Polygamy Based Genetic Algorithm for Unmanned Aerial Vehicle (UAV) Power Optimization: A proposal

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Abstract— **One of the challenges in the operation of Unmanned Aerial Vehicle (UAV) is power optimization under different operation mode. In solving the aforementioned problem, polygamy based selection Genetic Algorithm technique has been proposed in this work. The proposed technique involves parameter initialization, problem coding and optimization. The power requirement is coded as a bit of strings subject to power limit constraint. The initial solutions are evaluated based on the UAV power system objective function. The evaluated solutions are clustered into two different classes using K-Means algorithm. Chromosomes in the cluster with minimal centroid are then made to undergo polygamy mating subject to population control mechanism. Resulting solution were then mutated and the whole process continue till number of generation is reached or other termination criteria met. Application of the proposed technique shows that the average efficiency of UAV can be improved using the proposed algorithm.**

Keywords- Genetic Algorithm, K-Means Algorithm, Power Optimization, Unmanned Aerial Vehicle

I. INTRODUCTION

An Unmanned Aerial Vehicle (UAV) is an autonomous aircraft without human pilot on board and is sometimes called drone. The autonomous flight can be remotely control by a pilot on ground or in another vehicle [1]. The UAV is of significant use in various applications especially where it is extremely dangerous or difficult for human intervention [2]. The various areas of application of UAVs include: scientific research [3-4]; forest fire detection [5-6]; search and rescue operation [7-8]; mineral exploration and production [9]; domestic policing; commercial aerial surveillance [10]; remote sensing [11]; oil and gas exploration and armed attacks prevention [9].

The performance of UAV can be measured using three main features namely the range, endurance and payload. These three essential attribute of the UAV depends greatly on power, weight and efficiency.

In achieving optimal design and utilization of UAVs, there is need for optimization of power consumption by employing a hybrid Genetic Algorithm (GA) and K-Means algorithm approach. The GA is a universal search stochastic technique that has been widely reported to be of importance used in tackling various problems in different field of human endeavour [12-15]. GA is a robust large search space algorithm capable of searching through complex large space quickly and locating solution areas [16- 19]. GA has the strength of individual population consideration with each population representing a solution to the problem [18]. Also, the utilization of GA algorithm does not require much mathematical analysis but sometime may require longer time to converge.

K-means algorithm on the other hand is a clustering algorithm that is usually employed for classification, grouping or segmentation [20-23]. The algorithm classify or group data into K-clusters or groups, it utilizes an iterative method that minimizes the sum of distances from every object to its cluster centred. The algorithm works based on the principle of moving objects between clusters until the sum can no longer be reduced further [20].The K-means algorithm has the advantage of fast convergence, simplicity and its capability in effectively handling large datasets which prompt is usage in wide areas of applications [21-23].

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The rest of the paper is structures as follows: A review of various UAV power systems is presented in section II, the proposed methodology is presented in section III while section IV presents results analysis and discussion and the paper is concluded in section V.

II. DESCRIPTION OF UAV SYSTEMS

A concise review of power systems in a typical UAV with emphasis on various systems and subsystems that require electrical power for its operation is presented in this section. The subsystems are classified base on the main system. Usually, the payload system is made up of optical camera and synthetic aperture radar (SAR) camera as subsystems. All systems and subsystems are controlled by the control system which helps in managing, directing and commanding the activities of all other systems [1].This includes all systems contributing to the aircraft stability and controls such as navigation, servo-actuators, avionics, on-board software, air data system, control surfaces/servos, and other related subsystems.

The on-board computer system is used in collecting essential in-flight data which includes the states of the UAV; servo actuator deflection, sonar-measured altitude, main rotor's RPM (rotations per minute), on-board images; analysing data and images collecting and implementing flight control laws as well as logging data to the storage device. The on-board Computer system is made up of subsystems that include the Real-Time Module (RTM) Subsystem and the System Monitor Module (SMM) Subsystem [24].

The servomotor Subsystem and the propeller/ rotor subsystem are part of the propulsion system component [2]. The number of servomotor UAV depends on kind of design employed for the propulsion system. The main components of a servomotor are brushless electric motor which perform a dual role as a turbine, Gearbox, motor-generator controller (PI controller), Potentiometer and analogue to digital converter (ADC) [24].

The main rotor of the UAV provides horizontal force, vertical lift, and anti-torque [24-25]. Also, it produces the rotor stiffness (rolling and pitching moments) by flapping. The vertical motion of the UAV is a function of its weight and the lift force generated by the main rotor blades. If the lift force is greater than the weight, the UAV accelerates upwards (climb) but if it is less than the weight, the UAV accelerates downwards (descent). If the weight and the lift force generated by the main rotor blades are equal the UAV remains at a constant altitude (hover) [21].

The Descending mode is the pre-landing mode when the auto-pilot brings down the UAV to the required altitude for landing. For this to happen, the UAVs altitude-and-attitude controller causes the main rotor blades to generate a corresponding lift force less than the weight of the UAV.The Touch-Down Mode concludes the flight mission of the UAV with a successful touch-down on the ground. This Touch-down could be autonomous or remotely piloted.

