Quadcopter Controller Design Using Bio-inspired Metaheuristic Search Algorithms

Requested Funding: $5000

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Tags: 3,

Summary:

Recently, Unmanned Aerial Vehicle (UAV) has been ever-increasing utilized in industrial, business and military applications. However, controlling the stability, position and trajectory control of a Quadcopter is a challenging task due to the limited inputs and complex dynamics of the Quadcopter. Traditional methods such as Ziegler-Nichols (ZN) for Quadcopter controller tuning do not provide optimal control and might leave the system with potential instability conditions and cause significant losses and damages to the system. In this research, we suggest the use of metaheuristics search algorithms to tune the Proportional-Integral-Derivative (PID) controller parameters to gain a highly reliable performance.

Workplan

Our research plan consists of the following steps:

a) Literature Review: The literature review will cover the past and current state-of-the-art literature in the Quadcopter control and various possible controlling techniques to stabilize, position, and the trajectory a Quadcopter such as the PID controller.

b) Mathematical Modeling: A mathematical model is necessary to simulate/monitor the movement of a Quadcopter in 3D space. The proposed control model will help demonstrate the behavior of the Quadcopter under various operating conditions in respect of various inputs to the model. The Quadcopter structure [13] adopted in this study is illustrated in Figure 1.

c) Overall System Structure: The goal of this phase is to gain a deeper understanding of the dynamics of the Quadcopter and present a model that can effectively simulate and control its behavior [14]. A possible block diagram of a Quadcopter model is shown in Figure 2.

d) Controller Design Using Bio-inspired Metaheuristic Algorithms: Broadly speaking, nature-inspired-algorithms have intelligence behavior based on the collective behavior of a group of social individuals with multiple collaborating agents that sake to optimize a given problem. Although these algorithms are made up of relatively modest individuals, they offer harmonious social behavior to guide their individuals to their intended goals-these algorithms outset by randomly creating a predetermined number of possible solutions. The candidate solutions are then updated at each iteration loop using a mechanism inspired by nature.

e) Proposed Multi-Objective Fitness Function: The adaptation of a fitness function for the metaheuristics search algorithm supports the optimization method to measure the quality of the solution of the problem under study and evaluate how well the solution of the problem is. The fitness function used by the metaheuristic algorithms presented in this work, namely GA, CSA, and PSO, to optimize the Quadcopter parameters is an integration of the weighted absolute error time and other three parameters identified as overshoot, rise time and settling time of the Quadcopter.

Significance:

Quadcopter control is still one of the important problems that must be addressed to this day. Originally, the quadcopter was equipped with software and sensors to control and estimate the direction of the Quadcopter. Due to its unstable dynamics and complex structure [1], the Quadcopter control problem is difficult to work out by conventional techniques. Recently, a broad range of research efforts has been directed towards providing superior control over the Quadcopter. This field has rapidly spread to a wide range of disciplines. Several methods of controlling were presented in the literature to control the movements of the quadcopter, both for regulation and tracking of trajectory. The primary goal of different control strategies is to allow the quadrotorâ€™s states to follow a reference path based on variable input data over time. Two types of controllers were presented in the past, 1) one based on linearizing the quadrotor dynamics around a particular operating point [2], especially in the case of hovering and 2) another way is by using non-linear

control techniques that were considered a more general form of dynamics that allows the quadrotor to operate in all flight zones. Within these nonlinear control techniques, there are many methods such as backstepping, sliding mode [3] and feedback linearization [4] which are very effective.

Driven by the impressive results of metaheuristic algorithms in solving a varied types of optimization and control engineering applications [5-7], we put forward here three metaheuristics, namely Genetic Algorithm (GA) [8], Crow Search Algorithm (CSA) [9-10] and Particle Swarm Optimization (PSO) [11-12], to implement such a real-control problem. The artificial intelligence community has long accepted these metaheuristic algorithms in terms of their basis in solving a broad range of real applications by arriving at optimal or precise solutions concerning a compact set of parameters such as time or cost.

The main question to be addressed in this research is how to control the movements of a sufficiently reliable Quadcopter. Minutely, this work takes the advantages of metaheuristics optimization algorithms to optimize the Quadcopter flight using a PID controller. Specifically, these metaheuristics will be used to control the position and orientation of a Quadcopter based on a proposed multi-objective fitness function to achieve such a stable control mechanism.

Outcome:

The originality and significance of the proposed work are related to (1) providing three different metaheuristic algorithms, GA, CSA, and PSO, to control the movements and directions of a Quadcopter to obtain high gain for the PID controller of a Quadcopter, (2) provide a comparison of these metaheuristic algorithms for the presented problem as a second contribution, (3) a third contribution is to evaluate the developed results together with the results of a conventional method using a set of related performance metrics, and, (4) a fourth contribution is the use of a statistical test method to rank the results of the above methods. Thus, the proposed research shall provide a reliable control strategy for a Quadcopter by tuning the PID controller parameters. We plan to submit the results of this project to an impact factor journal and conference in the field of agricultural and machine learning.

Budget

Budget Item	Cost	Justification
Faculty Stipend	0	Stipend for Alaa Sheta
Support Services	1920	Student Assistance
Supplies and Equipment	1080	Buy Parrot Minidrone and Matlab License
Travel	2000	Attend a conference to present research outcomes