International Council on Systems Engineering
A better world through a systems approach

Using LLMs to Convert Documentation to SysML

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Intro

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Model Based Systems Engineering (MBSE)

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- What is **MBSE**?
  - **INCOSE Definition:** "A formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later lifecycle phases."
- Strengths of MBSE:
  - Enhanced collaboration and communication
  - Automate processes, identify errors more easily
  - Better adaptability to changes
  - Structured to manage complexity

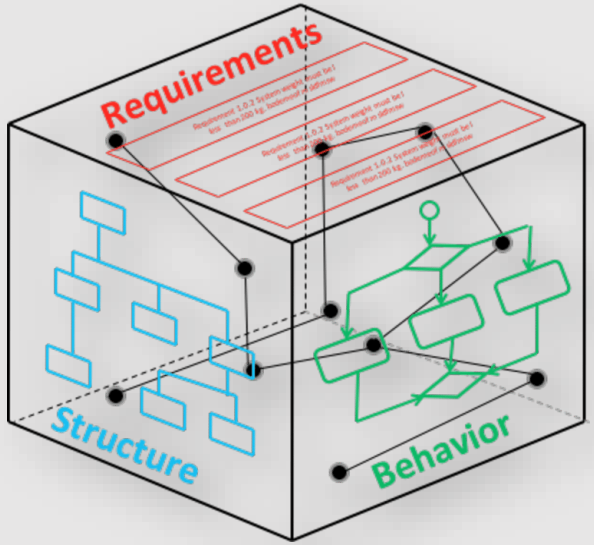
CAMEO SYSTEMS MODELER™

MapleMBSE™
Systems Engineering: Connected

ENTERPRISE ARCHITECT

Systems Modeling Language (SysML)

- What is **SysML**?
  - A means to enable MBSE
  - General purpose, typically a candidate to use for modeling **complex systems**
    - **Complex system** – A system composed of many interacting components, often exhibiting emergent behavior or non-linear relationships
  - Uses **elements** and **relations** to fully define a system of interest
    - **Element** – Fundamental building block of a system model
    - **Relation** – Defines how different elements connect and interact



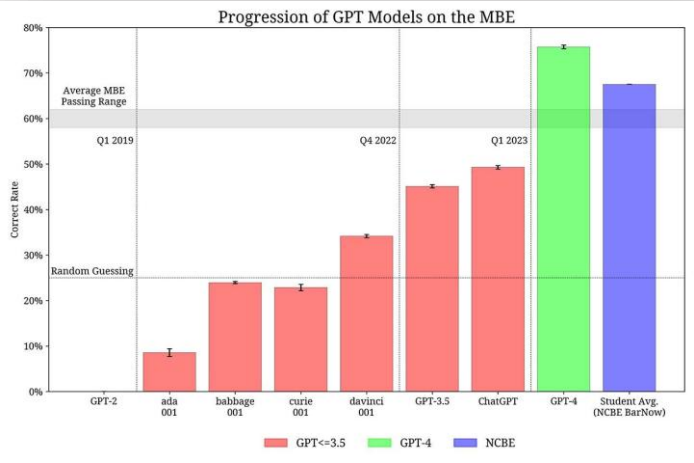
Automated Conversion of Documentation to SysML

- **The Problem with MBSE / SysML:** It is time consuming to create a system model based on system documentation.
  - Need to create elements and relations manually
  - Barrier to entry to adoption of MBSE from DBSE methodologies
- **Proposed Solution:** Use Large Language Models (LLMs) to automate conversion of documentation to a SysML model.
  - LLM creates elements and relations automatically by analyzing the system documentation
  - Legacy system documentation can quickly be used as a prompt to generate SysML diagrams

Large Language Models (LLMs)

What is an LLM?

- A large neural network trained to predict the next letter* in a piece of text
- Uses the **Transformer** architecture (the T in GPT)
- Anywhere from 1 billion to over 1 trillion parameters
- Demonstrate advanced understanding of language, problem solving, and world knowledge.

