Edge AI Academy Summer School 2025

Generative AI to gain data insights from the shopfloor intuitively

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What is a datapoint?

A Datapoint represents a piece of data e.g., a measurement from a machine

Datapoints

Equipment in physical world

App Developer

Energy monitoring / optimization app

Which datapoints indicate the energy Consumption of machines on the plant/ building?

Operator

Root cause of a fault on a machine

Which datapoints belong to the machine?
What does the datapoint indicate?

IT Engineer

Automate a production task / task in a buidling

Where is the datapoint located?
How is it related to other datapoints of the plant?

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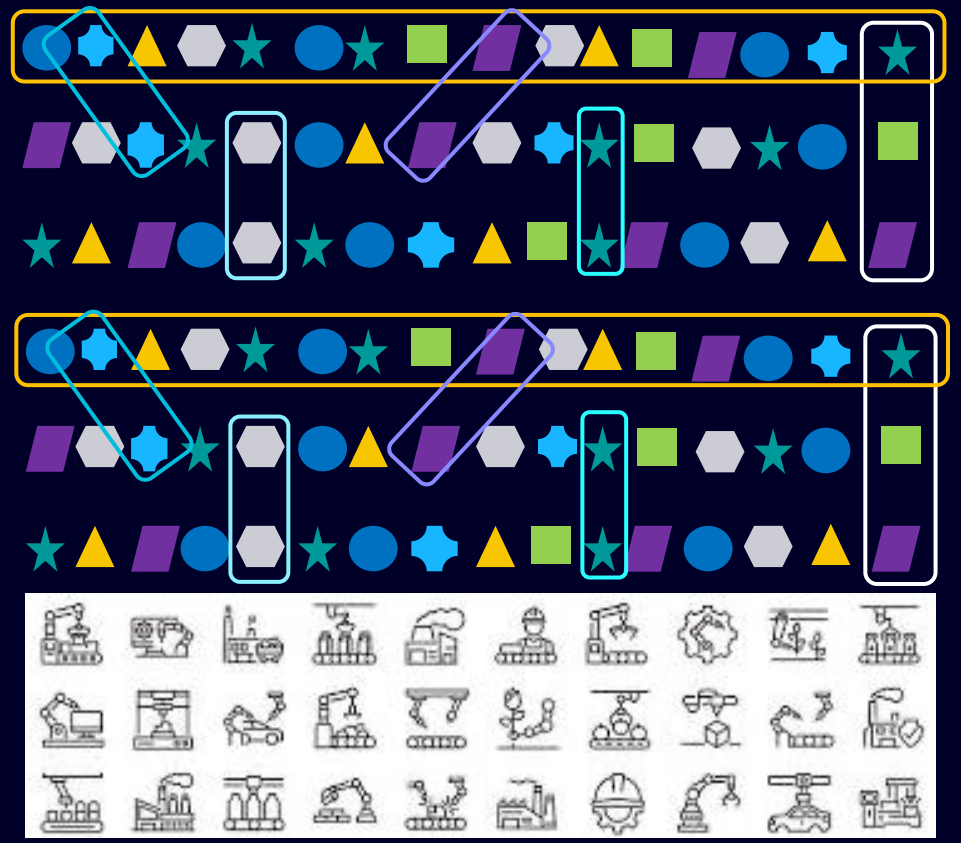
We need metadata & contextual information about a datapoint

Datapoints

Equipment in physical world

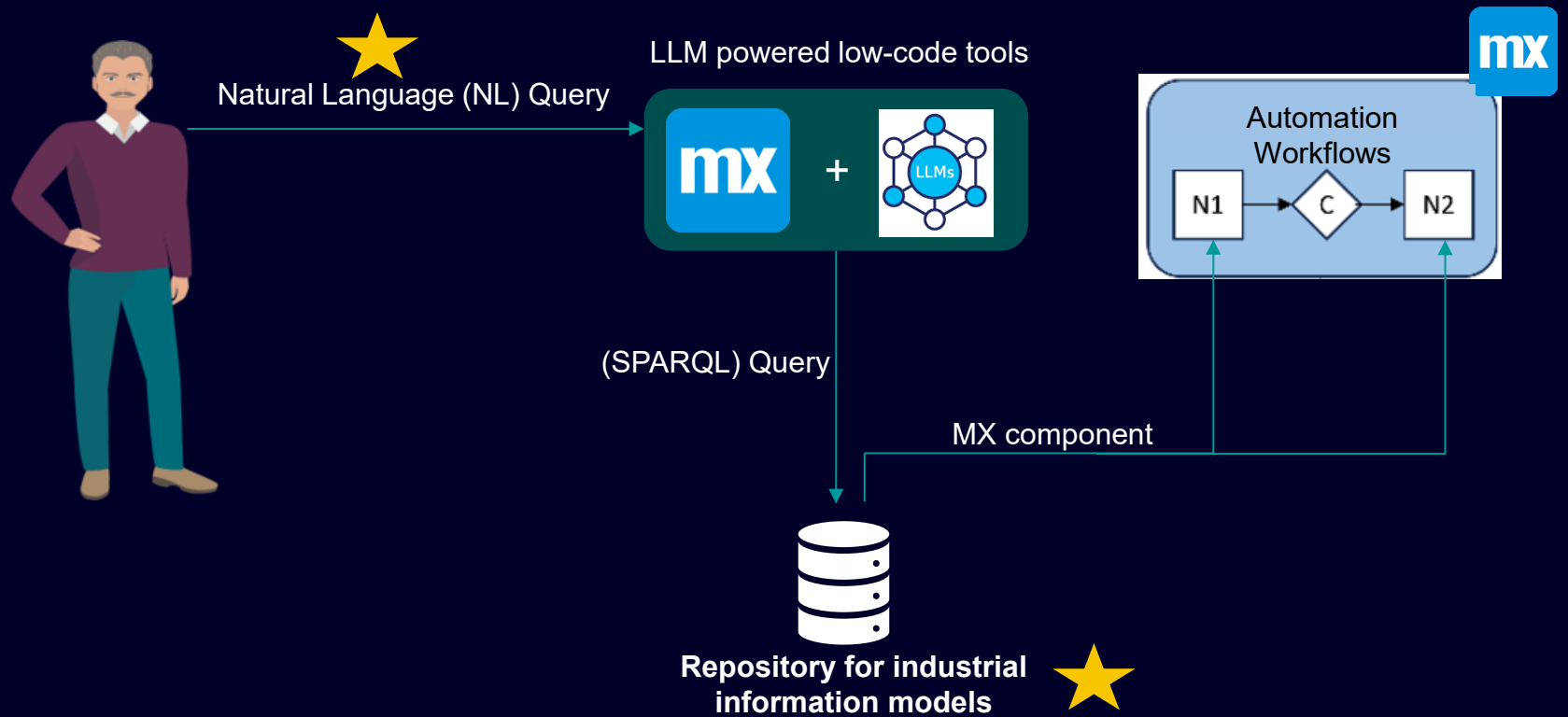


We need to assign metadata and context to the datapoints to cluster them. Clustering and structuring the datapoints is useful:

- All datapoints on a machine
- All datapoints in a location
- All datapoints that indicate a function.
- Relations between the datapoints
- Cluster them hierarchically
- Assign local context
- Assign global context

The metadata and contextual information about the datapoints on a machine, that is clustered and structured hierarchically is referred to as an Information model of the machine.

