

Trajectory Planning in 2D Space Using Evolutionary Algorithms



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Abstract Planning optimal trajectory in a 2D space with large number of nodes or coordinates is a challenging task. Path planning has various applications in the aviation industry, UAV, mobile robots, etc. So path planning algorithms should be efficient enough to manage the associated constraints such as time, travelling cost and energy in an optimal way. Evolutionary algorithm can be very effective in addressing such challenges. This paper reviews various approaches proposed for path planning of UAV using evolutionary algorithms. Formulating the appropriate fitness function according to the requirement of the problem is the major task, which affects the accuracy of the solution.

1 Introduction

The use of ‘Automated traversing’ object has increased in recent time. This automated traversing object could be a UAV or a mobile robot, which has to traverse a certain path for fulfillment of the purpose. It has wide applications in military missions, monitoring weather forecasting, traffic control, rescuing people and lot more. It may happen that UAV has to be used in a littered and obstacle-rich environment, for instance, in a metropolitan area and therefore, it is very much essential for a UAV

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to adopt a path planning mechanism to make sure that the path which is traversed by UAV should be free from collision and path length must be optimal [1]. One of the major problems in trajectory planning of these objects is that they have to traverse between the starting and the ending point, and there are chances that they may encounter a lot of obstacles and these obstacles can be fixed at one location or vary during the flight. To overcome the above problem, it is necessary to plan a path where automated objects could overcome the rough path, by optimizing and finding the feasible path.

This paper is based on planning the trajectory of automated traversing objects, in two-dimensional space, with the use of evolutionary algorithm. Over the last decade, evolutionary algorithms have emerged as very effective optimization and searching techniques. Evolutionary algorithms are a part of evolutionary computations and also belong to a group of modern heuristics-based search technique. As they have inherited the properties like flexibility and robustness from evolutionary computation, they can efficiently solve global optimization problems. In many applications, high complexity evolutionary algorithms have been used [2], such as Rathbun et al. [3] proposed an evolution based path planning algorithm for autonomous motion of a UAV through uncertain environments.

2 Evolutionary Algorithms

Path planning algorithms based on evolutionary algorithms use a population formed of possible solutions and gradually modify them to perform the stochastic search. The population is initialized randomly. At each step, various operations are performed upon the population. Then the cost function is used as a measure of fitness. Based on the fitness, population is either modified or selected for the next iteration. The same operations are repeated until stopping criteria are met. Figure 1 explains the basic

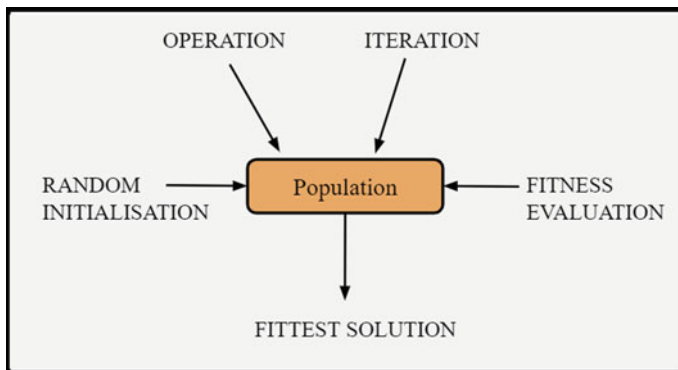


Fig. 1 Working of evolutionary algorithms

Table 1 Name of evolutionary algorithms and from where they have been inspired by

Sl no.	Year	Name of the paper	Name of the authors	Inspired by
1.	1988	Genetic algorithms [2]	Goldberg and Holland	Charles Darwin's theory of natural evolution
2.	1995	Particle swarm optimization [4]	James Kennedy and Russell Eberhart	Flocking of birds
3.	1997	Differential evolution [5]	Rainer Storn, Kenneth Price	Theory of evolution
4.	1999	Ant colony optimization [6]	Dorigo and Di Caro	The searching behaviour of ants, especially the pheromone communication between ants for finding the best path between the ants and the food source
5.	2009	Artificial bee colony [7]	Karaboga, Akay	The intelligent searching behaviour of honey bee
6.	2011	Teaching-learning-based optimization [8]	Rao, Savsani, Vakharia	The result of the guidance of a teacher on the performance of students/learner in class
7.	2016	Social group optimization [9]	Suresh Satapathy, Anima Naik	Basic concept of humans' social behaviour for solving a complex problem

working principle of evolutionary algorithms. It is not the best solution always, but an optimal solution, whose optimality can be increased, by modifying the control parameters, according to the complexity and scalability of the problem.

