Data Acquisition System for an Unmanned Aerial Vehicle

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Abstract

An Unmanned Aerial Vehicle (UAV) finds application in deploying cargo packages to war stricken or disaster affected areas where direct human intervention is not possible. The Society of Automotive Engineers (SAE) conducts an annual competition in the United States of America (USA), wherein the participants have to design and model the UAV according to the rulebook provided to them. The aim of the competition is to have a successful flight and drop an expellable payload on a specified location remotely. This paper discusses the coordination of the Data Acquisition System (DAS) with the Graphical User Interface (GUI) in a time restricted environment to fulfill the aim of the competition. The reliable and compact DAS provides the pilot with valuable information such as air speed, altitude and Global Positioning System (GPS) coordinates of the UAV. GPS, Inertial Measurement Unit, Altimeter and Airspeed modules are interfaced with the Arduino UNO microcontroller. The data acquired is wirelessly transmitted via the XBee radio module to a GUI at the base station. The GUI is specially designed to graphically depict the altitude and track the location of the UAV on an embedded map. The system performed to its fullest and gave the desired result. This innovative and rugged system of ours would give off-the-rack solutions a run for their money!

Keywords: UAV, DAS, UNO

I. INTRODUCTION

During the past 100+ years of aviation history, several innovations have greatly advanced the progress of aviation. These innovations include the radar, the jet engine and the Global Positioning System (GPS). All have served as a catalyst for major expansion in the aviation community. The Society of Automotive Engineers (SAE) is one such organization, which gives budding engineers opportunity to demonstrate their knowledge, ingenuity, teamwork and presentation skills. SAE conducts 'Aero Design Series', which is annually held in the United States of America (USA) since 1986. The competition involves student teams from all over the world designing and fabricating Unmanned Aerial Vehicle (UAV) to perform specified objectives. Depending on the design and event objectives the competition is divided into three classes: Micro class, Regular class and Advanced class. The advanced class of the 2014 edition of SAE involves challenges like designing and fabricating the most efficient of the UAV's in terms of weight and stability. The objective of the advanced class was to design a UAV capable of accurately dropping a three-pound (3 lb) humanitarian aid package from a minimum height of 100 ft from the ground. It also necessitated the design of a Data Acquisition System (DAS) which could record the altitude and assist in the expulsion of the packet using GPS coordinates. The Graphical User Interface (GUI) displayed the readings obtained from the UAV to the pilot.

II. BLOCK DIAGRAM

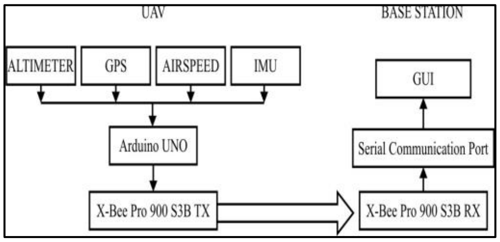

Fig. 1: Block Diagram

GPS and altimeter sensors interfaced with the Arduino UNO microcontroller gathered real-time readings of the UAV's location and altitude. The GPS module is interfaced with Arduino microcontroller using the

UART port. The GPS readings from the sensor were formatted using National Marine Electronics Association (NMEA) convention. The altimeter module uses I2C protocol to communicate with the microcontroller. These readings were transmitted using X-Bee radio modules mounted on the Arduino using X-Bee shield. They provide line-of-sight ranges up to 28 miles (with high gain antennas). At the base station, a X-Bee receiver is connected to the laptop via the COM port. The readings are displayed on the GUI screen. The GUI is equipped with an embedded map plotting the location of the UAV during its course of flight.

III. DATA ACQUISITION SYSTEM

The Data Acquisition System (DAS) consists of the altimeter, MS5607, the GPS module, U-Blox LEA-6H, the Inertial Measurement Unit (IMU), MPU6050, the airspeed sensor, AMP 2.6 MPXV 7002 and the X-Bee Pro 900-HP transceivers.