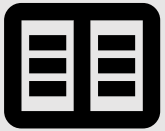


Source: Royal Society Publishing, 26-Feb-2024

ChatGPT

Gemini

Issues with LLMs



Hallucinations

When the LLM provides false information

Context Size

When an LLM is given to much text to reason about

Reasoning Capacities

A task may be too complicated for an LLM

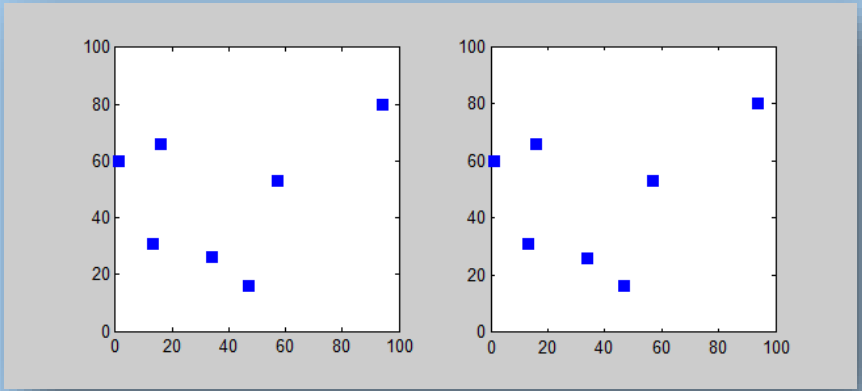
Security risks

For cloud-based LLMs, ensuring that private data stays private

Can LLMs be a scalable solution?

Traveling Salesman Problem

- Traveling Salesman Problem
  - Find the shortest path to visit a set of cities
  - Computational requirement scale exponentially
  - Cannot be solved by computers
- Engineering systems are large and complex



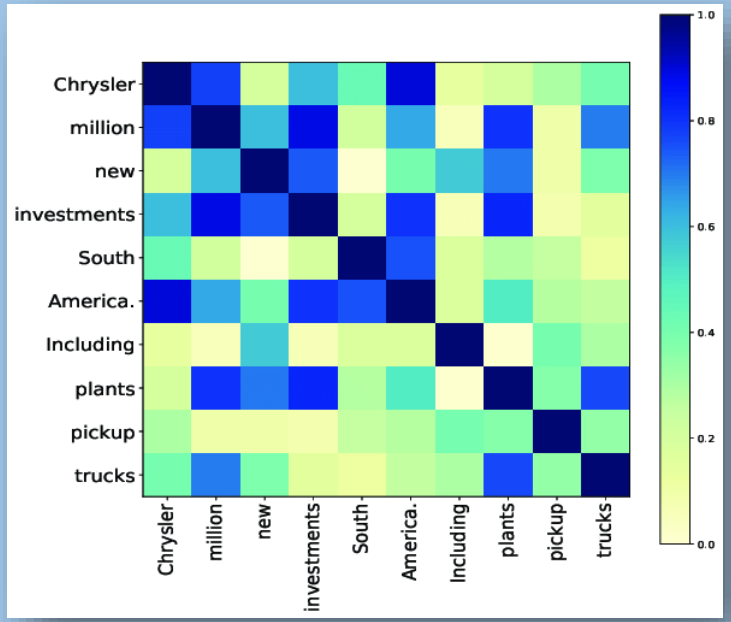
How much information is in a document?

- The numbers of facts (F) in a document is proportional to document length (D)
- There are at least as many facts as elements and relationships
- The size of the model (M) is the number or elements and relationships

- $D \propto F \leq E + R \approx M$

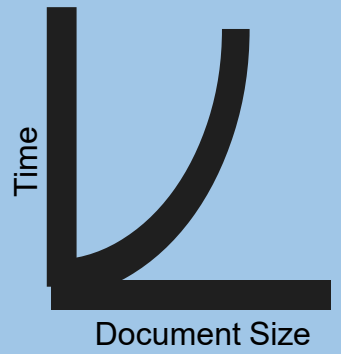
How does an LLM Scale?

- Self-Attention
  - Computes a relatedness score of each word to each other word
  - The most expensive part of the Transformer architecture
- LLM scale quadratically to “read and write”



How Would an LLM Pipeline Scale With Document Size?