Table 1 depicts some of the evolutionary algorithms and inspirations from where they have been taken from.

Genetic algorithm (GA) was coined in 1970 by John H. Holland and his student [2]. It was inspired by Charles Darwin's theory of natural evolution. GA uses several operators such as crossover and mutation to get the solution to a problem. Particle swarm optimization (PSO) was coined in 1995 by James Kennedy [4]. The theory was inspired by the flocking of birds. It is a method where the problem gets the optimal solution by repeatedly trying to enhance the particle best solution with regard to a given measure of quality. Ant colony optimization (ACO) algorithm was developed by Marco Dorigo in 1992 in his Ph.D. [6]. He was inspired by the searching behaviour of ants, especially the pheromone communication between ants for finding the best path between the ants and the food source. Also, it helps us solve the problem which can be optimized for finding the best path. Differential evolution (DE) is a new heuristic approach for minimizing the nonlinear and non-differentiable continuous space functions [5]. DE was proposed by Rainer Storn in 1996 and was inspired by the theory of evolution. The extensive tests demonstrated that it converges faster with more accuracy than any other existing global optimization methods. Artificial bee

colony (ACO) was developed by Dervis Karaboga in the year 2005, inspired by the searching behaviour of bees [7]. It commonly uses the parameters such as size of colony and cycle number should be maximum. It is an optimization technique that provides search on the basis of population procedure in which bees modify food's positions with time and they discover places with food resources with higher amount of nectar. Social group optimization is a population-based optimization technique [9] which is motivated by the concept of humans' social behaviour for solving a highly complex problem. It is observed that in the population-based category, social group optimization will enhance the class of effective and efficient evolutionary optimization techniques and will provide researchers a large scope to choose this in various problems and applications. Teaching–learning-based optimization was proposed by Rao et al. in 2011 [8]. Like other algorithms, it was also inspired by the effective guidance of the teacher on the performance by the students of the class. To get the global solution, TLBO uses a population (class of learners) of solutions so it also falls in the category of population-based method.

2.1 Application of Evolutionary Algorithm in Trajectory Planning

Evolutionary algorithms were inspired by the mechanism of how various species of nature interact and develop intelligence to solve their problem optimally. To maximize the function's quality, a set of elements (possible solutions) are generated randomly in function domain. The quality function is now the fitness function which is applied to the main problem domain. On the basis of the fitness function, the candidates with best fitness value are selected or modified for the next generation. This is realized by applying some biological operators inspired by the biological processes. This is repeatedly done until the best solution is found.

A suitable fitness function can be defined for trajectory planning that can be optimized using evolutionary algorithm. The designing of fitness function is the main challenge and the crucial part for optimizing the path planning. Figure 2 depicts the application of evolutionary algorithms to path planning. Though we have some specific algorithms like ACO, which is specifically designed for path planning, we can also apply other evolutionary algorithms if we can design an appropriate fitness function because most of the evolutionary algorithms focus on optimizing the fitness function. The more optimal the fitness value is, the more optimized the trajectory will be. Table 2 shows some of the evolutionary algorithms used for trajectory planning in UAV, mobile robots, etc.