SmartEdge Use case:
Flexible production with low-code shopfloor applications using shopfloor skills



- Customer expresses his requirements in natural language
- LLM produces a SPARQL query, which captures user's requirements
- Repository evaluates the query and provides answer to Mendix (MX)
- An extension of MX will generate a MX component, which connects to asset via a protocol. E.g, OPC UA
- Process will repeat for other components in the workflow.

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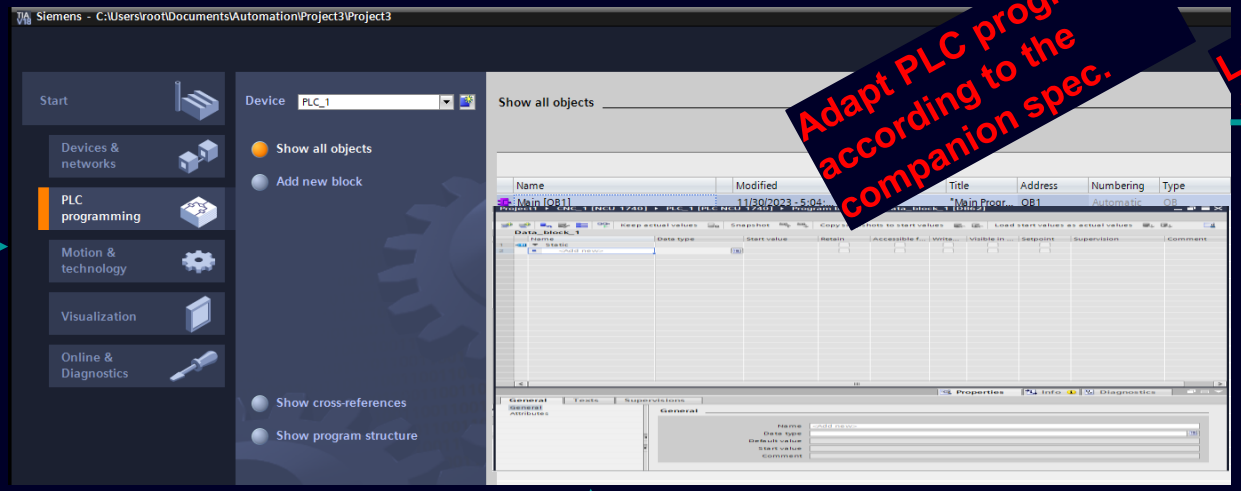
Today's process of implementing a machine and creating a standardized information model

1. Implement machine

PLC programming in an engineering tool

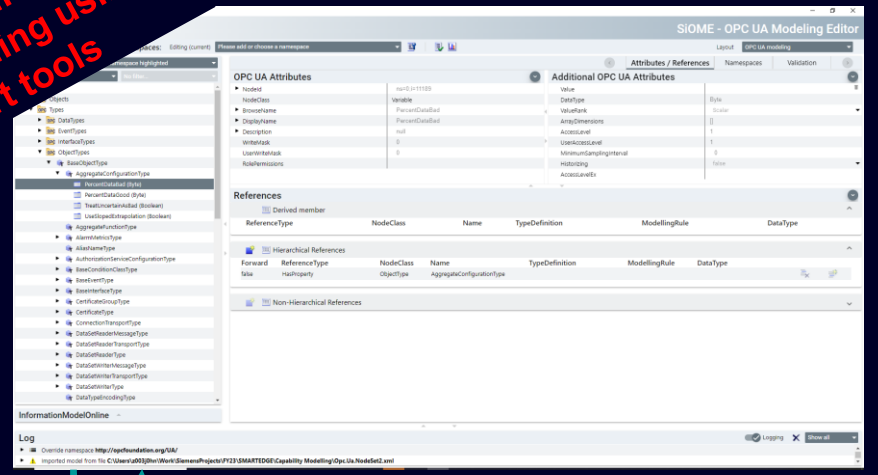


Adapt PLC program according to the companion spec.

Learn information modelling using expert tools

5. Map PLC tags to information model

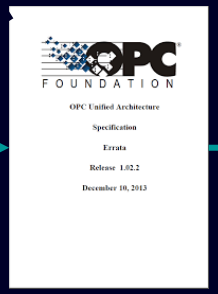
mation Modelling in a modelling tool



4. Build information model according to domain model

6. Import Server Interface

Read & understand 100s of pages of domain specific technical documentation



2. Find appropriate standard(s) (e.g.,some of the 140+ OPC UA domain models), read, and understand them

3. Import information models from standard into a modelling tool

Create information model correctly

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Challenges

- *Complex standards*
- *Steep learning curve* = *Skill Gap*
- *Expert tools for information modelling*

Solution

- *Beginner-friendly tools for information modelling using semantics from domain models.*

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Our solution for implementing a machine and creating its information model

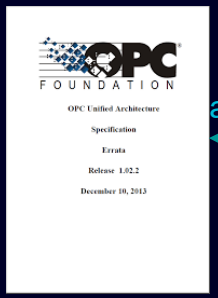
1. Specify requirements

Requirements

1. **Devices**
2. **Components**
3. **Data of components**

Generative AI
Match the requirements with available models

2. Import domain models and typical instance nodesets



Has Knowledge about Standards

Domain Expert

3. Generate customized instance model along with PLC code templates

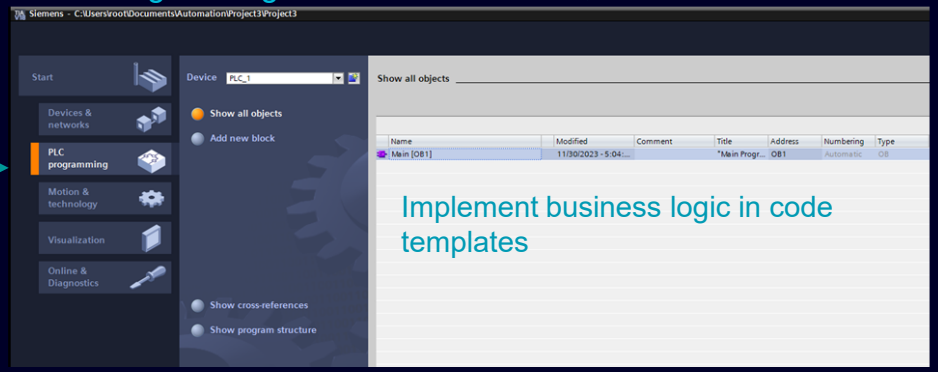
Instance Information Model for a machine

