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Research Article

The shortest path detection for unmanned aerial vehicles via genetic algorithm on aerial imaging of agricultural lands

Abdülkadir Gümüşçü [a,*], Mehmet Emin Tenekeci [b] and Ahmet Tabanlıoğlu [a]

[a]*Harran University, Electrical and Electronics Engineering Department, Şanlıurfa, Turkey*
[b]*Harran University, Computer Engineering Department, Şanlıurfa, Turkey*

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ABSTRACT

By using unmanned aerial vehicles (UAV) for improving fertility of large agricultural lands in the GAP region, it is aimed to guide the end users through processing of the aerial images obtained by using image processing algorithms. The productivity problem of "Agriculture" sector that has the most important role in the economic development of the region directly has been solved in an innovative way by improving the fertility of agricultural lands. Related to the UAVs used for this process, the most important problem to consider is limited battery life. Therefore, it is very important to calculate the optimum route to reduce the flight time and to scan the large agricultural lands in the shortest time. In this paper, the shortest path problem is optimized by using the genetic algorithm for scanning large agricultural lands and collecting data. In the study, the points taken by UAV according to the field of view of the images are determined. The shortest path has been calculated by using genetic algorithm so that images can be taken from these determined points within a minimum flight time.

1. Introduction

Recently, agriculture and food have become very important concepts [1]. In terms of agricultural productivity, many different technologies have begun to be used in agricultural areas [2, 3]. One of these technologies is unmanned aerial vehicle (UAV) [4, 5]. The monitoring of agricultural lands for a certain period of time is important especially in early disease detection and yield estimation. Monitoring the productivity of large agricultural areas in the GAP Region is not effective enough if it is conducted by monitoring techniques done in the ground. Also, this situation causes the problem of wasting time. Unmanned aerial vehicles are widely used today in aerial photography and imaging. Recently, it has been also begun to be used in industrial problems. UAVs are used to collect data by integrated cameras and sensors [6, 7]. Many applications such as monitoring and spraying of the agricultural lands can be achieved more easily and effectively with the widespread use of unmanned aerial vehicles. Analysis of the images of agricultural lands taken at a certain altitude by using image processing algorithms will increase the productivity and quality. Despite all these advantages, unmanned aerial vehicles need energy provided by Lithium Polymer (Li-Po) batteries. It can be said that the 4-engine unmanned aerial vehicle with a limited energy source does not have a very long flight time. Regarding the fact that the flight time of a quadcopter is estimated as 20 minutes on average, it is unlikely to be able to take images of a large agricultural land. Thus, scanning the entire agricultural area between the coordinates digitally marked within the limited time, and collecting data with sensors and cameras have become a purpose. Scanning of the maximum agricultural land with a limited energy source can actually be considered as an optimization problem.

In this study, the flight route was optimized by using genetic algorithm and the scanned maximum area with minimum flight time was provided. For this purpose, a designated agricultural land was considered. On this agricultural land, some stop points for the unmanned

* Corresponding author. Tel.: *+90 414 318 3000-1041*.
E-mail addresses: *agumuscu@harran.edu.tr (A. Gümüşçü), etenekeci@harran.edu.tr (M.E. Tenekeci), atabanlioglu@harran.edu.tr (A. Tabanlıoğlu).*

aerial vehicle to image all of the agricultural land had been identified. After this process, when the unmanned aerial vehicle arrived at all designated stops, it would be assumed that all agricultural land had been scanned. The genetic algorithm would decide the order in which the unmanned aerial vehicle would arrive at the determined point. The fitness function of the genetic algorithm would be the length of the flight path.

The rest of the paper is organized as follows. In the 2nd section, previous studies related to subject has been summarized. In the section 3, all the algorithms used are summarized. In the 4th section, the results obtained by the proposed method are presented and the performance of the study is evaluated by examining the results.

2. Related Works

Studies for real-time road extraction of UAVs have been investigated with realistic simulations in the 3D plane [6]. In that paper, workload and affection are taken as a strong parameter and 2D plane simulation is preferred. Many studies in the literature aimed to make the energy suitable for collecting data using the most efficient level of energy.

