TARGET GROUP
High-tech industry

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ESI

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Automated performance visualization and analysis to the rescue!

Performance problems? Catch them, quick!

The high-tech equipment industry of today is facing increasing complexity across its application domains. This is driven firstly by mass customization (variability) of systems, a trend that has moved product diversity from a few fixed variants within a product line towards the delivery of virtually unique systems. Furthermore, high-tech systems integrate ever more technologies, while its growing digital capabilities allow expansion in AI and other new domains.

Lastly, high-tech equipment has to be supported over very long lifetimes in the field, and needs to continuously evolve after deployment. Not only to enable safe and secure operation through updates, but alsol to deliver increased value by upgrades. Classical approaches of system testing, estimation and extrapolation can no longer be relied upon to guarantee the required performance over the variety of systems, upgrades and functionality. Therefore, improved system performance engineering methods are urgently sought after.

ESI has developed methodologies and tools that allow the user to visualize and automatically analyze various system performance aspects based on telemetry data. Standard or bespoke telemetry data can be used, visualized and converted to formats for automatic analysis of timing violations, outliers, critical paths, bottlenecks etc. Finally, the methodologies also include support for (automatic) analysis and conformance checking.

The need for telemetry based performance analysis

Performance issues often emerge in late stages of development and during integration. Finding and resolving problems in large, distributed systems is notoriously difficult and costs a lot of time and effort. Furthermore s,oftware-intensive systems are increasingly adopting microservices architectures at the expense of further diminishing clear performance insights. To address these rising challenges, new methodologies and tools for performance engineering are needed.

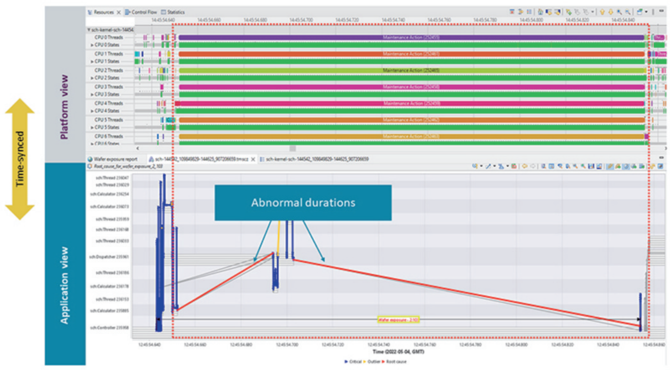
Functional testing of complex CPS alone does not yield sufficient information to analyze, debug and optimize the performance of these applications. Testing of systems presents a limited view of the (internal) execution of a system. Relating specification non-conformances to design artifacts, like modules or functions, Is extremely difficult without additional sources of information.

Historically, developers use debugging tools and dedicated logging to shed light on the situation. Telemetry based performance analysis provides insight into and allows visualization of system flow execution. Standard instrumentation tooling like Jaeger, LTTng and Prometheus can be applied for (desktop and cloud) based applications depending on its timing requirements. For very critical applications and realtime constraint environments bespoke implementations remain needed.

Over the past decade, standards and implementations for efficient large-scale logging and tracing have been established. Standard tools have now matured to the point that usage in many cyber-physical systems has become feasible from a cost, resource, and performance perspective. When applied, they can provide a detailed view of the execution flow and performance of a large application. However, as complex CPS may produce gigabytes of telemetry data in a short time, performance problems are difficult to catch through visualization alone.

Automated Visualization and Performance Analysis

ESI has worked on developing a proof-of-concept framework for telemetry-based system performance engineering to support developers in analyzing complex performance issues. The framework consists of a selection of both popular open source tools, like OpenTelemetry, Prometheus, and Jaeger, and of ESI developed tools like PPS [1] andTrace4CPS [2]. To help developers find the proverbial needle in the haystack, the framework complements visualization with a variety of automatic analysis methods. This allows analysis to be easily repeated for different system variants, as they evolve.



The framework contains a large number of tools to visualize and analyze large data sets:

- Visualization comes with features, like zooming and scrolling, and can relate events to execution threads, messages, and other interactions.
- Automatic analysis of large data sets, evaluating execution times for system flows, KPIs or use cases, identifying timing violations, generate performance statistics and identify the root-cause of a performance anomaly.
- Processing functions for dedicated purposes, like identifying critical paths or slack time in an execution. Combining system and application execution insights with execution platform performance metrics, like CPU and memory load, provides additional insights.
- Detecting architectural anti-patterns based on service interactions, and suggesting potential mitigations to address them.
- Verifying whether large execution sequences conform to a UML specification, in terms of both behavior and timing. This can also be used to detect (the absence of) undesirable events in sequences, e.g. for safety related requirements.
- Performance prediction by calibrating a performance model of an application (e.g. microservice) under various loads and deployments using telemetry data.

The framework has been set up as open platform, allowing integration with different tools and databases, easy addition of conversions from and to other formats, and addition of new processing functions.

Bibliography

1. PPS tool," TNO-ESI, 30 03 2024. [Online]. Available: https://esi.nl/research/output/tools/pps. [Geopend 03 2024]
2. TRACE4CPS," 2024. [Online]. Available: https://esi.nl/research/output/tools/trace [Geopend 2024].