Functional Size Measurement for Energy Needs early Estimation in Autonomous Drones

Hassan Soubra[1] and Toufik Azib[1]

[1] ESTACA, Montigny-le-Bretonneux 78180, France

hassan.soubra@estaca.fr

Abstract. A drone, or more formally known as an unmanned aerial vehicle (UAV), is a type of aircraft that is not designed to carry humans. Where in their early ver-sions, drones were often controlled remotely by a human operator; they have re-cently become fully or partially autonomous. Today, there is massive growth in the use of drones in a wide range of applications: military, aerial photography, search and rescue operations, in the field of agriculture, to name a few. The em-bedded software used in autonomous drones must perform in real-time, allowing the drone to interact with its environment. The Internet of drones (IoD) was born when drones were interconnected via a network allowing them to coordinate. Functional size measurement (FSM), a powerful tool for managing software pro-jects, provides an objective and quantitative base for management decisions. In this paper, we discuss work in progress on COSMIC functional size for estimat-ing energy consumption of drones as an illustration of the potential benefit of us-ing FSM in the context of IoD.

Keywords: COSMIC, Unmanned Aerial Vehicle, Internet of Drones (IoD), FSM, Energy consumption, Pixhawk Autopilot.

1 Introduction

A new era of UAV is emerging today: autonomous drones. These autonomous drones are no longer controlled by a human operator and they have a growing number of applications: in defense, transportation, photography, communication, agriculture, disaster mitigation and environment preservation [1]. Real-time embedded software (RTES) and embedded energy sources are what makes autonomous drones possible. RTES allows the drones to perform certain missions and coordinate in the context of IoD. Naturally, the capacity of the source of energy should be sufficient for the drone to operate a particular mission. Different types of missions have different power con-sumptions. Energy constraints are very important in the context of UAVs [2]. COSMIC Software functional size can be used for a number of purposes in domains where real-time embedded software is omnipresent [3]: to obtain system related technical indicators early in the design phase (e.g. processor load, network load, etc.). It can also be used to estimate development effort, manage project scope changes, measure productivity, benchmark and normalize quality and maintenance ratios. The COSMIC method is accepted as an International Standard: ISO/IEC 19761 Software Engineering – COSMIC – A functional size measurement method.

Among the many challenges facing autonomous drones today is energy consumption [4]. In fact, there are several types of energy sources that can be embedded in an autonomous drone.

This paper presents a work in progress on an estimation process, using COSMIC FSM, to predict energy consumption early in the project specification requirements phase.

The paper is organized as follows. Section 2 presents a literature review of energy consumption estimation. Section 3 presents an overview of COSMIC. Section 4 presents our work in progress including the experimental set-up. Section 5 presents our conclusions and a discussion of our work in progress.

2 Related Work on Energy Consumption Estimation

This section presents related work on methods or processes tackling energy estimation in the context of autonomous drones and the RTES domain generally.

In [5] an energy-aware path planning algorithm for UAV is proposed. The algorithm is based on an energy model derived from real measurements, and it is aimed to minimize energy consumption while satisfying coverage and resolution.

In [6] a study on flight mission planning of battery-operated autonomous drones, considering autonomous recharging is presented.

In [7], a review various aspects of work on Li-ion battery prognostics and health monitoring is presented. The study summarizes the techniques, algorithms and models used for state-of-charge (SOC) estimation, current/voltage estimation, capacity estimation and remaining-useful-life (RUL) prediction.

In [8] an electromotive force (EMF) model is proposed to estimate state of charge (SOC) of a power battery.

In [9] an architecture of a framework which enables secure end-to-end and reliable data transfer for heterogeneous mobile terminals by also describing and modeling its power demand, with the aim of achieving a robust and reliable ubiquitous data transfer service also minimizing the overall battery consumption in such devices has been proposed.

In [10] a research study evaluates complexity of proper security implementation in embedded devices possessing different constrains: limited memory, limited processing power and limited energy consumption. It has identified a relation between additional instructions processing against energy consumption.

In [11], energy and time related characteristics of widely used cryptographic algorithms for data-sensitive embedded real-time systems are analyzed. In addition, a multi-dimensional analysis framework that reveals power, speed, and unit energy cost of cryptographic algorithms is proposed.

The literature review shows no work proposed on energy consumption estimation early in the design phase.

3 COSMIC Overview

COSMIC [12] provides a standardized method for measuring the functional size of software from both Management Information Systems and real-time domains. COSMIC is considered a second-generation FSM and has been accepted as an International Standard (ISO/IEC 19761, Software Engineering – COSMIC – A functional size measurement method).

In COSMIC, a functional process is a set of data movements representing an elementary part of FUR for the software being measured. The set is unique within the FUR and is defined independently of any other functional process. A functional process may have only one triggering Entry. Each functional process begins processing on receipt of a data group moved by the triggering Entry data movement of the func-tional process. The set of all data movements of a functional process is the set need-ed to meet its FUR for all possible responses to the triggering Entry. According to COSMIC, software functionality is embedded within the functional flows of data groups. Data flows can be characterized by four distinct types of movement. Two types (Entries (E) and Exits X)) between the functional user FU and a COSMIC func-tional process allow the exchange of data with a functional user across a boundary. Two other types (Reads (R) and Writes (W) between a COSMIC functional process and the persistent storage allow exchange of data with the persistent storage hard-ware. The measurement result corresponds to the functional size of the FUR of the software measured, and is expressed in COSMIC Function Points (or CFP).

