Development of a Rotorcraft UAV Using NI CompactRIO Embedded System

Overview

At University of Bologna (UNIBO) DIEM Aerospace Department, a rotorcraft UAV has been developed, which can be used as flying test bed for researches in Unmanned Air Vehicle control and navigation laws; meanwhile it should be proposed as a technological prototype for industries interested in UAV development and manufacturing. The CompactRIO system has been used as flight computer in order to manage flight data acquisition and helicopter control. First flight have been already made in order to test the helicopter attitude controller. In the near future, navigation algorithms will be also implemented and tested.

The Challenge

To develop an helicopter platform capable of autonomous flight which could be used inside the Universities for researches in control and navigation laws, man-machine interfaces and system integration; meanwhile it should be proposed as a technological prototype for industries interested in Unmanned Air Vehicles (UAV) development and manufacturing.

The Solution

The rotorcraft UAV has been developed as an integrated modular system using off the shelf and cost effective technology. The NI CompactRIO (cRIO) solution has been chosen as onboard computer due to its reliability and reconfigurable architecture, to enable fast and easy integration of different input/output hardware and sensors. The whole system has been easily programmed through NI LabVIEW resulting in a sudden speed-up of hardware/software development and integration.

Introduction

The increasing interest in military Unmanned Air Vehicles (UAVs) is fuelling an equally ambitious build-up in the civil community. It is well known that UAVs may represent a promising and cost-effective alternative to manned aircraft for a large number of civil applications. Compared to traditional air vehicles, UAVs may offer significant advantages in terms of human safety (especially in dull, dirty and dangerous missions), operational cost reduction and work rate efficiency. Nevertheless, while researches in UAV or Rotary Wing UAV systems are very advanced in the United States, UAV interest in Europe began only in the last years. As a result, the European Union has sponsored the UAV development program CAPECON, to attempt to kick-start a civil UAV industry in Europe and try to fill the gap with the United States. In the last years, UNIBO has carried out several research projects concerning the development and manufacturing of fixed wing UAV systems for the civil aviation market. For that reason, when the EU decided to start the CAPECON program, UNIBO didn't hesitate to take part in, together with other many European universities, industries and research centres. Besides its partnership in the CAPECON program, UNIBO has also started a rotary wing UAV (RWUAV) research program, since RWUAV systems may represent an alternative to fixed wing UAVs (or even a more promising solution) for many UAV civil applications due to their versatile flight modes, manoeuvrability and vertical take-off and landing capability. The main goal of UNIBO Rotary wing UAV research program is to develop an helicopter capable of autonomous flight which could be used inside the Universities as a platform for researches in control and navigation laws; meanwhile it should be proposed as a technological prototype for industries interested in UAV development and manufacturing.

One important aspect, derived from the above mentioned EU program, is the real need of applying proven technologies to the UAV world in order to take advantage of existing and cost effective technology. For that reason UNIBO has decided to evaluate the CompactRIO technology on its rotary wing UAV platforms.

Hardware and System architecture

UNIBO has built up two model helicopter platforms with 5.5 kg payload capability. Autonomous flying vehicles require avionics systems that enable them to maintain a stable attitude and follow desired trajectories. Such an avionics package is comprised of sensors, computer and data link hardware as well as software to guide, navigate and control the air vehicle. These aspects are particularly critical for helicopters which are well known to be highly coupled and inherently unstable systems. At this aim, UNIBO has decided to evaluate the feasibility of the CompactRIO solution.

The Hirobo 60 and Graupner 90 hobby helicopters available at UNIBO have been modified to accommodate the avionics hardware. The system architecture and the hardware configuration are shown in figures 1 and 2.

