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Investigating the Performance of selected Data Storage Concepts for AutomationML Models

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Context & Motivation

Context

- Cyber-Physical Production Systems Engineering.
- Heterogeneous involved engineering disciplines and different engineering artifacts.
- Discipline-specific data formats.

Challenge

- Different artifact and data formats hinder efficient data exchange.

Well, there are some solution approaches ..

macrovector/Freepik

Solution Approaches & Key Questions

Solution Approaches

- Engineering platforms for data exchange.
- Standardized data exchange formats, e.g., AutomationML.
- Shared data repository for storing common engineering data.

However ..

Key Questions:

- Which data storage concept should be used?
- How to evaluate data storage concepts?

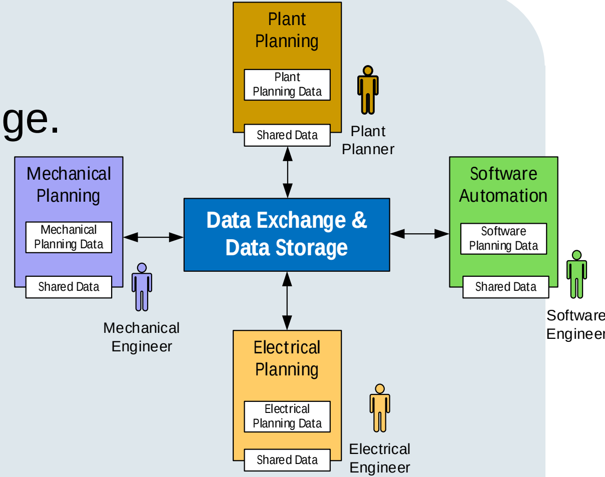
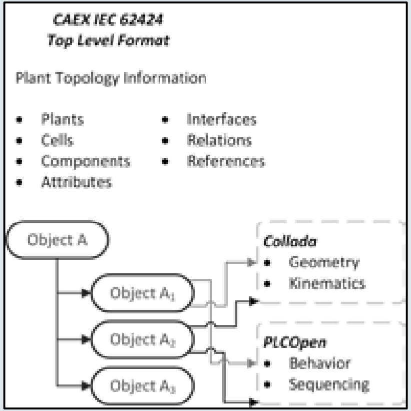


Fig. Round-Trip-Engineering Process.

AutomationML

Automation Markup Language (AML)

- Standardized engineering data exchange format.
- Based on XML and CAEX.
- Hierarchical structure.



