CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

Ever since the invention of automation, the industrial robots which are also known as fixed manipulators where in an unbeatable dominance that lasted for more than forty years till the end of twentieth century. Its application was, as we all know, used for all technically skilled labours like automobile welding, painting and other related jobs. As a wonder in the field of robotic science and with advent of the mobile robot resembling human in activities, most of the researchers turn their research eyes towards it for the last one decade. No one has gone so deep in research so far about the minute findings of this mobile robot. It is, indeed, obvious that most of the researchers are still on the threshold of mobile robot.

Very few researchers concentrate on the works relating to this topic of which the researcher is also one who is very much keen on concentrating on the problems. Mobile robot always poses unique challenge to the artificial intelligence community, since they are inherently autonomous and force the researchers to deal with issues such as uncertainty in sensing and action, planning, learning and real-time response.

To improve and expand the knowledge of how to successfully integrate these issues into one single system that is the localization and navigation of mobile robot, many contributions have been made on the
development of path tracking controllers and to artificial intelligence community by the researchers.

2.2 LITERATURE ON MOBILE ROBOT

Sugeno (1986) has first designed a controller based on fuzzy modeling of human operator’s control actions, to navigate and to park a car like mobile robot. The designed controller controls the car so that the process is of navigation and localization is succeeded in all the conditions. During 1989, the navigation and localization problems of mobile robots have been attended by many researchers. Sanjiv et al (1989) proposes an approach which discusses two issues, path representation and path tracking, in navigation for wheeled mobile robots. Vehicle and path models are proposed such that steering control can be decoupled from velocity of the vehicle. “Good” paths are defined, and it is shown that tracking performance is superior when the path is intrinsically easier to track. Khoukhi and Hamam (1989) considers the problem of the optimal dynamic navigation for a mobile robot in a crowded environment. First a kinematics study based trajectory control is addressed. A dynamic model based on the Euler- Lagrange equations is then developed and a mobility estimation function of the robot is considered. This dynamic estimation of the robot mobility takes into account of the velocity and the orientation of the robot. Then a scene structuration and path search with safety algorithm is introduced. Finally, the optimal trajectory search is formulated as a nonlinear programming problem under nonlinear equality and inequality constraints.

Zapata et al (1989) address the path planning and the trajectory planning problems for mobile robots moving in dynamic ill-structured environments. The obstacle avoidance problem during large motions is discussed and a multi-expert motion planning system is described. Then, the non holonomic constraints are studied for the fine motions. Wang (1989)
discusses the problem of deriving navigation strategies for a fleet of autonomous mobile robots moving in formation is considered. Here each robot is represented and specified cone of visibility. The global motion of each robot in the world space is described by the equations of motion of the robot’s center of mass. First, methods for formation generation are discussed. Then, simple navigation strategies for robots moving in formation are derived. A sufficient condition for the stability of a desired formation pattern for a fleet of robots each equipped with the navigation strategy based on nearest neighbor tracking is developed. The dynamic behavior of robot fleets consisting of three or more robots moving in formation in a plane is studied by means of computer simulation.

Toshio Fukuda et al (1989) deal with the methods of task planning, diagnosis and control for a pipeline inspection and maintenance robot. The pipe inspection robot in this paper as one of those plant service robots can be autonomous in terms of sensing, control and path planning in addition to the self-diagnosis. The inspection robot task is to inspect pipelines in a plant: (1) The target point for the robot to move can be generated from the diagnosis knowledge base. Thus the robot can estimate and search failure causes by sensing capabilities of the robot. (2) The path planning system is shown to find the path optimal for the robot to move from one point to the other point under some criteria. (3) The control command can be automatically generated from the result of the path planning.