1. Instance information model for the machine
2. PLC code templates

Focus only on business logic

4. import Nodeset & code templates to an engineering tool

5. Implement machine using templates



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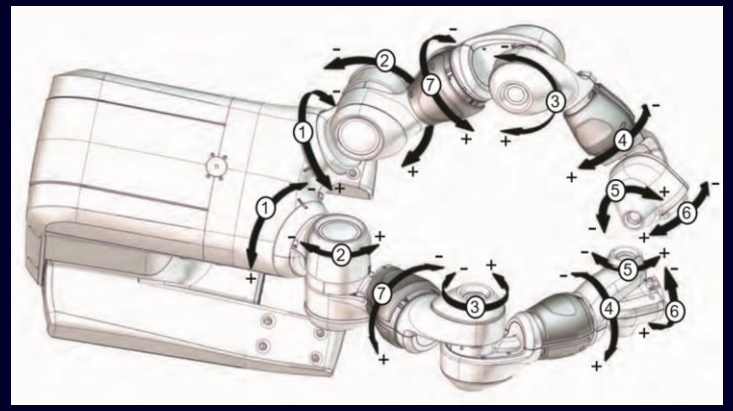
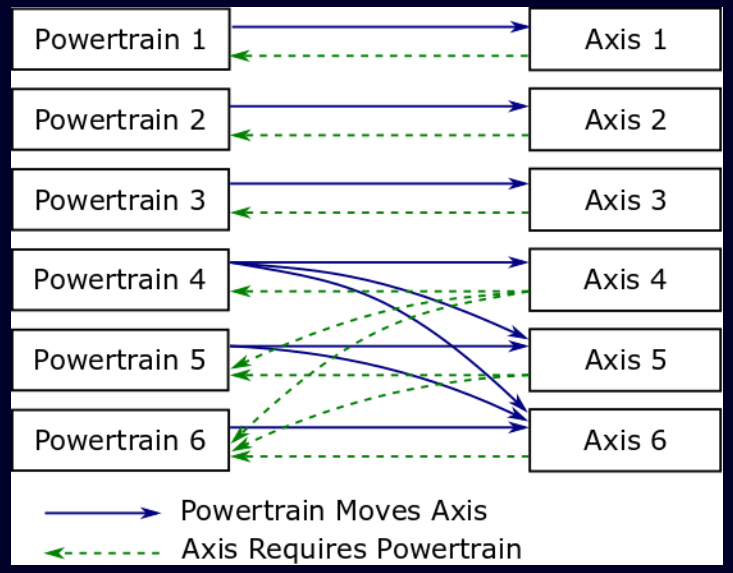
Example
Intutive data insights for an articulated six-axis industrial robot





Natural Language Input for information model generation:

Create an information model for the robot described below by using the semantics defined in the OPC UA Robotics domain model:

1. Create an industrial robot named MyTestRobot
2. Add power train1 to MyTestRobot
3. Add power train2 to MyTestRobot…
4. Add Axis1 to MyTestRobot
5. Add Axis2 to MyTestRobot..
6. Add a relation Powertrain1 moves Axis1…
7. Add actual position, speed and target position variables to Axis1

Not Straight forward

Natural Language queries for information retrieval:

1. What are the components of MyTestRobot
2. Which powertrain of MyTestRobot moves Axis 5?
3. How many axes does MyTestRobot has?
4. What is the actual position of Axis 1 of MyTestRobot?
5. What is the target position of Axis 2 of MyTestRobot?

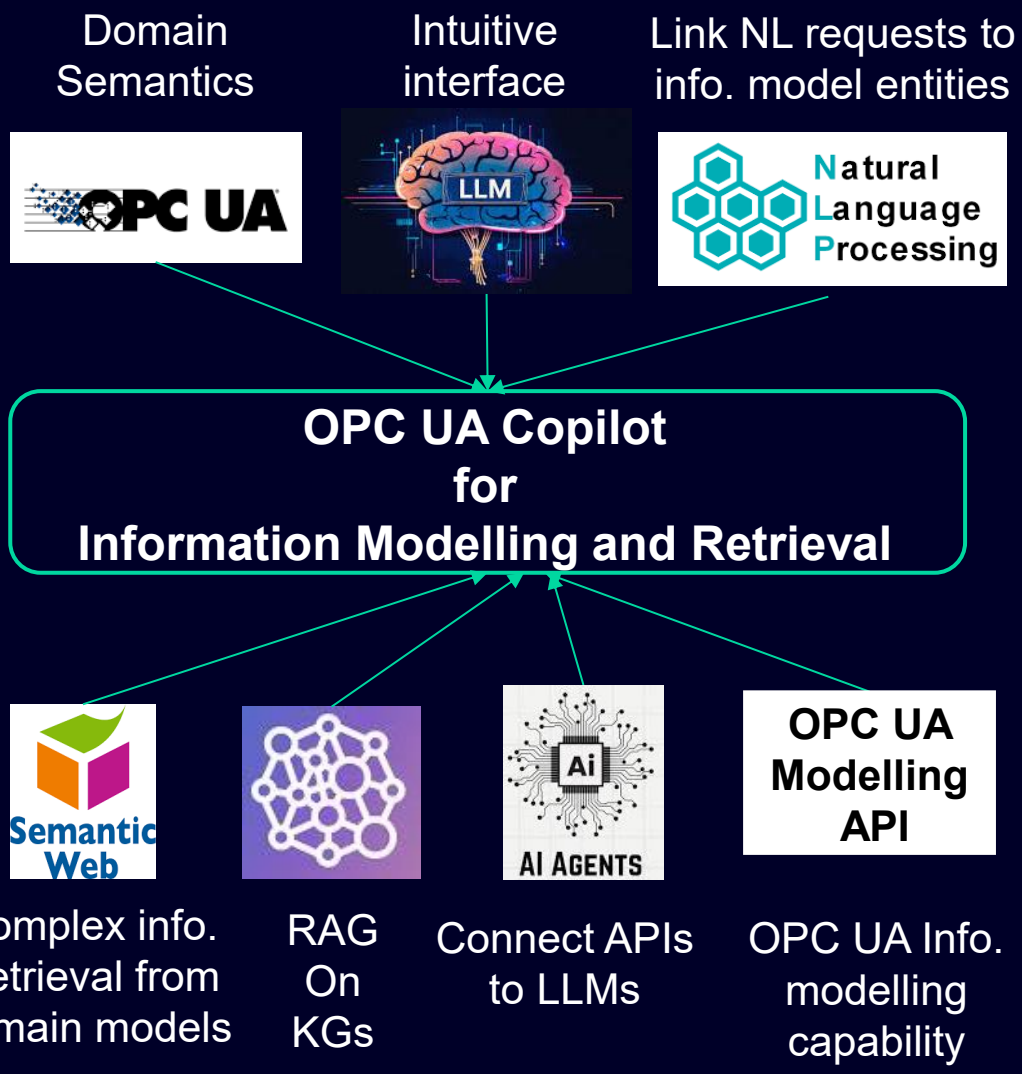
Challenges while using information models with LLMs

- *Highly nested and hierarchical structure in the information models*
- *Generated information models should follow all the constraints / rules specified by the standard*
- *Input domain information models are large in size*
- *Complex modelling techniques are required to model complex information*
- *Identifiers of entities in the information model may not be human-readable*
- *Hallucinations*

Generating highly nested, hierarchical and complex information models for machines only using LLMs is not reliable, inaccurate and not scalable

Information retrieval from highly nested, hierarchical and complex information models only using LLMs is unreliable, inaccurate and not scalable

Leaveraging latest technologies to simplify the process



Intuitive
Accurate
Scalable
Robust

A Copilot that generates a semantically enriched OPC UA information model, that is compliant to the standard.

