A project for a navigation and telemetrics system for unmanned aerial vehicles

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Abstract. *The development of electronic circuits (hardware) for autonomic flight control in unmanned aerial vehicle (UAV) is a new research area in Brazil. The cost of electronic equipment and sensors has been decreased. It has stimulated many universities to build their own aircrafts. The development of a new architecture that can be used for many other aplications, not for only scale aircrafts, and different from other commercial systems, is proposed. This research has generated new knowledge for the Air Force, as well as applications in environmental monitoring, weather forecast, agriculture, plague control since there is no need for exposing pilots to the risk of flying over dangerous or unknown areas.*

Keywords: *Unmanned Aerial Vehicle(UAV), Inertial Navigation System(INS), Robotic Control System, Remote Aerial Monitoring, Real-Time Data Acquisition*

1. Introduction

In the last few years, many universities around the world have kept research on unmanned aerial vehicles (UAV), of small and medium size aircraft. The research developed in these universities generated new knowledge for many areas related to aeronautics, such as design, fabrication, instrumentation and development of systems for autonomic flight (Dittrich 2002),(Dixon & Wickens 2003) and (de Oliveira Neris 2001).

The UAV capacity to carry on recognition missions over battle fields has motivated a growing military interest. After a successful demonstration of a missile launching from a Predator, the UAV role have change from a non-lethal device into a letal warcraft of great precision (Fig. 1).

After successful applications by the Air Force, the UAV have attracted attention for civil applications as well, such as agricultural plague control, monitoring of disasters and forest burning areas, weather forecast and scientific research.

Figure 1. Predator, General Atomic

Therefore, with the growing application of UAV, the development of these aircrafts took serious boost grown in the past few years. On the other hand, the low cost and miniaturization of components, necessary for the flight control of these king of aircrafts, have allowed the production of UAVs at low prices (Elfes & Maeta 1998),(Kahn & Kellog 2003).

Two brazilian projects have greater visibility their literature references are: ARARA (Autonomic and Radio-Assisted Recognition Aircrafts - Fig. 2) from USP-Sao Carlos, and AURORA (Meteorological Airship - Fig. 3) from ITI (Information Technology Institute)- Campinas. In this context, this work aims to develop a navigation, telemetrics and data acquisition system for UAV flight control.

Figure 2. Project ARARA

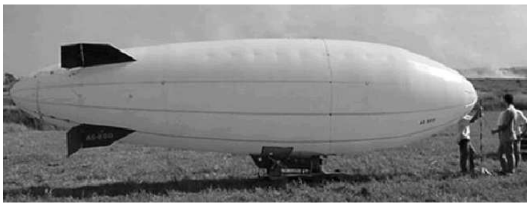

Figure 3. Project AURORA

2. The proposed System Architecture

”The heart“ of our architecture is a MCS-51 microcontroller, which will be connected to a group of circuits for interfacing I/O devices. Through a serial communication channel (RS-232), the microcontroller will receive the information (data, commands and instructions) generated by the control and the navigation algorithms, which will be executed either in land or at on board by Control and Navigation Unit. For the control system, many trials need to be done, such as: PID, PD, robust control, fuzzy logic (Hiliuta, Landry & Gagnon 2004) and others.

The proposed architecture has as its main characteristics, a low cost, greater miniaturization possible and a minimization of the on board hardware weight . Furthermore, we aimed to maximize the flexibility of the actuator’s comand and the control system program (models and algorithms) as well.

What is new in this architecture is the use of a basic microcontroller, which is very easy to use (other commercial systems work with a specific microcontroller or are dificult to change firmware for its own aplication, (*MicroPilot Control System* 2004) and (*U-NAV - Modular UAV Control System* 2004)). This system isn’t only for aircrafts but it can also be used for other aplications which need an inercial navigation system, like hovers (robots), and provides the possibility to use other actuators such as: step motors, servo-motors, DC motors, solenoids and even LCD (Liquid Crystal Display), when the system’s I/O expansion is used.

The conception of our embedded control system is compatible to a great number of commercial aeromodels. The use of an open architecture makes possible the expansion and the improvements of the system. This computational capacity will be explored according to the objectives of each group of trials and tests.

The architecture of the system is shown in Fig. 4. The MCS-51 microcontroller is responsible for the data acquisition from eight analogic sensors. Thur it generates the control signals for the PWM (Pulse Width Modulation) actuators in as well as sending information to the Navigation and Control Unit.

The sensoring of flight parameters will be achieved with three gyroscopes, three accelerometers (one for each coordinated axis), two barometric pressure sensors (one for altitude and another for wind velocity) and a digital compass. The compass will be used for the GPS (Global Position System) correction, being directly connected through the second a serial channel of GPS. The gyroscopes, accelerometers and pressure sensors are analogic. Thus, a conditioning of their output signals is needed, before digitalization by the analogic to digital converters (A/D) (*Datasheet ADS1286* 1998).

