex systems. The neural networks architectures cannot compete with the traditional techniques at performing accurate numerical operations. However, there are large classes of problems that often involve ambiguity, prediction, or classifications that are more agreeable to solution by neural networks than other available techniques.

Neural networks have various advantages such as it is feasible to train a NN by adjusting the values of weights between elements to execute a particular function. e.g. to train NN model to fairly accurate specific function the associate weight with each path has to be modify till the output of NN is similar to fucnction.. while applying robot path planning, the position space of the neural network is the configuration space of the robot, and the dynamically varying environment is represented by the dynamic activity landscape of the neural net. The goal object universally attracts the robot in the entire position space, whereas the obstacles globally push the robot away. Artificial neural network for navigation control of mobile robots have been developed.

Artificial neural network generally used in search optimization, pattern recognition, and learning problems as it provide effortless and optimal solutions

Conclusion:

This paper elaborate review on the used methods in mobile robot path planning and shortest path navigation problems. this review explained various methods and describe their advantages and disadvantages. There are some classical method may not be consistent in the real world application as they are unable to tackle with the unpredictable dynamic, and uncertain environment of live-world. The classical methods required large computation and memory while heuristic-based methods with some modifications can surmount the real-world problems. Inspite of computational efficiency and simplicity are most important advantages of mobile robot path planning, the system performance in these method are extremely depends on information generated through mapping. The mobile robot path planning techniques based on predefined mapping becomes more challenging due to unpredictable

noisy and dynamic nature of real world application. The cost factor increases due to huge amount required for recomputing system. It is almost impossible to forecast all possible conditions and potential actions that mobile robot come across in real world application. although heuristic-based methods can be used in dynamic environment, they have limitation in uncertain environments. Although a number of approaches are recommended to tackle such environments the solutions are predominantly area dependent and require the simplification.

Heuristic approaches particle swam optimization methodology, genetic algorithms, Fuzzy logic, neural networks, neuro-fuzzy approach, ant colony optimization and artificial immune systems approach especially the hybridized technique, provides appropriate and efficient results for an mobile robot navigation dynamic environment. Thus heuristic approach the autonomous mobile robots can steer safely along with the all type of obstacles without colliding with them. These techniques provides optimized solution to hard problems.

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