Proposal for Ground Shipping High Volume of Data Parameter in Supersampling Unmanned Aircraft Through Radio Modem

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***Abstract*—In an unmanned aircraft, large volumes of data are generated by the various sensors installed on the aircraft. At critical moments such as take-off, landing, parachute openings, or when the aircraft performs sudden maneuvers, additional parameters besides the default need to be sampled in order n to understand completely the behavior of the aircraft. We propose different alternatives for sending multiple data to land at sampling frequencies of up to 10 Hz at critical times Preliminary results are presented for the most extreme case, that is using full RS-232 bandwidth for the six most important parameters resulting in 210 samples per second for each parameter.**

Keywords-Information retrieval; unmanned aircraft; data processing; sensors; radio modem

I. INTRODUCTION

INTA is the Institute for Aerospace Technologies in Spain and flight tests have been part of INTA's activity since it was created in 1947. With the objective of upgrading such activities and modernizing its facilities, INTA created the Flight Test Area, Area de Ensayos en Vuelo (AEV) [1], AEV is responsible for providing flight test support for all current and future programs including RPV (Remotely Piloted Vehicle), Rocket Launches, Balloons and Missile Tests.

The problem is that that during critical moments, data from several sensors needs to be transmitted at rates in excess of 10 Hz which is not possible given the limitation of bandwidth that radio modem communications presents. To solve this problem, software alternatives are considered. These are one-dimensional array based on differentiated values, two-dimensional array with a fix number of rows and columns and time stamp, two-dimensional array with time stamp and parameter identification label, and finally two-dimensional array with time stamp, parameter identification label, controlling the last value sent. The paper starts with a description of the problem followed by the methodology used to arrive at the solution. Finally, a few preliminary results with the obtained conclusions are shown.

II. STATE OF THE ART

Currently, INTA is working on various unmanned aircraft under development such as SIVA (*Integrated System for Aerial Surveillance*), ALO (*Lightweight Observation Air Vehicle*), DIANA (*High speed target dr*one) and HADA (*Morphing VTOL Aircraft*) among others. In large UAV´s like SIVA (weight 300 Kg and wing span 5.81 m), data acquisition systems (DAQ) allow sending thousands of data samples per second of any parameter to ground in pulse code modulation (PCM) [2] format by using S-band telemetry frequency. However, in smaller UAV's like ALO shown in Figure 1 (weight 50 Kg and wing span 3.48 m), it is not possible to integrate a DAQ due to small payload. In such a case, it is necessary send data to ground using radio modems, with a frequency of ten samples per second for all sample parameters. The proposal presents alternatives to allow sending samples at a rate of more than ten times per second in critical periods for small UAVs that need ot use radio modems. In such a way, it will be possible to know the aircraft behavior and validate it using simulation.

Figure 1. ALO unmanned aircraft

Initially, the data types of parameters used for shipping are 32-bits floating points or 16-bits integers. The input data for each sensor is written in a memory buffer and then sent to earth using a specific frequency (ten samples per second). Parameters are not grouped hierarchically and each one is sent using the same sample rate [3]. Some data parameters are sampled by the onboard computer at frequencies up to 450 samples per second, while other parameters are sampled at a lower rate (e.g., one per second for GPS).

The idea of storing data on the aircraft is not feasible due to the process for managing interruptions used by the operating system that could result in a possible loss of data in real time**.** The final storage of data on land is the only feasible option. Fig. 2 shows a block diagram representative of the various elements that act on the aircraft, with the central part based on a control computer, along with their input chains, demand measures and associated communications.

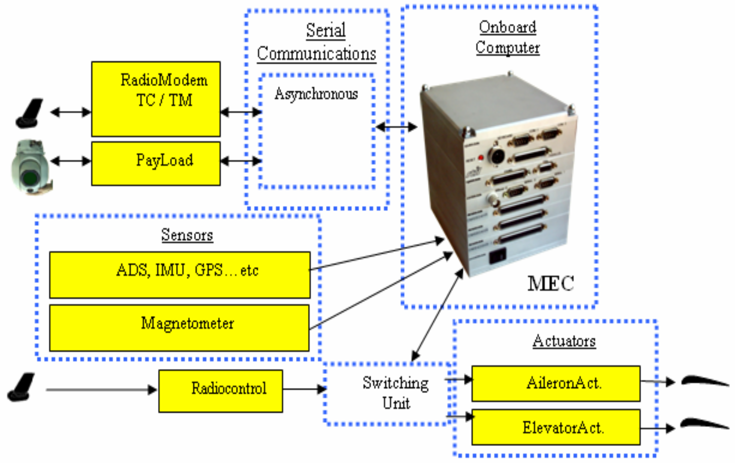

Figure 2. System onboard

III. METHODOLOGY

The objective is to investigate the features of the different models proposed, which will provide knowledge about what happens on certain aircraft sensors that suffer substantial alterations in its physical measures at critical moments. This process can be broken down into the following steps:

