Path Planning for Unmanned Aerial Vehicle Based on Genetic Algorithm & Artificial Neural Network in 2D

S Aditya Gautam[1] Nilmani Verma[2]
[1, 2]Computer Science Engineering Department
[1, 2]School of Engineering & IT, MATS University, Raipur

Abstract--- The planning of path for UAV is always considered to be a critical task. Path planning for UAV in multiple missions can be accomplished by finding the solution for an optimization problem. Genetic Algorithm which is a global optimization tool can be used to solve the optimization problem for path planning of UAV. Artificial Neural Networks (ANN) is good at function fitting quickly and can be used to approximate almost any function. The Genetic Algorithms are good at converging to the global optimum solution generation by generation. Neural Networks work faster than Genetic Algorithms but may converge at local optimum. In this paper a new method for path planning of UAV for escaping from obstacle based on the combination of Genetic Algorithms and Artificial Neural Networks has been proposed in which the output generated from the Genetic Algorithms is used to train the network of Artificial Neural Networks. The model for path planning is based on 2D digital map.

I. INTRODUCTION

An Unmanned Aerial Vehicle (UAV), commonly known as drone is an aircraft which is not having a human pilot onboard. Its flight is controlled either automatically using AI techniques employed in onboard computers or by the remote control of the pilot in the ground or in some other vehicle. UAVs are usually used in military and special operations but can also be used in a multitude of civil applications like policing, firefighting areas where floods, earthquake and other natural or manmade calamities have occurred. Their importance can never be neglected in rescuing operations and military war fields where there is a great threat to human life. UAVs can also be used in surveillance operations.

In order to move from one position to another position safely, the UAV needs to avoid the obstacles coming in its path and take an alternate path which could let the UAV travel safely and also care must be exercised that it takes shortest path from all the available options. Secure and impressive path planning techniques are usually prepared by solving the optimization problems [6]. The problem of path planning in UAV can be viewed as a path planning in robotic navigation [4].

Number of highly interconnected processing elements (neurons) which are working in agreement for solving specific problems.

The ANN is set for solving a specific problem through a learning process in which the weights of links between interconnecting neurons are adjusted so as to map the input to the target and once the neural network is trained it can be used for obtaining the output for unknown inputs also.

With the advent in computational intelligence research area so many methods of path planning for obstacle avoidance in robotic navigation have been proposed. Among them Evolutionary Algorithms are used to form the strategy of path planning in a natural manner [1]. In [1] a method has been proposed for UAV path planning in adversarial environment in which Genetic Algorithms based optimization techniques are used to plan a path which is shorter in length and following which can lead the UAV to avoid the radar which is an obstacle in the path for movement of UAV.

As compared to other approaches for path planning the Genetic Algorithms try to find the solution for a given problem in a globally optimum way instead of converging early to local optima. Genetic Algorithms employ operations like selection which is the process through which the elite solutions are selected at every generation and then the crossover operation is performed in which the parts of the solutions are interchanged with each other to form a new solution. After that the mutation operation is performed in which some parts of the solution are replaced by new solution thereby introducing the diversity in the population. The idea is that the newly formed population at each and every generation is better that previous generation which formed as a result of applying the genetic operators namely selection, crossover and mutation.

The algorithm proposed in [1] consists of several steps: initialization of random set of population consisting of several solutions. Then various solutions are analyzed in terms of their fitness and then crossover and mutation operations are applied which result in new set of solutions which is nothing but the new generation of solutions which is assumed to be better than its ancestor.

Neural networks are used in association with the computer industry since 1950's. Neural Networks are capable of performing sophisticated computational tasks like fitting of a function, pattern recognition, associative recall and learning [2]. The origin of neural network can be found from the paper written by McCulloch and Pitts (1943), through the perceptron work in the 1950s and 1960s (Rosenblatt 1958; Minsky and Papert 1969).

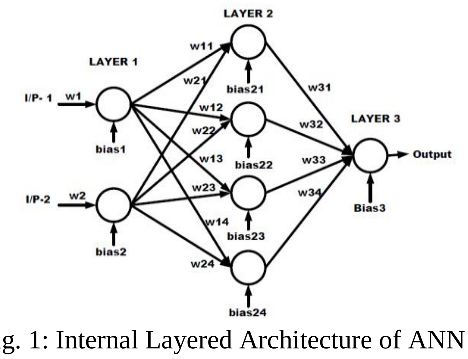

Fig. 1: Internal Layered Architecture of ANN [3].