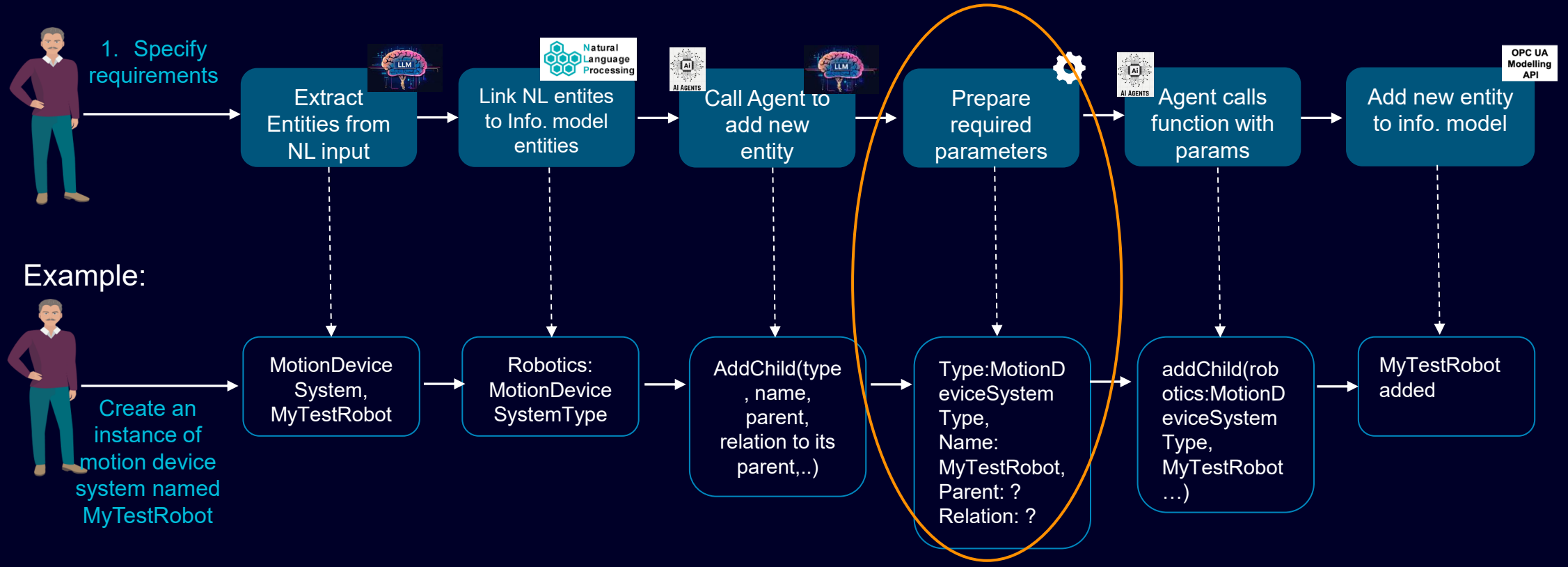
An information model that is tailored according to the machine specifications given by an engineer in natural language.

A Copilot that retrieves complex information from OPC UA information models.

Technical Details of the Approach
AI Agents on OPC UA Information Modelling API

Goal: Instantiate an OPC UA domain information model as per engineer's specifications for a machine.

Approach:



Challenges in Information Model Generation with AI Agents

Challenges:

- *Identifying all the required parameters to call API functions is not intuitive.*
- *Some of the parameters can be extracted from natural language input of the engineer, but not all of them.*
- *Domain knowledge is required to identify the remaining parameters*

What is the type of the entity?

What is the name of the entity?

MyTestRobot

What is the parent entity of the new node in the model?

What is its relation its parent entity in the model?

Challenges in Information Model Generation with AI Agents

Challenges:

- *Identifying all the required parameters to call API functions is not intuitive.*
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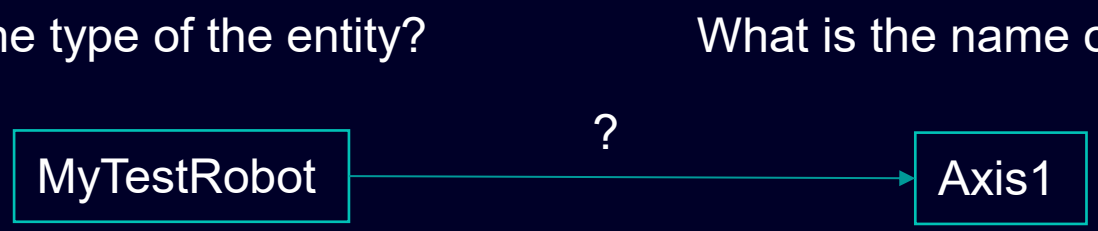
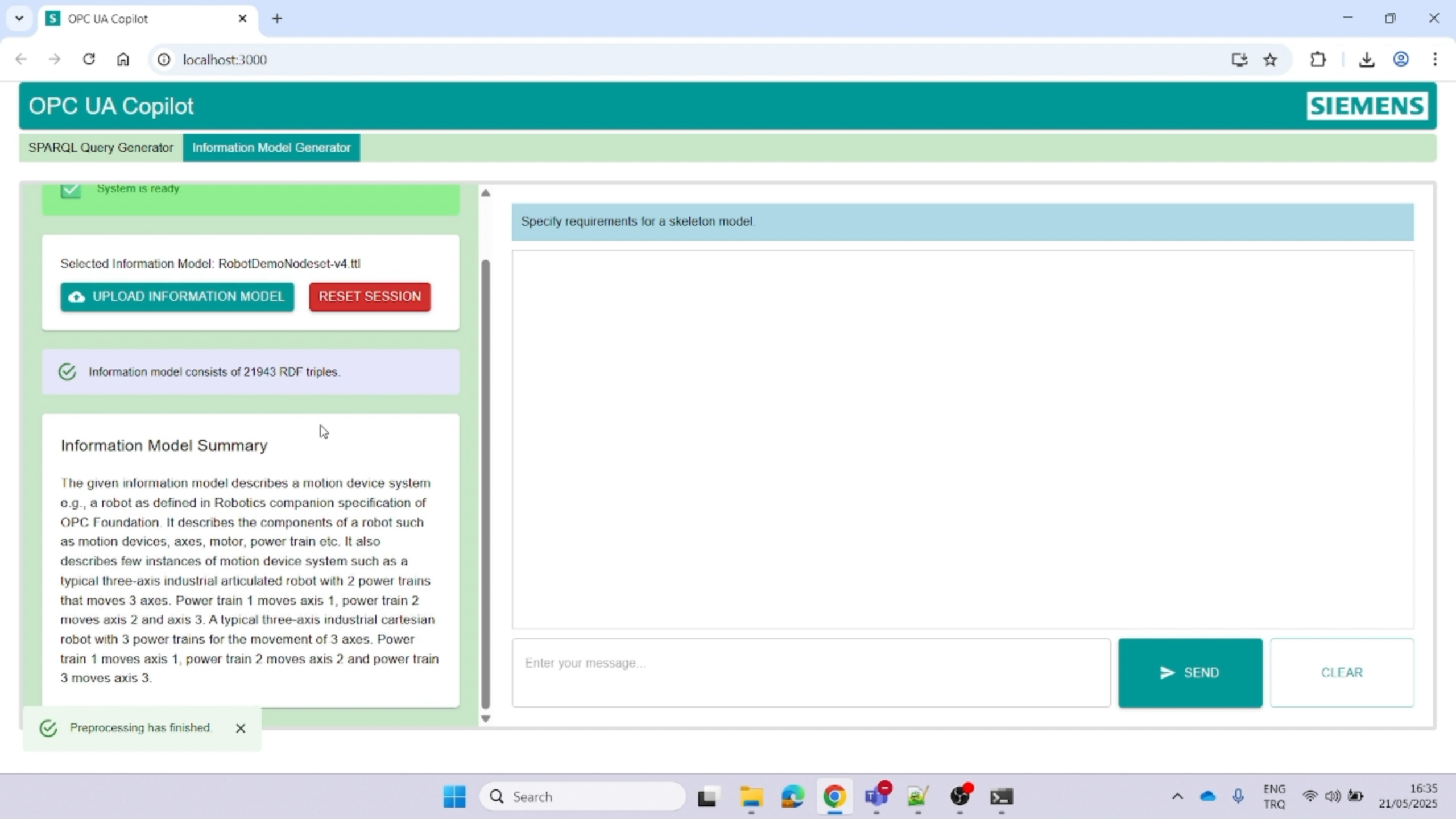