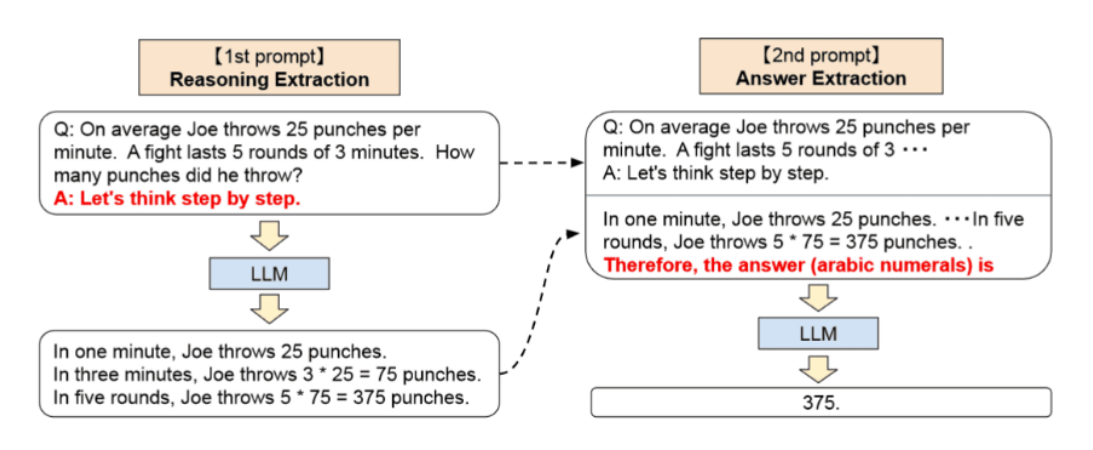
- It would be a quadratic time operation to read the entire text
- The output could be written in two ways:
  - A linearly scaled number of constant sized chunks resulting in a linear time operation
  - A single linearly scaling chunk resulting in a quadratic time operation
- Overall, this results in a quadratic time operation