Chien and Koivo (1989) describe a method that uses computer vision to detect a moving obstacle in the three-dimensional robot workspace. The movements of the obstacle of unknown dynamics are predicted by means of a recursive autoregressive time series model, in which the parameters are estimated by the least mean squared error method. This algorithm is combined with an on-line robot trajectory planning algorithm to generate a collision-free
trajectory for the cylindrical robot. The approach is demonstrated by laboratory experiments. Habib and Yuta (1989) propose a simple and efficient method for modeling an actual in-door environment is proposed. This method describes the significant features of an in-door world consists of either single building or network of buildings environment connected through common bridges, in which the world environment is divided hierarchically using tree structure into three levels. These levels are buildings, corridor and room respectively. Then, based on the modeled environment, simple, fast and computationally efficient automated optimal path finding with obstacle avoidance strategy is proposed for mobile robots to work within an actual in-door environment.

Junichi Iijima et al (1989) present an efficient algorithm for autonomous mobile robot to construct a two dimensional world modem consists of straight line segments, using the robot’s range sensor and a suitable observation sequence planned by itself. Since the environment is observed locally at a point, global geometric model will be generated incrementally. In this procedure, the robot observes the environment iteratively and constructs the environment map using the all sensory information of the previous observation. Then, it finds the next suitable position in the area which is recognized safe in the constructing map and moves to it until it completes the map construction. Carl Owen and Nehmzow (1996) propose Recursive Compensation Algorithm used to find the collision-free shortest path for mobile robots in 2D without increasing the complexity of the VGraph and it is proved to guarantee the convergence to the shortest path in 3D. Simplifying the VGraph, the Recursive Compensation Algorithm can save not only the memory space to represent the VGraph but also the graph-searching time. Takahashi Morita et al (1989) describe a local navigation strategy for obstacle avoidance of autonomous mobile robots. Primarily a vision sensor was employed to navigate the robot and ultrasonic
sensors were used to avoid collision when a robot neared obstacles. Instead of building a local map, the heading angle and speed of the robot is determined from the image and range data by the use of approximate reasoning during every feedback control cycle.

2.3 LITERATURE ON TRUCK LIKE MOBILE ROBOT

In the year 1989 and 1990, Nguyen and Prof. Bernard Widrow have developed a neural network controller for the truck backer upper, which is the unmanned autonomous mobile robot, to a loading dock problem from an arbitrary initial position by manipulating the steering. In that work, they extended the use of neural networks to solve the highly nonlinear problem by forming two layer neural network containing 26 elements have learned to backup a truck like mobile robot in a loading zone. A neural network controller steering a truck like mobile robot while backing up to a loading dock is demonstrated. In his doctorate dissertation, Kaspar Althoefer (1996) quotes the advantage of fuzzy based controller over neural network controller to track the path of truck like mobile robot. He pointed out the important drawback i.e. the black box behavior of neural network that prevents the user from investigating the network’s weight matrix and changes of the weight can be only achieved by going through further training cycles.

Kong and Kosko (1990, 1992) have proposed a fuzzy control strategy for the same problem. They developed fuzzy and neural system to back up simulated truck and trailer to a loading dock in a planar parking lot from training data taken from the fuzzy and neural simulation. They generated FAM (Fuzzy Associated Memory) rules to control the truck-trailer. They have trained the neural truck systems with the back propagation algorithm. Wang and Mental (1992) have solved the same problem by generating fuzzy rules using learning algorithms. However, all the above studies do not treat the path finding problem and have not analyzed stability of the control systems.
Ramamurthy and Song Huang (1991) provide some insights along with the neural network and fuzzy logic on truck backer upper control problem. New network architectures by merging these concepts and simulation results for the same were discussed about the path finding problem elaborately.

Berenji (1992) developed an FLC that is capable of learning as well as tuning of its parameters by using neural networks trained through a reinforcement learning method. The learning by examples way of creating the fuzzy rules is done for extracting the rule base. Jang (1992, 1993) developed a self-learning FLC based on a neural network trained by temporal back-propagation. This self learned network can be adaptively used for various applications. Freeman (1994) introduced a tool in the advanced automation toolbox. This basis of fuzzy logic lies in the ambiguity in our thinking about concepts such as big, tall, slow or bright, whose meanings are not only context dependent, but also ambiguous within a particular context. Using fuzzy sets named by these ambiguous linguistic variables, we can build applications that can outperform many of their traditional counterparts. As an example of the application of this technology, he develops a fuzzy control system that automatically backs up a truck to a specified point on a loading dock.