III. METHODOLOGY

This section provides a concise and precise explanation on the proposed Polygamy based GA technique for UAV power optimization. The flow chart of the proposed technique is shown in Figure 1.

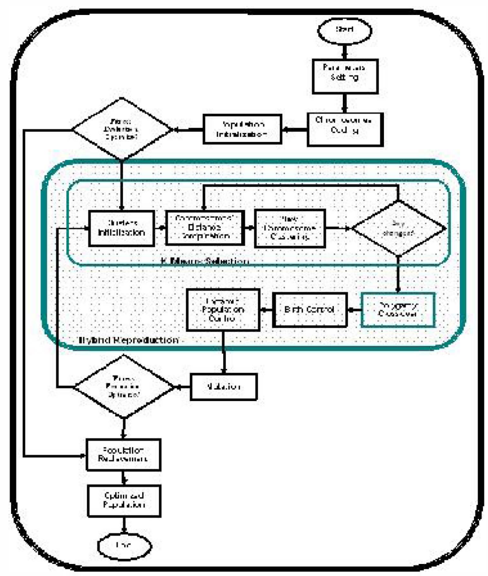

Figure 1: Flow Chart of the Proposed Polygamy based GA technique for UAV Power Optimization

1) Initialize: The initial population of candidate solutions was created arbitrarily across the solution domain. The initial population size (N); Mutation rate (α) and number of generations (n) were also initialized at this stage.
2) Fitness function evaluation: Evaluation of the fitness of the initial population involves computation governed by the objective function subject to available constraints. In this work, the objective function is derived as follows.

Let x_i be a variable that describes the amount of power consumed by a system/subsystem in a particular operation mode. Detail descriptions of the modes have been presented in section II. e.g Control = x_1 Payload = x_2 Propulsion = x_3 Telemetry = x_4.

Similarly, let a_i be the state determining coefficients for each system or subsystems, thus the state determining coefficients are Control = a_1 Payload = a_2 Propulsion = a_3 Telemetry = a_4. The state coefficients a_i can either be "ON" with binary value of 1 or "OFF" with binary value of 0.

The power consumed by each of the mode are also subjected to certain constrains, namely the lower bound and upper bound power consumption by the subsystem, hence, the objective function can be formulated as

$$f(x_i) = \sum_{k=1}^{N} a_i x_i \qquad (1)$$

Subject to $LF_i \leq x_i \leq UF_i$ where x_1, x_2, x_3... x_N are the power consumed by each subsystems and LF_i, UF_i are the lower and upper bound power consumed by each subsystem respectively a_i are binary state coefficient determining the state of each subsystems.

3) Reproduction Operations: A three stage polygamy approach involving K-Means operation, polygamy selection and population control process have been developed in this work. K-Means algorithm ensures selection of the fittest chromosomes for reproduction purposes since it is a method of vector quantization that is popular for cluster analysis and classification. It is introduced in order to partition the evaluated chromosomes into two clusters namely fitter and less fit clusters.
    - I Selection Using K-Means: Selection allots more copies of those solutions with superior fitness values thereby imposing the survival-of-the-fittest apparatus on the candidate solutions. In this work, Selection function of GA is replaced by the K-Means process.
    - II Polygamy Selection and Population Control Process: K-Means selections reduce the population size from N to $N1$ where $N >> N1$. This population reduction affects the likely chromosomes to be available for mating process in subsequent generation. In ensuring a sizeable number of chromosomes are available for mating and subsequent generation, a polygamy selection process for mating has been proposed.
    - III Population Control: In ensuring that the population per generation is contant, population control mechanism was introduced. This ensure that polygamy process does not arbitrarily increase the poplation thereby increasing the computation time. Population control of the offsprings have been achieved using child population control and irth rate control. These two schemes ensures control in the growth rate.
    - IV Crossover: This work adopts the two point crossover technique. In the two point crossover technique, two points are randomly selected as the cut-points and exchanges the right parts of two parents to generate offspring.
    - V Mutate: Mutation alters one or more genes with a probability equal to the mutation rate. As an example, when given a mutation rate $p_m = 0.02$, the expectation is that 2% of the genes in the population will mutate.
    - VI Replace: The original parental population is replaced by the created offspring population (solution).
    - VII Repeat: Reiterate steps 2–8 pending convergence or a predefined ending condition is met

IV. RPRELIMINARY RESULTS, OBSERVATIONS AND CONCLUSIONS

Performance analysis of the proposed algorithm is presently ongoing. Preliminary results shows that the without population control in the proposed algorithm, it usually takes longer time to converge in comparison with the introduction of population control variant. It was also observed that polygamy mating technique introduced usually lead to improve generation solution as compared to the use of Roulette wheel selection technique.

It was observed that the proposed technique work best on a very low initial population and increase this population by mimicking human natural population increase.

It has also been shown that the proposed technique is appropriate for UAV power optimization in which the power requirement for each system and subsystem are coded as chromosomes in the solution space. State subsystem and control mode are later optimized using the proposed technique subject to certain constraint.

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