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Comparison between the two methods of optimization: Genetic algorithm (GA) and ant colony algorithm (ACO) for the propulsion system of UAV

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ABSTRACT

A propeller generates lift in the direction of revolution, similar to a revolving wing. Many previous propeller optimization techniques exist; nevertheless, they often find the optimal thrust coefficient at a constant power coefficient and vice versa. Using two types of algorithms, the genetic algorithm (GA), and the ant colony algorithm (ACO), and comparing with each other, this study will discover the optimal value of the thrust coefficient and the power coefficient combined to obtain the optimum value of the thrust and the lowest value of the power at the same time. A Simple Blade Element Theory Blade served as the foundation for all assumptions. This article examined over 80 various designs, brands, and types of propellers in a 2-blade configuration with diameters ranging from 2.5 to 19 inches and varying pitch values. The data for the baseline propeller was obtained from the UIUC Propeller Database. The inputs for the optimization are the propeller type, diameter, pitch angle, rotational speed, thrust coefficient, and power coefficient. The results show that by determining the factor of interest in the thrust coefficient (FITC), the algorithm can find the optimal propeller specifications. When the (FITC) is 100%, the algorithm will ignore the effect of the power coefficient and vice versa. In the instance (FITC) is 100 percent, the genetic algorithm performed much better than the ant colony algorithm (ACO). But the Ant colony algorithm is more accurate than the genetic algorithm.

1. Introduction

Unmanned aerial vehicles (UAVs) are aircraft that don't have a pilot on board. UAVs were originally created for military usage, but they are currently utilized in a variety of civilian applications such as policing, cinematography, and shipping. A tilt-rotor or multi-rotor provides the power source for UAVs. Multi-rotor UAVs, for example, can take off and land vertically and are easy to maneuver in tight spaces[1]. The propulsion system is the most significant component of a UAV since it consumes around 90% of the electricity. In order to achieve a long flight period, a UAV's propulsion system must be efficient and adequate for the vehicle's mass[2]. Therefore, choosing the type of propeller in the drone is very important in order to generate the required thrust with the least torque. The study on multi-rotor UAVs was undertaken based on rising usage in a

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variety of methods [3] investigated a method for optimizing the geometry of a helicopter's rotor blades for hover flight aerodynamics. A unique geometry representation approach based on the class function/shape function transformation (CST) is employed to construct airfoil coordinates. This approach considers the shape of the airfoil while determining design factors. Many of the author's programs are combined to form his optimization approach. Twist, taper ratio, point of taper commencement, blade root chord, and airfoil distribution function coefficients are some of the design variables. [4] presented a strategy for optimizing the design of multicopper (UAVs). In reality, datasheets for various components such as the battery pack, motor, and propellers are available to the designer. The designer is usually limited to choosing components from published datasheets and cannot freely create the actuator system's properties. The research demonstrates that mixed-integer programming is well suited to multicopper UAV design optimization and that the modeling assumptions closely match the experimental validation. [1] Studied a genetic algorithm was employed in conjunction with computational fluid dynamics to improve the aerodynamic design of UAV rotor blades (CFD). There are many researchers used to find the optimal value for the thrust coefficient, but with the power coefficient constant and vice versa. In our current work, an algorithm was created to find the optimal thrust coefficient and power coefficient at the same time. To reduce the computational cost of determining the ideal value using a genetic algorithm, a function approximation using artificial neural networks (ANN) based on a radial basis function was applied. In this study, a comparison will be made between two types of optimization Genetic Algorithm and Ant Colony Algorithm for several small-scale propellers to find the optimum thrust factor value and the optimum power factor value at the same time