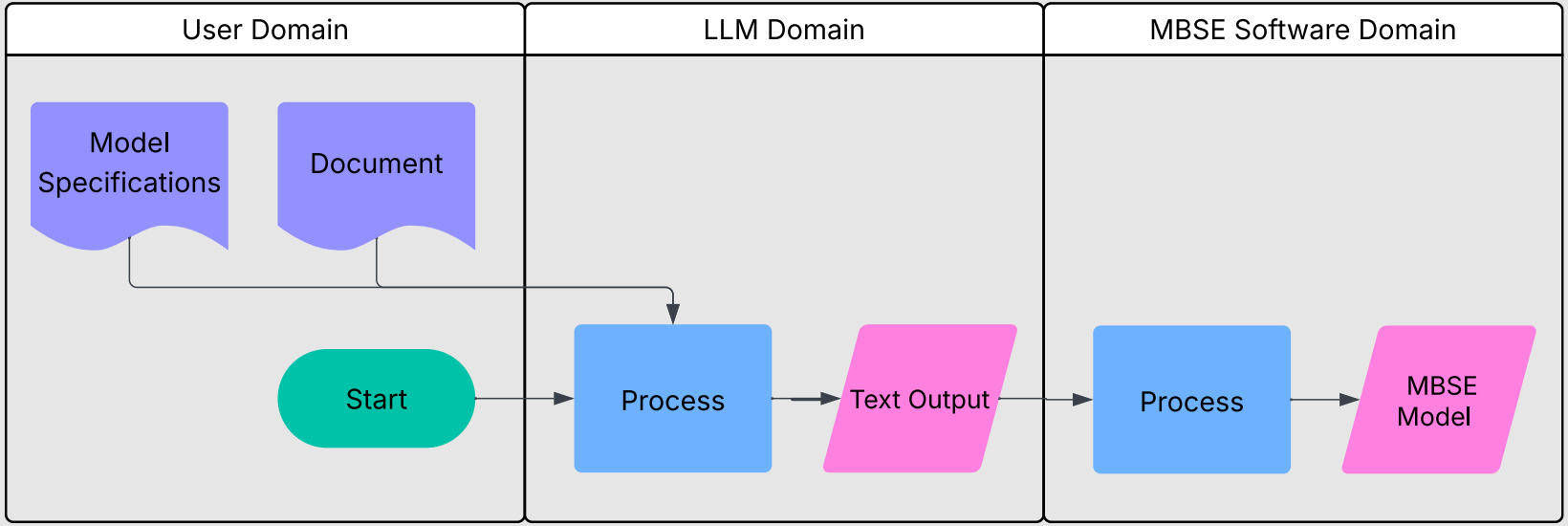
Our Pipeline

Key Strategies

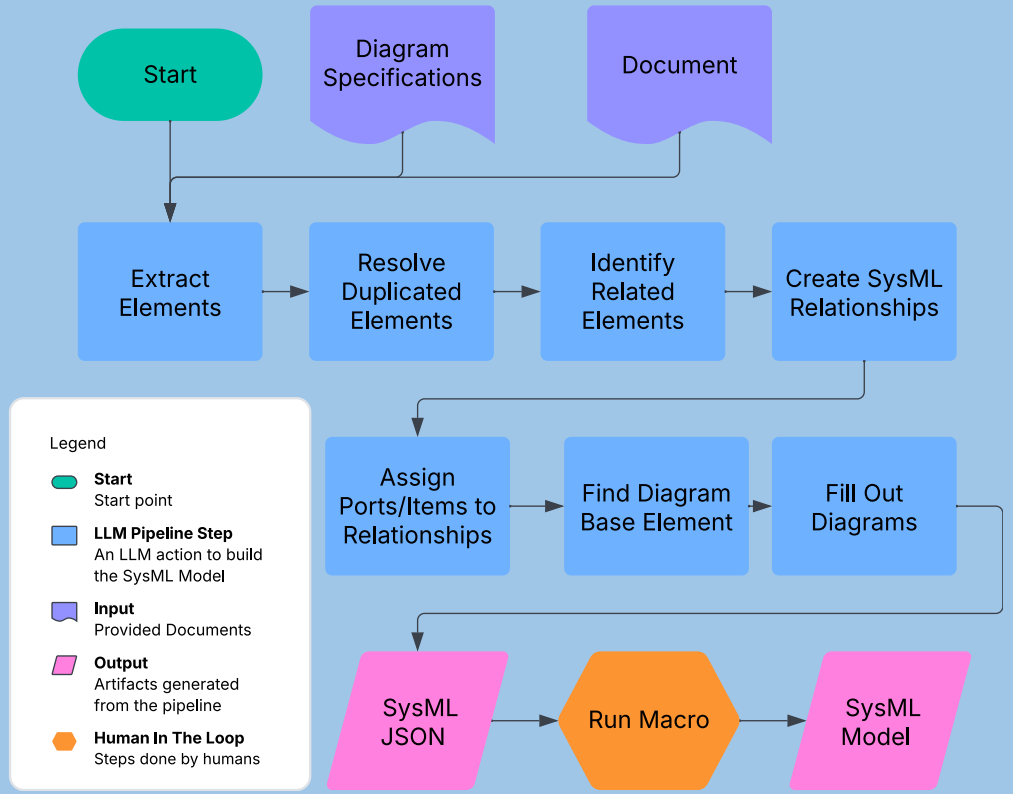
- Use of minimal parallelizable steps
- Chain of Thought Prompting
- Support for any language model
- Support for local LLMs



