DEVELOPMENT AND IMPLEMENTATION OF AN AUTOMATED PILOT SYSTEM FOR A FIXED-WING TWIN-ENGINE AIRPLANE UAV

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Abstract: When controlling a UAV, we have to rely on the line of site of the operator and aft wards on the communication with the ground control station. This implies expensive equipment used in communication, a skilled operator and a UAV with low autonomy. In order to address these issues an automated piloting system needs to be implemented thus offering the needed autonomy to the UAV. An automated pilot can also stabilize the aircraft and allow for the control of the UAV to be done by people without intensive training or special skills. In the present paper we present the development and implementation of such a system, built on Cube Orange flight controller, and implemented on a fixed-wing UAV with twin-engines, fabricated using additive manufacture technologies.

Keywords: Aerospace, Fixed-wing UAV, Automated Pilot, GCS, Additive manufacture

1. INTRODUCTION

Unmanned Aerial Vehicles systems have become more affordable to build, but still, there is the need for careful planning, designing and implementation. The research is focused on a couple of directions: UAV quad-copter development [1,2,4,5,7], UAV fixed wing development [6], UAV automated system integration [1,2,3,4,5,6], Communication interfaces [3,8,9], Simulation, Navigation, Stability and missions types [1,2,3,4,5,6,7].

In general, a fixed-wing UAV system is composed from main 3 subsystems: GCS (Ground control station), Communications link and the actual UAV with receivers and autopilot (Fig. 1, Fig. 3) [1,2,3,4,5,6].

The Ground control station is a Digital Micro Device and XLRS extended device. The station model is GCSD4, professional ground station for FPV and UAV up to la 200KM (Fig. 2) [10].

The GCSD4 includes [10] (Fig. 3): Directional patch antenna (SMP-4G-LTE); 5dBi omnidirectional antenna; Latest generation long range radio control and telemetry transmitter; Video screen with analog video receiver at 5.8Ghz and HDMI input for Digital video; Embedded and integrated PC with touch screen and windows 10; Software; Joysticks and command buttons; Suitcase and an analogical video system (RXVID3 video receiver with 5.8Ghz transmitter and patch antenna 2.4Ghz 17dBi (ANTPLA24G17DB).
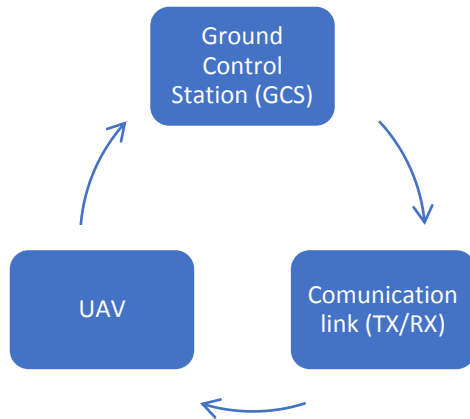
FIG. 1 UAV system

FIG. 2 Ground control station [10]

The communication link is comprised from a Smart Base Station (SMBTS) which actually is a transmitter of radio control and Telemetry to and from the UAV, mounted on a 12dBi directional biquad antenna (BQ89) that significantly improves the performance, safety and range of the signal without loss of radio frequency (RF).

There is no RF loss because of the way the antenna is build, the transmitter is mounted on the antenna itself, so the length of the antenna cable is minimal. The connection with the GCS case is done using a standard ethernet cable.

The combination between the transmitter and antenna assembly (SMBTS + BQ89) is called a Smart Antenna. Because of this system the UAV is capable to carry out long distance missions up to 100 KM.