Alejandro Ramirez-Serrano and Marc Boumedine (1996) designed a fuzzy logic navigation controller in order to deal with the uncertainty and ambiguity the information of the system (truck like mobile robot) receives. The technique has been used on MOBIRO, an experimental mobile robot using a set of seven ultrasonic sensors to perceive its surroundings. The fuzzy control designed maps the input space (information coming from ultrasonic sensors) to a safe collision avoidance trajectory (output space). This is accomplished by an inference process based on rules (list of IF-THEN statements) taken from a common sense knowledge base. The technique
generates satisfactory real time movements of the autonomous vehicle to reach so that the method can be satisfactorily used by mobile robots moving in unknown static terrains. Christain Balkenius and Lars Kopp (1996) describe how tracking and target selection are used in two behavior systems of the XT-1 vision architecture for truck like mobile robots. The first system is concerned with active tracking of moving targets and the second is used for visually controlled spatial navigation.

Bianco and Cassinis (1996) present a proposal for an autonomous truck like mobile robot path planning system that uses several strategies to reach a target also in an unknown environment. The proposed method has learning capabilities that allow the robot to take advantage of previous experience, thus improving its performance during successive traveling in the same environment. Bentalba et al (1998) deals with the path following problem of a truck like mobile robot. A unified kinematics model is derived for this problem. The mobile target configuration is represented by the motion of a reference car which has the same kinematics constrains as the real one. The generated kinematics model is added to the mobile robot dynamics in order to obtain a general state representation for the path following problem. Initially, this problem is solved by means of a state feedback control law, then by a fuzzy control one. The stability analysis of the fuzzy control system of the vehicle dynamics is discussed using Lyapunov's approach and convex optimization techniques based on Linear Matrix Inequalities (LMI). Finally, simulation results are given to demonstrate the controller's effectiveness. Bart Kosko (1998) explored the stability of a class of feedback fuzzy systems for the truck like mobile robot. The class consists of generalized additive fuzzy systems that compute a system output as a convex sum of linear operators.

Balakrishna and Ashitavaghosal (1995) implemented an easy approach to fuzzy system identification. The approach consists of two phases.
The first phase involves a baseline design to effectively identify a prototype fuzzy system for a target system from a collection of input output data pairs. This is implemented by incorporating the subtractive clustering method to determine the number of clusters and the fuzzy c-means (FCM) clustering algorithm to build the actual clusters. If the resulting prototype fuzzy system cannot describe the target system appropriately with respect to input-output data pairs, the second phase fine tuning process to adjust the parameters identified in the baseline design is necessary. This process can be realized by using the steepest descent and recursive least-square estimation methods. The proposed approach is validated by applying it to a function approximation type of problem, the truck backer-upper problem with an obstacle in the center of the field. David Zhu and Latombe (1991) describe a problem of multi-agent path planning in environment with obstacles. Novel approach to multi-agent optimal path planning, using graph representation of environment models is described. When planning the path of each truck like mobile robot, the graph model of environment is dynamically changed for path correction and collision avoidance. New algorithm applies changes of robot’s paths and speeds to avoid collisions in multi-agent environment. Giuseppe Borghi and Vincenzo (1998) describe the problem of goals non-reachable with obstacles nearby when using potential field methods for truck like mobile robot path planning. Then, the new kind of repulsive potential functions by taking the relative distance between the robot and the goal into consideration, which ensure that the goal position is the global minimum of the total potential.

Claudio Altafini (2001) proposes a control scheme for stabilization of backward driving along simple paths for a miniaturized vehicle composed of a truck and a two-axle trailer. The paths chosen are straight lines and arcs of circles. When reversing, the truck and trailer under examination can be modeled as an unstable nonlinear system with state and input saturations. The simplified goal of stabilizing along a trajectory (instead of a point) allows us
to consider a system with controllable linearization. Still, the combination of instability and saturations makes the task impossible with a single controller. In fact, the system cannot be driven backward from all initial states because of the jack-knife effects between the parts of the multimode vehicle; it is sometimes necessary to drive forward to enter into a specific region of attraction. This leads to the use of hybrid controllers. The scheme has been implemented and successfully used to reverse the radio-controlled vehicle.