A. **Analyze the initial conditions**: parameters, frequencies of transmission, limits of communications, data storage and display; 280 bytes were sent in parameters 32 and 16 bits length, and 19 bytes of payload (camera) as the focus or zoom, which makes an approximate size of 300 bytes, every 100 milliseconds. This is a guaranteed rate for a RS-232, modem, but for reasons of data loss in communications (distance, weather conditions, etc.), it is not advisable to exceed this rate.

B. **Identify critical moments and the variables concerned**, establishing a proposal for grouping variables based on objective criteria. As an initial proposal, the parameters are grouped into three categories, the first (most important) contains those parameters that require a very high sampling and also with a high changing capacity on their values per time unit (e.g., acceleration and angular velocity). A second group includes those parameters that may require sampling rates of 10 Hz such as measured angles of attack, pitch, yaw and roll. The other parameters would be part of the group with lower necessities of sampling frequency.

C. **Define strategies** to establish optimal mechanisms for approaching the desired goal, which is to obtain more information about certain parameters at critical moments. Experimental as well as quantitative methods will be used. A toolkit that approaches and solves the problem will be designed. Prototypes will be developed using a specific programming language for each alternative to allow for a comparative analysis of the different designs and techniques.

The techniques used for this proposal lie in the combination of the following fields or areas:

- Standards of measurement processes and data acquisition [4].
- Transmission of information via radio modem [5].
- Mechanisms of compression techniques based on data compression standards [6].

According to CVT (Current Value Table) technology, each sensor stores the sampled value on a cell, overwriting the previous value, and each sensor has a different sampling frequency. A process is activated and traverses all the cells, building an image of the values found at that moment. Using pointers and information about the order of the parameters (32-bit floats or 16-bit integers), the pointer moves through all the parameters to capture in a one-dimensional array the set of all values that are subsequently sent to land via radio modem, a transmission format of 8, n, 1 (8 data bits, no parity and one stop bit). This process is repeated ten times per second; when information is received on land, decoding is simply done in an analogous way. The proposed approach entails replacing the one-dimension array with a two-dimensional array with a variable number of rows and columns, depending on the different types of techniques. This array will also contain time stamps that will indicate the moment corresponding with the value sampled by the sensor. This is concept missing nowadays, because of the linearity used for the land consignment of the resulting array. The variability of a two-dimensional array can be done in real time, either automatically, so that it can be integrated into the onboard computer program of the flight to be done by the aircraft, or manually, by sending signals from the ground through the radio modem. Independently of the format of the cell in rows and columns, land transmitting will be done in the same way as a PCM (*Pulse Code Modulation*) stream, going trough the array and sending the values byte by byte via RS-232.

The approach will start in a basic form and progress to increasing levels of complexity, reaching the best solutions for specific needs. For the early stage, the value of the parameters of the most important category are sent as along with the average between time units using functions specifically designed for this purpose (with optional insertion of timestamps). We can then proceed to defining a different array, mixing several values of the three categories, adding more values of the first category and less parameters of the last category. Each parameter will have a time stamp (either the measured values or the average between instances). Finally, at more complex stages, compression-based techniques for sending data values will

 ISBN: 978-1-61208-165-6

be considered (e.g., using differential values, similar to sending data using differential PCM).

IV. PRELIMINARY RESULTS AND CONCLUSIONS

As preliminary results, we present a graph obtained in the initial tests performed on a simulation with data array generation which corresponds to angular acceleration on the aircraft x body parameter [7] (cataloged on the first class or category). Fig. 3 presents the variation of this parameter in a wide period of the flight. Data circled is the basis for Fig. 4 that presents the values of the parameter every 10 milliseconds, thus offering more detail. Finally the resulting graph (Fig. 5) is obtained in the most extreme case, that is, using full RS-232 bandwidth for the six more important parameters, resulting in 210 samples per second for every parameter. It can be observed, that some parameter variations are not obtained using 10 samples per second. And it is necessary to know that during post-processing, these unobserved variations can appear using an increased data rate. Information about 6 parameters has been sent but there are 33 and therefore, there is not information about the other 27. Subsequent proposals should have the goal of sampling all the parameters, at a frequency rate depending on the category of the parameter, trying to find a balance between information loss for every parameter and the additional data variations obtained for more sensitive ones.