Artificial Neural Network (ANN) is non-linear mapping structures which are based on the functioning of human brain. They are found to be good in function fitting and modeling, especially when the input output interrelationship is unknown [3]. The basic element of this model is the structure of information processing system. It has large.

Each link which connects the neurons is associated with some weight which specifies the strength of interconnection of neurons. The weights of links connecting the neurons are adjusted during the training process so that when the input is given the output generated can be matched to the desired output .This process is known as training the Artificial Neural Network. The training can be supervised, unsupervised or reinforced [3].

II. Genetic Algorithm, Neural Network And Path Planning For UAVs

The GA is used to find the solution for a given problem which is in the form of a fitness function which has to be minimized. So GA finds the minimum value of the variable for which the value of the entire fitness function is found to be minimum in a globally optimum way [1].

For optimization and hence finding the solution for a given fitness function, the GA starts from the initial set of population which could be far away from the globally optimum solution which is created randomly based on the given linear, non-linear and bound constraints. Then three operations of selection, crossover and mutation are performed over the population consisting of set of solutions and then the new set of solutions is produced which is assumed to be better than the previous generation. The process is repeated many times till the final solution is arrived which is also known as the final generation [1].

In case of UAV path planning problem, the solution is the path from the initial position to the goal position. Each path is consisting of intermediate waypoints which are called the genes. The set of genes or waypoints which make a path is called a chromosome. At any given generation, the population consists of set of chromosomes or paths. The GA works by applying the operators to produce new paths which are assumed to be better than the previous set of paths from the previous generation [1].

A. *Initial population*

The population at any generation for the Genetic Algorithm consists of some paths which are known as a set of solutions or chromosomes made up of way points which are joined together to form a path. Each way point is called a gene. The initial set of solutions or paths following can lead the Unmanned Aerial Vehicle to travel from starting to the goal position is called the initial population.

The initial population is created randomly based on the given linear, nonlinear and bound constraints imposed to the Genetic Algorithm. The initial population can be far away from the final global optimum set of solutions or chromosomes of final generation.

The Unmanned Aerial Vehicle starts it movement along the straight line and continues to move as long as it doesn’t perceive the radar signals, but once it perceives the radar signals it starts generating the initial set of population which consist of paths which are away from the radar but their length may not be global minima.

B. *Evaluation*

Each of the generated paths is evaluated by its fitness value which is directly proportional to the distance from the radar and inversely proportional to the total length of path from the initial position to the goal position.

$$\text{Length}(p) = \sum_{i=1}^{N-1} l(wp_i, wp_{i+1}) \qquad -(1.1)$$

Where Length (p) denotes the total length of the path p, $l(wp_i, wpi_{+1})$ is the length of line segment from neighboring waypoint wp_i to wp_{i+1} in the path.

Obstacle (p) =distance of the path (p) from the obstacle - (1.2)

The fitness is computed as follows:

$$\text{Fitness}(p) = w*\text{obstacle}(p)/\text{length}(p) \qquad -(1.3)$$

Where the coefficients “w” is a proportionality factor.

Equation (1.3) indicates that fitness of the function must be directly proportional to distance of the UAV from the obstacle and inversely proportional to the total length of the path from initial to the final position.

C. *Operators*

Selection operator decides which paths from the population should survive and hence participate in forming the next generation of population.

Crossover operator selects the portions of two paths and then combines them to form a new path. Crossover can be single point or multipoint which means single or multiple portions of the paths can be selected to generate a new path.

Mutation operation brings diversity in the population by changing some portions of solution in the population. Here some waypoints of paths are changed for bringing the diversity in the solution space so that the new generation of population can be different from its previous generation.

After applying the above three operators the newly generated population is expected to be better than its previous generation in terms of satisfying fitness function i.e. the new generation of population can be better than its previous generations.

The Genetic Algorithm tries to optimize the population generation by generation and the final generation of population can be assumed to be the best in terms of satisfying the fitness criteria given in equation (1.3).

Artificial neural networks are found to be good at fitting a function. Given input and target pairs, ANN can approximate the function which can produce the output for the given input which approximately matches the given target values in case of supervised learning. They are found to produce results fast as compared to GA. But ANN may converge early to local optima and GA produces results which are found to be globally optimum. So using the results produced from the GA to train the ANN is a good alternative for finding solutions fast which are globally optimum.

