Review of Heuristic Based Techniques for Path Planning of UAV

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Abstract— Path planning for UAV comprises of two components. One component deals with finding out the actual position of UAV in a real world environment. The second component deals with discovering a shortest collision free path from starting point towards the golat point. This paper investigates different heuristic based approaches for effective UAV path planning and also discusses about their strengths and weaknesses.

Key words: UAV, Path planning, Evolutionary Algorithms, Swarm Intelligence, Artificial Neural Networks, Genetic Algorithms, Ant Colony Optimization, Particle Swarm Optimization, Artificial Bee colony optimization Algorithm, Cuckoo Search, Bee Algorithm, Intelligent Water Droplets Algorithm

I. INTRODUCTION

An Unmanned Aerial Vehicle (UAV), which is also commonly known as a drone is an aircraft which doesn’t have an on board human pilot. Its flight is controlled either by the remote control of the pilot in the ground or in some other vehicle or automatically using AI techniques which is being employed in on board computers. Military and special operations usually deploy UAV but these can also be used in a large number of civil applications like policing, firefighting, and in areas where floods, earthquake and other natural or manmade calamities have occurred. At the places like military, risk oriented rescuing operations; UAV’s are always be an asset and can prove to be helpful in saving precious lives of human beings who are involved in such dangerous activities.

For safely moving from one position to another position, the UAV must adopt a path which could let it avoid the incoming obstacles and also ensure that the path chosen is of shortest length and maintains safe distance away from the obstacle. Solving optimization problems could let us to create impressive and effective path which could best fulfill the objective criteria [6]. The problem of path planning in UAV can be viewed as a path planning in robotic navigation [7].

The advent in computational intelligence research area gave rise to plenty of methods in path planning for avoiding obstacle in robotic navigation. Among them the heuristic techniques especially Evolutionary Algorithms have been used for the strategy formation of path planning in a natural manner [1]. In [8] 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.

II. HEURISTIC BASED TECHNIQUES AND THEIR APPLICATION IN PATH PLANNING FOR UAV

In the field of Artificial Intelligence, an Evolutionary Algorithm (EA) is a generic population based metaheuristic optimization algorithm, which is a subset of evolutionary computation. EA deploys the natural phenomenon which also includes biological processes like reproduction, mutation, recombination and selection. Candidate solutions which are the solutions which are not globally optimum or best form the population set. The natural operators are applied over the candidate solutions or population with the purpose of achieving the global optimum which is inspired by the natural processes. Some of the most prominent Evolutionary algorithms are like Genetic Algorithm (GA), Genetic Programming (GP), Evolutionary Programming (EP), Gene Expression Programming (GEP), Evolution Strategy, Differential Evolution (DE), Neuro Evolution (NE), Learning Classifier System (LCS).

Apart from the above Evolutionary Algorithms, Swarm intelligence which also comes under the category of Evolutionary Algorithms generally refers to a collection of natural objects or elements which works collectively and exhibits intelligence. Examples include Ant Colony Optimization (ACO), Artificial Bee Colony Algorithm (ABCA), Bees Algorithm (BA), Cuckoo Search (CS), Particle Swarm Optimization (PSO).

As compared to other approaches like classical methods viz. cell decomposition, potential field, road map, sub goal network for path planning the heuristic evolutionary methods like Genetic Algorithms, Ant Colony Optimization, Artificial Bee Colony Optimization, Particle Swarm Optimization, etc, try to find the solution for a given problem in a method greatly inspired by nature by applying the same set of operators over and again for different generation of population.

A. Genetic Algorithms

Genetic Algorithms involves operations like selection which is the process through which the best solutions are selected at every generation and then the operation of crossover is performed in which some parts of the solutions are interchanged with each other to form a new solution. Followed by crossover the mutation operation is performed which involves replacement of some parts of the solution by new solution hence introducing the population diversity. The Genetic Algorithm assumes that the population of solutions generated at every new step is better than its previous generation of population as it is also derives this principle from natural adaptation [3]. In [10], only GA has been used for path planning of UAV.

