DEVELOPMENT OF AN AUTONOMOUS UAV

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Abstract: *The development of vehicles capable of flying autonomously is of great interest in respect to research and development. This is justified by the importance of avoiding the exposure of people to hazardous work or even to reduce the cost of certain operations. Around the world, Unmanned Autonomous Vehicles (UAVs) are already employed by several fire departments such as that of the city of Bedford, USA, where they are used to conduct search and rescue operations, and also for rapid localization of fires. (DRONE, 2015).*
This research project addresses some questions on the use of autonomous UAVs to access hard access areas, in a safe way. This type of operation is possible by developing an navigation system based on a Real Time Operating System, which collects the current location through a GPS and calculates the route to the previously defined destination. The system acts by constantly creating intermediary setpoints to be followed by the UAV, based on the obstacles detected and coordinates from both the destination and the current UAV location, once it reaches the final point, the payload is commanded to proceed with its processes. At the end of the processing tasks, the UAV returns to initial point using the same setpoints based system.

Keywords: *RTOS, Autonomous UAVs, Microcontrollers, Setpoints, GPS)*

1. INTRODUCTION

Unmanned Aerial Vehicle are aircrafts that do not require an on-board professional to pilot it, instead, they operate in stand-alone mode or with a remote operator (DE PAULA, 2012). This is an equipment with multiple capacities that had its origin in the military milieu, however, has been widely used in the civil arena. According to Gomes et al. (2014), the use of UAVs is increasingly common due to their low cost and the possibility of performing tasks where human presence could be dispensable, risky or even impossible.

An UAV, or drone, becomes an alternative to make it easier to access hard to reach areas. Grémillet et. al (2006, p.49) states that drones are still used less than they could be in Environmental Engineering, but they can be essential because they can go top laces that were inaccessible before, for being remote or dangerous, and still revolutionizing the data acquisition in terms of precision and speed. Drones are easy to operate and have good reception of GPS signals that allows easy guidance, being controlled by human or operating autonomously - identifying and mapping objects and areas in an automatic way, without interferences to the habitat, given the small size of the equipment.

Vissière et. al (2011, p. 1477) ensures that it is possible to equip drones with low cost sensors, incorporating algorithms, allowing stability and robustness. Drones has aroused interest in many fields, because they offer space information in real time with low cost. Aerial views allow better perspectives with the advantage of covering a bigger area, besides being movable with real time solutions, the drones can be used in a lot of operations, working with speed, low cost, security, flexibility, precision, and accessibility.

Inside this scenario, this paper presents the development of an autonomous UAV that consists in design a CAD modeled chassis, print it on a 3D printer, assemble with a drone components kit and develop its autonomous navigation system based on a MSP430 microcontroller running over RTOS.

2. EXPERIMENTAL PROCEDURE

This project consists of joining 3D printed parts and off-the-shelf equipment used to develop an UAV and its onboard computer, which runs the navigation system developed over a RTOS.

The off-the-shelf materials were:

- 4 kits with brushless motor, ESCs for speed control and a propeller;

- CC3D Flight Controller;
- MSP430FR6989 Launchpad with GPS expansion card;
- Battery Pack;

The methodology adopted was divided into 4 stages:
1. 3D designing and printing of the structure
2. Assembly and configuration of the UAV for independent operation;
3. Board the RTOS based autonomous navigation control;
4. Test and analyze the results;

On the process of 3D designing, parts were printed based on the MSP430FR6989 Launchpad`s dimensions and docking using the MSP itself as an anchoring platform for the rods with the motors and ESC's. The MSP stands exactly in the UAV`s middle with four pins securing the other parts in the center, always prioritizing the lightness of the parts but not leaving aside the necessary resistance to sustain all the aircraft`s components.

For the UAV operation, 4 brushless motors that have their speeds regulated by ESCs (one for each motor) were used. The control part is performed by a CC3D Flight Controller, which already performs the UAV's characteristic movements (Yaw, pitch, roll), also using a battery (11.1V) to power the motors and ESCs. The commands for the UAV (SP-Setpoint) are generated on the fly by the code embedded on the MSP430 and then sent to the CC3D for performing the UAV movement.

For the stand-alone navigation system, two external modules were attached on the MSP430FR6989 Launchpad, one for receiving GPS data for the location and another for Wi-Fi communication, with all the navigation system running over a RTOS.