CAEX IEC 62424
Top Level Format

Plant Topology Information

- Plants
- Cells
- Components
- Attributes
- Interfaces
- Relations
- References

Object A

Object A_1

Object A_2

Object A_3

Collada

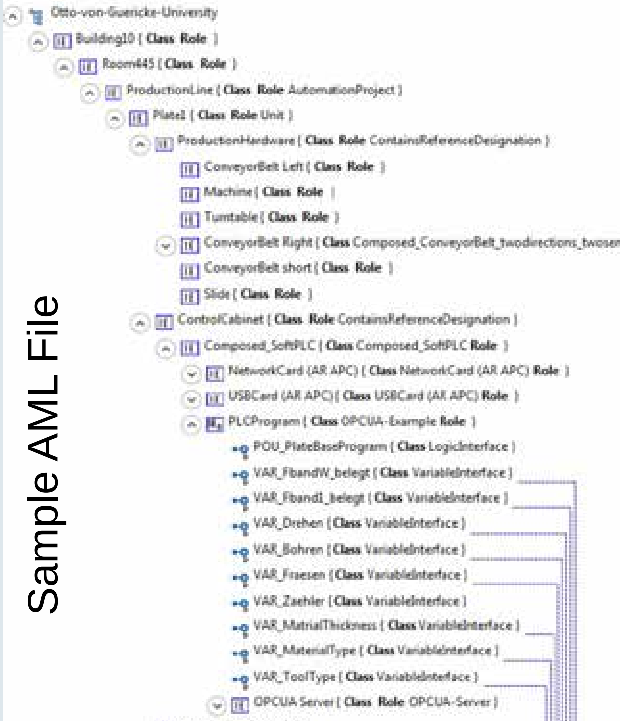
- Geometry
- Kinematics

PLCOpen

- Behavior
- Sequencing

www.automationml.org

Sample AML File



```
Otto-von-Guericke-University
  Building10 { Class Role }
    Room445 { Class Role }
      ProductionLine { Class Role AutomationProject }
        Plate1 { Class Role Unit }
          ProductionHardware { Class Role ContainsReferenceDesignation }
            ConveyorBelt Left { Class Role }
            Machine { Class Role }
            Turntable { Class Role }
            ConveyorBelt Right { Class Composed_ConveyorBelt_twodirections_twose
            ConveyorBelt short { Class Role }
            Slide { Class Role }
          ControlCabinet { Class Role ContainsReferenceDesignation }
            Composed_SoftPLC { Class Composed_SoftPLC Role }
              NetworkCard (AR APC) { Class NetworkCard (AR APC) Role }
              USBCard (AR APC) { Class USBCard (AR APC) Role }
              PLCProgram { Class OPCUA-Example Role }
                POU_PlateBaseProgram { Class LogicInterface }
                VAR_FbandW_belegt { Class VariableInterface }
                VAR_Fband1_belegt { Class VariableInterface }
                VAR_Drehen { Class VariableInterface }
                VAR_Bohren { Class VariableInterface }
                VAR_Fraesen { Class VariableInterface }
                VAR_Zaehler { Class VariableInterface }
                VAR_MatrialThickness { Class VariableInterface }
                VAR_MaterialType { Class VariableInterface }
                VAR_ToolType { Class VariableInterface }
              OPCUA Server { Class Role OPCUA-Server }
```

Research Questions

RQ1: How can we evaluate storage approaches in AML context?

- Systematic evaluation of storage approaches (flexible exchange of data storages).
- Focus on an evaluation architecture for benchmarking purposes.

RQ2: What are the critical requirements for storing AML data?

- Test scenario definition for standardized benchmarks.
- Focus on scenarios, requirements, and use cases.
- Evaluation of selected data storages in AML context.

Database Criteria

Basic AutomationML Characteristics

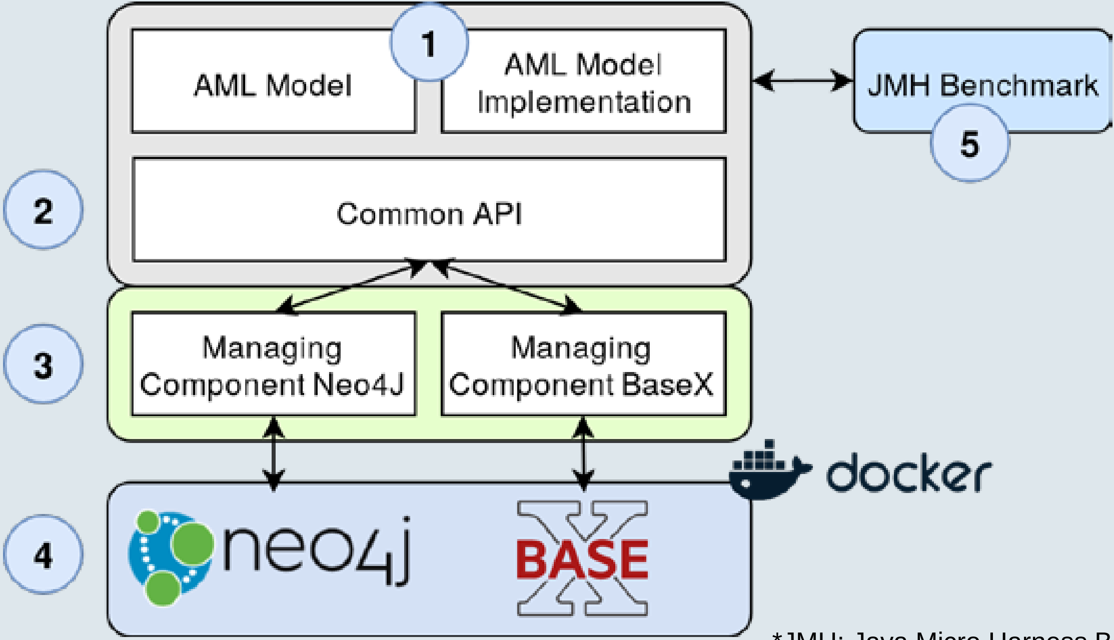
- XML-based engineering data exchange format.
- Hierarchical structure of engineering data.
- Different semantic meanings of entities.
- Links and relationships between engineering data.