2. Optimization methods

several computer scientists independently investigated evolving systems in the 1950s and 1960s with the hope of using evolution as an optimization technique for engineering challenges. All of these systems were designed to create a population of potential solutions to a given issue utilizing genetic algorithm operators influenced by natural genetic diversity and natural selection [5]. This method was used by modeling it using the MATLAB program to find the optimal properties for any required propeller. Another method was used to find the optimum of these properties, which is Ant Colony Optimization. Marco Dorigo devised ant colony optimization in his Ph.D. thesis in the 1990s. An ant's foraging activities when looking for a method to travel from their colony to a food source inspired this algorithm. Ants are colony-dwelling social insects. Colonies are what they call home. The ants' behavior is influenced by their drive to find food, which is their major goal. Ants forage for food across their colony. An ant hops from one area to the next in search of food. It produces a pheromone-like chemical compound on the ground as it passes. Pheromone trails are used by ants to communicate with one another. When an ant encounters food, it transports as much as it can[6]. A Simple Blade Element Theory Blade served as the foundation for all assumptions. This article examined over 80 different designs of propellers in 2-blade configurations with diameters ranging from 2.5 to 19 inches and varying pitch values. The propellers were gathered from the UIUC Propeller Data Site and the Unmanned Aerial Vehicle Database. Each propeller has numerous properties, including style, diameter, and pitch angle, with the thrust coefficient and power coefficient changing with the propeller rotation speed. The results of [7], [8], and [9] will all be used as essential inputs in the optimization process. The inputs for the optimization include propeller style, pitch angle, rotational speed, diameter, thrust coefficient, and power coefficient. When the rotational speed varies, each of these variables has a large number of thrust and power coefficients that vary.

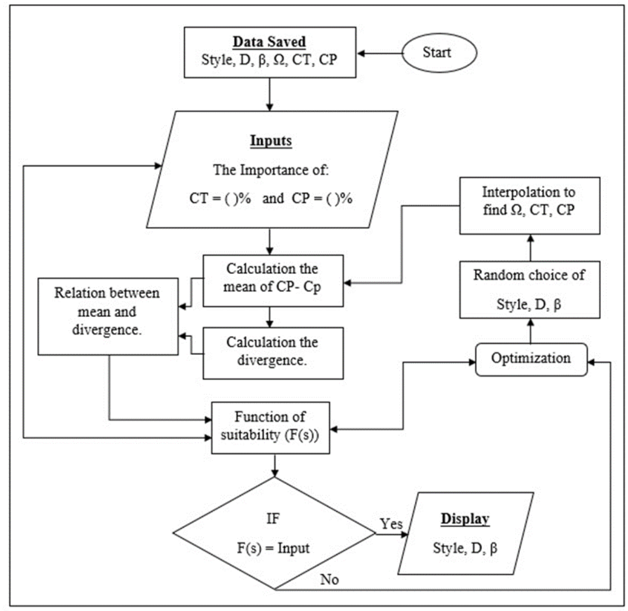

Figure 1. Flowchart for Propeller Optimization Process.

2.1. Steps to build optimization using MATLAB Software

I. Using the six criteria as inputs, create a function that analyzes the acceptability of any propeller that enters the program (propeller style, diameter, pitch angle, rotational speed, thrust coefficient, and power coefficient).
II. Calculate the mean of the thrust coefficient and a power coefficient to create an equation for the divergence. Then look for a link between the mean and the deviation.
III. Choosing the best data interpolation method to evaluate a fictional propeller that the optimization would offer later.
IV. Select random values for the three propeller variables for the function (propeller style, diameter, and pitch angle). There are two options for the initial stage, which is to search:
V. If the data includes a random selection, suitability will be established in the first stage.
VI. If the input data does not contain a random selection, the third step will be utilized to interpolate, and the suitability will be determined using the first step.

Based on the preceding phases, the results of the optimization process will be (propeller style, diameter, and pitch angle). A flow diagram of the technique is shown in Figure 1. The equation for the Objective Function is:

$$\boldsymbol{O.F_{min} = GC_Q + \frac{(1-G)}{C_T}} \tag{1}$$

Where:
$O.F_{min}$= Objective Function minimum.
G = gain.
C_Q = power coefficient.
C_T = thrust coefficient.