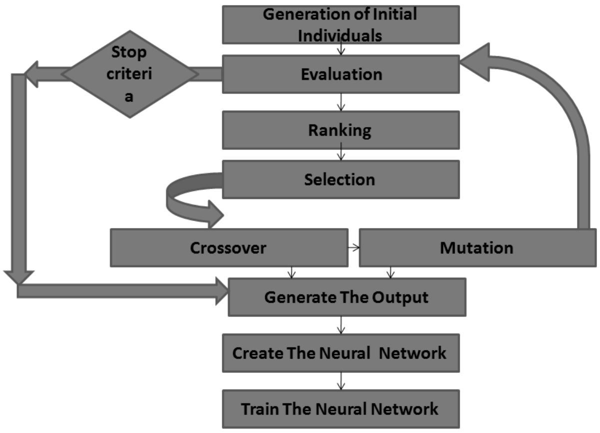

Fig. 2: Flow Diagram of Algorithm.

The UAV starts moving from its initial position towards its final position along the straight line connecting the initial and final position as it is assumed to be the shortest path without obstacles. When the onboard sensors in the UAV perceive that there is a radar in its path, then GA starts working as shown in Fig.2 as follows:

Step 1: Generation of Initial Individuals- The initial individuals are generated randomly which may not perfectly fit the fitness criteria specified in equation (1.3).

Step 2: Evaluation- Here the individuals generated are tested for their quality in terms of fulfilling the fitness function of equation (1.3).

Step 3: Ranking- The generated individuals are ranked according to their fitness.

Step 4: Selection- The best or elite individuals from the population are selected for further processing. The top individuals of the solution are ranked in ascending order of their fitness values.

Step 5: Crossover- Some parts of two or more individuals are interchanged to form a new individual. The crossover can be single point or multi point crossover.

Stopping criteria: It is the condition at which the Genetic Algorithm stops and produces the final results. There can be so many reasons, maximum number of generation specified reached, time exceed, stall limit, etc.

Step 7: Generate the Output- The final population is taken to be the result of Genetic Algorithm. The generated output along with the input i.e. input output pair is stored safely so that they can be used to train the ANN.

Step 8: Create the Neural Network- The neural network is created with input, hidden and output layers [5].

Step 9: Train the Neural Network- the output generated at step 7 is used to train the Artificial Neural Network created at step 8 using the Supervised Learning.

Repeating the steps 1 to 7 for various inputs can generate the dataset. The output generated from the Genetic Algorithms is found to be globally optimum [2]. So the output generated from the Genetic Algorithm can be used as a training data set for the Artificial Neural Networks.

III. SIMULATION

This section gives details about the simulation. All the simulations are performed on a computer with 2GB RAM and 2.20GHz Pentium core2 Duo processor. The operating system used is windows7 operating system. The above discussed algorithm is implemented in MATLAB R2012a.

Let us assume that it belongs to a security application, i.e. military UAV searching task, the UAV starts flying from its initial position to the goal position. It assumes a straight line initially from the initial to the goal position. It continues its movement along the straight line till its onboard sensors detects the presence of radar in its path. Then genetic algorithm is called which computes a path, UAV can follow this path to escape from the radar with minimum possible distance. Here the number of intermediate waypoints is taken to be three, if the number of intermediate waypoints is increased, more smooth path could be generated i.e. the smoothness of curve and perfection of path is directly proportional to the number of intermediate waypoints in the path. It means increasing the number of waypoints through which the UAV moves can find much better solution for the path planning problem.

In Fig.3 the UAV is shown to be moving in horizontal direction from initial position to final position.

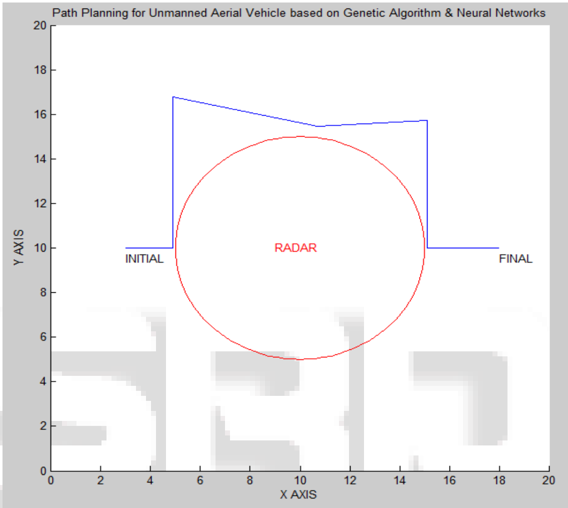

Fig. 3: Horizontal movement of UAV.

In Fig.4 the UAV is shown to be moving along the vertical direction.