In this context, during the more data collection process by using multiple UAVs, this problem becomes more important [7] [8]. The fact that this problem is real-time is also important because it will save time in order to be able to make online tactical plan for UAVs [9]. Regarding their ability to bring tactics to the UAVs, five different heuristic algorithms were compared. These algorithms were Search algorithm, the Dijkstra algorithm, the Bellman Ford algorithm, the Floyd-Warshall algorithm, and the Primer algorithm. As a result, the Dijkstra algorithm was found to be the fastest [10]. For the problem of finding the shortest path, there are a genetic algorithm and a search algorithm that working well for heuristic algorithms used optimally for this problem [9] [11-15].

Unlike the studies in the literature, in this study, it was assumed that the height of the unmanned aerial vehicle was constant and this problem was considered as the traveling salesman problem.

3. Material and Methods

3.1 Genetic Algorithm

The Genetic Algorithm, developed by John Holland in 1975, is a search and optimization method based on natural selection principles. Genetic algorithms are considered as effective search techniques in many areas. [16] Genetic algorithms are based on the initial populations, and they create new populations by using methods such as crossover and mutation in those populations [17]. Steps of the Genetic Algorithm process are shown in Fig.1.

As shown in Fig.1, firstly, a population is generated. Then the fitness function is calculated. If the value of the fitness function is the desired value, the loop is terminated. If the fitness function does not reach the desired value, the selection, crossover and mutation procedures are applied, and the fitness function for the obtained new population is recalculated. This cycle is repeated until the desired fitness value is reached.

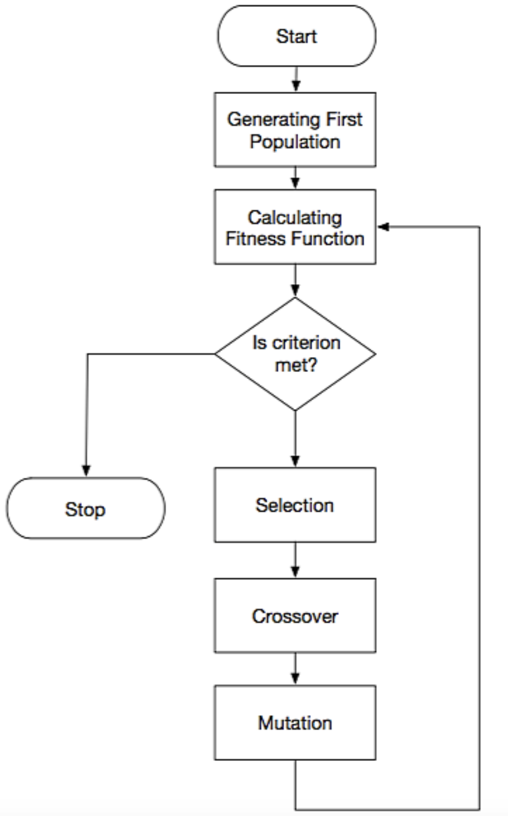


Figure 1. Genetic Algorithm Flow Chart

In this study, the genetic algorithm was used to determine the order in which the unmanned aerial vehicle was supposed to stop at the determined stop points for the shortest flight route.

$$Fitness\ Function = Flight\ distance(route) \quad (1)$$

$$Flight\ distance = \sum_{i=1}^{P}\sum_{j=1}^{P} x_{ij} \quad (2)$$

The fitness function shown in Equation (1) gives the shortest route that arrives to all stop points determined in the agricultural land. Equation (2) calculates the total route distance for the fitness function. The p value in the Equation (2) refers to the number of stop points.

3.2 Travelling Salesman Problem

It is a problem that is explored in the field of operations research and theoretical computer science. It is assumed that a travelling salesman has to go through *n* different towns. In this case, the travelling salesman should take its route in the shortest way, and every city must be visited once. As such, the problem addressed in this study was evaluated and interpreted in this way.