Database Selection

- BaseX – XML-based Database
- Neo4J – Graph-based Database

Defined with Industry Partners

Results: Evaluation Architecture (RQ1)

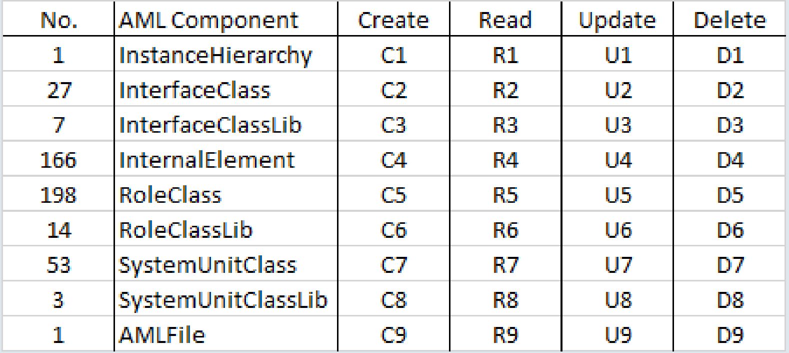


*JMH: Java Micro Harness Benchmark

Evaluation Use Case (RQ2)

Basic Key Use Cases

- CRUD Operations: **C**reate, **R**ead, **U**pdate, **D**elete for each AML component
 à 36 Use Cases.



No.	AML Component	Create	Read	Update	Delete
1	InstanceHierarchy	C1	R1	U1	D1
27	InterfaceClass	C2	R2	U2	D2
7	InterfaceClassLib	C3	R3	U3	D3
166	InternalElement	C4	R4	U4	D4
198	RoleClass	C5	R5	U5	D5
14	RoleClassLib	C6	R6	U6	D6
53	SystemUnitClass	C7	R7	U7	D7
3	SystemUnitClassLib	C8	R8	U8	D8
1	AMLFile	C9	R9	U9	D9

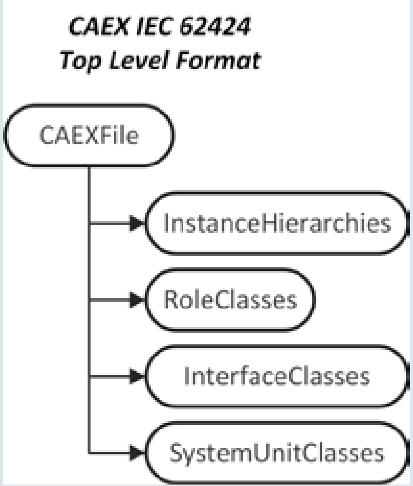
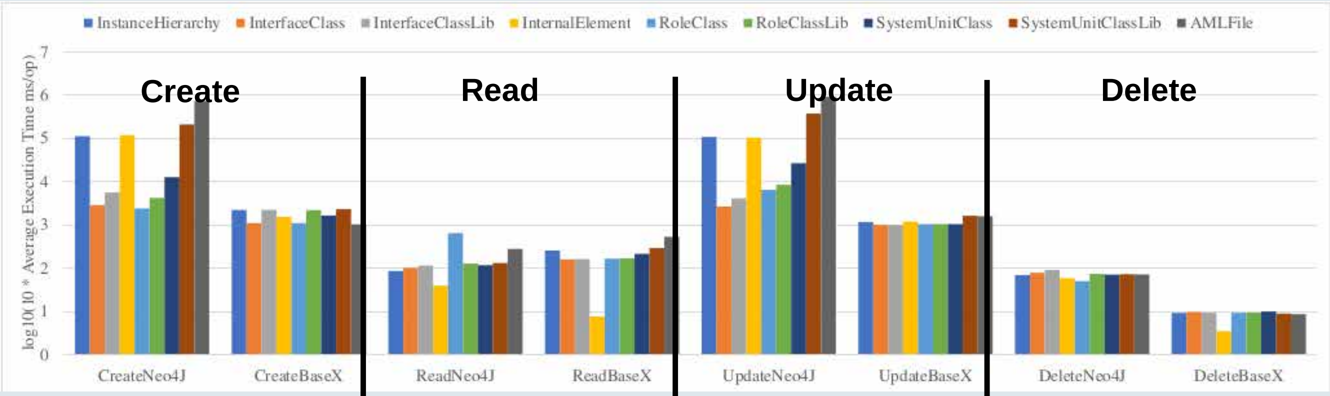