Bernard Widrow (2002) proposes a nonlinear filtering system based on neural networks that serves as a coupler between human operators and a nonlinear system or plant that is to be controlled or directed. The purpose of the coupler is to ease the task of the human controller. The equations of the plant are assumed to be known. If the plant is unstable, it must be stabilized by feedback first. Using the plant equations, off-line automatic learning algorithms are developed for training the weights of the neurointerface and the weights of an adaptive plant disturbance canceller. Application of these ideas to backing a truck with two trailers under human direction is described. The truck backer-upper has been successfully demonstrated by computer simulation and by physical implementation with a small radio-controlled truck and trailers.

Petru Rusu et al (2003) discuss an experimental neuro-fuzzy controller for sensor-based truck like mobile robot navigation in indoor environments. The autonomous mobile robot uses infrared and contact sensors for detecting targets and avoiding collisions. The control system is organized in a top-bottom hierarchy of various tasks and behaviors. When multiple low-level behaviors are required, command fusion is used to combine the output of several neuro-fuzzy sub-systems. A switching coordination technique selects a suitable behavior from the set of possible higher level behaviors. Fekete et al (2005) demonstrated how one of the classical areas of computational geometry has reached practical application,
which in turn gives rise to new, fascinating geometric problems. In particular, they discussed the problem of developing a good online strategy for an autonomous truck like mobile robot to locate an object that is hidden behind a corner or door.

2.4 LITERATURE ON FLC CONTROLLER FOR TRUCK LIKE MOBILE ROBOT

The simplicity of designing the fuzzy logic systems has been the main advantage of their successful implementation over traditional approaches such as optimal and adaptive control techniques. Van Amerongen (1997) has designed an autopilot for ships by translating the steering behavior of a human controller into a fuzzy mathematical model. The operator experiences are modeled to design the rule base of the fuzzy logic controller. Yasunobu et al (1983) designed a fuzzy control that uses rules based on a skilled human operator's experience applied to automatic train operations. The skilled experiences of the operator are transformed into fuzzy rules and efficient controller performance is achieved.

Langer et al (1994) has proposed a fuzzy controller for aircraft flight control where the fuzzy rules are generated by interrogating an experienced pilot and asking him a number of highly structured questions. Kim et al (1994, 1996) used a similar method, however, with different shapes of fuzzy membership functions applied to different processes. This paper presents an insight to various membership functions and their input-output mapping behavior. Lee and Takagi (1993) proposed a method of determining the parameters of a Takagi–Sugeno type of FLC, which used chromosomes of 2880-bit length strings. The optimization procedure of genetic algorithm finely tunes the membership functions and the rule consequent parameters. Kikuchi et al (1994) propose a vehicle-following model that employs the fuzzy inference system. It predicts the reaction of the driver by analyzing the
fuzzy values of the leading vehicle’s acceleration and the distance between
the leading vehicle and the following vehicle.

Furthermore, Kim et al extends the above results to a fuzzy throttle
and brake control for a smart car. However, fuzzy systems encounter different
difficulties, such as how to determine the fuzzy logic rules and the
membership functions. To solve these problems, Neural Fuzzy Networks
(NFNs) have been suggested in the literature for implementing fuzzy logic
systems. NFNs are multilayer connectionist models with improved learning
capabilities that combine the benefits of neural networks and the fuzzy logic
systems into a unified framework. In particular, NFN’s share the
computational power of neural networks and the reasoning and the decision
making of fuzzy systems. Hence, the NFN’s constructs exhibit, generally,
better performance for controlling plants and adapting to their environments
as compared to the conventional fuzzy systems and neural networks. The
authors use the Takagi–Sugeno rule of inference with bell-shaped
membership functions. The premise space is uniformly partitioned and all
possible combinations of the linguistic sets are considered in the formulation
of the rule base, thus fixing the structure of the NFN architecture. A hybrid
learning scheme is employed to adjust the network parameters. In particular,
the parameters of the rule output functions are updated using the least-squares
algorithm, while the membership parameters are tuned by means of the back
propagation algorithm.