3.3 Unmanned Aerial Vehicles

Unmanned aerial vehicles are used to collect data with integrated cameras and sensors [6, 7]. As shown in Figure 2, an angle has been given to the camera by the anti-shake gimbal mechanism.

Figure 2. DJI Phantom 2 Vision

In this study, it was assumed that the unmanned aerial vehicle flew at a fixed height of 40 meters. In this case, it was also assumed that in the agricultural land, a circular area with radius of 50 meters was scanned.

3.4 Shortest Path Detection for UAVs via Genetic Algorithm on Aerial Imaging of Agricultural Lands

The workflow of the proposed method is shown in Figure 3.

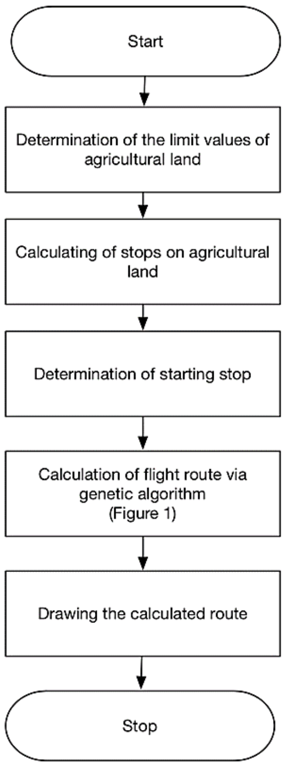


Figure 3. Proposed Method

As shown in Figure 3, in the proposed method, the boundaries of the agricultural land are primarily determined by the user. According to the determined land, the places where the unmanned aerial vehicles will stop are calculated and the starting point is selected. Then, the travelling salesman problem is set up to stop at the designated stop points once. The genetic algorithm optimizes the travelling salesman problem and provides scanning of the entire agricultural land with less flight route length. Thus, the limited battery should be used very efficiently.

In this study, the agricultural lands required to be scanned by the unmanned aerial vehicle was determined as shown in Figure 4.

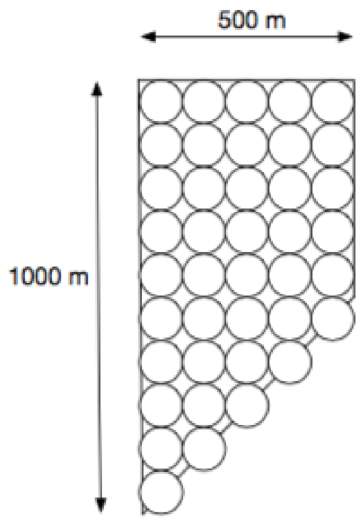


Figure 4. Agricultural Land

As seen in Figure 4, 40 stop points were identified. Therefore, it was necessary to calculate the distances between the stop points, and to determine a flight route between those points by the genetic algorithm. The genetic algorithm was applied respectively with 20, 40, 60 population sizes, and the results were compared.

The results were calculated by a computer having an Intel Core i7 processor with a frequency of 2.8 GHz, 8 GB RAM. Matlab 2016b software was also used for calculations.

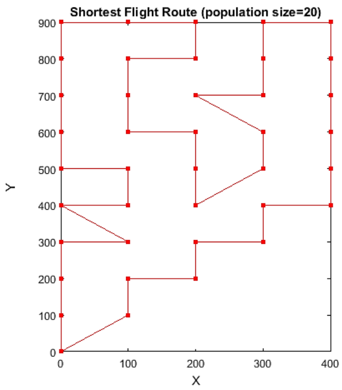
4. Results and Discussion

In this study, the shortest flight route of unmanned aerial vehicles was optimized via genetic algorithm. The population size parameter of the genetic algorithm was given as 3 different values (20, 40, 60) and the results were obtained. In addition to this, in case of no optimization, the length of the flight as a result of stopping at the stop points sequentially was also calculated.