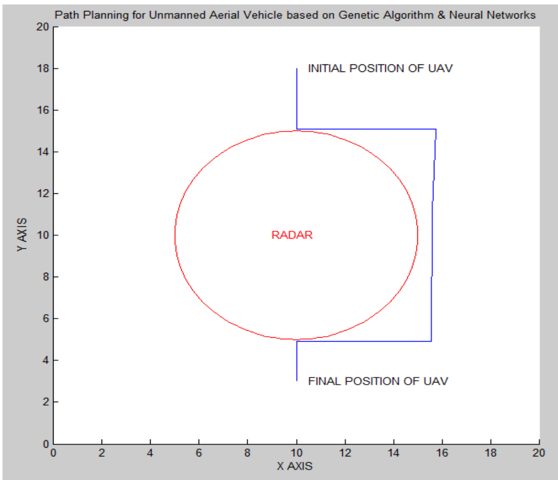

Fig. 4: Vertical movement of UAV.

Fig.5, Fig.6, Fig.7, Fig.8 shows the performance of training of the Artificial Neural Network using the output generated from the Genetic Algorithms.

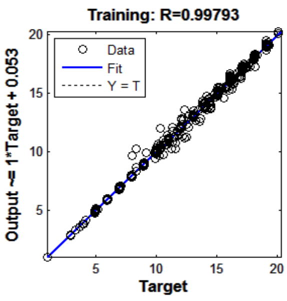

Fig. 5: Performance of Neural Network training over training data set

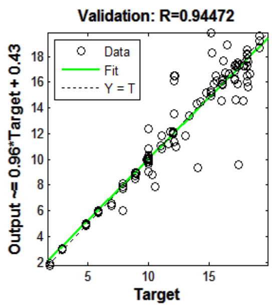

Fig. 6: Performance of Neural Network Training over Validation data set.

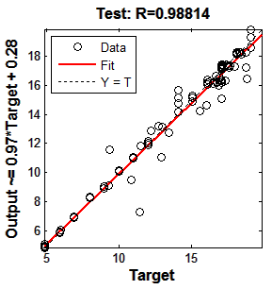

Fig. 7: Performance of Neural Network over test data set.

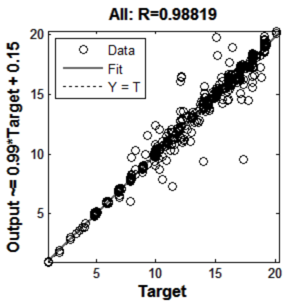

Fig. 8: Overall performance of Neural Network Training.

The available data set is subdivided into three parts namely training data set used for training the ANN, validation data set used for validating the ANN, test data set used for testing the performance of Network over unknown inputs.

The value of R*10 indicates the percentage up to which the ANN has been successfully trained.

IV. CONCLUSIONS

In this paper, a novel and efficient method based on Genetic Algorithms and Artificial Neural network is presented for path planning of UAV, for avoiding the obstacle which is radar in this case. The output obtained from the Genetic Algorithms has been successfully used to train the Artificial Neural Networks and its performance in all the cases is realized using simulations. It is found that the above approach of training the Neural Networks using the output of Genetic Algorithms can let the UAV plan its path faster and better as compared to using GA alone. The future scope of this research can include multiple UAVs communicating with each other during a mission for sharing of information regarding obstacle.

V. ACKNOWLEDGEMENT

The author wish to thank Mr. Nilmani Verma sir for his valuable comments and suggestions.

REFERENCES

[1] Si-Yao Fu, Li-Wei Han, Yu Tian, and Guo-Sheng Yang, "Path Planning for Unmanned Aerial Vehicle based on Genetic Algorithm," Proc. 11th IEEE Int. Conf. on Cognitive Informatics & Cognitive Computing, 2012.

[2] J. David Schaffer, Darrell Whitley, Larry J. Eshelman, "Combinations of Genetic Algorithms and Neural Networks"; a Survey of the State of the Art, IEEE, 1992.

[3] Ms.Dharmistha, D.Vishwakarma, "Genetic Algorithm based Weights Optimization of Artificial Neural Network," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering. Vol.1, issue 3, August 2012.

[4] S. Thrun, "Bayesian landmark learning for mobile robot localization," Machine Learning, vol. 33, no.1, pp. 41-76, 1998.

[5] Imran Shafil, Jamil Ahmad2, MIEEE, Syed Ismail Shah2, Sr. MIEEE, and Faisal M Kashif3, "Impact of Varying Neurons and Hidden Layers in Neural Network Architecture for a Time Frequency Application," IEEE, 2006.

[6] E. Lawler, A. Rinnooy, J. Lenstr, "The traveling salesman problem: a guided tour of combinatorial optimization," John Wiley and Sons, 1985.