Pipeline Domains



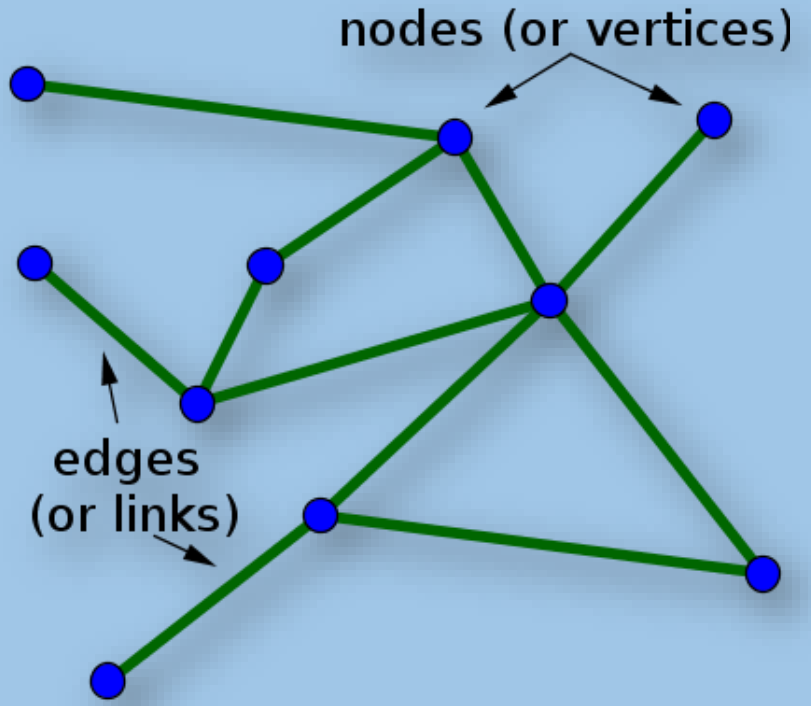
LLM Processing Pipeline



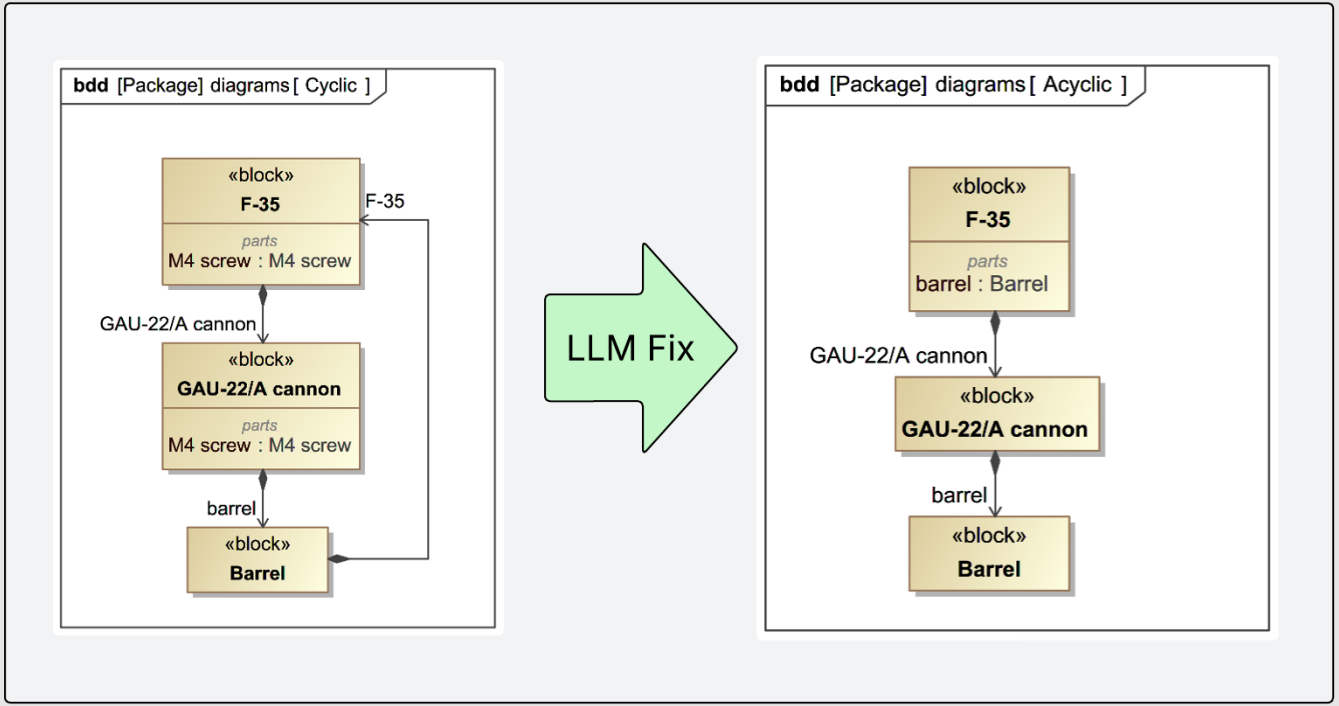
Graph Theory Checks

Graph Theory

- Graph Theory: Study of network made of nodes and edges
- Well studied with many algorithms and applications
- System models can be thought of as graphs
  - Elements => Nodes
  - Relationships => Edges
- In our pipeline:
  - Use existing algorithms to identify problematic areas
  - Show the LLM the issue so it can choose to correct