In Fig. 4 one can see two communication channels between the base and the on-board stations. One of those (left corner of Fig. 4) is responsable for the radio-control flight in taking-off and landing maneuvers of the UAV without any command or connection with station base. This channel can also be used in cases of misfunctioning of the autonomus flight control system, since it does not interfere with it. The second radio-link allows the operator at the base station to adjust the control system and change the course of the UAV during a flight.

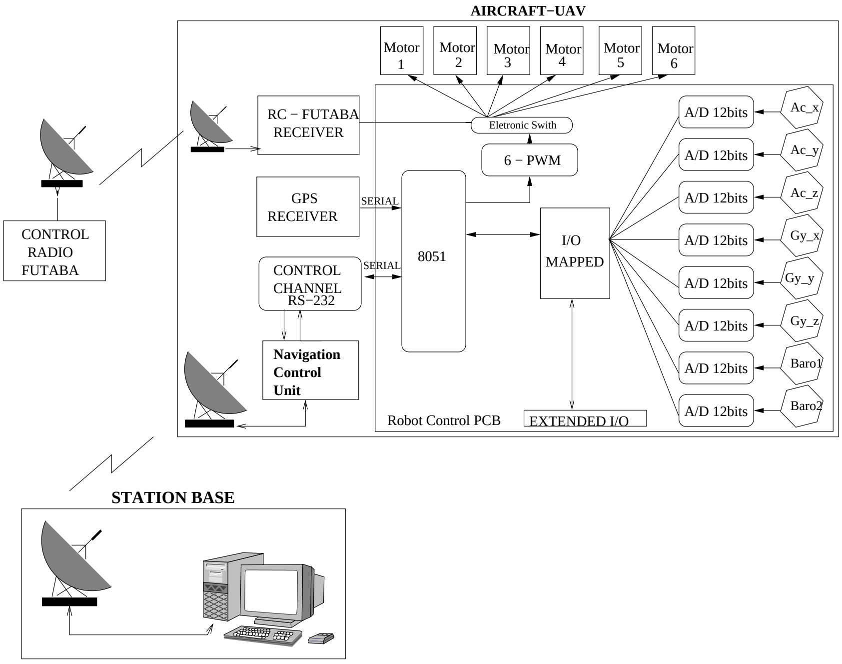

Figure 4. Proposed System Architecture

Table 1. Basic System Specifications

8	Analogic Inputs with A/D
7	Digital I/O with 8 bits;
8	Outputs PWM, expanded for 40 Outputs with card PWM;
1	Serial Full-Duplex Comunication (9600bps -> 28800bps)
	Power Dissipation 6W.

Originally, with the proposed configuration, the hardware can be used by a large number of aeromodels available in the market, since the control model is not on board, but at the base station or at the Navigation and Control Unit. This flexible architecture allows the application of different control models and algorithms. For the Navigation and Control Unit, several computational devices can be used, such as: an embedded Handheld, a Stargate kit (microcomputer)(*Datasheet Stargate Developer's Guide* 2004) and even mobile phone system can be used for data communication between the base station and the aircraft. The hardware will provide this information through a protocol of communication via serial RS-232. Therefore, any computational device with a serial communication channel available can be used.

3. The proposed Hardware

In this project, we chose to use components which can be easily found in the brazilian market, at low price and satisfactory performance for this application.

As mentioned above, there is a communication channel between the aircraft and the base station. This channel can be made with a radio-modem found in the market, with no need of authorization for its use. The specific radio-modem was a Warwick Wireless DS146-X7200 model, with a 20km range in open field and up to 3km with obstacles. The distance between the modems can be monitored by the radio it self. This equipment has already been adjusted according to the ETSI300-220, ETSI300-113, ETSI300-683, MPT1329 and MPT1411 specifications (*Datasheet DS146-X7200/X7400* 2003).

The chosen sensors for flight and altitude monitoring of the aircraft were: the barometric pressure sensor MPX4115A by Motorola (*Datasheet MPX4115A Pressure Sensor* 2001), a Vector 2X Compass by Precision Navigation (*Datasheet VECTOR 2X and 2XG Electronic Compass Modue* 2001), the CG-16D0 gyroscope by Tokin (*Datasheet CG-16D Ceramic Gyroscope* 2001) and the MMA1200D (z-axis) and MMA3200D (x and y -axis) by Motorola (*Datasheet MM1200D Micromachined Acelerometer* 2001),(*Datasheet MM2300D Micromachined Acelerometer* 2001). Each one signals from sensors need to be adjusted to full scale of A/D. This circuit is based on an operational amplifier TL071 by Texas Instruments (Fig. 6).