The standard cable length is 3m but it can reach 10 m or more if we improve the quality of the cable (from CAT5 we go to CAT6.A or CAT7).
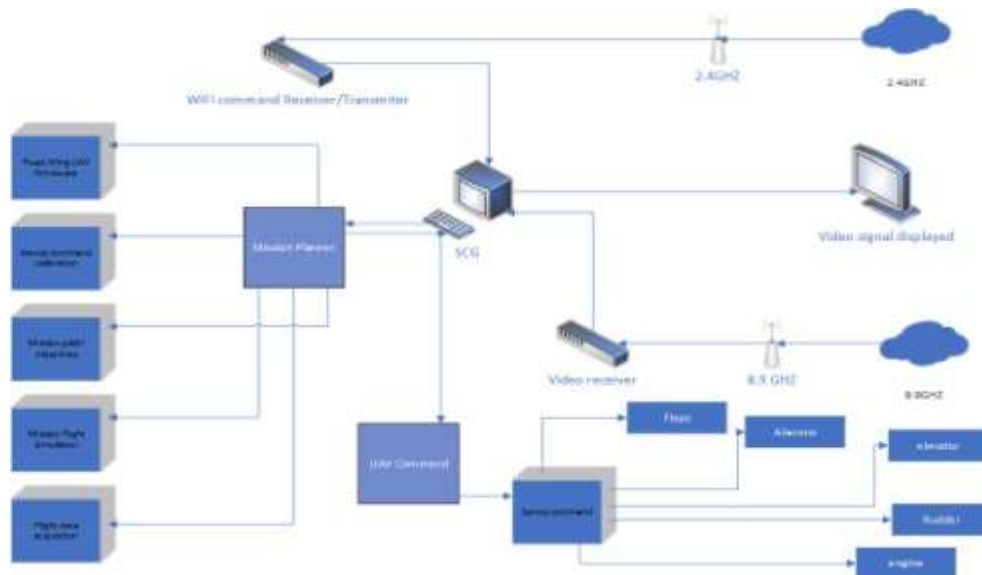

FIG. 3 GCS – Ground control station and connection

Regarding the telemetry transmission from the UAV to the GCS there is an internal radiomodem (data link) with radio control, a MAVLINK and a transparent protocol. The MAVLINK data is retreive via USB-PC or bluetooth from GCSD4-V2.

FIG. 4 The Smart Antennas SMBTS (Smart Base Station) back view

FIG. 5 The Smart Antennas SMBTS (Smart Base Station) front view

This communication technology is compatible with the major entry level Flight Controller platforms like RXLRS receiver, Pixhawk autopilots and APM. As a software framework everything is implemented over Mission Planner.

The ethernet connection cables from the SMBTS to the GCSD4-V2 do not work in straight or crossover ethernet connection, instead the protocol and the interfaced used are RCBus and FastRCBus with power for SMBTS.
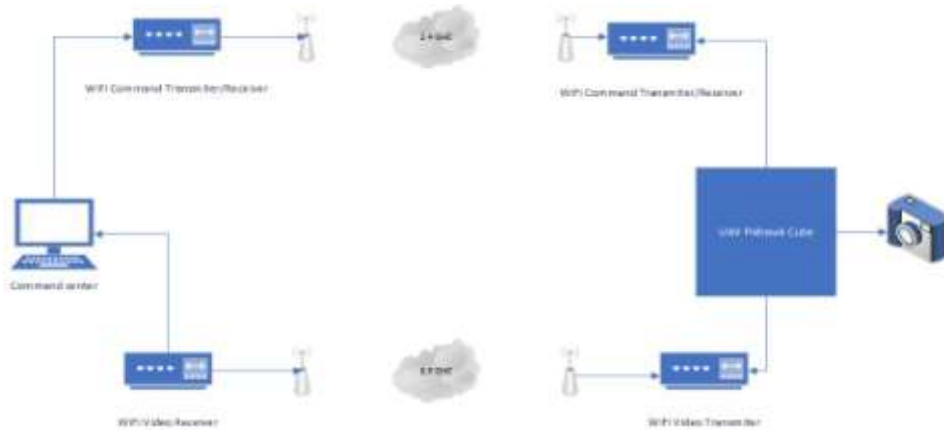

FIG. 6 Model that shows the connection between Ground Control Station with Smart Antenna (GCSD4V2) and the UAV systems

The UAV configuration is that of a fixed wing with twin engines mounted in front of the leading edge. The tail has the horizontal stabilizer mounted on top of the vertical stabilizer; empennage configuration known as a T-tail. Also, for landing, the UAV uses a conventional fix three-wheel landing gear.

FIG. 7 Simulation of the model aircraft made from 3D printed composite materials

The engines of the UAV were manufactured from A6 steel using Selective Laser Sintering (SLS), which is a layered based additive manufacturing technique, on a 3D System SPRO 60 SD machine. Each engine is equipped with can be equipped with a 15-inch or 17-inch propeller made from carbon fiber or other materials. The manufacture engines are brushless DC electric motors, known as synchronous DC motor or electronically commuted motors ECM.