4 Work in Progress

4.1 Approach

To estimate energy consumption early in the design phase, our research is divided into five steps:

1. Hardware: Design and assemble an autonomous drone platform. The drone must be able to support different types of energy sources (e.g. batteries, supercapacitors, etc.).
2. Software: Create different mission profiles for the autonomous drone and implement them.
3. FSM: Measure the COSMIC functional size of each mission profile.
4. Energy needs: Observe the energy consumption for each mission profile and for each energy source.
5. Estimation: Use the measurement results in step 3 and 4 to build energy consumption estimation models for new mission profiles.

Fig.1 shows the steps of our work in progress. Today, only step 1 has been realized. Steps 2 to 5 are still in progress.

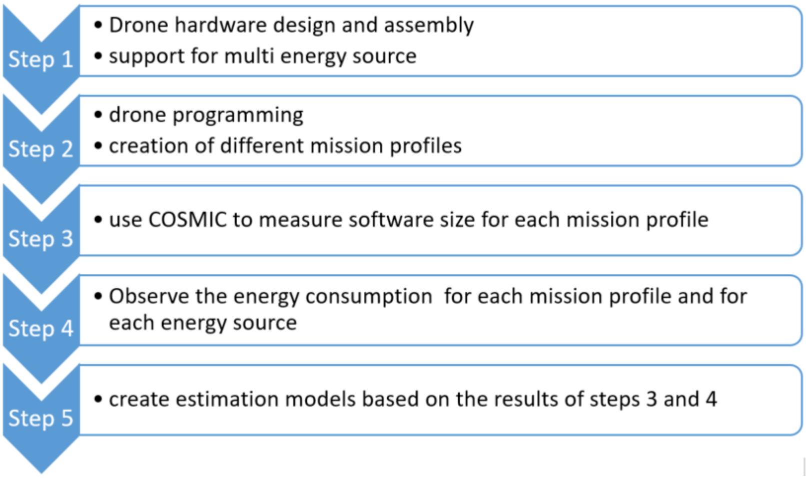

Fig. 1. Towards an energy consumption estimation model.

4.2 Experimental set-up

Step 1 of our research has been realized. An autonomous drone has been assembled at ESTACA (Fig.2) using the following modules:

- DJI F550 Flame Wheel E305 Kit ARF V2 + NAZA M-LITE GPS + Landing Legs: Chassis and GPS.
- Pixhawk PX4 2.4.6: autopilote module.
- Turnigy Graphene 2700mAh 4S 65C Lipo Pack w/ XT60U: energy source
- FrSky X8R 8/16CH Full Duplex: Telemetry (for safety reasons).

As shown in Fig.2, the drone is designed to support different energy sources. Fig.2 also shows the drone in the langing process.

The drone has been tested using a pilot mission programmed using QGroundControl [13]. QGroundControl provides flight control and vehicle setup for PX4 powered vehicles. QGroundControl enables mission planning for autonomous flight. QGroundControl will be used to define the mission profiles in step 2 of our methodology.

Fig. 2. The autonomous drone assembled at ESTACA. The drone in the landing process.

Fig. 3 shows the mission planned using QGroundControl. The mission that the drone has been tested with is as follows:

1. Takeoff.
2. Move forward 88 meters.
3. Land.

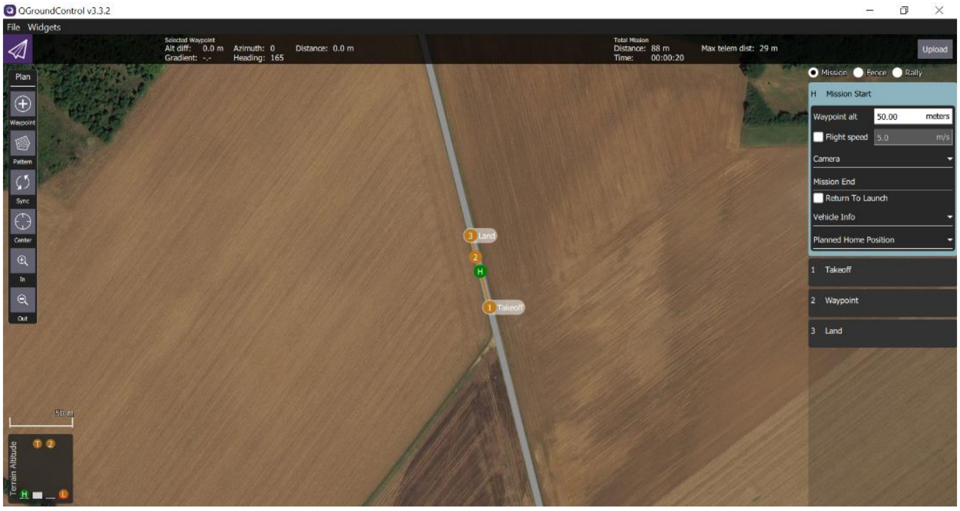

Fig. 3. The first mission plan of the autonomous drone.

5 Conclusion

Today, there is massive growth in the use of autonomous drones for different applications. Energy constraints are very important in the context of UAVs.

This paper described work in progress towards energy needs estimation early in the mission-planning phase for UAV or drones.

The steps of a method for estimation energy needs using FSM has been described. Then, a drone has been designed and assembled at ESTACA in order to verify the feasibility of the method proposed. We are currently continuing to work on defining new mission profiles for the drone, before starting both the FSM and the energy con-sumption measurement processes. Later we will map the results and create estimation models for power consumption for future missions.

Acknowledgements

This work would not be possible without the contribution of two ESTACA stu-dents: Nathan BAILET and Antoine CASABIANCA. We are grateful to them for designing, assembling and testing the drone.

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