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Towards autonomous spacecraft operations using machine learning

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Introduction

There is an increasing desire in many organizations, including NASA and therefore the DoD, to use onboard decision-making to accomplish complex mission objectives. The Air Force lab (AFRL) has initiated the TechSat 21 program to function an indication mission for a replacement paradigm for space missions. This paradigm seeks to scale back costs and increase system robustness and maintainability by using onboard autonomy to enable faster response times and improve operations efficiency. TechSat 21 is scheduled for launch in January 2006 and can fly three satellites during a near circular orbit at an altitude of roughly 550 Km. the first mission is one-year long with the likelihood for an extended mission of 1 or more additional years. During the mission lifetime the cluster of satellites will fly in various configurations with relative separation distances of roughly 100 meters to five Km. one among the objectives of TechSat 21 is to assess the utility of the space-based, sparse-array aperture formed by the satellite cluster. For TechSat 21, the sparse array are going to be wont to synthesize an outsized radar antenna. Three modes of radar sensing are planned: synthetic aperture radar (SAR) imaging, moving target indication (MTI), and geo-location. The principal processor onboard each of the three TechSat 21 spacecraft may be a BAE Radiation hardened 175 MIPS, 133MHz PowerPC 750 running the OSE 4.3 OS from Enea Systems. OSE was chosen because it's inherently message passing based and particularly suitable for distributed applications. Each satellite will have 256 Kbytes of EEPROM for boot loads and 128 Mbytes of SDRAM.

Communications are going to be through a Compact PCI bus. Many various capabilities are used synergistically to enable the spacecraft to behave as an autonomous exploration agent. In our agent architecture, ASE allocates responsibilities both supported abstraction level and domain (e.g., same level of abstraction but a selected discipline like science or maneuver planning). Specifically, each of the software components has responsibilities as follows. First, for the areas of science decision-making and maneuvers, responsibilities are delegated supported the discipline involved. All of the processing and analysis of science data analysis is performed by the Onboard Science software. This design is sensible because the science processing we are performing is extremely specialized image processing and pattern recognition and requires special purpose algorithms. Because this is often primarily a batch process, there's no real-time decision-making component to the Onboard Science software. However, this is often a TechSat 21 specific distinction. Many other autonomous science missions may need a real-time science component, like to rapidly detect a really short duration science event (such as a supernova) or to regulate a science instrument rapidly supported science analysis. The Observation Planner software is employed to reason about maneuvers, determine when a target are often observed, and determine when communication with the spacecraft is feasible. Again, this architecture is chosen because this decision-making capability relies on highly specialized reasoning algorithms to attenuate fuel consumption and to reason geometrically about orbits and orbital dynamics. During this case there's both a plantime and real-time execution component.

OBSERVATION PLANNING SOFTWARE

The Observation Planner (OP) interfaces to flight software that automatically determines the present spacecraft position and orbit. This software uses GPS signals to very accurately pinpoint the situation and velocity of the TechSat 21 constellation. Onboard, the OP features a potential observation target list. Periodically, it takes the present orbit solution and simulates forward to predict over flights for subsequent 15 days of every and each potential target. These over flights are then employed by CASPER as observation opportunities when planning future science observations. 7. ASE AND MULTI-AGENT SYSTEMS While TechSat 21 may be a multi-spacecraft constellation, ASE isn't a multi-agent system. within the ASE architecture, the constellation is treated as one agent, with each of the spacecraft being a redundant subsystem. On one spacecraft, the "master" spacecraft, CASPER is running so as to perform the design (and replanning) for the whole constellation of three spacecraft. The plans developed on the "master" spacecraft are sent on to the opposite two "slave" spacecraft. due to this architecture there's no decentralized coordination problem. While there's significant interest in multi-agent coordinating spacecraft at NASA (Clement, et al., 2001), for the TechSat 21 mission, use of a multi-agent, distributed architecture was viewed as too risky for flight at this point . 8. RELATED WORK AND CONCLUSIONS In 1999, the Remote Agent experiment (RAX) (Remote Agent, 2002) executed for a couple of days onboard the NASA region One mission. RAX is an example of a classic three-tiered architecture (Bonasso, et al., 1997), as is ASE. RAX demonstrated a batch onboard planning capability (as against ASE's continuous planning) and RAX didn't demonstrate onboard science. RAX also included an earlier version of the Livingstone and Burton mode identification and fault recovery software.

Abstract

Space exploration democratization is largely due to open source developments of small satellites (e.g. Cubesats, 10x10x10cm cubic satellites). One of the critical near future need for space exploration is scaling up spacecraft operations to be able to manage tens of thousands of satellites; literally multiple robots in space with complex dynamic systems. The Polaris project is fully open source, it aims at analyzing robotics systems telemetry, learning from it, keeping operators aware, and generating knowledge transferable to different missions with similar robotics assets.

This project comes in threefold: fetching and normalizing data from radio signals collected by the SatNOGS stations (200 open source ground stations across the world), machine learning models to have dependencies analysis, timeseries contextual behavior segmentation, and predictions for anomalies prevention, and in the end data visualization to explain the machine learning models and provide widgets for situational awareness of operators.

In this talk, I will go over the developed machine learning models and how we track dependencies between telemetries and how graph visualization permits us to navigate high dimension dataset. I will share the steps we are following to compose future autonomous satellite operations and monitoring and how being open source plays an essential role.

Conclusion

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Biography

Red Boumghar is PhD in Robotics and Embedded Systems. After working 10 years as researcher in the robotics and satellite imagery industry, he followed different entrepreneurship projects about data analytics for the Internet of Things. Taking position at the European Space Agency for developing artificial intelligence tools for spacecraft operations, Red became a mentor at the NASA Frontier Development Lab, an AI Accelerator to solve space challenges. As community leader, Red managed the development of several machine learning applications in the central banking systems. He acts as a keynote speaker and startup adviser. Red is now a core contributor at the Libre Space Foundation, creating advanced open source assets for the development of humanity in space, in a fair and ethical way.