After finishing the development of the structure, the operation of the UAV and the navigation system, the last step is to board the experiment to be used on the desired area.

3. DEVELOPMENT PROCESS

The UAV development process was divided into three phases:
1. Develop the CAD chassis for the UAV, print it on a 3D printer and assemble using a regular drone kit controlled by a Radio Controller
2. Board the MSP430 on the UAV to replace the radio controller, so the commands were sent from pilot to the CC3D controller via microcontroller
3. Develop the autonomous control to run on the MSP430, removing the need of a pilot to control the UAV

But before reach this process some ideas were tested and will be described on the sequence.

The first idea was to buy a commercial drone and just replace the radio control for the autonomous navigation system, but it was discarded due to the unnecessary work of understanding and hacking the commands protocols of the commercial drone, diverting from the main goal of the project that is demonstrate the autonomous navigation control.

The second idea and the first adopted was to build the whole aircraft from the ground using electronics parts individually acquired and assembled on the printed chassis. Among the components purchased for the initial UAV are motors, ESCs and batteries. For the development of the flight navigation system, an MSP430 chip with RTOS support was purchased. But the lack of experience on flight control and the difficulty of calibrating different components for working together made the development process to be over delayed.

The CAD model of the first idea adopted, that can be viewed on Picture 1, was developed to house the MAS340 LaunchPad on the center.
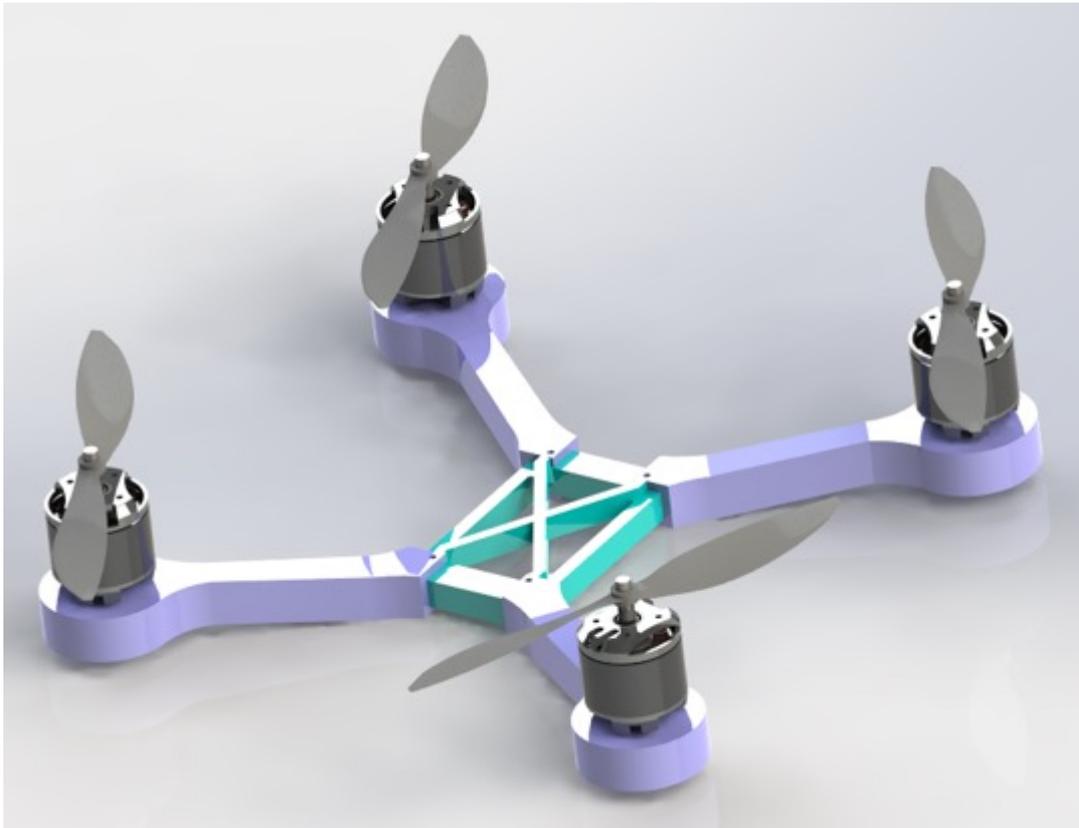
Picture 1. First CAD model developed.