Further research is based on an approach using alternative methods, as to develop 2D array with different sample rate and timestamps, as explained earlier. At this second stage, it is necessary to use some techniques similar to those of a differential PCM for not-so-important important parameters: sending a first value with 32 bits of accuracy and the next ones using 16 or even 8 bits, not with the value but with an offset in relation to the first or previous record. In such a way some bits could be saved, so that more samples of important parameters could be obtained.

A final approach could be two-dimensional array with a fix number of rows and columns. Each row will also contain timestamps that will indicate the instant that corresponds with the value sampled by the sensor.

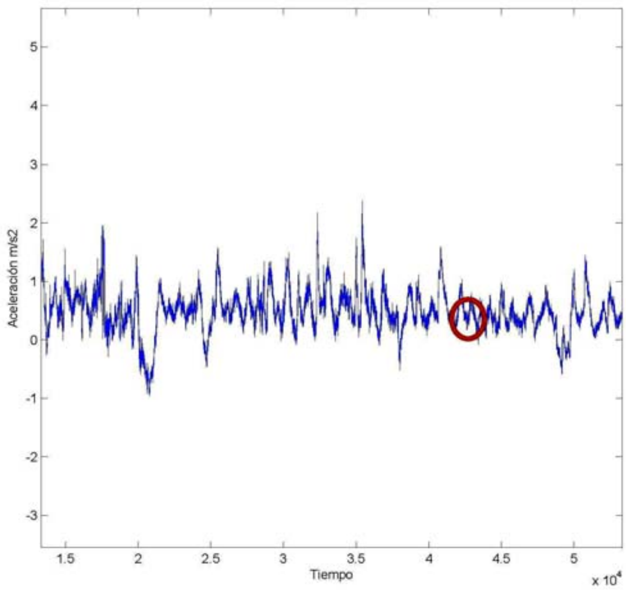

Figure 3. Acceleration in the x-axis (full flight)

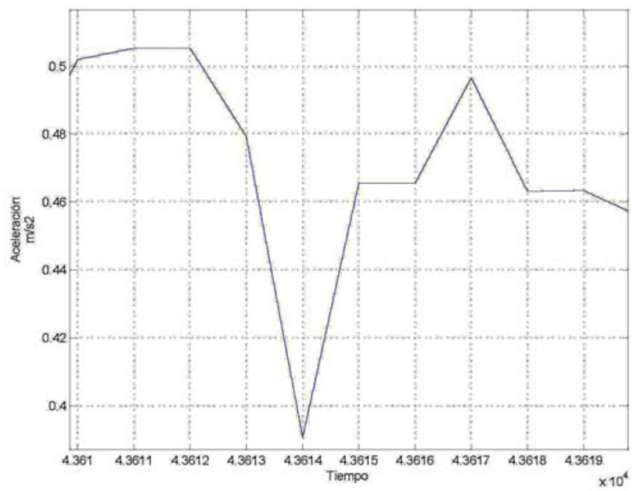

Figure 4. Extension of section marked in Figure 3

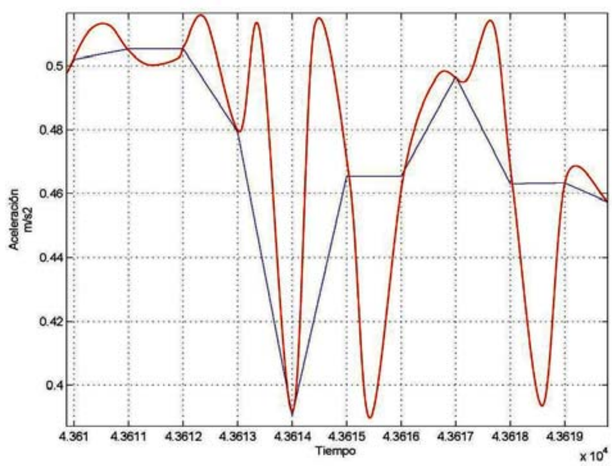

Figure 5. Values obtained

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