Arantes et al. derived a heuristic approach for UAV path planning by using genetic algorithm under critical situation. The algorithm defines a new path to land UAV by considering all the constraints. Similarly, Atencia et al. solved complex multi-UAV problem by using multi-objective genetic algorithm [11]. It defined various hybrid fitness functions which satisfy the constraints and try to find the optimal solution by

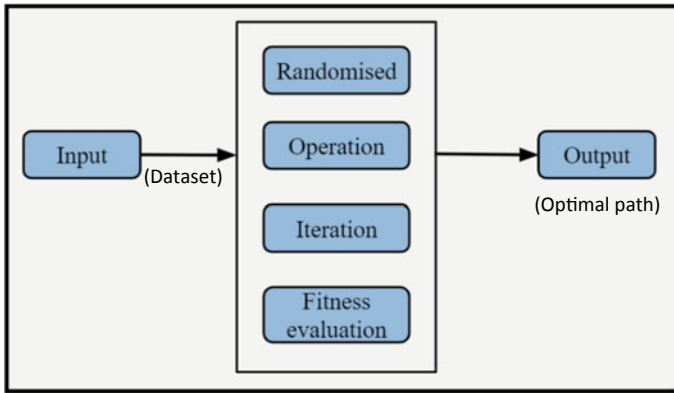


Fig. 2 Working of evolutionary algorithms in trajectory planning

Table 2 Evolutionary algorithms in trajectory planning

Sl no.	Year	Name of the authors	Evolutionary algorithms
1.	2017	Arantes et al. [10]	Genetic algorithm (GA)
2.	2016	Atencia et al. [11]	Genetic algorithm (GA)
3.	2017	Ghamry et al. [12]	Particle swarm optimization (PSO)
4.	2017	Phunga et al. [13]	Particle swarm optimization (PSO)
5.	2019	Mirjalili et al. [14]	Ant colony optimization (ACO)
6.	2017	Chen et al. [15]	Ant colony optimization (ACO)
7.	2017	Pan et al. [16]	Artificial bee colony optimization (ABCO)
8.	2018	Liu et al. [7]	Artificial bee colony optimization (ABCO)

checking whether the solution is valid or not. Ghamry et al. with the help of PSO coined a forest fire fighting application by using multi-UAV [12]. The major challenge in firefighting mission was to carry out tasks with higher efficiency and efficiently minimize amount of time. In the similar manner, Phunga et al. enhanced more by considering vision-based surface [13]. The algorithm assumes the fire spots are pre-detect and by considering input constraints while surpassing UAV collisions during motion. Mirjalili et al. with the help of ant colony optimization (ACO) designed the trajectory planning for AUV [14]. It also included that the algorithm may all achieve the optimal path for UAV when the obstacle number is increased gradually from one number to many numbers. Similarly, Chen et al. considered path planning by avoiding the obstacles in path planning [15]. Pan et al. optimized the route planning of UAV by using artificial bee colony (ABCO) and also focused on saving memory [16]. Liu et al. also enhanced his approach by using ABCO by making the application of evacuation of crowd in buildings [7].

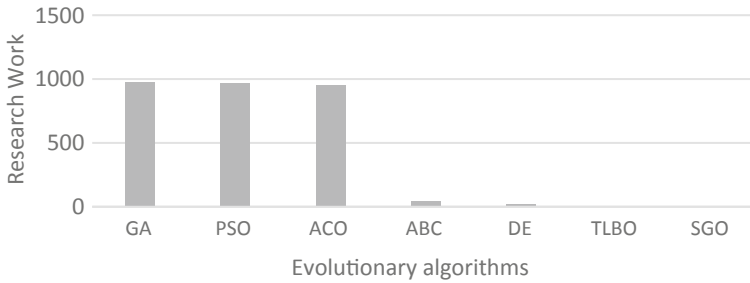


Fig. 3 Graph showing approximate number of research work based on some of the evolutionary algorithms

3 Conclusion and Future Work

There have been various approaches to find an optimal path while planning a trajectory, but solving it by using evolutionary algorithms makes the process simple and efficient. Evolutionary algorithms are easy to implement, simple, and time-efficient. Hence, they can be applied for real-time trajectory planning. There are several optimization algorithms which have not been used for trajectory planning till date. Figure 3 represents an approximate number of research works using some of the evolutionary algorithms taken from Google Scholar database (<https://scholar.google.com/>). Hence, application of other algorithms to this problem may serve as an emerging area of research.

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