Data Analytics for Industrial Control Systems

Abhit Patil, on behalf of BE-ICS and Siemens openlab collaboration
Subprojects

• Openlab seventh phase: 2021-2023
  • Device Monitoring
  • Edge Computing
• Openlab eighth phase: 2024-2026
  • Device Monitoring (Continued)
  • Industrial co-pilot
Collaborative model

• Siemens provides the latest solutions to tackle challenges at CERN.
• CERN’s complex control infrastructure is a testbed for evaluating and refining these solutions.
• Siemens product owners receive feedback, enabling them to modify or add new features.
• We co-develop prototype applications that integrate with various Siemens tools
Device Monitoring
Objective

- Monitor & Diagnose large array of heterogenous industrial control devices
- Two main components
  - Data Aggregation
  - Data Visualization
- Aggregation
  - Collect and consolidate device diagnostics info in real-time
- Visualization
  - Visualize the entire system’s status in an intuitive manner
Challenges

- **Autonomy leading to heterogeneity:** The engineering teams responsible for their control system select the PLC models and software frameworks.

- **Limited Influence:** Our group, BE-ICS, provides centralized service and product recommendations but cannot make procurement decisions.

- **Lack of standardization:** The teams develop their code independently and hence BE-ICS cannot enforce uniform standards for diagnostics.
Example scenario

- During upgrades, cooling & ventilation engineering team decides to procure several S7-1500 PLCs
- They develop the control code using frameworks developed by BE-ICS
- They do not transfer diagnostics information to PLC data block, preventing it from being transmitted northbound
- Consequently, a monitoring agent based on reverse-engineered library, has to be used to retrieve diagnostic information
Monitoring agents

• Different methods for extracting diagnostics based on the PLC model

• S7-300/400 - Agent based on LIBNODAVE
  • Old reverse-engineered library not supported or maintained by Siemens

• S7-1500 - Web scraping
  • Extraction of HTML data from the PLC’s web server

• SE PLCs
Agents retrieving diagnostic information from variety of PLCs and converting it to standard formats (JSON)
Data visualization

- We developed an application for real-time visualization of system health
- Based on finite state machine concepts
- Tree representation to capture the hierarchical relationship between devices
- Intuitive navigation, enabling operators to locate errors quickly
User-interface to configure the device tree
Parameters configured to interact with Siemens monitoring solutions

<table>
<thead>
<tr>
<th>Name:</th>
<th>Device B11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disable:</td>
<td>[ ]</td>
</tr>
<tr>
<td>Tags:</td>
<td>54-400 X SCADA X</td>
</tr>
<tr>
<td>Agent:</td>
<td>AgentB1</td>
</tr>
<tr>
<td>IP-Address:</td>
<td>192.168.1.6</td>
</tr>
<tr>
<td>Labels:</td>
<td>cryo, plc</td>
</tr>
</tbody>
</table>

Main-view that runs the logic that updates visualization in real-time
Next steps

- Explore officially supported communication drivers and libraries that allow retrieval of diagnostic information
- Build tools around it and integrate it with the visualization tool
- Collaboratively work with product owners to add or modify features of the existing Siemens monitoring solutions
Edge Computing
Use case: Optimising HVAC systems

- Advanced control algorithms can optimize HVAC processes to reduce energy consumption
- Model Predictive Control for Air Handling Units - [F Ghawash et al. 2022](#)
- Previous setup: Run the algorithm on SCADA servers and send control signals to PLC
- Proposed Upgrade: Develop, Run, and Test the algorithm on an Edge device
DevOps on Edge

The architecture of ‘Template Framework’ - A DevOps platform for Edge

- PLC S7 400/1500
- Postgres DB
- IE Flow Creator
- MQTT Broker
- S7 Connector
- MQTT Broker
- IE Databus

Template Runtime Environment

- Template 1
- Template 2
- Template N
HMI on Edge

• Web application to interact with the MPC algorithm
• Developed with another Edge application: IE flow creator
  • Based on flow-based programming tool: Node-red
• The application provides node.js components and angular.js templates to build a full-stack web application with less effort
Model Predictive Control of Air Handling Unit

Measurement
Sampling Rate (Seconds)

Air Temperature
Outside: 12.0°C
Mixed: 26.0°C
Heated: 23.0°C
Cooled: 22.0°C
Supply: 29.0°C
Zone: 27.0°C

Algorithm
Current time: 07/03/2023, 02:54:46
Last process completed at: 07/03/2023, 02:54:45
Algorithm status: Running

Elapsed time (Seconds)

Actuators
Fan speed: 62%
Damper: 27%
LEVERAGING LOCAL INTELLIGENCE TO CERN INDUSTRIAL CONTROL SYSTEMS THROUGH EDGE TECHNOLOGIES

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Abstract

Industrial processes often use advanced control algorithms such as Model Predictive Control (MPC) and Machine Learning (ML) to improve performance and efficiency. However, deploying these algorithms can be challenging, particularly when they require significant computational resources and involve complex communication protocols between different control system components. To address these challenges, we showcase an approach leveraging industrial edge technologies to deploy such algorithms. An edge device is a compact and powerful computing device placed on the network edge, close to the process control. It executes the algorithms without extensive communication with other control system components, thus reducing latency and load on the central control system. We also employ an analytics function platform to manage the life cycle of the algorithms, including modifications and replacements, without disrupting the industrial process.

