

Energy Efficiency Optimization in UAVs: a review

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Abstract. In recent years, development of Unmanned Aerial Vehicles (UAV) has become a significant growing segment of the global aviation industry. The present paper provides an overview of the research conducted on the field of UAV energy efficiency optimization.

1. Introduction

Efficient energy utilisation on an UAV is essential to its functioning, often needed to achieve the operational goals of range, endurance and other specific mission requirements. The considerable amount of data produced by the UAVs requires high data rate connectivity such as that offered by free space optical (FSO) communication. When using FSO links some important issues need be considered in power consumption for pointing, acquisition and tracking (PAT) subsystem of the FSO. Due to the limitations of the space available and the mass budget on the UAV, it is often a delicate balance between the onboard energy available (i.e. fuel) and the achievement of the operational goals [1].

Two methods of achieving energy efficiency onboard the UAV are encountered in the relevant literature, namely:

- optimisation of mission waypoints
- utilisation of a Hybrid-Electric Propulsion System onboard the UAV.

2. Mission Waypoint Optimization

One of the challenges in the control of UAVs is to make them autonomous or semi-autonomous in order to relieve the operator from the constant monitoring. One such application is the area coverage, where the task is to find the minimal route that connects the defined set of waypoints. Both deterministic and non-deterministic methods have been applied for the solution of the trajectory optimization problem: Ant Colony Optimization [2], Mixed Integer Linear Programming [3] [4], Evolutionary Algorithms [5][6] as well as Neural Networks [7]. A methodology to generate optimal trajectories that utilize the vertical component of wind to enable flights that would otherwise be impossible given the performance constraints of the UAV, is also presented in [8].

3. Hybrid-Electric Propulsion System

Efficient energy utilisation on an UAV is essential to its functioning, often required to achieve the operational goals of range, endurance and other specific mission requirements. Due to the limitations of the space available and the mass budget on the UAV, there is often a need to compromise between the onboard energy available (i.e. fuel) and achieving the operational goals. One technology with potential in this area is the use of Hybrid-Electric Propulsion System (HEPS) [9]. Hybrid technology combines the advantages of two or more power sources to create a more efficient propulsion system for a vehicle. While many variants of hybrid systems are available today, most derive from three basic categories: series, parallel and power-split. While most systems utilize an internal combustion engine as the primary power source, others use fuel cells or turbine engines. Each system has unique advantages and disadvantages adaptable to the specific needs of a vehicle [10].

3.1 Series Configuration

In a series hybrid configuration, the primary propulsion source is an electric motor (EM). Typically, an internal combustion engine (ICE) drives a generator, which then provides power to the motor and an energy storage system. As the combustion engine is not mechanically linked to the driveshaft, it is able to operate at its optimum torque and speed range independent of power demand. Excess energy from the generator may be stored in a battery, capacitor or flywheel for high demand operation [10]. Large vehicles, like buses and locomotives, are the most common use for this type of configuration [11].

3.2 Parallel Configuration

The parallel HEPS configuration enables the powering of the UAV using the ICE alone, the EM alone, or a combination of both powerplants depending on the operating conditions. This results in the advantage of redundancy, which is important in both civilian and military applications [12].

3.3 Power-Split (Series-Parallel) Configuration

The power-split (or series-parallel) configuration lacks a driveline clutch, but uses a system of planetary (epicyclic) gears to transfer power from the combustion engine and the electric motor to the wheels. The engine delivers torque to the wheels for propulsion after splitting a portion to a generator for conversion to electricity. The electric power recombines with engine mechanical power at the planetary gear. Since the combustion engine power and speed are decoupled from the overall propulsive demand, the engine is able to run at or near optimal conditions [10].

3.4 HEPS control and power management

Various HEPS control systems are encountered in the relevant literature, based on Neural Networks [13] or Fuzzy Logic [14]. HEPS optimization is also performed in [15][16].

The use of alternative power sources such as solar or fuel cells is also investigated in [14][17]. In terms of HEPS power management, two types of power control logics are investigated: passive and active [17]. The passive power management simulation shows that the behaviour of each power source and its integrated system is adequate for the overall flight envelope. In addition, the active power management simulation demonstrates that active power management yields more efficient power distribution and better system safety than passive power management does.

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