Fig: Basic AML Aspects

Reference AML File:

- ~21k Lines of Code (Academic AML data set)

Evaluation Results

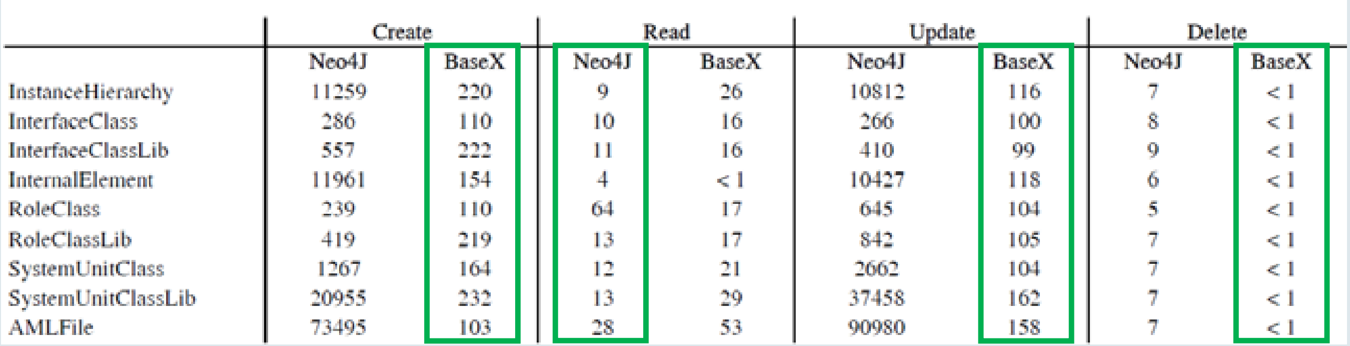


Note: Logarithmic scale because individual values differ to a large extent (log10(10*x))

- **BaseX:** Performs good for create, update and delete.
- **Neo4J**: Performs good for read.

Operation	Neo4J	BaseX
Read	✓	
Create		✓
Update		✓
Delete		✓

Detailed Data & Limitations



	Create		Read		Update		Delete	
	Neo4J	BaseX	Neo4J	BaseX	Neo4J	BaseX	Neo4J	BaseX
InstanceHierarchy	11259	220	9	26	10812	116	7	< 1
InterfaceClass	286	110	10	16	266	100	8	< 1
InterfaceClassLib	557	222	11	16	410	99	9	< 1
InternalElement	11961	154	4	< 1	10427	118	6	< 1
RoleClass	239	110	64	17	645	104	5	< 1
RoleClassLib	419	219	13	17	842	105	7	< 1
SystemUnitClass	1267	164	12	21	2662	104	7	< 1
SystemUnitClassLib	20955	232	13	29	37458	162	7	< 1
AMLFile	73495	103	28	53	90980	158	7	< 1

Quantiative Data in [ms]; average value of 10 test runs.

Operation	Neo4J	BaseX
Read	✓	
Create		✓
Update		✓
Delete		✓

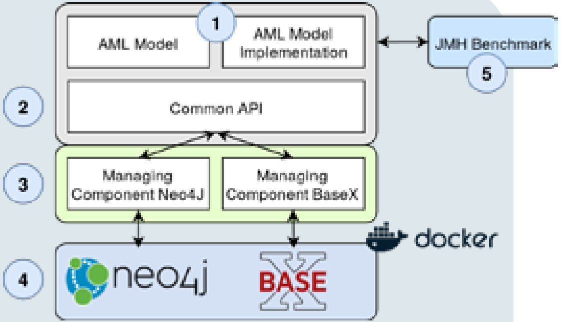
Selected Limitations

- Focus on 2 representative databases.
- Representative but Academic AML Data.
- Focus on execution time.

Contributions & Future Work

Contributions of this paper:

- RQ1: Data Storage Evaluation Architecture.
- RQ2: Evaluation Use Cases / Test Data for Benchmarking Purposes.
- Evaluation of two representative data storage approaches.



Future Work:

- Address limitations.
- Include additional storage approaches.
- Extending test data set towards large-scale and/or industry data.

Operation	Neo4J	BaseX
Read	✓	
Create		✓
Update		✓
Delete		✓

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