B. Ant Colony Optimization

Similarly the Ant Colony Optimization (ACO) is inspired from the foraging behavior of ants through which the ants find the shortest safe rout away from the obstacle from its nest to food source. This principle is utilized for path planning of UAV for moving from initial to final destination position thereby avoiding the incoming obstacle. The ants start traveling from their nest and move towards the food.
source considering a straight path, but as soon as they encounter the obstacle they spread across in different possible directions and start moving towards their destination. Meanwhile the ants also lay pheromone while they move. The ants which reach the destination earlier compared to other ants which take longer route lay more amounts of pheromones than the ants which take shorter route as the ants which follow shorter route are able to take more number of round trips from source to destination and deposit more pheromone [15]. In [16], ACO Algorithm has been used for robotic path planning.

C. Artificial Neural Networks

Since 1950’s, Artificial Neural Networks (ANNs) have been used in association with computer industry. Sophisticated computational tasks like fitting of a function, pattern recognition, associative recall and learning are some of the crucial tasks which are being performed by ANNs [9]. The ANN finds its origin from the paper written by McCulloch and Pitts (1943), through the work of perceptron in the 1950s and 1960s (Rosenblatt 1958; Minsky and Papert 1969).

Artificial Neural Network (ANN) is a non-linear mapping structure which is 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 consists of large number of interconnected elements which are known as neurons. The information is stored in ANN in the form of weights of links which connects different neurons together.

Learning is the activity of updating of weights of links which connects the different neurons together. ANNs can be classified according to the type of learning which they undergo for updating the weights of links connecting the different neurons. They can be classified as supervised, unsupervised and reinforcement learning. In supervised learning the set of inputs and desired outputs are provided, the ANN undergoes multitude of stages known as epoch for updating the weights of links which connects different neurons in the Artificial Neural Networks. In case of unsupervised learning, the set of inputs and outputs are not given. In case of reinforcement learning, no explicit set of inputs and outputs are provided in advance. When the network gets trained in correct direction, a reward is being given and the training propagates in that direction.

In [2] the use of ANN for robotic navigation has been classified into three categories viz. interpretation of sensory data, avoiding the obstacle and planning of path. In [1], it has also been suggested that the hybrid approaches which use combinations of ANN and other Artificial Intelligence techniques like GA, etc. are found to exhibit far better performance than ANN used alone.

D. Particle Swarm Optimization

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, which is inspired by social behavior of bird flocking or fish schooling. In PSO, the potential solutions are called particles, which fly through the problem space by following the current optimum particles.

Every particle keeps tracks of its coordinates in the problem space which represent the best solution the particle has achieved so far along with the fitness value which is known as pbest. Another value which is tracked by the particle is known as lbest which is the best value of fitness achieved by the particle’s neighbors so far is also stored by the particle. When a particle considers all the topological neighbors as its own neighbors then the best fitness value is known as the gbest or global best.

PSO works by changing the velocity of each particle at each time step towards its pbest and lbest locations [1].

E. Artificial Bee Colony Algorithm

Artificial Bee Colony Algorithm (ABCA) has been proposed by Dervis Karaboga in 2005, which is inspired by the intelligent behavior of honey bees. It uses common control parameters like maximum cycle number and colony size. ABC can be used as an optimization tool which provides a population based search procedure in which the individuals called the food positions are modified by the artificial bees with time and bee’s aim is to discover the places of food sources which has high nectar value and ultimately the one having highest nectar. In the system of ABC, flies around a multidimensional search space and some of the bees like onlooker bees and employee bees choose the food sources based on their own experience and their nest mates and they adjust their position among themselves. Some of the bees known as scouts fly and randomly choose the food sources without making use of experience. They update the information regarding the nectar amount contained in a food source by remembering the place having the food source containing higher nectar amount and forgetting the place having the food source with lesser amounts of nectar.