What is the parent entity of the new node in the model? What is its relation its parent entity in the model?


OPC UA Copilot
localhost:3000
OPC UA Copilot
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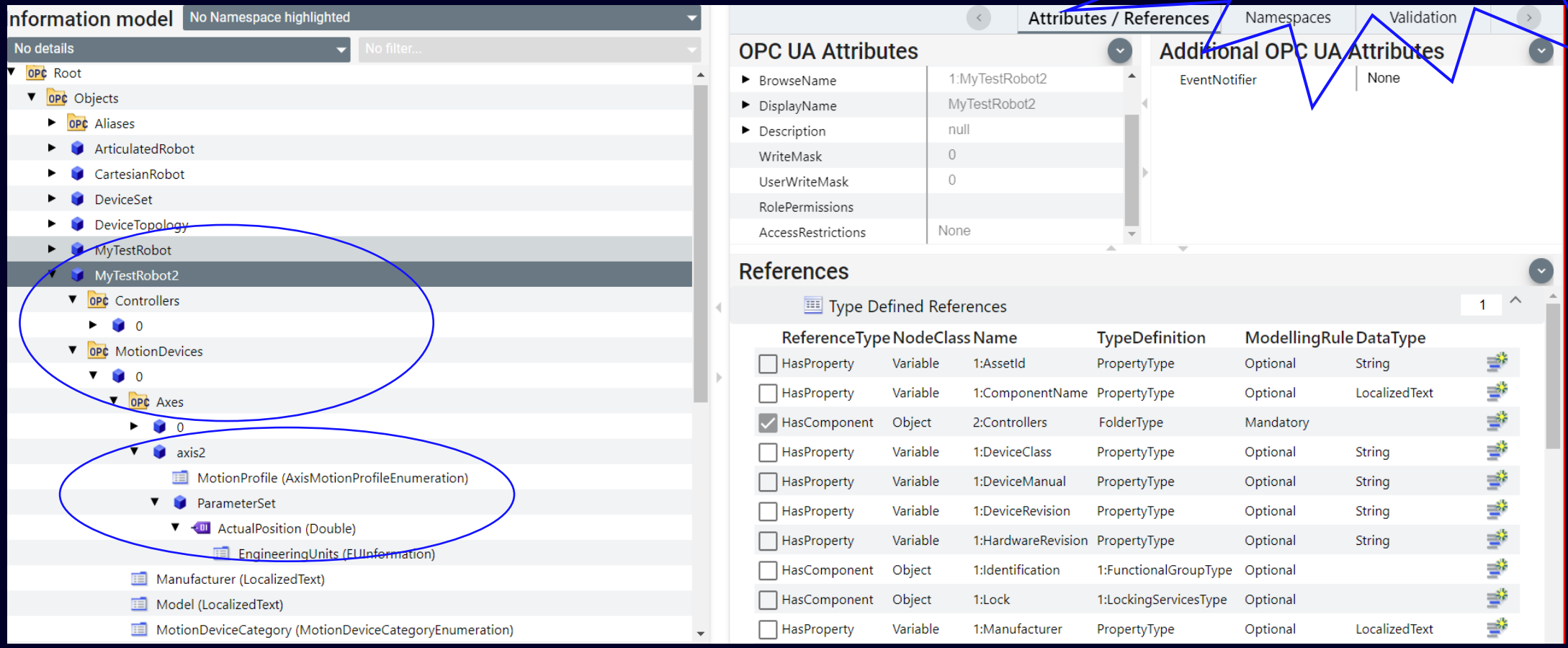
SPARQL Query Generator
Information Model Generator
System is ready
Selected Information Model: RobotDemoNodeset-v4.ttl
UPLOAD INFORMATION MODEL
RESET SESSION
Information model consists of 21943 RDF triples.
Information Model Summary
The given information model describes a motion device system e.g., a robot as defined in Robotics companion specification of OPC Foundation. It describes the components of a robot such as motion devices, axes, motor, power train etc. It also describes few instances of motion device system such as a typical three-axis industrial articulated robot with 2 power trains that moves 3 axes. Power train 1 moves axis 1, power train 2 moves axis 2 and axis 3. A typical three-axis industrial cartesian robot with 3 power trains for the movement of 3 axes. Power train 1 moves axis 1, power train 2 moves axis 2 and power train 3 moves axis 3.
Preprocessing has finished.
Specify requirements for a skeleton model.
Enter your message...
SEND
CLEAR
Search
ENG
TRQ
16:35
21/05/2025

Sample Information model generated by an LLM visualized in OPC UA Modelling Edit

Natural language input:

1. Create an instance of motion device system named MyTestRobot
2. Add an instance of Axis named Axis1 to MyTestRobot

Semantically-enriched
Compliant to the standard
Customized info. model



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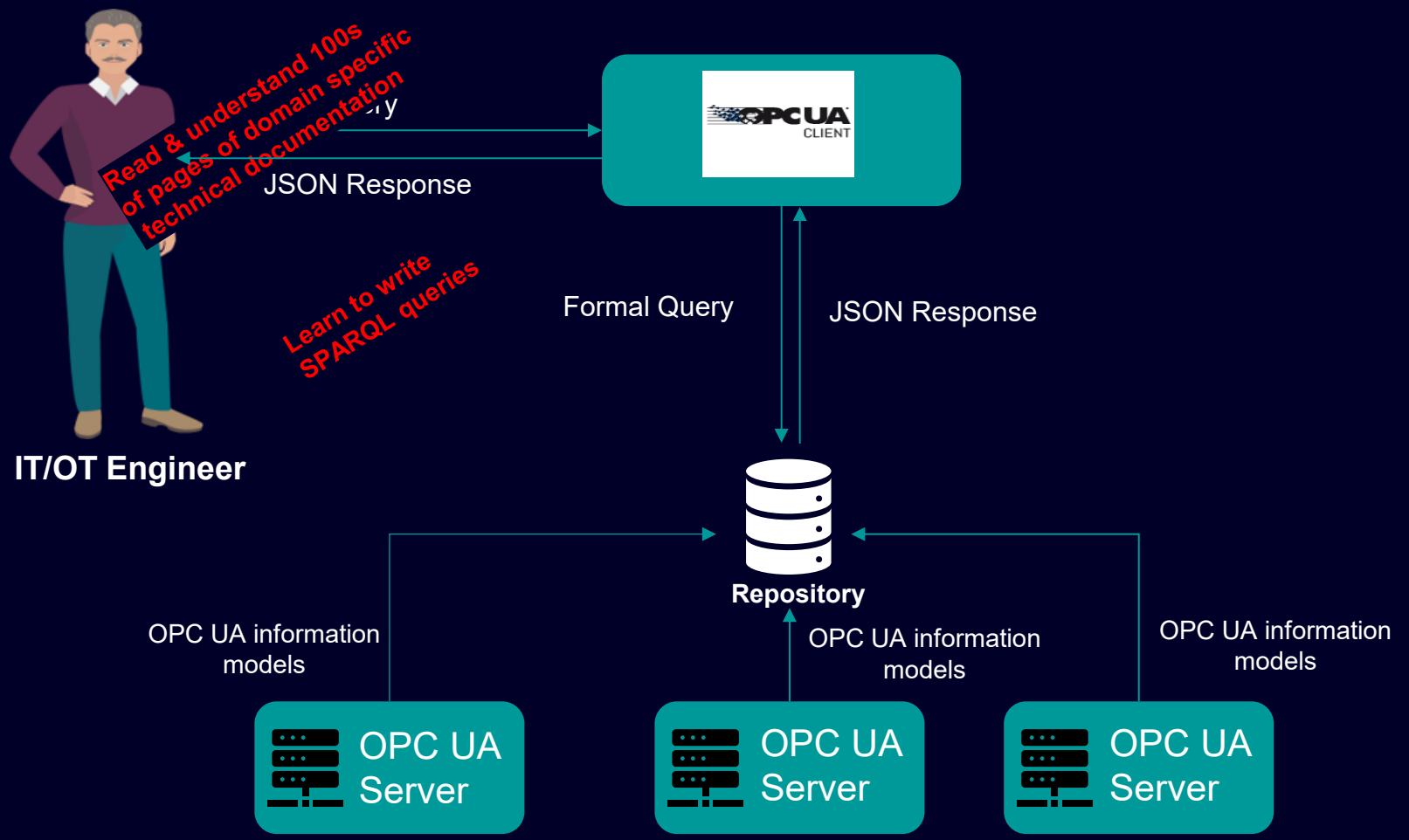
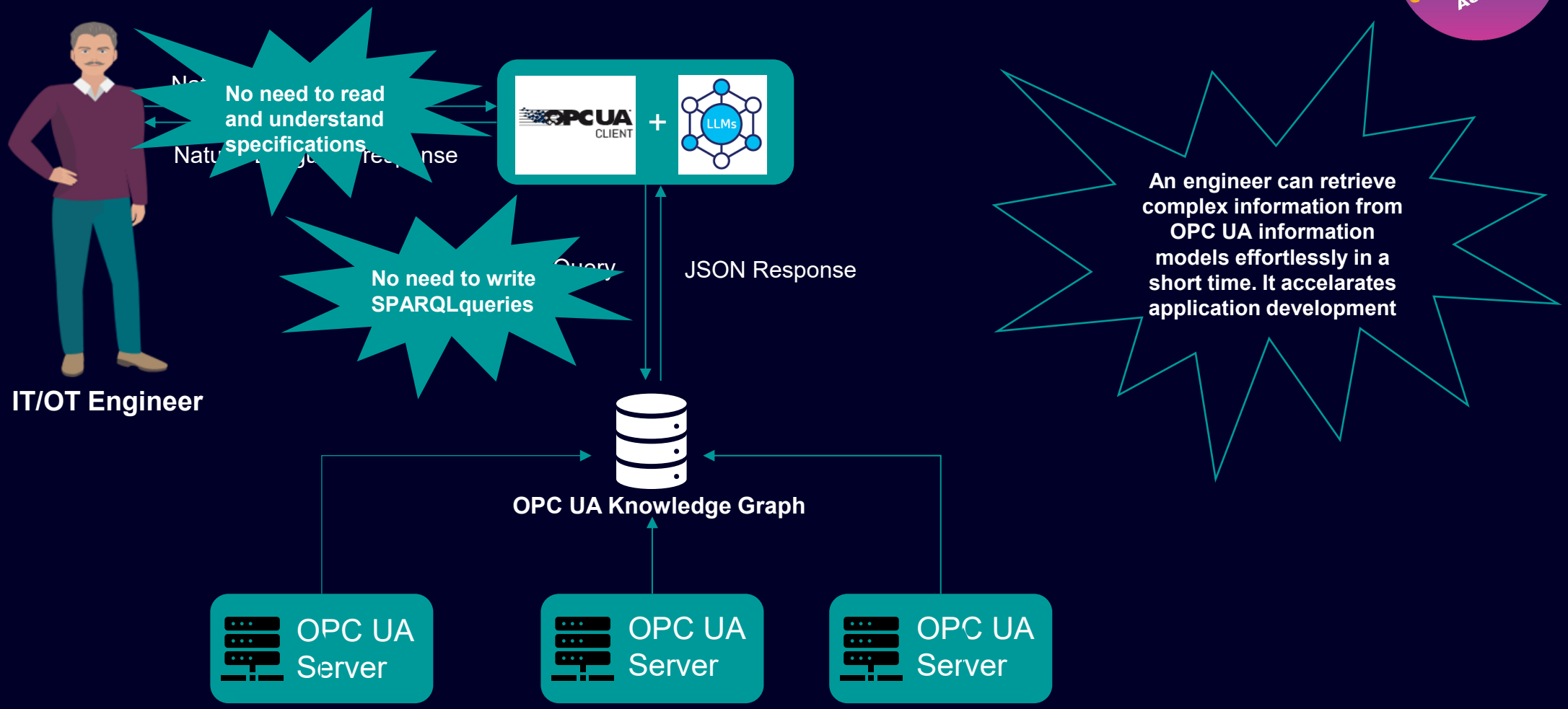
Intuitive Complex Information Retrieval