A. Altimeter Module MS5607:

The DAS design objective states the use of a Data Acquisition System (DAS) to record the altitude (in feet) with a precision of at least 1 feet. The altitude must also be recorded at the time of release of the expellable cargo.
The following requirement was implemented using the Parallax altimeter module MS5607. The MS5607 module includes a pressure sensor and a temperature output and can be used for implementing an altimeter.
The features of the module are given as:

- High resolution : 20cm
- Pressure range : 10 to 1200 mbar
- Supports I2C and SPI communications
- Power requirements : 3.3 to 6.5 VDC
- Dimensions : 0.85 in x 0.80 in
- Weight : 5 grams

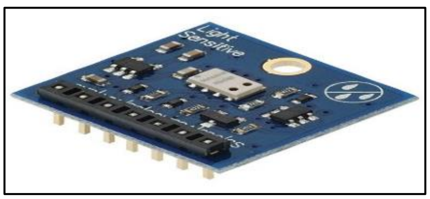

Fig. 2: Parallax MS-5607 Altimeter Module

Owing to its low weight, small dimensions and high resolution, the particular module was found to be suitable for use in the UAV.

B. U-blox LEA-6H GPS Module:

The rules do not specify the requirement of a GPS module. The GPS module has been incorporated into the system to obtain the real-time location co-ordinates of the UAV with respect to a set reference point. The on-field GPS coordinates of the target helps in determining the course of UAV to the drop point. The module has been selected for the following features:

- 5Hz update rate
- High precision-2.5m accuracy
- Super Sense® Indoor GPS: -160 dBm Tracking Sensitivity
- Dimensions: 37x37x9mm
- UART, USB and DDC (I2C compliant) interfaces

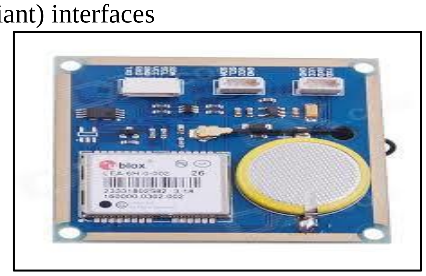

Fig. 3: GPS Module Consisting of U-Blox LEA 6-H

The GPS module can also be used in weak signal environments. The antennae should be exposed to the sky to get proper locking of the GPS module.

C. Inertial Measurement Unit- MPU6050:

The InvenSense MPU-6050 sensor incorporates an MEMS accelerometer and a MEMS gyro on a single chip. It is very accurate, as it contains 16-bits analog to digital conversion hardware for each channel. Therefore it captures the x, y, and z channel at the same time. The sensor gives 6 Degree of Freedom (DOF), 3 DOF for the accelerometer and 3 DOF for the gyroscope. The sensor uses the I2C-bus to interface with the Arduino.

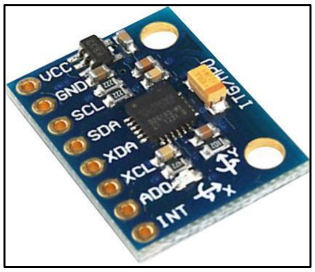

Fig. 4: IMU MPU-6050

The MPU 6050 was selected as a part of DAS because of its precise reading and updating process. It gives the Yaw Pitch and Roll of the UAV with respect to a predefined point. This helps us in understanding the flight in a 3-dimensional manner.

D. Air Speed Sensor AMP 2.6 MPXV7002:

The MPXV7002 series piezoresistive transducer in the small outline package (SOP) is a state-of-the-art monolithic silicon pressure sensor designed for a wide range of applications, but particularly those employing a microcontroller or microprocessor with A/D inputs. This patented, single element transducer combines advanced micromachining techniques, thin-film metallization, and bipolar processing to provide an accurate, high level analog output signal that is proportional to the applied pressure.

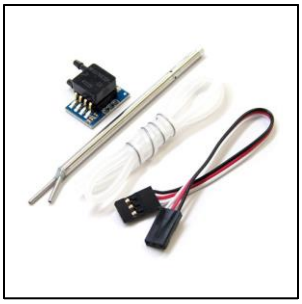

Fig. 5: Air Speed Sensor AMP 2.6 MPXV7002

The MPXV7002 is designed to measure positive and negative pressure. In addition, with an offset specifically at 2.5V instead of the conventional 0V, this new series allows to measure pressure up to 7kPa through each port for pressure sensing and also for vacuum sensing.

E. X-bee Pro 900-HP:

The rulebook states that the telemetry system should not use 2.4GHz frequency. For this reason, we have chosen X-Bee Pro 900 HP.
Frequency band: 902 to 928 MHz
Data Rate: 10 Kbps or 200 Kbps
Data Interface: UART (3V), SPI

Fig. 6: X-bee Pro 900-HP

The processed data obtained from the Arduino is transmitted to the base station via the XBee modules. The X-Bee usually sends data to the computer terminal. But when the package is to be deployed i.e., the "Fire" button is pressed on the GUI, the X-Bee module works in full duplex mode.