The user may define limitations for the propeller diameter and advance angle in the MATLAB method, as well as determine the level of interest in the value of the thrust coefficient at the expense of the power coefficient as a percentage.

3. Result and discussion

The method can calculate the optimal propeller specifications by defining the factor of interest in the thrust coefficient and the power coefficient. When the thrust coefficient's factor of interest is 100 percent, the algorithm ignores the influence of the power factor, focusing instead on finding the greatest value of the thrust factor regardless of the power factor's value, and vice versa. The algorithm will determine the optimal value of the thrust coefficient and the optimal value of the power coefficient at the same time if the factor of interest is 50%, and it is not necessary that the value of the thrust coefficient be the maximal value. As a result, the thrust factor's proportion of interest has an impact on the thrust factor's proportion of interest. An illustrative example will be taken to illustrate the results of the optimization work.

An illustrative example of PROPDRIVE v2 4248 650KV is the brushless electric motor, its designed to work on a group of propellers of multiple diameters and pitch angles, as it works on propellers with a diameter of 12 to 14 inches and pitch angles from 6 to 8 degrees. It is not possible to predict which propeller are used to be optimal. The values of the parameters of the diameters and pitch angles for this motor will be entered with the genetic and Ant Colony algorithms, and the optimum values for the propeller used in this motor will be found. Table 1 below shows the results obtained from the algorithms genetic and Ant Colony.

For verification and validation of the results, all the results obtained from the algorithm are used in the same algorithm in reference [10]. As noted in Tables 1 and 2 above that when the factor of interest in the thrust coefficient (FITC) is 100%, the genetic algorithm will choose the diameter of the propeller to be 12 inches and at an angle of 7.83 degrees for the APC Free flight type to choose the maximum value for the thrust coefficient as well as for the ant colony algorithm the same diameter but greater angle was chosen for the type of GWS fan Direct drive. Although the ACO chose a larger angle, the value of the resulting thrust coefficient was smaller than the thrust coefficient value calculated by the GA, and the power coefficient is equal in both algorithms. So, we can say that the results of the GA were better by selection in this case. When the FITC was 75%, GA chose a larger diameter with a lower angle than ACO, and the result was that the thrust coefficient and power coefficient were smaller than the results obtained in ACO.

Table 1. Genetic Algorithm result.

Factor of interest in the thrust coefficient (FITC)	Standard (Brand)	Diameter (inch)	Pitch angle (degree)	Optimal Mean TH. Coeff.	Optimal Mean Power Coeff.	Standard (Brand)
100%	APC Free flight	12	7.83	0.1277	0.0607	100%
75%	Graupner CAM slim	12.14	7.15	0.1039	0.0414	75%
50%	Graupner CAM slim	12	6.88	0.1042	0.0417	50%
25%	Graupner CAM slim	12.19	7.23	0.1038	0.0413	25%
0%	Graupner CAM slim	12.24	7.33	0.1037	0.0412	0%

When choosing the FITC 50%, GA chose a propeller with a smaller diameter and angle than that chosen in ACO, but the results obtained from the two algorithms were almost close. Also note that the two algorithms chose the same type of propeller.

Table 2. Ant Colony Algorithm result.

The factor of interest in the thrust coefficient (FITC)	Standard (Brand)	Diameter (inch)	Pitch angle (degree)	Optimal Mean TH. Coeff.	Optimal Mean Power Coeff.	Standard (Brand)
100%	GWS Direct drive	12	8	0.1254	0.0606	100%
75%	Graupner Super nylon	12	7.92	0.1158	0.0504	75%
50%	Graupner CAM slim	12.50	7.66	0.1036	0.0409	50%
25%	Graupner CAM slim	12.03	6.94	0.1041	0.0416	25%
0%	Graupner CAM slim	12.04	6.967	0.1041	0.0416	0%

