Instrumentation of a Small Fixed Wing UAV for Research in Flight Mechanics and Control

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Introduction

Research in flight mechanics and control requires good mathematical models for the aircraft under study. In particular, for fixed wing aircraft is well documented in the literature the mathematical model based on the equations of motion that are stated assuming that the aircraft is a rigid body, but the heart of these equations that determine the actual dynamic behavior of the aircraft is the knowledge of a good model for propulsive and aerodynamic forces and moments [1]. There are approximate analytical methods to model propulsive and aerodynamic forces and moments but all those methods require validation and it is difficult to model all of the nonlinear behavior involved. It was recognized that to leverage the research if flight mechanics and control it is fundamental to get good mathematical models based on actual flight data. For that purpose many UAV test beds have been implemented. Some of them are reported in the literature, see for instance [2]. In this article the hardware selection and integration, and the software development for a test bed based on a small fixed wing UAV is presented.

Hardware selection

- Airframe
  - RC trainer with 1.655 m wing span, 1.33 m of length, 3.5 kg of weight.
- Power System
  - Lithium polymer battery 5000mAh 6S (22.2V).
  - 5V DC/DC converter.
  - 3.3V DC/DC converter.
- Propulsion System
  - Turnigy Aerodrive SK3 4250-350KV brushless outrunner motor.
  - Electronic speed control (ESC) Skywalker ESC (80A UBEC).
  - 15x6E APC propeller.
- Embedded Procesor
  - Raspberry PI 3 B based on single board computer with the Broadcom BCM2837, which includes a 1.2 GHz 64-bit quad core ARM Cortex A53 (ARM v8) processor.
  - Linux Raspbian with the RT_PREEMPT patch.
  - 40 GPIO header including SPI, I2C and UART interfaces.
- Sensor Suite
  - Navio 2 attached on top of the Raspberry PI 3 B and communicates with it through the 40 pin header using the UART, SPI, and I2C interfaces [4].
  - The sensors included in Navio 2 are listed in Table 1.

Sensor	Chip	Interface
GPS	Ublox NEO-M8N	SPI
IMU-Magnetometer	MPU9250	SPI
IMU-Magnetometer	LSM9DS1	SPI
Barometer	MS5611	I2C
PPM/SB, PWM, ADC	STM32F103RC MCU with a ARM Cortex-M3 core	

Table 1: Navio 2 sensors

- RPM Sensor
  - Optical sensor to measure the propeller RPM based on the TCRT5000 reflective optical sensor.
  - Connecteted to a GPIO port.
- Pitot Tube and Differential Pressure Sensor
  - Pitot tube and a Measurement Specialties 4525DO differential pressure sensor.
  - I2C interface.
- Angle of Attack and Angle of Sideslip Vanes
  - Two vanes with potentiometers in their axes to measure the angle of attack and the angle of sideslip.
- Analog to Digital Converter
  - Analog to digital converter ADS1115 from Texas Instruments.
  - 16 bits ADC, with conversion rates up to 860 samples per second, I2C interface.
- RF modem
  - RF modem, RFD 900+ developed by RFDesign Pty Ltd.
  - Serial rate up to 115200 baud.