The microcontroller AT89S8252 by ATMEL was used. It has an 8K byte EEPROM flash, three 16 bit timers/counters,

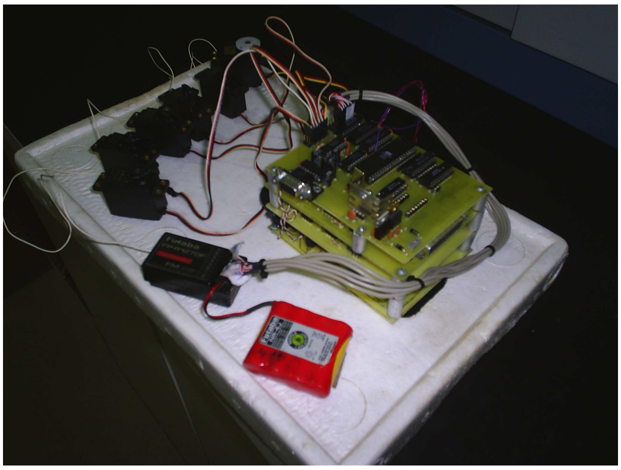

Figure 5. The First Propotype

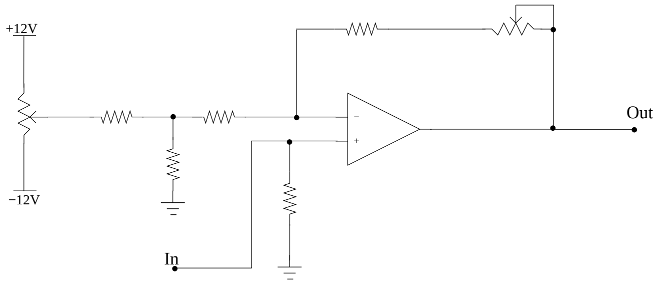

Figure 6. Signal adjust and condition

an 8 bit CPU, 32 I/O lines, full duplex serial communication and low power. The processing speed is approximately 22MHz. The firmware was written in assembler language using a 8051-IDE compiler by ACEBus.

In order to allow radio-control and autonomic control, we used the extra radio-control channel to activate the electronic switch. If the receptor is inside the transmitter range its output is modulated by PWM, otherwise one has a positive logic level. A group of Op-Amps is necessary to guaranteed the electronic switch. Therefore, one of them is in an integrator configuration and the other functioning as a level discriminator (Fig. 7).

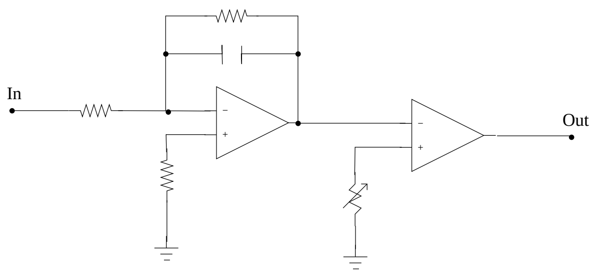

Figure 7. Swith mode operation

4. Control and Navigation Unit

In the control and navigation unit RAD (Rapid Application Development) tools going to be use such as C Builder, C++, Visual Basic, Qt Designer and Matlab. Therefore, block diagrams can be used to modeling linear and non-linear systems.

To control an aircraft in a straight and leveled flight, a single gyroscope, a compass and a pressure sensor would be necessary, as tested by Aaron D. Kahn and James C. Kellog (Kahn & Kellog 2003). Never the less the telemetrics and navigation system must be able to control an extensive goes a group of maneuvers, necessary for exemple in a survey flight.

As in theory, the knematic and the dynamics of controlled system should be studied (system modeling). This modeling also involves an aircraft model applied to the UAV. Since the proposed architecture aims to be compatible to a large number of commercial scale aircrafts, a fuzzy controller would be more adequate(Hiliuta et al. 2004) and (Doitsidis, Valavanis, Tsouveloudis & Kontitsis 2004). It is known that, the knowledge of the model of the aircraft in scale is not a fundamental parameter for the fuzzy controller.

Once the Navigation and Control Unit is programmed with the fuzzy controller or any other mentioned above, a long flight autonomy will be possible, since it will not depend on the base-station for controling (independent of human sight, the notion of control is generally losted in less than 400m). Then, the system will send the collected data and information to the base-station.

The navigation system has a GPS on board. The information available at the base-station is: latitude, longitude, direction, orientation, date, time and speed. With this data, the navigation system will determine the UAV route, and pass the information to the control unit, that it can be changed in the actuators on board.

5. Flight Simulation Environment

The flight simulation environment are the LaPO laboratory (Optical Property Laboratory) and the Mecatronic Prototyping Laboratory of the UFBA (Universidade Federal da Bahia). Within the Matlab environment, block diagrams will be created initially, which will represent the aircraft's linear and non-linear systems, and the algorithms will be developed, tested in different types of external interferences and cleared, so that the final codes can be generated for the navigation and control system.