Kazuo Tanaka et al (1994) deal with a robust stabilization problem
for fuzzy control systems with premise parameter uncertainty. The fuzzy
model and the fuzzy controller are represented by Takagi and Sugeno’s model
whose consequent parts are described by linear equations. The purpose of the
robust stabilization problem is to find out an admissible region such that the
fuzzy control system is asymptotically stable. Lin and Lee (1995) propose a
fuzzy neural network to realize the fuzzy rules with fuzzy consequences. A real-time training scheme is proposed that combines both structure and parameter learning. Structure learning, which is focused on the consequent side of the fuzzy inference system, decides the proper output partitions and the respective rule connections. This task is achieved by using the fuzzy similarity measure which indicates the degree to which two fuzzy sets are equal. The parameter learning task is performed using the back propagation algorithm. The fuzzy neural construct is incorporated into a unified control architecture which uses the reinforcement learning technique to decide the proper control actions. Mark Nelsan (1998) proposed a systematic approach for determining the grades of membership of fuzzy subsets that represent the behavior of a control practitioner. Abe and Lan (1995) developed a method for extracting fuzzy rules directly from numerical input-output data for pattern classification and function approximation.

Rovatti et al (1995, 1996) proposed a new methodology for the minimization of a given set of fuzzy rules. The procedure tunes the set of rules and provides an optimal rule base for the controller. Lee et al (1995) proposed a self-organizing fuzzified basis function based on the competitive learning scheme. The competitive learning structure selects a winner and hence efficient learning is performed for parameter tuning of the network. Waneck (1997) proposed a fuzzy controller for an autonomous boat without initially having to develop nonlinear dynamics model of the vehicle. This paper proves that fuzzy logic can be effectively used for imprecisely defined processes. Joong Hyup Ko et al (1996) described an efficient method for localizing a mobile robot in an environment with landmarks. They assume that the robot can identify the landmarks and measure their bearings relative to each other. Given such noisy input, the algorithm estimates the robot’s position and orientation with respect to the map of the environment. The
algorithm makes efficient use of representation of the landmarks by complex numbers. The algorithm runs in time linear in the number of landmarks.

2.5 SCOPE FOR THE RESEARCH

Existing researchers have made few attempts to design the controller for tracking the path of truck-like mobile robot by using fuzzy logic system and the proportionate integral derivative controlling methods. Despite the advantages of the conventional fuzzy logic controller (FLC) over traditional approaches, there remain a number of drawbacks in the design stages. Even though rules can be developed for many control applications, they need to be set up through expert observation of the process. The complexity in developing these rules increases with the complexity of the process. FLCs also consist of a number of parameters that are needed to be selected and configured in prior, such as selection of scaling factors, configuration of the center and width of the membership functions and selection of the appropriate fuzzy control rules. Nowadays a more recent technique in implementing adaptive or self-tuning fuzzy logic controller rather than other intelligent techniques are by using evolutionary computational techniques genetic algorithm, particle swarm optimization, that are used in the tuning of fuzzy controller parameters on a stage by stage basis. However, partial or stage by stage optimization of the FLC parameters and control rules restrict the searching spaces of GA, thus causing higher possibility of partial or sub-optimal solutions. Hence, in this work, genetic algorithm, particle swarm optimization based self-tuning has been employed to sharpen the design of path tracking controller of truck-like mobile robot.