ABC system thus best utilizes both the local and global search methods by combining the local search methods which is managed by employed and onlooker bees with that of the global search methods which are managed by onlookers and scouts and hence attempts to balance the exploitation (by means of experience of employed and onlookers bees) and exploration (by means of scouts and onlooker bees).

F. Cuckoo Search

Cuckoo Search is an optimization algorithm which was developed by Xin-she yang and Suash Deb in the year 2009. There is a simple idea behind Cuckoo Search for optimization problems. A Cuckoo is a bird which places its eggs in the nest of other birds. Usually the other birds conflict with Cuckoo bird and throw the eggs of the Cuckoo bird outside of their nest [11].

The above concept of Cuckoo bird is used for the purpose of optimization. Each egg in the nest represents a solution. When a Cuckoo bird introduces its egg in the nest, then that egg is considered as a new solution. The aim is to replace the sub optimal or not so good solutions with the good or optimal solutions [11].

The Cuckoo Search algorithm has been used in association with path planning problem in [12].

G. Bees Algorithm

Bees Algorithm was developed in the year 2005, which are a population based search algorithm, which mimics the food foraging behavior of honey bee colonies. A bee colony can extend itself for long distance up-to 14 kms, in multiple
directions simultaneously for harvesting pollen or nectar from multiple food sources or flower patches. A fraction of bee colony population known as scouts continuously searches for new flower patches. When the scout bees return to the hive, they deposit the food harvested. Those individual scout bees which found the food which is highly profitable food source or food having food net energy goes to an area in hive called dance floor and perform a ritual called waggle dance. The waggle dance is meant to communicate the location of the food source to the idle onlooker bees and the intensity of waggle dance is proportional to the scout’s rating of the food source in terms of nutrition value. The waggle dance of scout bees attracts more foragers to join them and go to the food source discovered by scout and hence more and more number of bees get themselves engaged in getting the food from the food source which has been recognized as having potential net energy value. Latter on the other forager bees also starts advertising the food source which has high nutrition value by means of waggle dance and hence attracts more and more number of bees to join them for collecting the food from the recognized food source. In this way the bees starts searching for the food source from random without having prior knowledge of location of food source which has best net energy value or nutrition value but later on by means of heuristic approach discovers the best food source and majority of bees get engaged in fetching the food from that food source which is considered to have best net energy value or best nutrition value. This concept could be used in finding the optimum solution from a solution space, and hence could be used for finding an optimal path for UAV which could let the UAV plan a path which is of shortest length and at a safe distance away from obstacle [13].

H. Intelligent Water Drops Algorithm

Intelligent Water Drops Algorithm (IWD) is a swarm based optimization algorithm which was introduced for solving Travelling Salesman Problem in 2007. The algorithm contains a few elements which are considered to be essential for natural water drops and posses some properties which are influenced by the actions and reactions which occur river’s bed and water drops that flow within. Most of the IWD algorithms posses two parts, a graph which acts like a distributed memory which is meant to preserve the soils of different edges, and a few water drops which is considered to be the moving part of the algorithm.

The Intelligent Water Drops (IWD) both compete and cooperate to find the better solutions by changing the soils of the graph through which they flow, the paths to better solution become more reachable. In [14], IWD Algorithm has been used for path planning for UAV. The proposed algorithm works at two levels; first level, finds best global path or optimal path. Second level, performs local search at relatively near distances of global path and reduces its length and response time in order to find out the sub optimal path and investigate whether any other optimal solution exist which is better than the current one. IWD algorithm, like other nature-inspired algorithms, does not pose a mechanism for dealing with constrained optimization problem. So, a mechanism has been proposed which is based on repair of infeasible solutions. In this mechanism, proposed local search operator repairs some of infeasible solutions. Simulation result shows ability of IWD algorithm in finding the optimal path.

ACKNOWLEDGEMENT

The author wish to thank for his valuable comments and suggestions.

REFERENCES

