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Exploiting Artificial Intelligence for Analysis and Data Selection on-board the Puerto Rico CubeSat

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Abstract

CubeSat missions are constrained by the limited resources provided by the platform. Many payload providers have learned to cope with the low mass and power but the poor telemetry allocation remains a bottleneck. In the end, it is the data delivered to ground which determines the value of the mission. However, transmitting more data does not necessarily guarantee high value, since the value also depends on the data quality. By exploiting fast on-board computing and efficient artificial intelligence (AI) algorithms for analysis and data selection one could optimize the usage of the telemetry link and so increase the value of the mission. In a pilot project, we attempt to do this on the Puerto Rico CubeSat, where science objectives include the acquisition of space weather data to aid better understanding of the Sun to Earth connection.

1. Introduction

We focus on detecting and investigating strong natural [1] and artificially induced [2] radio emissions in the Earth's ionosphere. Artificially induced emissions are driven by a high-power radio transmitter on the ground and occur only in the antenna beam. Natural emissions occur unpredictably over long periods of time in the auroral zones and possibly at the equator. The Puerto Rico 3U CubeSat (Figure 1) will carry two scientific payloads: CARLO (Charge Analyzer Responsive to Local Oscillation), which is a Faraday cup designed to measure ion turbulence from 0 to 10 kHz, and GIMME-RF, which consists of four electrically short monopole antennas and a miniaturized digital receiver for measurement of radio waves in the 0 to 30 MHz range.

2. On-board signal processing

The GIMME-RF receiver incorporates massively parallelized hardware for digital signal processing at up to 2 TFLOPS [3]. The four antenna inputs, filters, amplifiers, and 14-bit 250 MHz ADCs are located on a carrier board, with a processor daughterboard on one side and a science module on the other. GIMME-RF can accommodate internal data rates of up to 40 Gb/s and we expect to collect about 5 Tb of data per orbit. This is a factor 10^6 to 10^7 larger than the amount of data that can be transmitted to ground. AI methods and techniques will therefore be used to automatically identify and select interesting events. In addition to using well-known spectral characteristics to classify the signals, we will take full advantage of the instrument's capability to measure the 3D electric field vector, which, in turn, makes it possible to characterize the radio emissions in terms of the four Stokes parameters and to perform direction finding. The AI algorithms, and specifically Case-Based Reasoning, designed to learn from examples [4], will be used to separate uninteresting data from interesting data. Also, knowledge discovery algorithms [5] will be used to detect new interesting features in data. After automatic classification, an importance ranking will determine which data to transmit to the ground. The CARLO and GIMME-RF payloads are complementary instruments, as CARLO will measure low-frequency plasma turbulence, which affects radio propagation in the high-frequency radio band. Radio data can therefore be correlated with ion turbulence data from CARLO and subsequently, on the ground, with geophysical data from instruments such as radars, magnetometers, and optical imagers.

3. Summary and Conclusions

By using fast on-board computing and state-of-the-art AI algorithms, we intend to increase the science return of the Puerto Rico CubeSat mission, expected to be ready for launch in 2017. The methods and technologies developed in this pilot project could have applications in future planetary and interplanetary CubeSat missions, where telemetry is likely to remain a bottleneck.

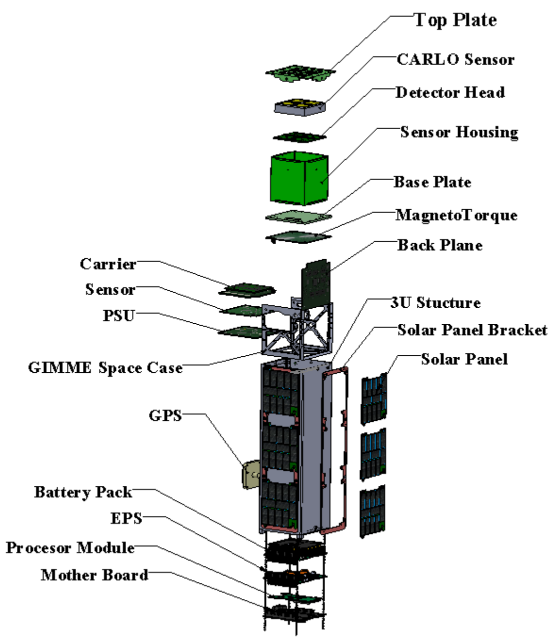

Figure 1: Exploded view of the Puerto Rico CubeSat.

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