Problem Description
Complex information retrieval from OPC UA Servers & their information models



OPC UA Co-pilot for effortless Information Retrieval from OPC UA servers



Preprocessing of the domain information models

- *Conversion of the info. model from xml to RDF format using declarative mapping tool called Chimera**
- *Simplification of OWL axioms*
- *RAG on large knowledge graphs*
- *Linking from natural language entities to knowledge graph entities*

* Chimera: https://github.com/cefriel/chimera

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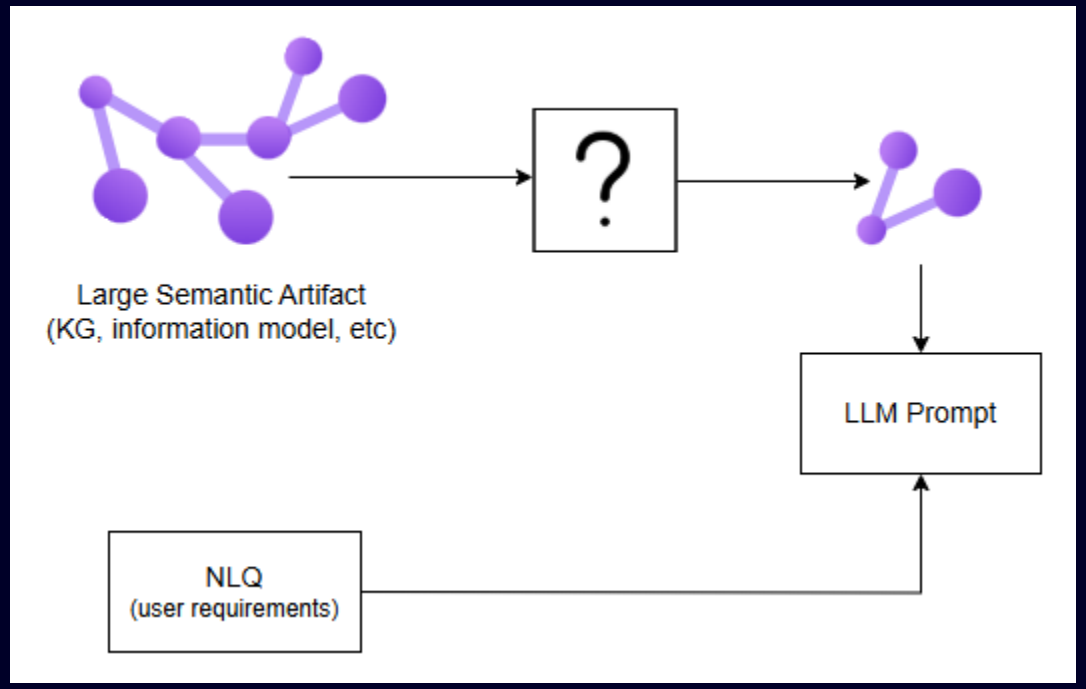
Technical Details of the Approach
RAG on Knowledge Graphs

Goal: Retrieve a core sub-graph of the domain information model that matches to engineer's requirements

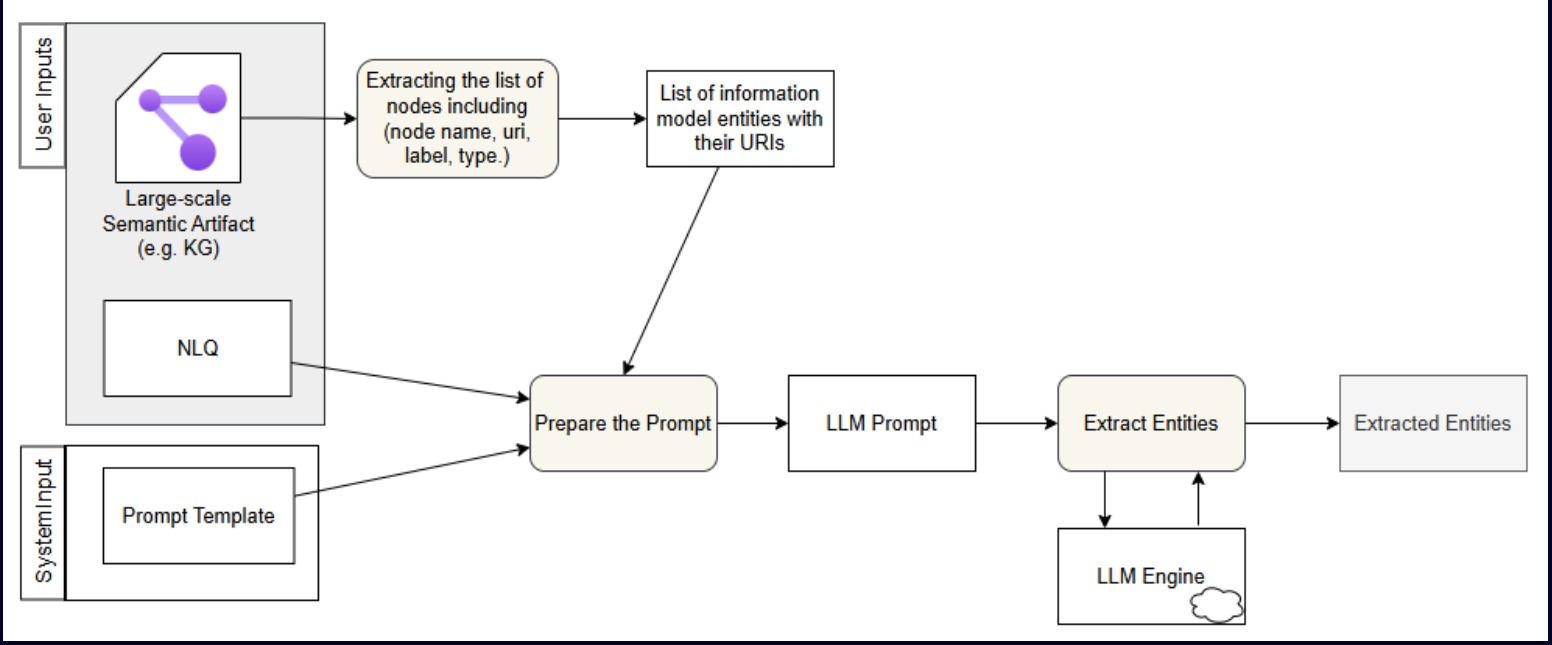


Challenges:

- LLMs are constrained by input prompt size limitations.
- Their usage incurs significant computational costs.
- Therefore, a relevant subgraph should be extracted from the Knowledge Graph (KG) using graph modularization techniques.
- the entities expressed in the Natural Language Query (NLQ) should be retrieved from the KG to enable the LLM to leverage this context effectively.