De-Cycling


bdd [Package] diagrams [Cyclic]
«block»
F-35
parts
M4 screw : M4 screw
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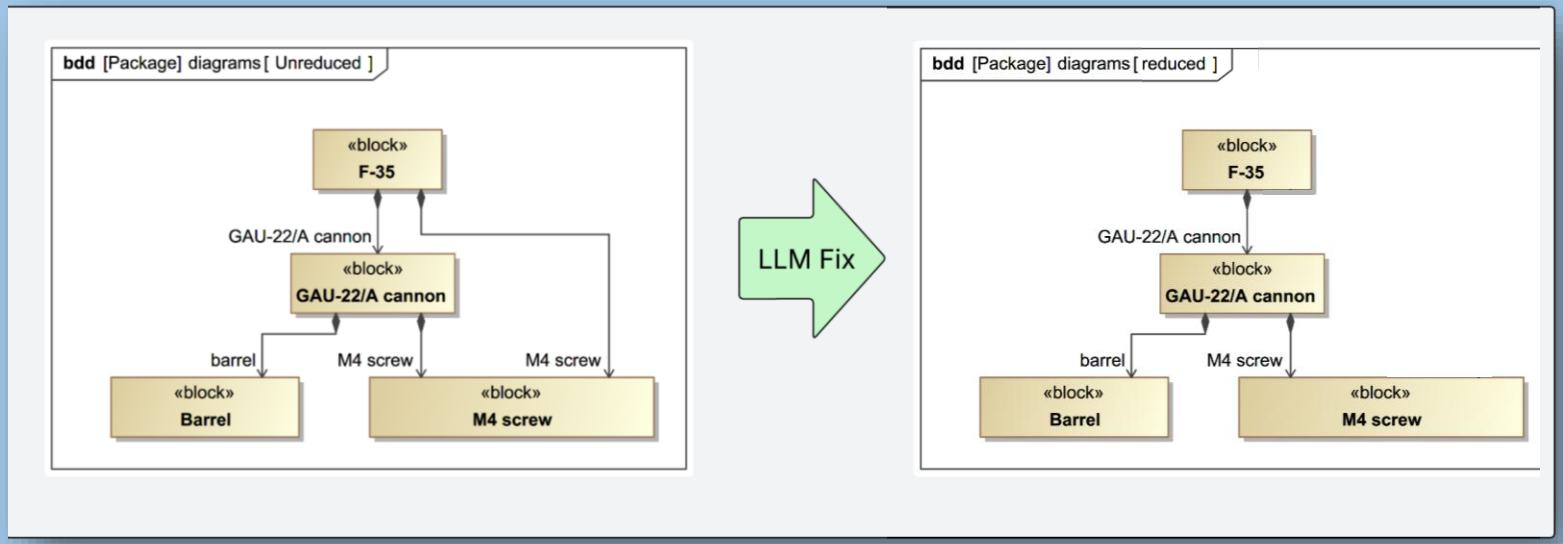
Transitive Reduction