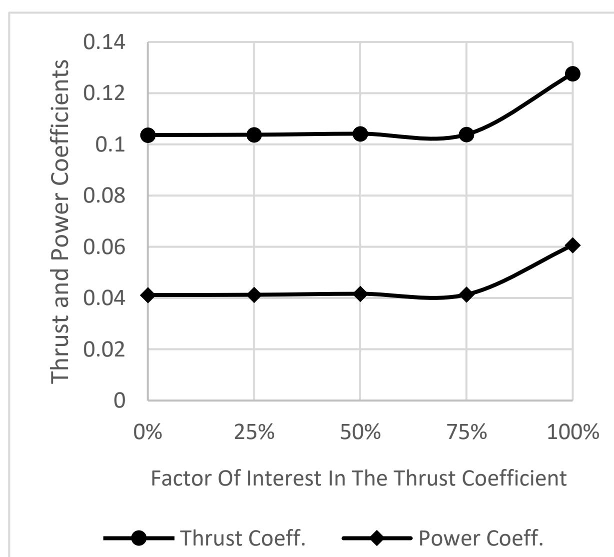

Figure 2. FITC vs (Thrust Coeff.) and (Power Coeff.) for Genetic algorithm.

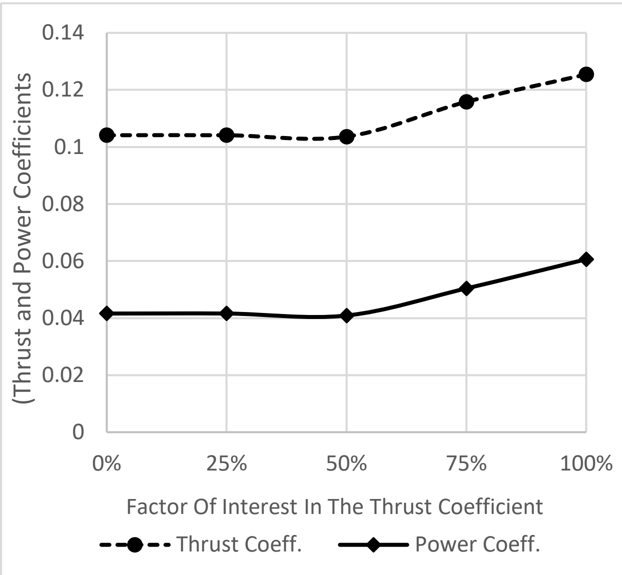

Figure 3. FITC vs (Thrust Coeff.) and (Power Coeff.) for Ant Colony Algorithm.

Choosing the FITC 25% shows the opposite of what happened in the FITC 50%, as GA chose a fan with a larger diameter and angle than the one chosen in ACO, but the results obtained from the two algorithms were almost similar as well. Finally, choosing the FITC 0% shows the same what happened in the FITC 25%, as GA chose a fan with a diameter and angle greater than that chosen in ACO, and the results obtained were also close.

Figure 3, which shows finding the optimum power and thrust coefficients when changing the factor of interest FITC for the Ant Colony algorithm, also notes that the best value for the thrust coefficient is at the expense of the power factor when FITC is 50%, but with an increase FITC The values of power coefficient and thrust coefficient will increase more than the increase shown by the genetic algorithm, so the Ant colony algorithm is more accurate than the genetic algorithm.

4. Conclusions

The algorithms ensure that the thrust coefficient increases as the propeller length increases and the pitch angle increase as the FITC increases, and vice versa. The algorithm is looking for an optimum increase in the momentum coefficient's value and an optimum low rate in the power coefficient's value. In the instance of FITC 100 percent, the genetic algorithm performed much better than the ant colony algorithm. When FITC is 50%, the best value for the thrust coefficient is at the expense of the power factor, but as FITC increases, the values of the power coefficient and thrust coefficient will increase more rapidly than the increase shown by the genetic algorithm, indicating that the Ant colony algorithm is more accurate than the genetic algorithm.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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