Concept and Design of an Extensible Middle-Layer Application Framework for Accelerator Operation and Development

Talk at the 19th Biennial International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS'23)

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01 Motivation

Problems We See

… in accelerator R&D and operation

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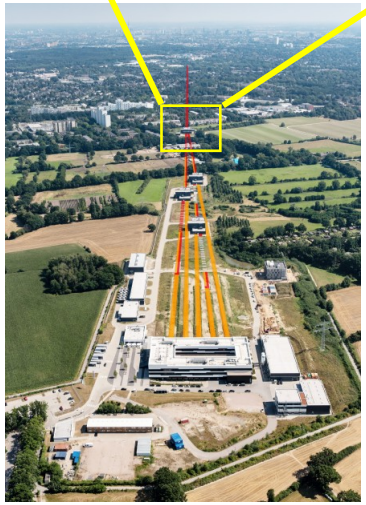

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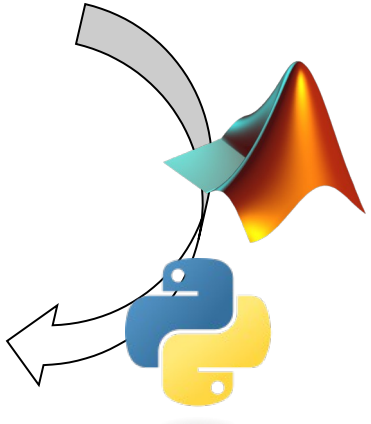
DOOCS.

The Distributed Object-Oriented Control System Framework

9 Million Data Channels

PhD Student



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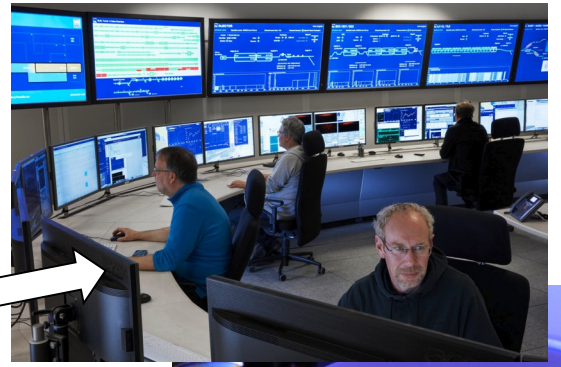

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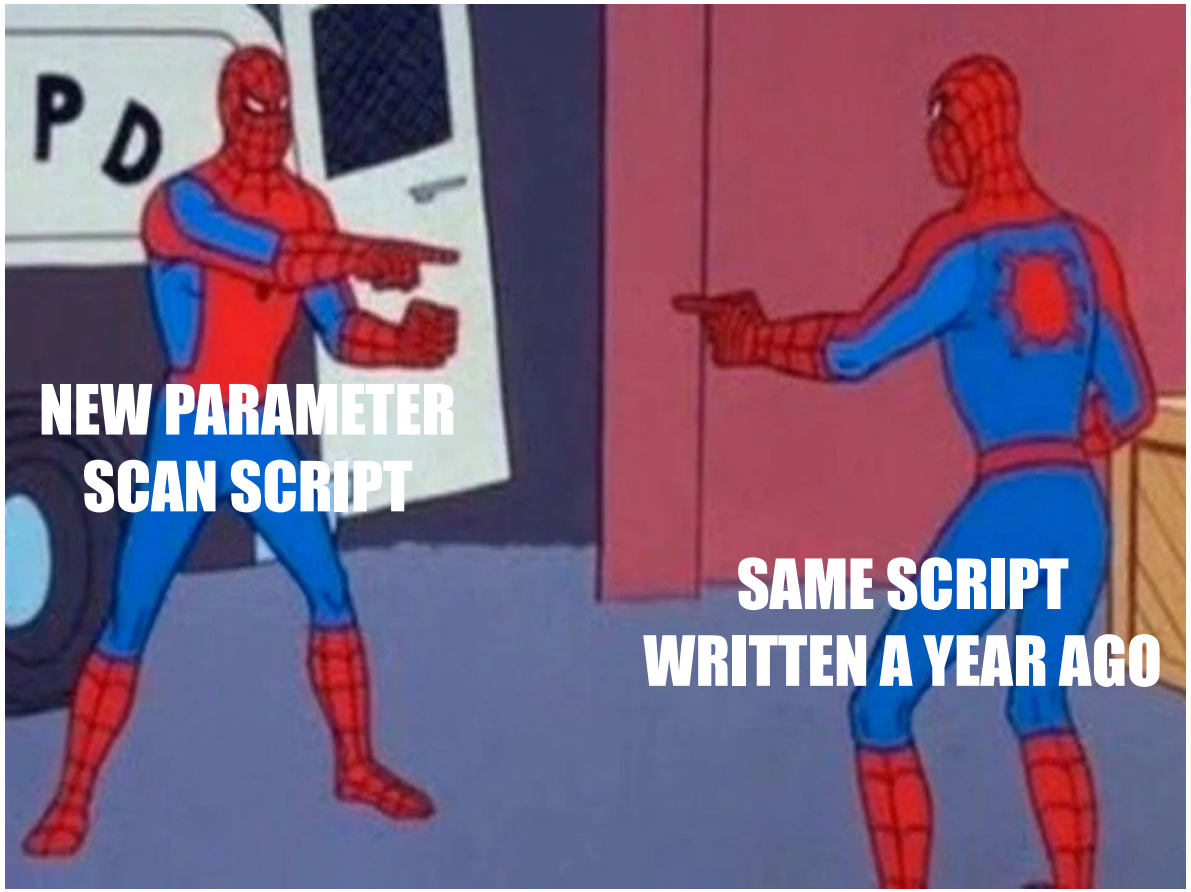
Problems We See