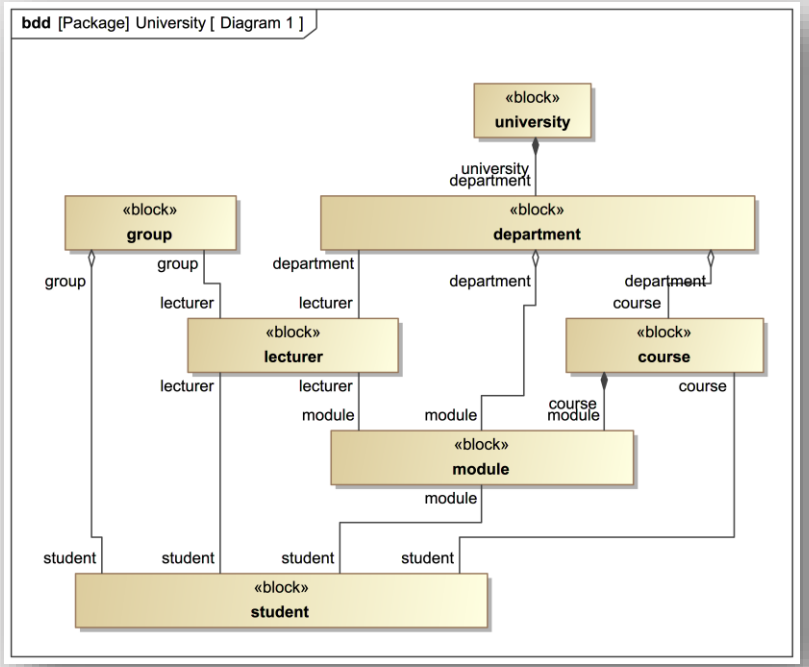
Experiment

Experiment Setup

- Language Model
  - Qwen 2.5 32b (Released November 12th, 2024)
  - Open source model developed by Alibaba Cloud
- Hardware
  - NVIDIA A100-SXM4-80GB (Part of GTRI's ICEHAMMER HPC Cluster)
- Datasets
  - University and Summer School Text from (Akundi et al., 2024)
    - Used a lexical model to make UML models from prose
  - Chair Text is a markdown table of our own creation

University Text

“A university consists of a number of departments. Each department offers several courses. A number of modules make up each course. Students enroll in a particular course and take modules towards the completion of that course. Each module is taught by a lecturer from the appropriate department, and each lecturer tutors a group of students.”



Source: Akundi et al., 2024

Summer School Text

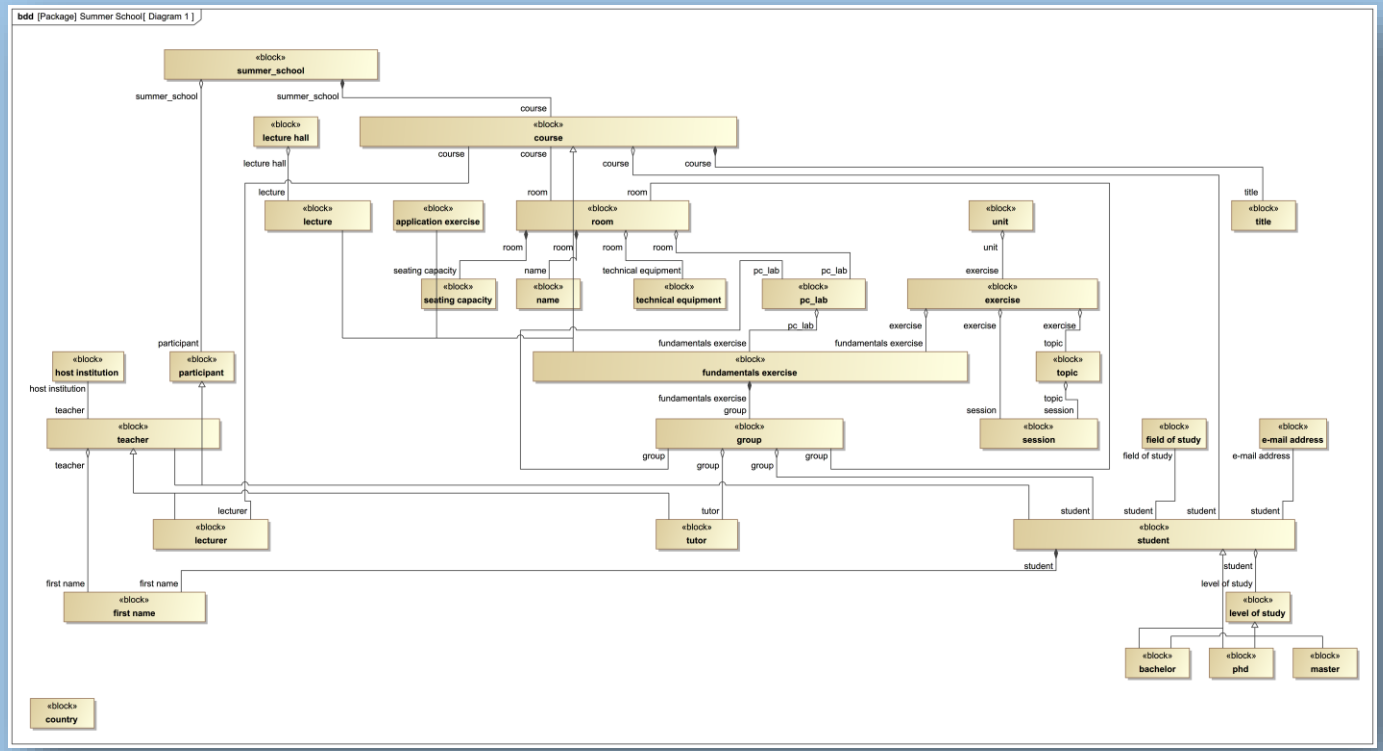
“Participants at the summer school are either students or teachers. Each student registers for the NEMO Summer School providing, amongst others, their level of study (Bachelor, Master or PhD) and their field of study. Additionally, each student provides her/his first name, last name, their country of province and e-mail address. Students attend courses during the summer school.