F. Arduino Uno microcontroller:

The features of Arduino microcontroller are given below.

Table -1
Arduino Microcontroller

Microcontroller	*ATmega328*
Operating Voltage	*5V*
Clock Speed	*16 MHz*
Digital I/O Pins	*14 (of which 6 provide PWM output)*
Weight	*28 grams*

The Arduino is an inexpensive, easy-to-use microcontroller board. Its flexible programming environment provides the user the freedom to program either in Java, C++ or C language. With various libraries available online, the Arduino is one of the most sought after microcontroller boards available in the market. The Arduino is powered using Turnigy 1000mah 3S 11.1V Li-Po battery.

Fig. 7: Arduino Uno Microcontroller

IV. GRAPHICAL USER INTERFACE (GUI)

Sensors from the DAS system were used for gathering real-time readings of the UAV's position and altitude and was interfaced with the Arduino board. The readings obtained from the sensors were transmitted using XigBee Pro transmitters which were mounted on the DAS box in the UAV. The XigBee receiver was connected to the USB port of the base station system.

Our base station is hardware independent and could be made executable on any browser as scripting languages such as HTML5, JavaScript and AJAX is used. The data transmitted from the UAV is collected at USB ports hence, Serial Communication synchronization was essential with XigBee Pro recieat the UAV. The serial data would be gathered from communication ports using codes written in the java language using rxtx2.1 package libraries. The NMEA string received from the DAS box would then parse into categories to obtain latitude- longitude and altimeter and thrash garbage data if any. The essential data from the code would then be interfaced on the GUI, which is built using Java Swing framework. The GUI was embedded with the real-time location of the UAV along with the accurate tracker using Google Maps.

For tracking the UAV's position, AJAX was used, so that we could implement Google Maps v3.1 API and reduce the asynchronous refreshing of the maps. The scripting of Google Maps was done using JavaScript, it uses conventional markers from the maps API to represent the current instance of the UAV, depending on which the probable target zone would be mapped using projectile and cosine equations. The 'target zone' would dynamically alter with respect to the current cruise speed and direction of travel of the UAV. Hence it was daunting to achieve hard real-time synchronous communication with the UAV's DAS box and the base station, which required elimination of redundant delays occurring.

Signals also needed to be transmitted from the base station to the UAV for releasing the package. Transmission of signals from the base station was used to deploy the expellable payload cargo from the UAV, whenever the UAV was accurately tracked in the 'target zone' of the maps at the base station. Hence, the base station would serve as the secondary pilot for navigation and deployment of cargo. Also, to assist the pilot whilst deployment of cargo, the altimeter readings were plotted on a 2 Dimensional Cartesian graph for projection of the reference height of the UAV. We also needed to store the value of air speed and altitude once we deploy the package. Hence, we used the 'Fire' button on the UAV to freeze and store the required value on clipboard. Thus the GUI assists the navigation for the UAV, also the ease of user interface allows novice flyers to pursue flying under the purview of the safety norms. Our system coagulates with the latest technologies to make flying of Unmanned Aerial Vehicle simpler and safer. The picture below depicts the GUI of the UAV.

Fig. 8: Graphical User Interface (GUI)

V. FUTURE SCOPE AND CONCLUSION

The Data Acquisition System (DAS) has applications in defense like targeted deployment, surveillance etc. Image processing can be used in drones for video surveillance of target areas and acquiring various parameters of the surrounding target area like temperature, air speed etc. For UAV the DAS can help the pilot with the orientation with respect to the horizon and also can run the UAV in Autopilot by using a 9DOF IMU whose feedback will help in balancing and the GPS co-ordinates will help in auto-navigation from point-to-point geographic locations.

In future the DAS can be built to carry out thermal imaging of target area to know information of existence of living beings with the help of image processing and also carry out facial recognition of unidentified humans in disaster prone area and also can be advanced to gain full information of missiles or various drones that are being fired in the air at that moment. It can also be used to pick and drop objects from one place to other like dropping food/medical packets in disaster prone areas where manned aircrafts cannot enter. The DAS has been built to survive crashes and send information even after a crash.

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