Genetic Algorithm (GA) developed by Goldberg (1989) is used in tuning the fuzzy controller parameters on a stage by stage basis. Hwang and Thomson (1993) used genetic algorithm to search for optimal fuzzy control rules with prior fixed membership functions. The randomized searching

The parameter tuning using GA optimizes the fuzzy logic controller and the rules also get finely tuned. Hu et al (1994) showed how cell-map information can be incorporated with GA for tuning output variable parameters of the Takagi–Sugeno type of FLC. Homaifar and McCormick (1995) examined the applicability of genetic algorithms in the simultaneous design of membership functions and rule sets for fuzzy logic controllers. Karr and Gentry (1995) applied GA in the tuning of fuzzy membership functions which was applied to a pH control process and a cart-pole balancing system. In another development, Shimojima et al (1995) used GA to tune a type of RBF based fuzzy model, with only three fuzzy memberships for each fuzzy variable. However, the fuzzy system was used to model a mathematical function, and was not implemented as a controller. Ishibuchi et al (1995) used genetic algorithms for selecting a small number of significant fuzzy IF-THEN rules to construct a compact fuzzy classification system with high classification power.

Perneel et al (1995) used genetic algorithms and neural networks as optimization methods to improve the performance of the fuzzy decision-making system for heuristic search algorithms. Teo Lian Seng (1999) proposes an approach in which the GA is implemented using dynamic crossover and mutation probability rates for better exploitation of the optimal Neuro-FLC parameters. Furthermore, a flexible position coding strategy for the fuzzy membership functions is introduced to configure the fuzzy membership partitions in the corresponding universes of discourse.
Wen-hua Tao (2004) presented a kind of fuzzy neural network based on hybrid genetic algorithms. It is proposed to train the fuzzy neural network. The hybrid genetic algorithm improved normal genetic algorithm. The BP algorithm is added to genetic algorithm. In particularly the global convergent characteristic of the genetic algorithm is used to find the possible universal optimum and the great feature of the BP algorithm, that is, error descend in the direction of grads, is used to fast search about the optimum. Thus, the fast learning capability and accurate approximation ability are obtained. The fuzzy neural network is used to the control problem of truck backer-upper. Yair Malachi and Sigmond Singer (2006), proposes the genetic algorithm for the selection of corrective control actions for bus voltage and generator reactive power in a power system. A genetic algorithm using linear approximation of load flow equations and a heuristic selection of participating controls were combined in a search method for the minimum number of control actions.

In recent years, various Particle Swarm Optimization (PSO), Kennedy (1997), Shi and Ebehart (1998) algorithms have been successfully applied to many engineering problems. Among them, the hybrid PSO satisfactorily handled problems such as distribution state estimation proposed by Naka et al (2003) and loss power minimization proposed by Esmine et al (2005) are performing better convergence characteristics than conventional methods.

Vlachogiannis and Lee (2006) proposes three new particle swarm optimization (PSO) algorithms which are compared with the state of the art PSO algorithms for the optimal steady-state performance of power systems, namely, the reactive power and voltage control. Two of the three introduced, the enhanced GPAC PSO and LPAC PSO, are based on the global and local-neighborhood variant PSOs, respectively. They are hybridized with the
constriction factor approach together with a new operator, reflecting the physical force of passive congregation observed in swarms. The third one is based on a new concept of coordinated aggregation and simulates how the achievements of particles can be distributed in the swarm affecting its manipulation. AlRashidi et al (2007) presents a hybrid particle swarm optimization algorithm as a modern optimization tool to solve the discrete optimal power flow problem that has both discrete and continuous optimization variables. The proposed algorithm makes use of the PSO, known for its global searching capabilities, to allocate the optimal control settings.

A hybrid inequality constraint handling mechanism that preserves only feasible solutions without the need to augment the original objective function is incorporated in the proposed approach. This technique combines social psychology principles in socio-cognition human agents and evolutionary computations. PSO has been motivated by the behavior of organisms, such as fish schooling and bird flocking. Generally, PSO is characterized as a simple concept, easy to implement and computationally efficient.

Unlike the other heuristic techniques, PSO has a flexible and well-balanced mechanism to enhance the global and local exploration abilities. The applicability of particle swarm algorithms in the simultaneous design of membership functions and rule sets for fuzzy logic controllers proves its superior performance. The proved superior performance of the above discussed algorithms leads a motivation and a need in eliminating the drawbacks in the design of controller of mobile robot i.e. the truck backer-upper problem.