Hardware integration

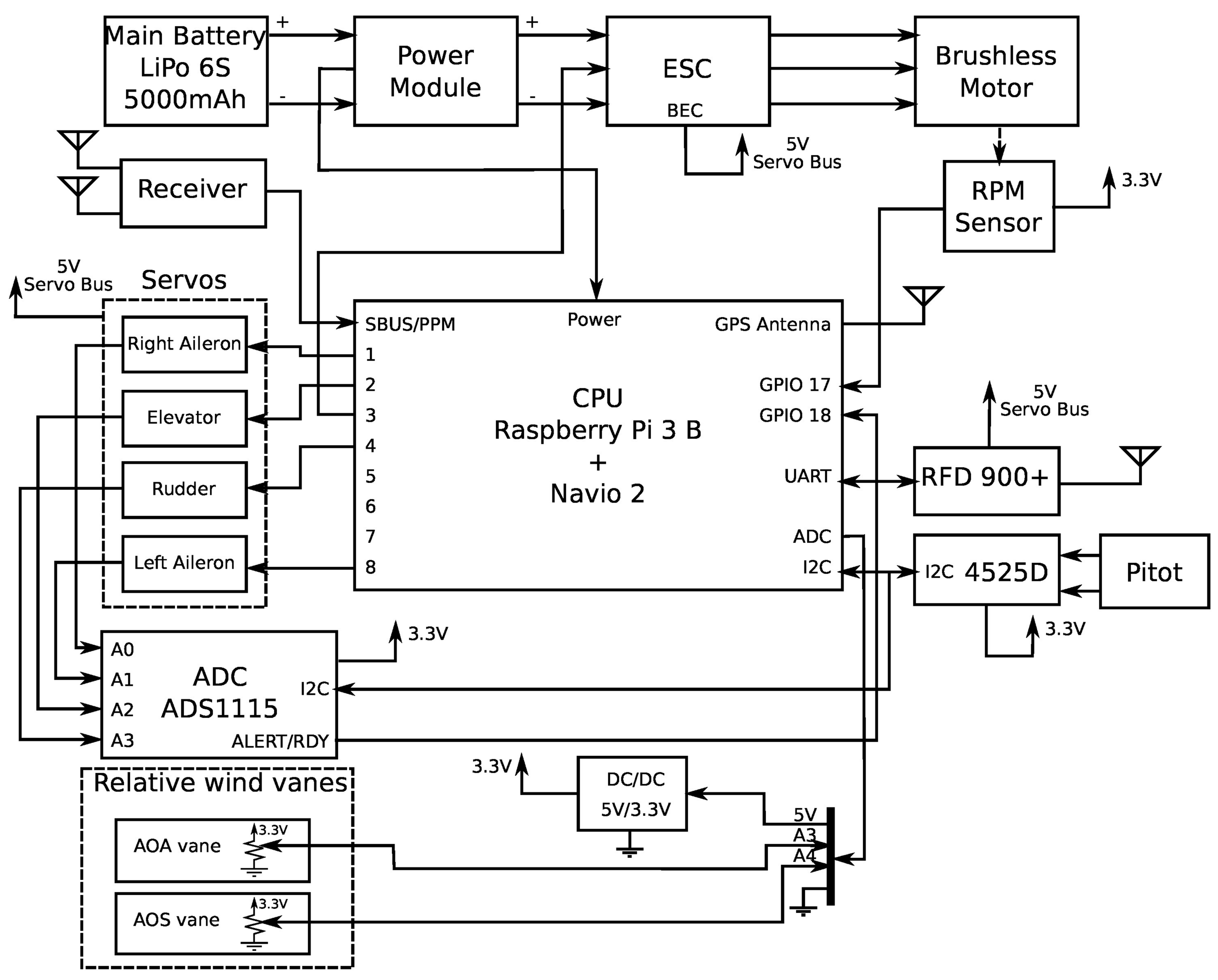

Figure 1: UAV hardware block diagram.

Figure 2: UAV test bed.

Software development

- Software for data logging and comunication with the ground station was implemented in C language.
- Drivers that communicates with the sensors though the appropriate interfaces.
- Flexible command line interface and scripting language to control data logging and manage the communications of the CPU with the ground station.
- Event based logic that controls the execution of all the tasks in real time.
- Eight threads of execution: *IMU_MPU9250_interruptService*, *updateFDR_GPS*, *updateFDRbarometer*, *updateFDR_ADC*, *updateFDR_RCin*, *updateFDRstatusMonitor*, *updateFDR*, and *keyInput* or *remoteKeyInput*.

Conclusions

In this article, the implementation of a small fixed wing UAV for research in flight mechanics and control was presented. All of the hardware components selected for the UAV were described. The hardware architecture showing how all the sensors were integrated was explained and the software that enables data logging and communication with a ground station was described. The developed test bed is expected to be used for research in aircraft system mathematical modeling and identification, research in flight mechanics and development of flight control algorithms.

References

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