… in accelerator R&D and operation

Many middle-layer applications & scripts are..

- quickly hacked together,
- done from scratch over and over,
- not shared,
- buggy,
- inefficient,
- not maintained.



02 An Extensible Middle-Layer Application Framework (ExMAF)

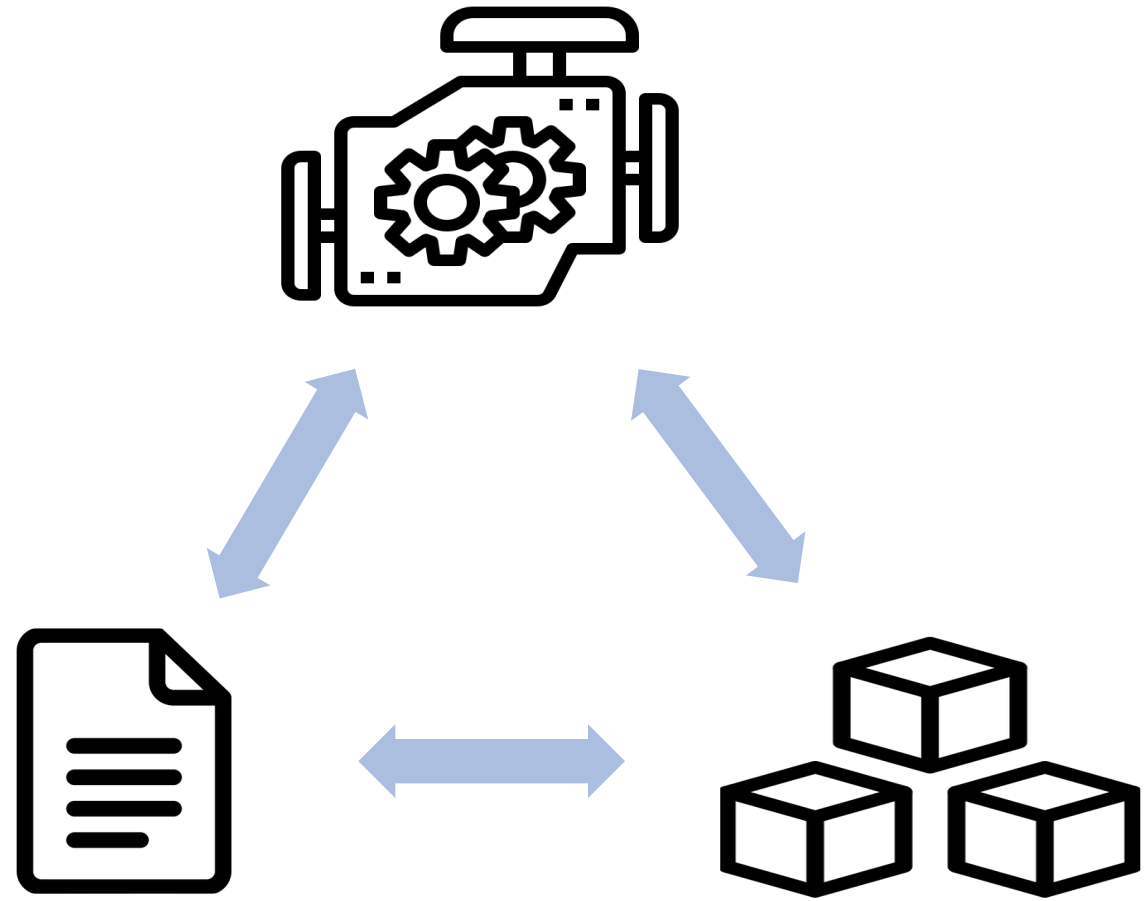
The Vision

… for middle-layer application development

Easy Configuration	Extendable	Maintained & Quality Checked
• Easy **adaption** to new use case. • **Human**-oriented config format. • Self-validating.	• Just add what's missing, not everything from scratch. • **Share** functionality. • Open.	• Ensure code lives on. • High **confidence** in tried & tested code.

Three Pillars of ExMAF

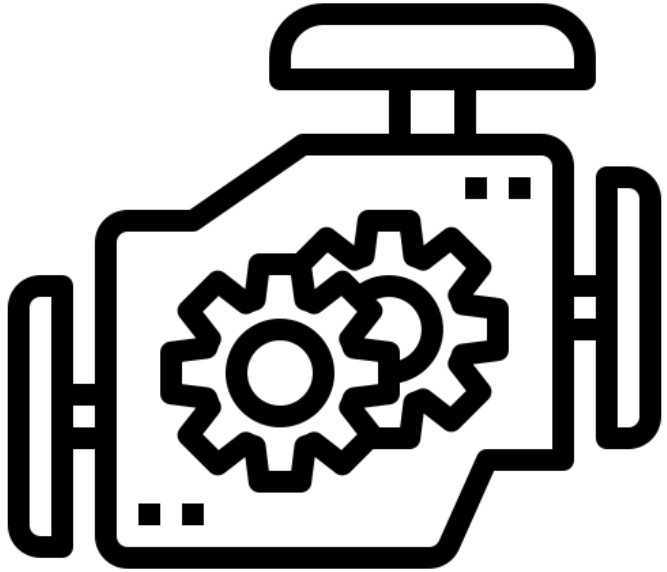
… core, configuration and modules



Core

… bootstrapping & data piping

- Read & validate configuration file.
- Load and instantiate modules.
- Pipe data from control system to modules.
- Pipe messages between modules.



Configuration File

… application specification

```
# DxMAF configuration file
# Defines a simple trip event logger for high jitter events

extensions: ./dxmaf/extensions

duration: 14d
# stop_time: 2042-01-01T00:00:00
```

Configuration File

… application specification

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# Defines a simple trip event logger for high jitter events

extensions: ./dxmaf/extensions

duration: 14d
# stop_time: 2042-01-01T00:00:00

application:
- type: ThresholdChecker
  channels:
  - XFEL.SYNC/LASER.LOCK.XLO/XTIN.MLO1/CURRENT_INPUT_JITTER.RD
  args:
    lower_limit: -inf
    upper_limit: 20
    topics: high_jitter
```

Configuration File

… application specification

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application:
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  args:
    lower_limit: -inf
    upper_limit: 20
    topics: high_jitter
- type: NpyRingFileWriter
  channels:
  - XFEL.SYNC/LASER.LOCK.XLO/XTIN.MLO1/CURRENT_INPUT_JITTER.RD
  - XFEL.SYNC/LASER.LOCK.XLO/XTIN.MLO1/OXC_IN.SPEC
  - XFEL.SYNC/LASER.LOCK.XLO/XTIN.MLO1/LOCK_STATUS.VALUE.RD
  args:
    output_dir: high_jitter_trip_%Y-%m-%d_%H%M%S
    ring_file_size: 1024
    memory_buffering: true
  topics:
  - high_jitter
```