Due to the previous problems, the line of development was changed to using an out of the box, flight ready controller and replace its radio input for the MSP430 based navigation system. For this flight, the chassis was redesigned to house the CC3D flight controller, at this point in time the intention was to make the radio-controlled UAV and develop the autonomous control system in parallel for future joining, among the components used in the first attempt are a 2-cell 1000MHa LiPo battery, a HobbyKing radio control, and other components purchased for the first version of the UAV:
- Brushless motors 2200 kva
- ESC 30A Brushless
- Propellers 7x5
- CC3D control board
- Screws for mounting printed parts

The result was a short flight and an accident due to rupture of the printed structure, which eventually damaged one of the ESCs in the fall, causing problems in the use of CC3D calibration software. The first prototype built and its first flight can be viewed on pictures 2 and 3 and the rupture point of the structure can be observed on picture 4
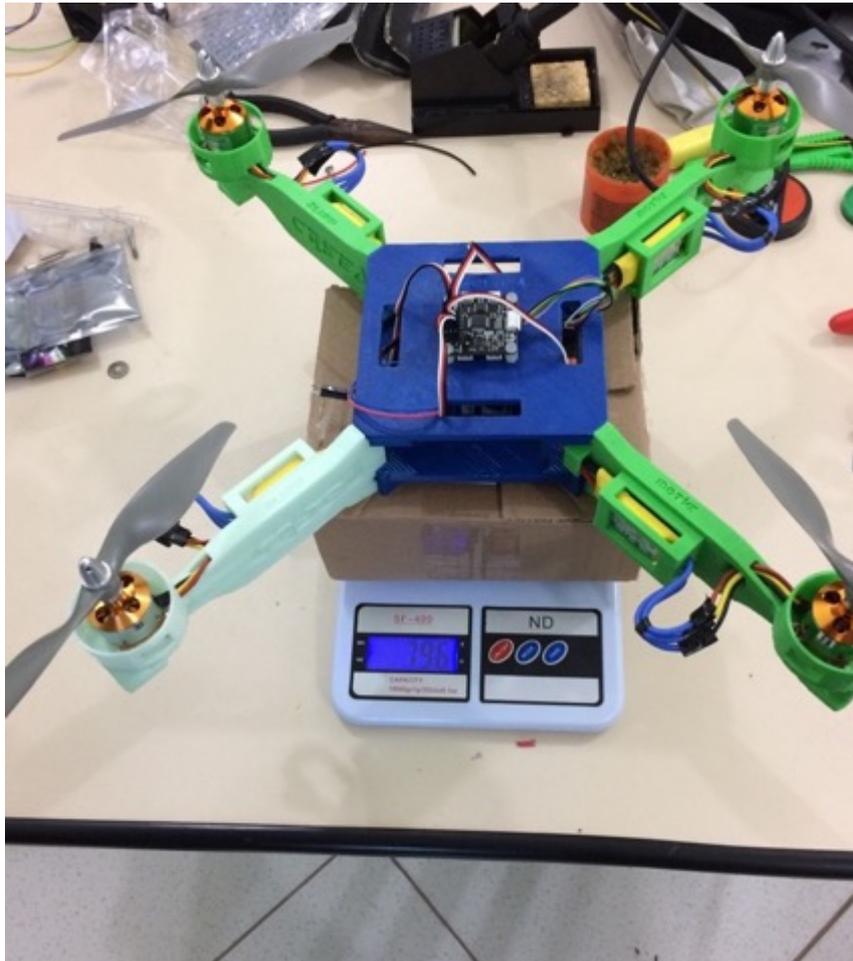
Picture 2. Printed prototype used on the first flight.

**Picture 3. Moment of first flight takeoff**

Picture 4. Rupture point of the chassis first printed version.

For the second attempt, some measures were taken to mitigate the problems encountered in the first flight:

• The point where the structure had broken was reinforced and the new projected pieces were printed to replace the old ones.

• The screws used in the assembly were replaced by larger ones so that they would cross the entire structure printed at the docking points.

• In addition to screws in the fittings epoxy glue was used to prevent twisting of the structure during flight

This reinforced chassis can be viewed on pictures 5 and 6.