Furthermore, we demonstrate a use case where an MPC algorithm is run on an edge device to control a Heating, Ventilation, and Air Conditioning (HVAC) system. An edge device running the algorithm can analyze data from temperature sensors, perform complex calculations, and adjust the operation of the HVAC system accordingly. In summary, our approach of utilizing edge technologies enables us to overcome the limitations of traditional approaches to deploying advanced control algorithms to industrial settings, providing more intelligent and efficient control of industrial processes.

INTRODUCTION

The latest advances in AI and ML, along with time-tested methods like MPC, offer new ways to enhance the functionality of industrial control systems [1]. For instance, these techniques can improve system reliability through anomaly detection, enable energy-efficient operation of complex industrial processes, and extend equipment life through predictive maintenance. Nevertheless, enhancing industrial control systems through such techniques poses several challenges.

One significant challenge is ensuring that the core processes of the system and the algorithms operate independently and do not interfere with one another. This independence ensures that the demands of complex algorithms do not jeopardize the safe operation of the core process and overload its resources. Also, deploying complex algorithms on the existing control infrastructure may only be possible if specialized hardware components like GPUs or AI processors are available. These components were relatively uncommon in industrial control setups until recently. However, new control hardware, such as multi-processor PLCS and AI expansion cards, have emerged, making this deployment possible.

Another challenge is the need to adapt these systems for the evolution of control engineers and data scientists when devising control systems. Control engineers primarily concentrate on industrial communication protocols, control devices, PLC programming, and SCADA development. In contrast, data scientists and software engineers focus on creating new control strategies using Python or C++ and utilizing software development tools like edge managers and containers. New computing paradigms tailored to industrial control systems have been developed that bridge this divide and integrate information technology (IT) tools into operational technology (OT). Examples include integrating control systems with Cloud computing, High-Performance Computing (HPC), and Edge computing.

This article mainly focuses on solutions that address these challenges and provides local intelligence to a control system, i.e., intelligence close to the process, allowing faster analysis of streamed data and lightening the load on the different layers of the control system by reducing network latency and traffic. We start by comparing various techniques for leveraging local intelligence. We emphasize industrial Edge Computing as an emerging solution that provides benefits such as separation of concern, simplification of algorithm development, and easy application lifecycle management. Finally, we will share insights from implementing an advanced optimization algorithm on state-of-the-art edge technologies and validating its use in a real-world setting at CERN.

LEVERAGING INTELLIGENCE TO INDUSTRIAL CONTROL SYSTEMS

In recent years, the capability to deliver intelligence close to industrial processes has progressed from conventional setups such as bare-metal Industrial PCs to more advanced systems like multi-process controllers and edge technologies. Some of these setups are outlined below.

- Multi-process controllers: PLC vendors have acknowledged developers’ needs to program control components in languages beyond the IEC 61131-3 standard [2], adopting higher-level languages like C++ and Python. For instance, the Siemens S7-1500 Multi-Functional Platform (MFP) has a Linux OS alongside its standard PLC OS that primarily supports C++. Communication between the OSs is via an Ethernet switch, eliminating additional hardware and separating

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Conclusion

- Edge ecosystem consists of Drivers, Applications, and Runtime environments to augment a PLC with complex algorithms.
- Supports various industrial communication protocols.
- Advanced control algorithms can be deployed using a specific DevOps platform.
- Web applications using flow-based programming can be developed to provide a user interface.
Industrial Co-Pilot
Background

- The recent rise of Large Language Models with billions of parameters
- It can be leveraged as a tool for industrial control code development
- Many popular LLMs are proprietary and require a license
- Parallel movement in the LLM space: open source LLMs
  - Llama 2, BLOOM, etc.
- Possibility for more flexibility and customization and transparency
Objective

• Initiate the development of a tool to generate industrial control code
  • WinCC OA Control Code for the SCADA layer
  • PLC Code for the Control layer
• Explore the application of LLMs in generating code documentation
• Build a benchmarking suite to test the quality of various open-source LLMs
Thank you