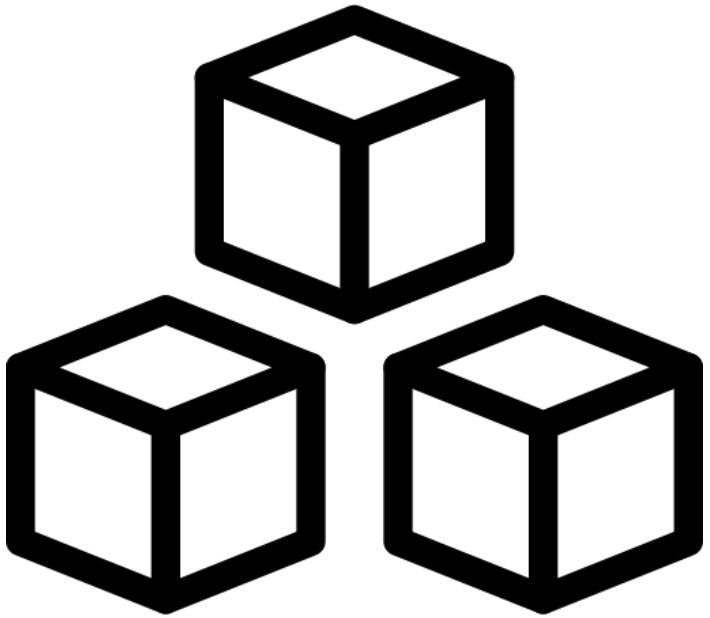
Modules

… independent functionality blocks

- **Independent** code plug-ins (e.g. Python class).
- Implement **interfaces** to receive data from control system automatically from core.
- Module-module communication with **named pipes**.

- **Easy** to get started with module development, or
- Use **module library** to plug together app.

- Examples: **ThresholdChecker**, EmailDispatcher, FileWriter, GridScanner



03 Implementation for DOOCS (DxMAF)

Modules in DxMAF

… implemented or WIP

ThresholdChecker

- Compares all data channels against threshold.
- Emits latched signal when limits exceeded.

NpyFileWriter / NpyRingFileWriter

- Writes data channels to NPY files.
- On signal, closes files and continues in new files.

EmailDispatcher

- On signal, prints signal context to to configured E-Mail address.

SpectrumChecker

- Computes PSD estimate.
- Emits signal when integral over frequency bounds exceeds threshold.

FileMover

- On signal, moves files to configured destination.

CommandRunner

- On signal, executes system call.
- Signal context can be used as arguments.

Configuration Schema Validation

… avoiding “bad surprises”

```python
from dxmaf.data_subscriber import DataSubscriber
from dxmaf.event_publisher import EventPublisher

class ThresholdChecker(DataSubscriber,
EventPublisher):
    """<docstring>"""“

    def __init__(self, channels: Set[str], topics:
Set[str], lower_limit: float, upper_limit: float,
spectrum_mode: bool = False):
        """<docstring>"""

        DataSubscriber.__init__(self, channels)
        EventPublisher.__init__(self, topics)


        self.lower_limit = lower_limit
        self.upper_limit = upper_limit
```

```yaml
- type: ThresholdChecker
  channels:
  - XFEL.SYNC/LASER.LOCK.XLO/XTIN.MLO1/…
  args:
    lower_limit: -inf
    upper_limit: 20
    topics: high_jitter
```

Optional parameter omitted.

- YAML schema is automatically generated for modules (strictYAML).
- Python type hints allow type validation.
- Avoids unnoticed configuration errors.

04 First Experiences from European XFEL and FLASH

Projects that Benefitted from DxMAF

… since 2021

A. Grünhagen et al. – "*Fault Analysis of the Beam Acceleration Control System at the European XFEL using Data Mining*" (2021)

- 100 data channels from
- 25 LLRF stations
- Fault analysis

Optical Synchronization Team (MSK)

- Snapshots for training pred. maintenance models
- Post mortem trip / failure analysis

Machine Control Systems Group

- Long-term data scraping for Klystrons
- Fault detection and analysis

Machine Beam Controls Group

- Seismic influence on European XFEL & FLASH
- Earthquakes Turkey & Morocco

05 Conclusion

Conclusion

… almost done

Summary

- Modular middle-layer application framework concept.
- Reusable & reliable code.
- Less redundant work for scientists.
- Positive feedback from users.

Outlook

- Stable 1.0 release.
- Data pipelines.
- Support for other control systems?

Thank you!

Contact

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