The UAV parts were also constructed using additive manufacture method. But instead of SLS was used the FDM (Fused Deposition Modeling) method o construction. So, for the fuselage and vertical tail, as a printing material, short fiber glass composites were used, and for the rest of the components short carbon filament composites. Everting was printed on Zotrax M300 dual and Ultimaker S5.

FIG. 8 Firmware upload selection window from Mission Planner software.

As a main board controller is set up a Cube Orange platform from CubePilot PTY LTD, which can support multiple drone configurations. The controller was flashed with an open-source firmware, ArduPlane V4.2.0 firmware. Arduplane is the fixed-wing branch of the Ardupilot which gives full autonomous capabilities to an aircraft. The firmware is uploaded in the Cube Orange using Mission Planer software throw the path Setup->Install Firmware->ArduPlane V4.2 (Fig 8.). All these steps are done on the GCS station where the software resides, and the Cube Orange is linked with the GCS via the USB port.

Cube Orange I/O ports [11]:
- 14 PWM servo outputs (8 from IO, 6 from FMU);
- Radio control receiver (R/C) inputs for
  - CPPM (Combinatorial Pulse Position Modulation) – analog signal;
  - Spektrum / DSM – digital signal;
  - and Serial Bus – serial communication protocol;
- Analogue / PWM (Pulse width Modulation) RSSI input;
- Serial Bus servo output;
- 5 general purpose serial ports, 2 with full flow control;
- Two I2C ports;
- One SPI port (un-buffered, for short cables only not recommended for use);
- Two CAN Bus interface;
- 3 Analogue inputs;
- High-powered piezo buzzer driver; High-power RGB LED; Safety switch / LED.

Table 1. Cube Orange characteristics [11]

Characteristics name	Characteristics value
Processor	STM32H753
Remote Signal	PPM/SBUS/DSM
I/O PWN Voltage	3.3V/5V software selectable
Redundancy	Triple Redundancy
Isolation system	Y
Temp regulator	Y
Number of Accelerometer	3
Number of Gyroscope	3
Number of Magnetometer	1
Number of Barometer	2
Compass	1

FIG. 9 Cube Orange with Pixhawk motherboard

The Cube Orange accessories can be expanded using CAN Bus interface. We connected on the CAN a Here 3 RTK and GNSS positioning device which has a built-in magnetometer, gyroscope, accelerometer and compass.

FIG. 10 Ground control station linked with Cube Orange and Here 3

FIG. 11 Enabling CAN settings on Mission Planer software

The Here 3 needs to be configured and paired with the Cube Orange. This step is made using again the Mission Planner software installed on the GCS.

Steps to configure Hero 3 RTK GNNS system:

Connected with the USB cable to the Cube Orange, but without pressing the connecting button we select Initial Setup from Mission Planner, then we go to Optional Hardware-> UAVCAN and we select SLCan Mode CAN1 (Fig. 11). At this moment the settings for Here 3 will pop-up and we choose Parameters from the right menu (Fig. 12).

FIG. 12 Initializing CAN port parameters setting on Mission Planner software

In parameter setting page, we need to change uavcan.node_id to 0-125 and click Commit Params to save the changes and completed manual CAN id allocation.

After manually setting the Here3 node id, we need to connect the Here3 interfaces to the flight controller CAN 1.

FIG 13 CAN port parameters editing on Mission Planner software

The last step is to turn on the flight controller and connect it to Mission Planner. Then we go to Config Tuning then Full Parameter List and we need to modify the parameters from table 2.

To be sure that the Hero3 indication are in accordance with the date provided by the cube we need to mount the cube Orange and the Hero 3 with they're directional arrows (marked with paint on both devices – on the image we colored them in green for better contrast) pointing in the same directions (Fig. 14.).