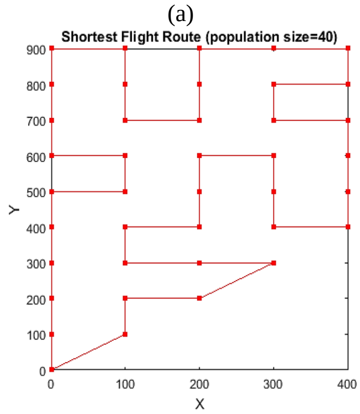
Table 1. Obtained Results

Population Size	Number of Iteration	Shortest Flight Route Length
No Optimization		4482,84
20	2132	4165,68
40	827	4082,84
60	3604	4082,84

Table 1 shows the results obtained from different population sizes. It is seen that the shortest flight route having more population size is optimized better.



(a)



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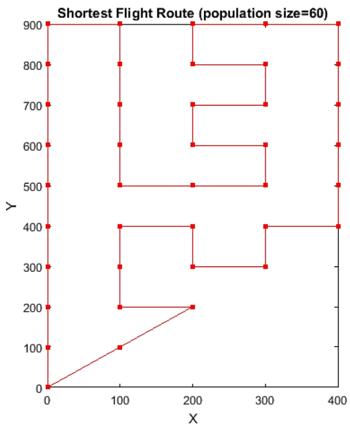
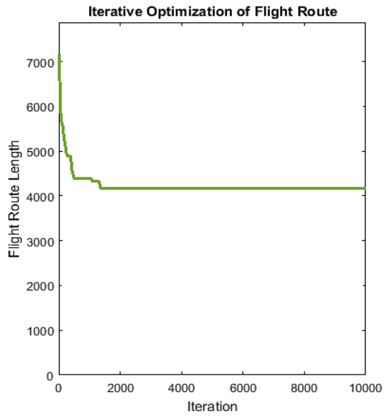


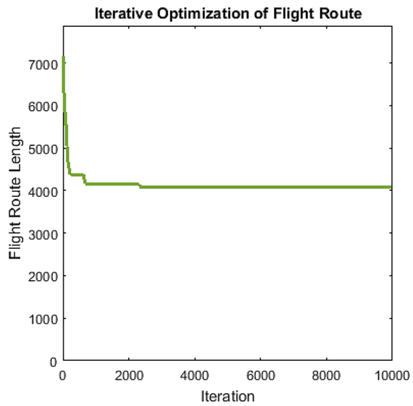
(c)

Figure 5. Shortest Flight Routes for Determined Agricultural Land

Figure 5a, 5b, 5c shows the shortest path found via genetic algorithm respectively when the number of populations of 20, 40, and 60 were selected.



(a)



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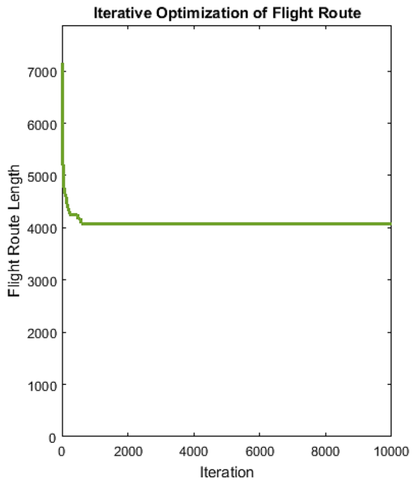

(c)

Figure 6. Optimization of Flight Route (population size=20,40,60)

Figure 6a, 6b, 6c shows the total flight length calculated in iterations respectively when the population size of 20, 40, and 60 were selected.

Examining the results of this study, it is seen that the calculated flight length was not suitable when there was no optimization. The flight route length was reduced when optimization was done by genetic algorithm. As seen in genetic algorithm results, the fastest and best result was obtained when population of 40 was selected.

This study shows that same agriculture land can be scanned with a shorter flight length by determining the route of the unmanned aerial vehicles via the genetic algorithm. As seen in Figure 6, the scanning process, initially provided at about 7000 meters, was optimized by the genetic algorithm and reduced to 4082.84 meters. Regarding the results of this study, it can be said that with this kind of optimization in flight route, limited batteries, which are already the biggest disadvantage of unmanned aerial vehicles, will be much more efficient.

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