Picture 5. Reinforced structure viewed from above, the places for screws at the mounting points can be observed.
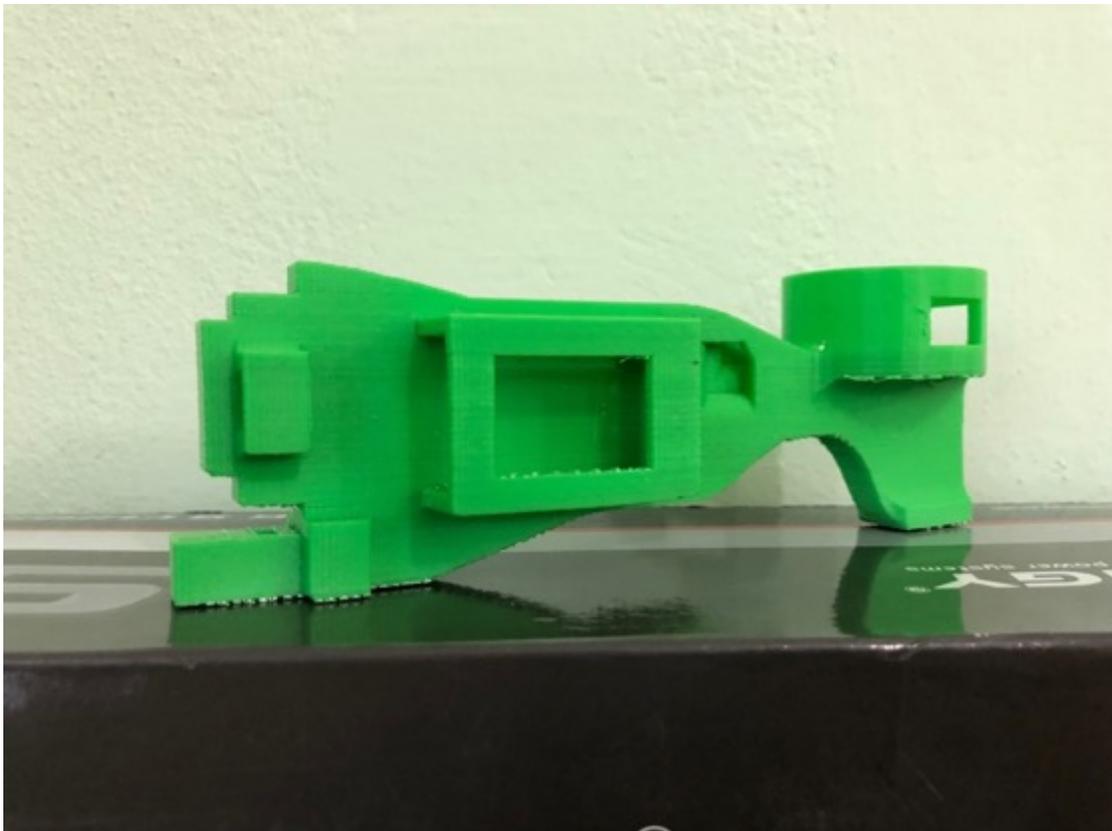
Picture 6. Reinforced stem, side view isolated from set.

The result, however, could not be checked because, due to the damages suffered by the ESCs on the first flight, the calibration process of the engines was not correctly carried out. So, it was decided that a regular drone kit would be acquired and assembled on the reinforced structure, leading to the final development process described initially.

The drone kit acquired was successfully assembled on the new printed structure and its last radio controlled flight can be viewed on picture 7.


Picture 7. Head high stable radio controlled flight.

Once the first phase of development was successfully completed, it was time to replace the radio controller for the MSP430. To achieve it, since it is known that the Radio Receiver-CC3D flight controller communication is via PWM, it was necessary to discover the exactly wave forms generated by the receiver, so it can be reproduced in the MS430 digital output. These data were collected with the aid of an oscilloscope.

With that information, the waves were reproduced using a MSP-EXP430FR6989 LaunchPad, that is an easy-to-use evaluation module for the MSP40FR6989 microcontroller that contains everything needed to begin developing the ultra-low power FRAM MSP430FRx microcontroller platform, including on-board emulation for programming, debugging and power measurements. The board has on-board buttons and LEDs for quick integration of a simple user interface as well as a liquid crystal display (LCD) screen that shows the integrated driver that can drive up to 320 segments. It also provides direct access to the Extended Scan Interface, which is a Dual Analog Front End (AFE) designed for low power spin detection. The MSP430FR6989 features ultra-low power consumption, 128 KB of built-in FRAM, non-volatile memory known for its high-power, high-strength, high-speed ultra-low power access.