Now the first prototype is finished. In a few days we are going to start the system tests on the ground. Many tests are going to be planned to certificate that the system is going to work well at real situation. After a long time of testing routine, the system is going to be able to embedded in the aircraft and its performance will be monitored through the base-station.

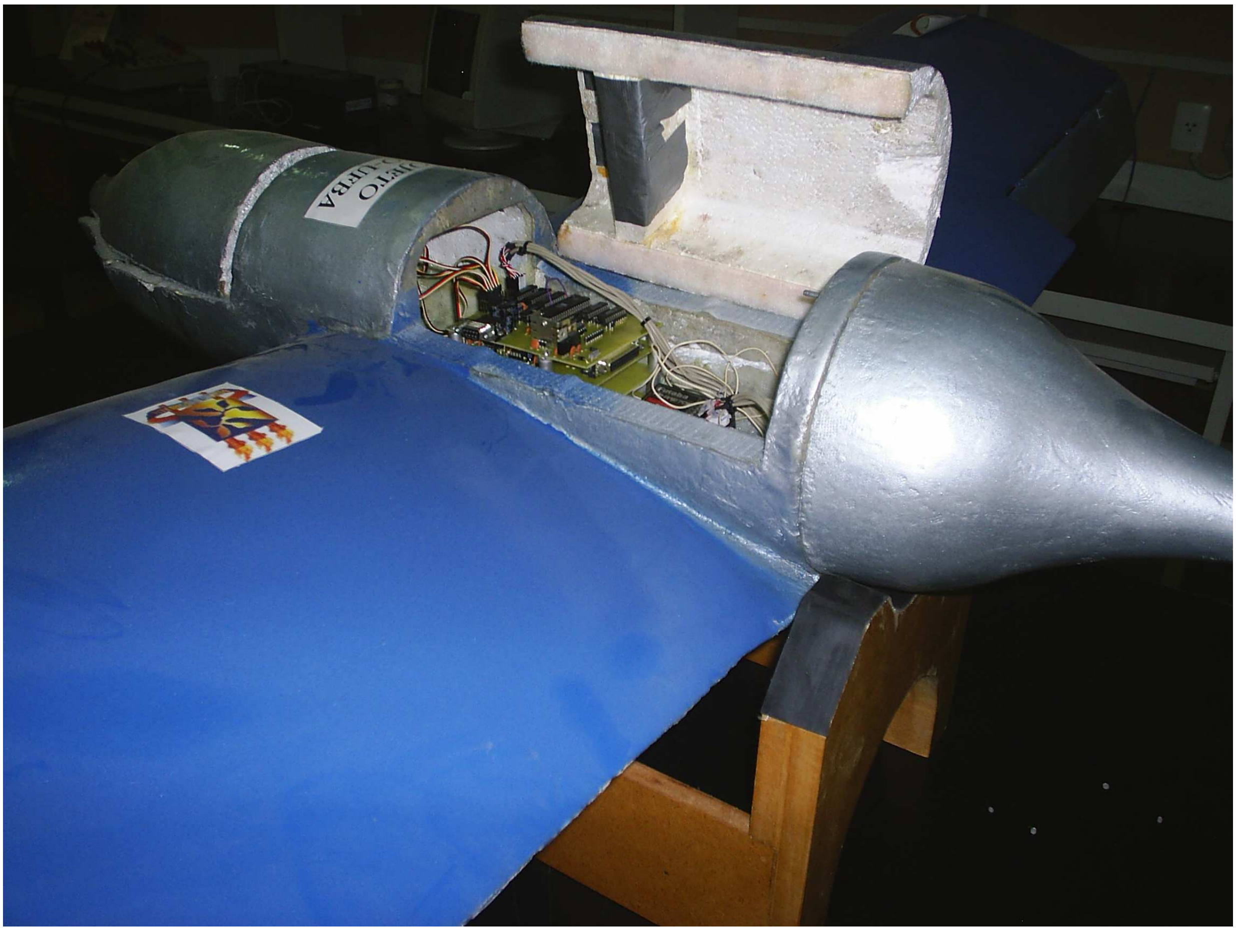

Figure 8. Embedded in the aircraft for inicial tests

6. Conclusion

In this paper, the applications of the UAVs have been described, as well as the aspects involved in similar works published in Brazil. We also present a detailed description of the hardware and some of the technical aspects of signal processing. The architecture of the system was described with its control and programming aspects, as well as the simulation environment.

The AERO-UFBA project has reached the electronic prototyping and ground testing controller phases. The data acquisition and sensor testing phases have already been concluded. Now the ground tests will be started to certify the system for real flight tests.

7. Acknowledgments

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9. Responsibility notice

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