

An Architecture for Monitoring and Anomaly Detection for Space Systems

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ABSTRACT

Complex aerospace engineering systems require innovative methods for performance monitoring and anomaly detection. The interface of a real-time data stream to a system for analysis, pattern recognition, and anomaly detection can require distributed system architectures and sophisticated custom programming. This paper presents a case study of a simplified interface between Programmable Logic Controller (PLC) real-time data output, signal processing, cloud computing, and tablet systems. The discussed approach consists of three parts:

- First, the connectivity of real-time data from PLCs to the signal processing algorithms, using standard communication technologies.
- Second, the interface of legacy routines, such as NASA's Inductive Monitoring System (IMS), with a hybrid signal processing system.
- Third, the connectivity and interaction of the signal processing system with a wireless and distributed tablet, (iPhone/iPad) in a hybrid system configuration using cloud computing.

This proposed configuration allows for back-and-forth interactivity between tablet logic, standard signal processing systems, PLC logic, and remote aerospace system hardware. The application of tablet computing in the cloud can provide flexibility of operations in spacecraft systems. Astronauts can use tablets as a mobile device for monitoring and visualization of space hardware. The tablet can work as a display interface, while all computing and processing is done in the cloud. The preliminary study will involve a case of the propulsion system of a spacecraft.

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INTRODUCTION

The ability to interface real-time instrumentation data from remote hardware to local data analysis systems is important and essential in the space industry. NASA, for example, is currently developing efficient systems to interface with real-time data for command, control, and monitor of rocket and supporting hardware systems. Kennedy Space Center (KSC) uses Allen-Bradley PLC-based control systems to interact with remote hardware at launch PAD: cryogenic, pneumatic, sound suppression, and other hardware subsystems. Since PLCs can utilize OLE For Process Control (OPC) communication protocols to interact with remote systems, using signal processing applications that are OPC-capable can greatly enhance the monitoring, processing, and

data analysis of remote aerospace hardware signals and industrial processes [4].

The advantage of the architecture discussed in this research is that by incorporating analysis and monitoring algorithms such as Inductive Monitoring System (IMS) [3], neural networks, and recent advances in deep learning, within the architecture's signal processing system- engineers have a flexible and powerful end-to-end data analysis and monitoring system for instrumented remote aerospace hardware.

Space Launch System (SLS) rocket engine RS-25 data, for example, can be received and analyzed by the proposed system/architecture during testing and launch countdown operations. Space station hardware may also be wirelessly monitored by distributed remote tablets interfacing with the

proposed architecture. Anomaly detection and advanced monitoring systems are key capabilities for future human missions beyond Earth orbit.

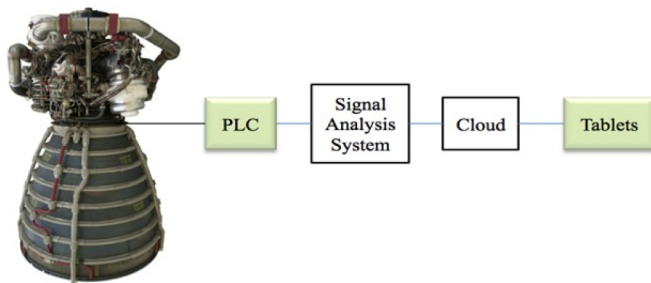


Figure 1. RS-25 Engine Data Analysis and Monitoring

The following sections describe a Hybrid Architecture for Monitoring and Anomaly Detection of Aerospace Systems (HAMADAS.)

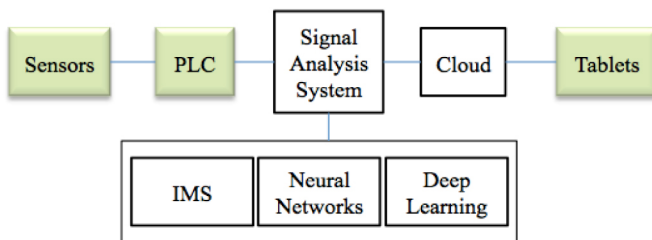


Figure 2. HAMADAS

Figure 2 shows a simple architecture to interface remote aerospace hardware systems controlled by PLC with a data processing/analysis system using OPC technology. The configuration also provides wireless connectivity with tablets via cloud computing. Ultimately, the architecture enables a two-way communication between the distributed tablets, analysis system, PLC, and remote aerospace hardware.

HYBRID ARCHITECTURE

HAMADAS encompasses hybrid systems within different layers of the design. In the signal/data analysis system layer (Simulink and MATLAB, Figure 3) the implementation of data processing and analysis logic, using different types of languages to process PLC data, provides a flexible and expandable mechanism for engineering analysis. Using C++ language legacy routines as well as MATLAB routines inside of a Simulink model creates a hybrid model that combines three programming languages: Simulink graphical, MATLAB scripting, and C++. This configuration takes advantage of a large array of analysis functions, visualization, anomaly detection, pattern recognition, and built-in tools available in different programming languages within Simulink models.

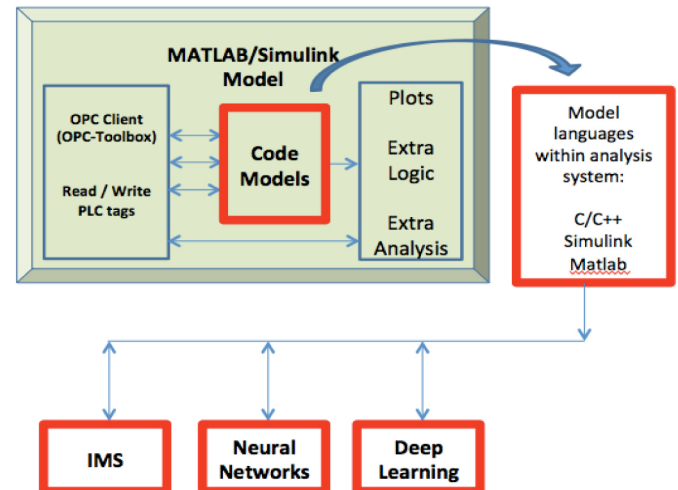


Figure 3. Hybrid Languages within Signal Analysis System.

The distributed layer (Figure 4) allows for the interface of tablets and PC's with hybrid operating systems. This research tested tablets using cloud Dropbox API's [8], which were iOS operating system native. However, APIs are also available for the Android platform. Dropbox API's were implemented in an iPad/iPhone application that was written to access and display data vectors from files within the cloud.

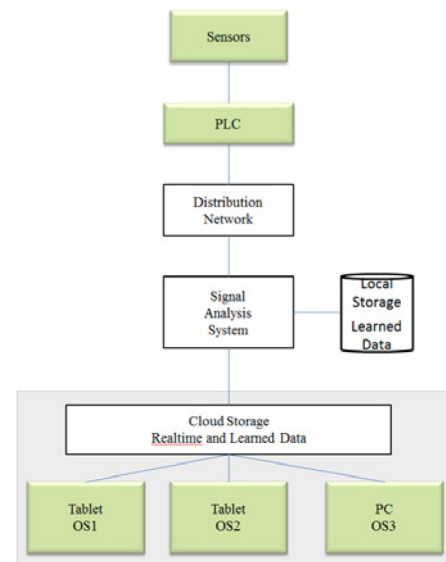


Figure 4. Hybrid Operating System: Remote Tablets and PC's.

SIMULATION

The four basic system components of HAMADAS are instrumented hardware, PLC, signal analysis, and remote tablets. This architecture, however, can be prototyped and tested even when real instrumented space hardware and