Table 2. CAN protocol parameters

Parameter name	Parameter value
CAN_D1_PROTOCOL	1
CAN_P1_DRIVER	1
GPS_TYPE	9
NTF_LED_TYPES	231

FIG. 14 Here 3 and Cube Orange linked together

Once the Hero 3 is linked with the Cube Pro the initial setup can be initialized. This is done from Setup -> Mandatory Hardware and here we calibrate first the accelerometer (Fig. 15).
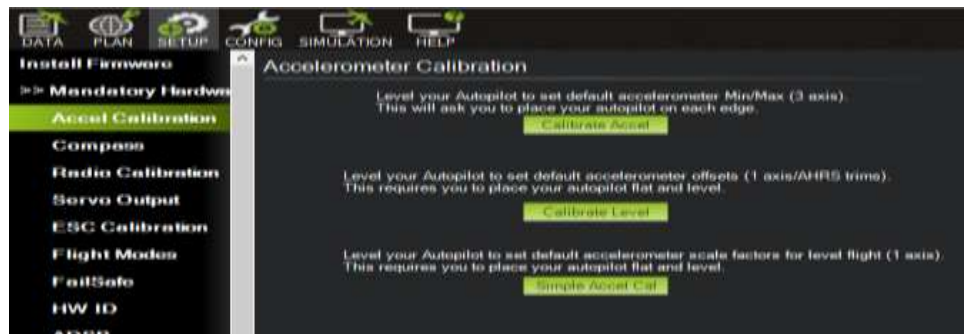

FIG. 15 Accelerometer Calibration on Mission Planner software

As it can be seen in table 1 the Cube Orange has 3 Accelerometers (one for each axis of the airplane) so we need to calibrate each one. The steps are easy we just need to tilt the UAV, or in this particular case the Cube pro and the Here 3 mounted on a plane Styrofoam board, on each axis (Fig. 14, Fig. 16, Fig. 17). The directions are: Place vehicle Level, Place vehicle Left and Place vehicle nose Down.

FIG. 16 Accelerometer calibration nose down

FIG. 17 Accelerometer calibration Left

At this point the internal sensors of the Cube orange and the Here 3 are calibrated and the next logical step is to connect the Manual receptor RXLRS or more exactly the radio control and data link receiver. This is the device that enables the long-range communicating with MAVLINK telemetry and transparent radio modem up to 100 kb RF.

The device can also control up to 16 servos (Fig. 18), 8 multifunction outputs for servos or other functions and another 8 using a double RXLRS configuration.

FIG. 18 RXLRS- radio control and data link receiver [10]

The RXLRS has the following connections:
- Ch1 – to Ch8 – multifunction outputs for servos and other functions
    - Any channel can be used as power supply;
    - Chanel 7 is used for cube orange also SPPM connection;
    - Chanel 8 can be used as RCBUS 2 connection (two RXLRS configuration or RXLRS with OSD and Video transmitter configuration);
- One RCBUS connection (two RXLRS configuration or RXLRS with OSD and Video transmitter configuration);
- One modem connection (TX and RX);
- One antenna connector;
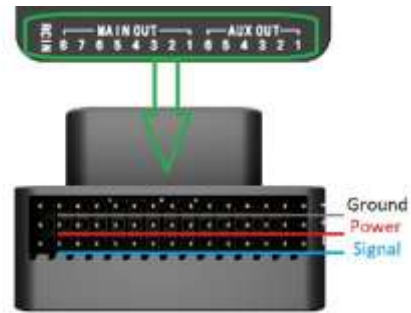
FIG. 19 Cube Top connectors [12]

FIG. 20 Cube front connectors [12]

On the Cube Orange flight controller there are the following connectors (Fig. 19, Fig. 20) [12]: 2 GPS connectors, 2 Telemetry connectors, One IC2 connector, One USB connector, One analog to digital converter 3.3 V, 2 CAN connectors (one with internal 3.3V transceiver, one on expansion connector), One Spektrum DSM receiver, 2 Power connectors, One S BUS connector, One serial 5 Connector, One RCIN connector, IO Ports: 14 PWM servo outputs (8 from IO, 6 from FMU), Internal microUSB port and external microUSB port extension.