The MSP-EXP430FR6989 LaunchPad can be viewed on Picture 8.
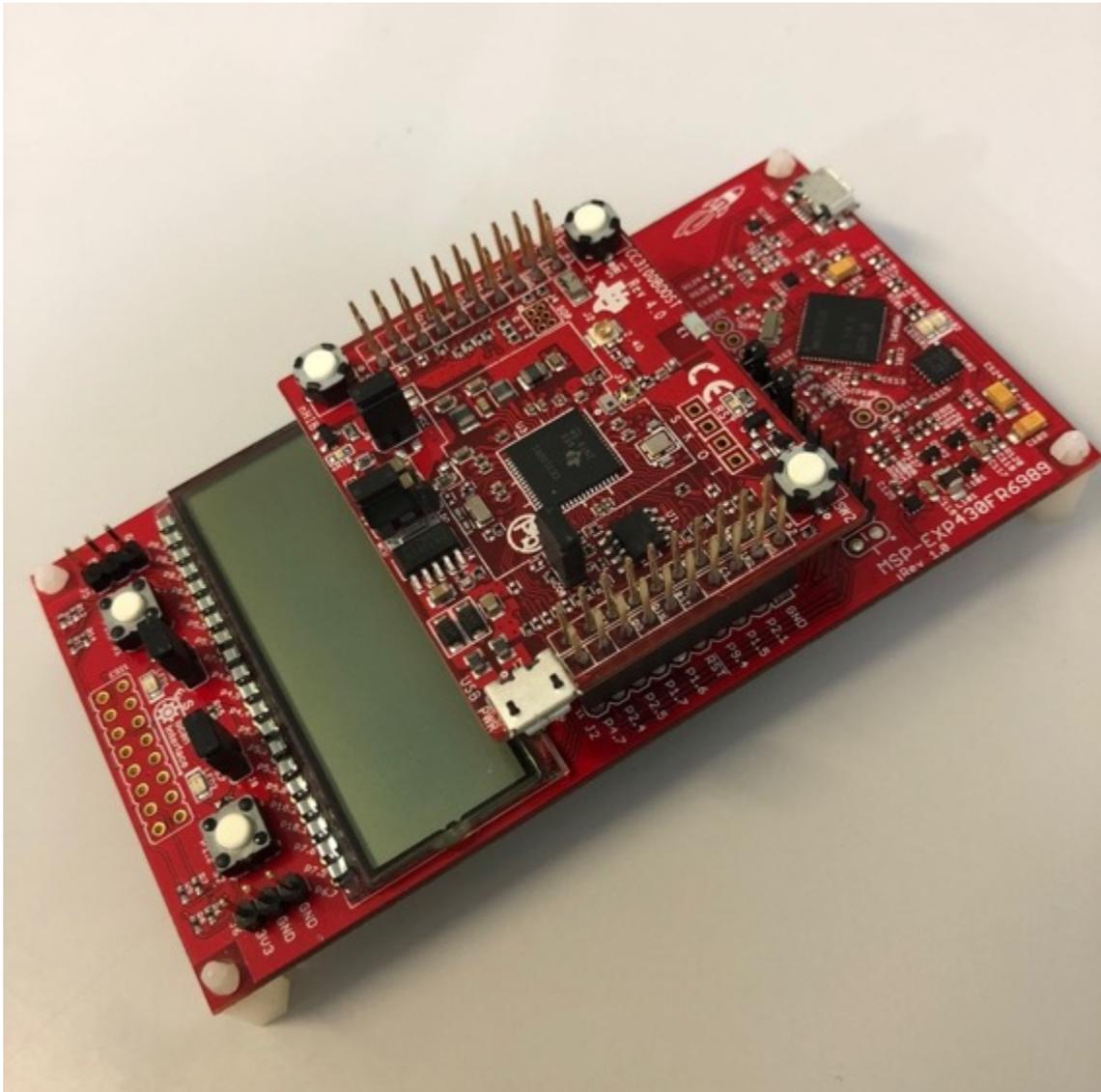
Picture 8. The MSP-EXP430FR6989 LaunchPad.

4. RESULTS AND DISCUSSION

The result of the project was an UAV, able to board experiments that can bring benefits to the society, offering the possibility to the experiment's author just indicate the place and the time that the vehicle needs to be without care about the navigation that will be done autonomously by the aircraft.

5. ACKNOWLEDGMENTS

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7. RESPONSABILIDADE AUTORAL

"Os autores são os únicos responsáveis pelo conteúdo deste trabalho"