Named Entity Recognition and Disambiguation (NERD) & Entity Linking (EL)

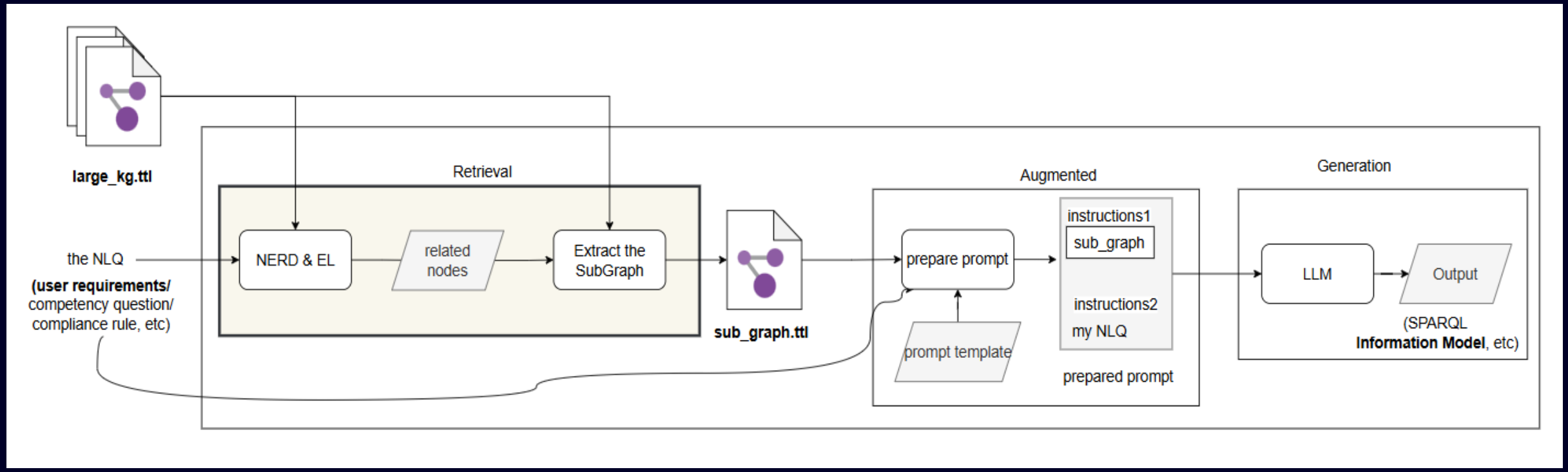
Input: Semantically Equivalent NLQs	Expected Output:	
	Matched Entity Labels	Node URIs
Get the model for a Robot with the Axis and actual position.	Robot ->Robot	http://siemens.com/opcua/demo/i1002
	Axis ->Axis	https://opcfoundation/Robotics/i1003
	actual position ->ActualPosition	http://siemens.com/opcua/Robotics/ActualPosition
Extract the model current position of the axes of all robots.	robots ->Robot	http://siemens.com/opcua/demo/i1002
	axes ->Axis	https://opcfoundation/Robotics/i1003
	current position ->ActualPosition	http://siemens.com/opcua/Robotics/ActualPosition



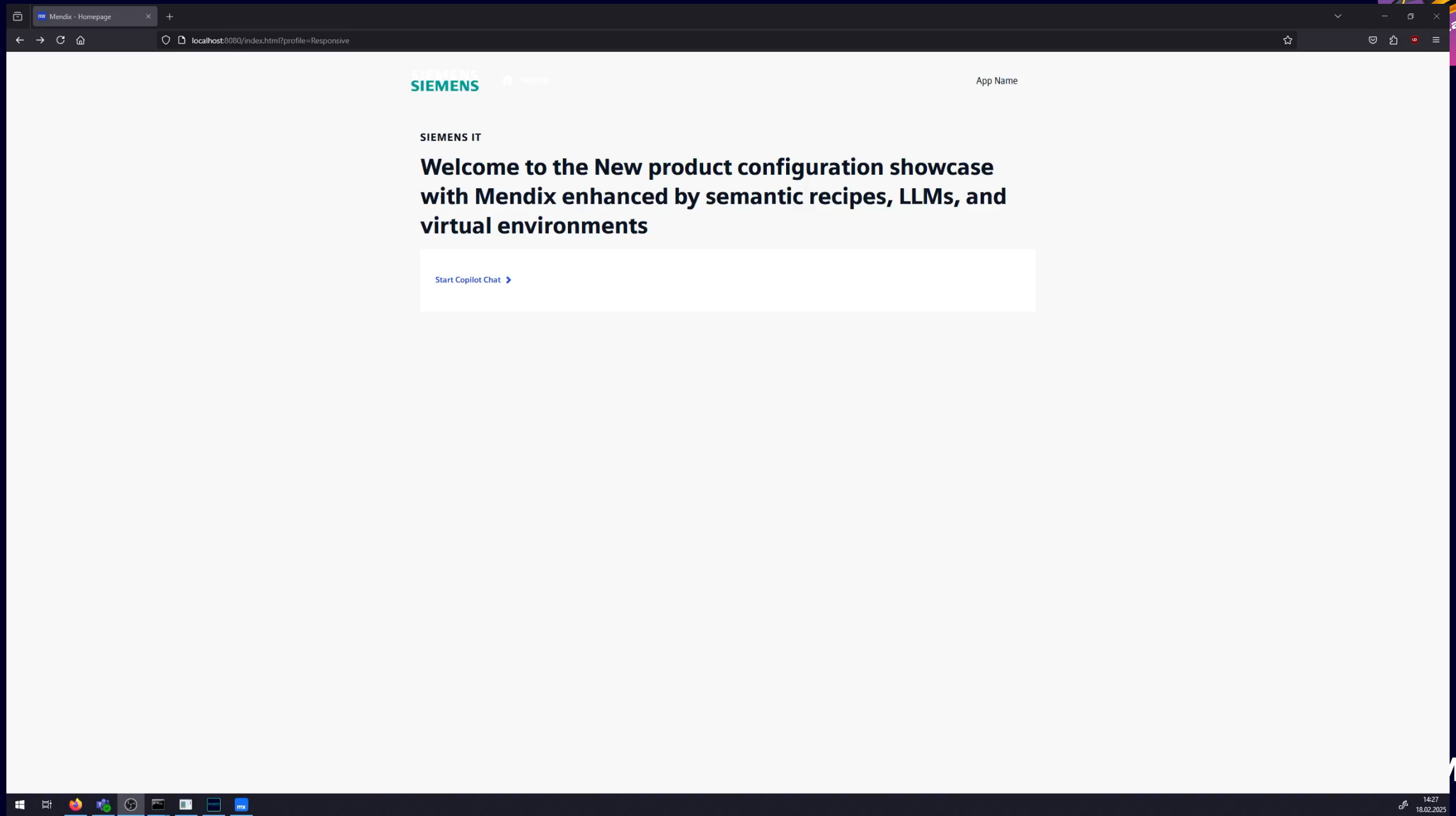
Entity Matching

1. Clean the Knowledge Graph (KG)
2. Generate a mapping file between KG node URIs and their labels
3. Send the mapping file and the NLQ to the LLM
4. LLM identifies the matching entities

End-to-end RAG Approach for Information Retrieval



SmartEdge Use case demo



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