FIG. 21 Cube Orange, RXLRS, and antennas that make the data link

FIG. 22 Servo

The servo connection with the RCIN connector for the cube is situated on the side, Fig. 20 we, and is divided in two; main output and aux output.
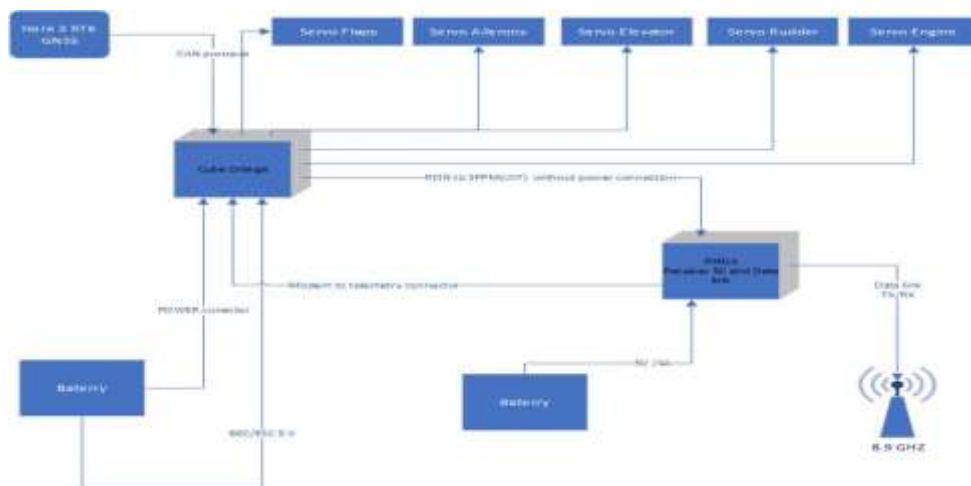

FIG. 23 Flight controller schematics for the UAV made with Cube Orange, RXRLS, Here 3 and servos

Flight controller schematic can be seen on Fig. 23 and a test connection with all the equipment is seen on Fig. 21.
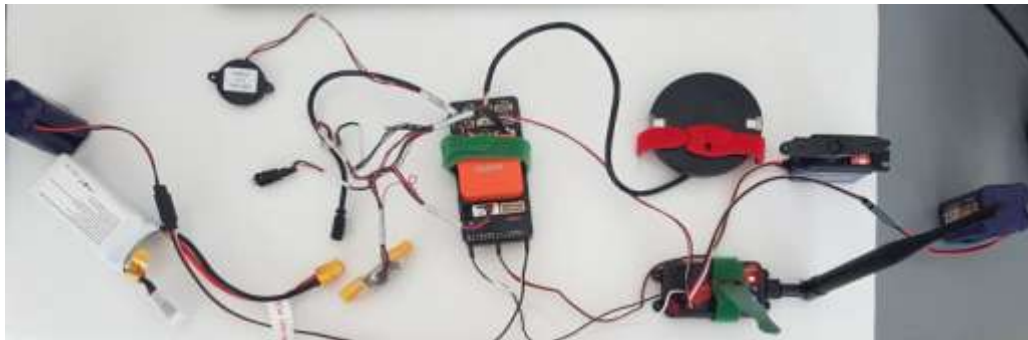

FIG. 24 Flight controller schematics for the UAV made with Cube Orange, RXRLS, Here 3 and servos

The brain of the flight controller is the Cube Orange with the Pixhawk board which is power on the power port from a 12V battery. From the same battery, using the CubeOrange splitter, power is transmitted to a 5V Output Voltage Regulator Modules (BEC) from where we sent a 5V connector to the 1 from the aux out connector from the Pixhawk. In doing this we power the cube and the servos with the same battery.

On the main out we connect the five servos and on the RCIN connection comes the RXLRS- radio control and data link receiver. On the RXLRS comes the 8.9 GHZ airplane antenna, and from the modem connector we go to the telemetry (TELEM 1) port from the Pixhawk.

CONCLUSIONS

Using this configuration, the UAV is flown in Autotune mode, on his first takeoff; this will start the tuning process for the autopilot. On the second flight, after takeoff, the airplane will be put in RTL mode (Return To Launch mode), thus testing navigation and finishing the autopilot calibration

Once the hole configuration is finished, we move to mission planer software from the SGC and begin configuring the communication between the SGS and servos command.

Automated piloting system can assist the pilot in normal flight by stabilizing the aircraft and letting the pilot focus on the mission at hand.

By using an automated piloting system we can pilot UAV even when is out of the line of site or I out of signal range.

An airplane cannot hover, this functionality is available only if it has tilt wing, tilt rotor or directional reaction streams. So, the airplane, cannot be stopped in midair and wait commands for the next move, but by using an autonomous pilot, we can put the aircraft in loiter mode (encircling a point in space) until we decide for the next move.

When we have to pilot more than one UAV (a swarm) we really need an autonomous flying system, this is not something that cannot be achieve with a simple controller.

ACKNOWLEDGEMENT

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