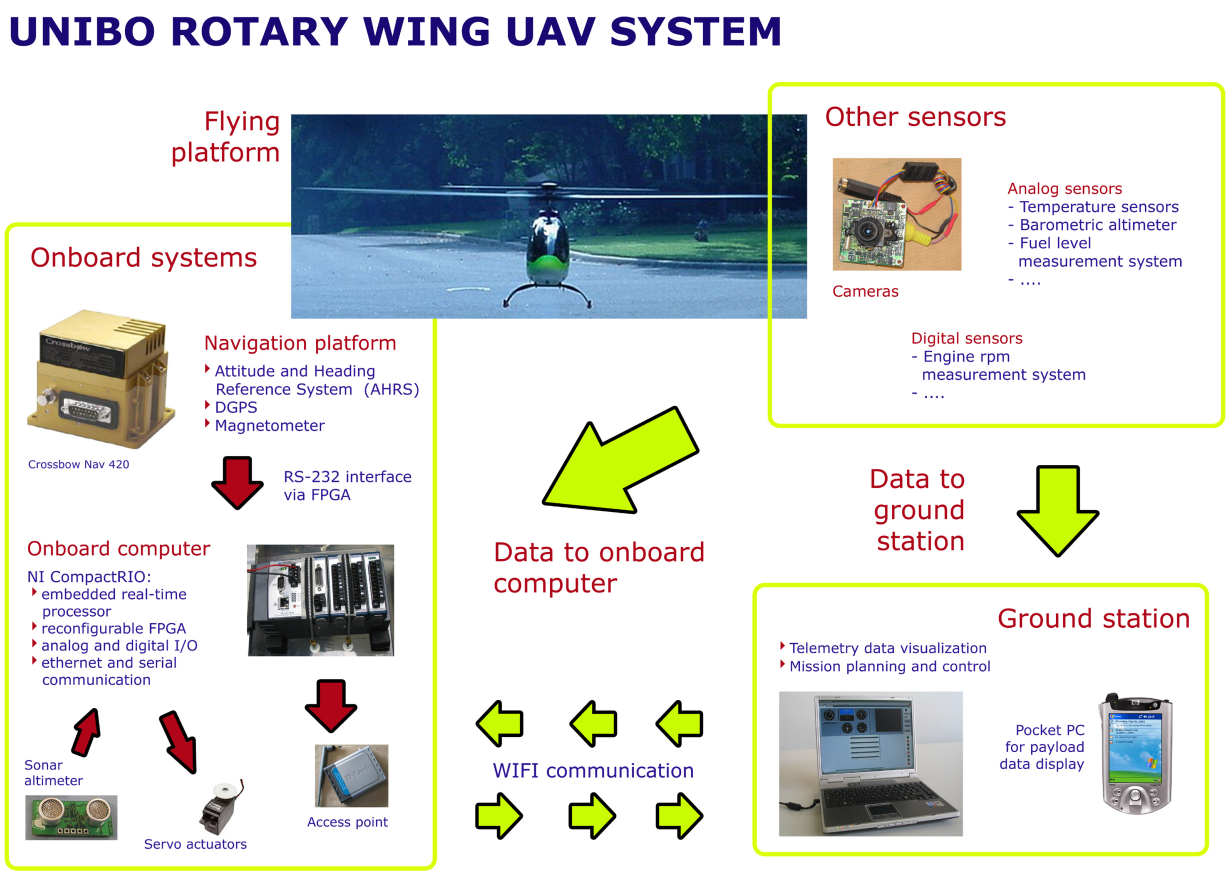

Fig. 1

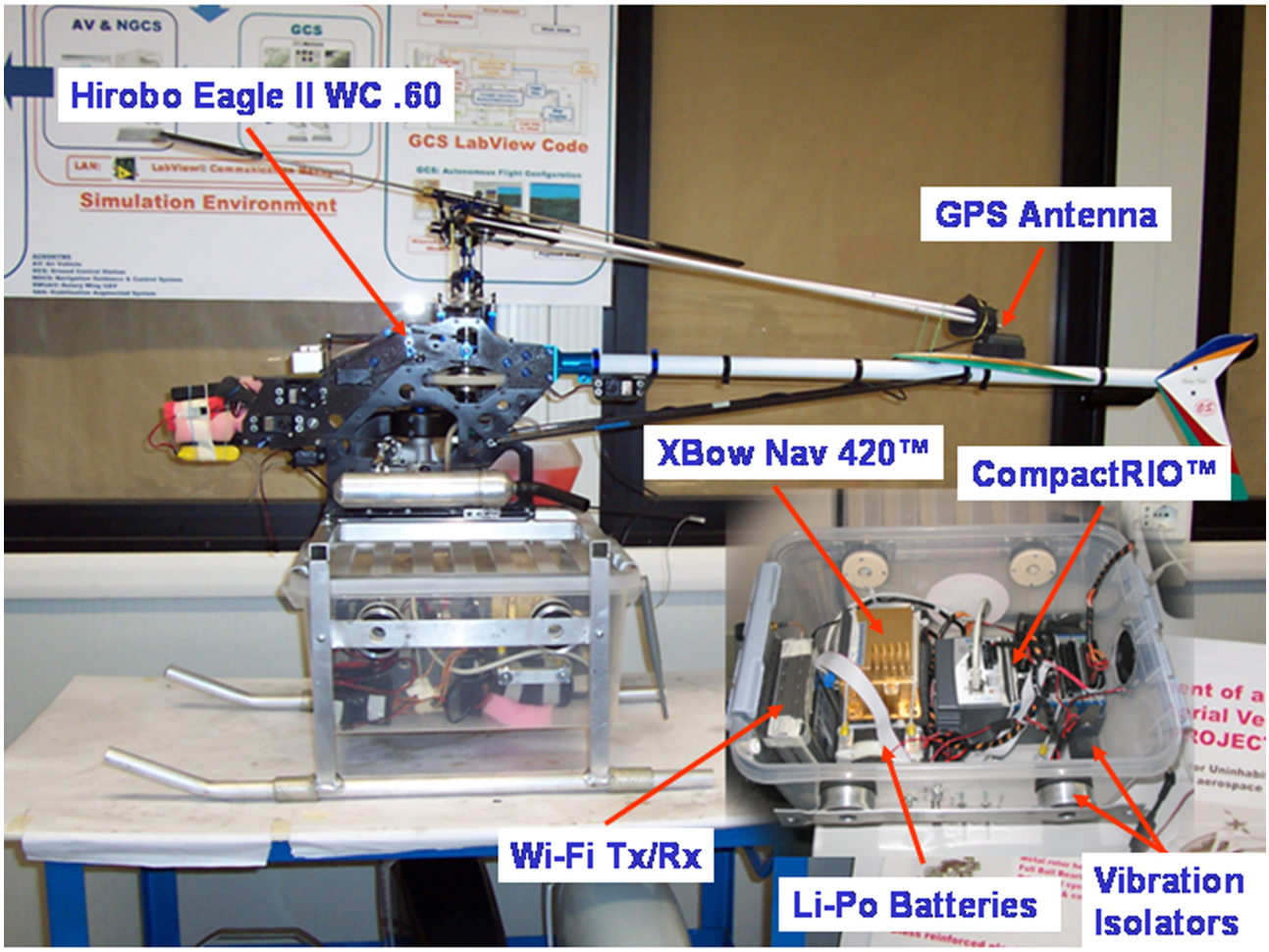

Fig. 2

The CompactRIO works as Flight Computer:

- the CompactRIO FPGA modules acquire sensors information and generates PWM actuator signals based on the control algorithms implemented on it;

- the CompactRIO Real-Time core receives sensor information from the FPGA and records all the flight data; meanwhile it manages also wireless ethernet communication with the ground control station;

Particularly:

· the CompactRIO FPGA receives flight data infornation from the Crossbow NAV420 AHRS (Attitude Heading Reference System) Digital Input cRIO-9411;

· the CompactRIO FPGA receives and sends PWM actuators signals through digital input NI cRIO-9411and output NI cRIO-9474 respectively;

· the CompactRIO acquires system status parameters such as battery voltage by means of the analog input NI cRIO-9201.

The whole system weights about 5 kg which is well within the payload capability of the small scale helicopters available at UNIBO RWUAV laboratories. If bigger helicopter platforms will be available, one or more NI CompactRIO devices could also act as back up and safety systems for the unmanned air vehicle.

Software

Fig.3 shows the LabVIEW code which manages the whole RWUAV system. It has the typical CompactRIO application design architecture. The FPGA code uses four different timed read/write loops and one PID control loop for helicopter attitude control. By now the PID loop is closed at 50 Hz. The write loops send PWM command to the helicopter servo actuators in order to control main rotor cyclics and collective, tail rotor collective and engine. PWM commands are also sent to the slewable stabilized camera mount actuators. The first read loop acquires helicopter attitudes, angular rates, velocities and GPS position from the Crossbow NAV 420 which uses a RS232 protocol; the RS232 protocol has been managed using the FPGA Digital Input to guarantee deterministic data acquisition which couldn't be achieved using a Real-Time application. Another read loop manages PWM commands data acquisition.

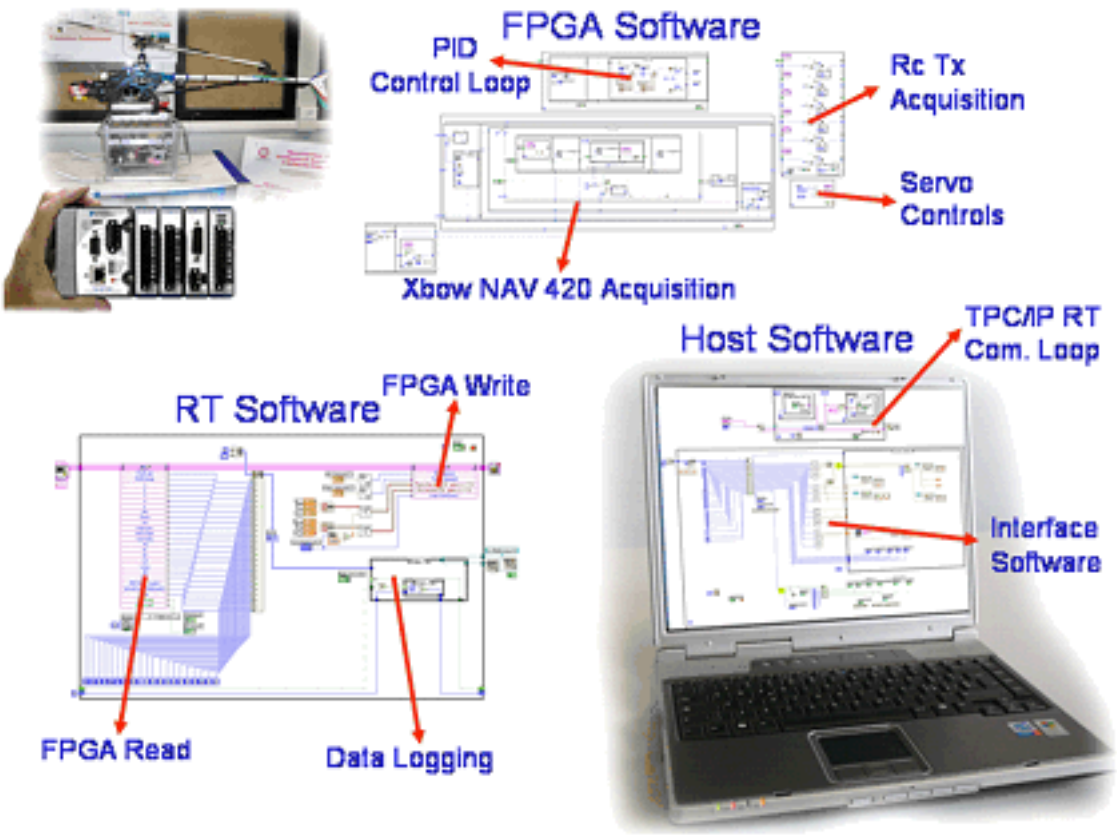

Figure 3

The CompactRIO Real-Time software is used for FPGA data acquisition, embedded flight data logging and wireless Ethernet communication with the ground control station. The ground control station communication is managed by means of the LabVIEW Real-Time communication wizard.

The ground control station software is also developed in LabVIEW for Windows and runs on a laptop computer using Windows XP OS (Host computer). The remote graphical user interface is constituted by two windows (fig 3) the virtual cockpit window and the telemetry window for Real- Time display of flight data information. The first one has been developed using also ActiveX controls, such as aircraft instrumentation available from Global Majic Software House. Additional information are available such as GPS and inertial measurement unit status and system warnings.

Conclusion and Outlook

A rotorcraft UAV is currently under development at UNIBO laboratories as an integrated reconfigurable system for research in control/navigation laws and in rotary wing /fixed wing Unmanned Air Vehicle concept development. A first flight campaign has been performed in order to test onboard sensor data acquisition and PID attitude control system in hovering conditions. The NI CompactRIO proved to be an easy programmable tool and reliable enough for helicopter control. In the near future additional sensors such as sonar altimeters will be integrated into the avionics package. Flight test for more advanced manoeuvres will be performed and navigation algorithms will be implemented in order to build up a fully autonomous rotary wing system.

Products

NI CompactRIO, NI FPGA Module, NI Real-Time Module, NI LabVIEW