Courses can be a lecture, a fundamentals exercise or application exercises. [The fundamental exercise is considered as one unit as it covers one topic, although it takes place in several sessions.] Each course has a title, is being given by one or more lecturers and takes places in a room. Every room has a name, a seating capacity, and technical equipment.

Lectures and application exercises take place in a lecture hall, while fundamental exercises are conducted in PC-labs. Within the fundamentals exercise students are split in groups. Each group has a group number, a room (i.e., PC-lab) and a tutor. Teachers can be either lecturers or tutors. Each teacher has a first name, last name, host institution, and country.”

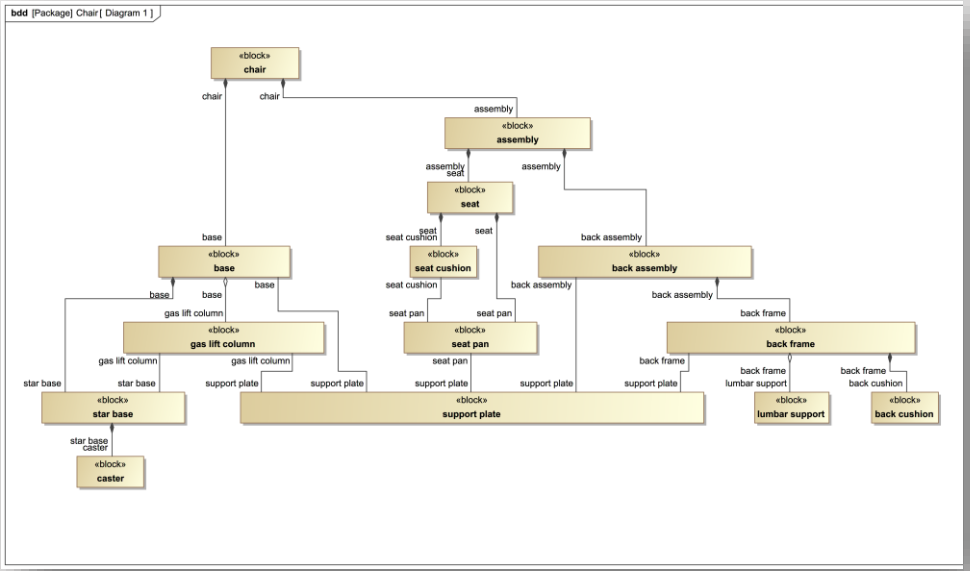
Source: Akundi et al., 2024

Summer School Text



Chair Text

Structural Member Name	Parent Assembly	Connects To
Seat Cushion	Seat Assembly	Seat Pan
Seat Pan	Seat Assembly	Seat Cushion, Support Plate
Support Plate	Seat Assembly	Seat Pan, Base Assembly
Back Cushion	Back Assembly	Back Frame
Back Frame	Back Assembly	Support Plate, Back Cushion
Lumbar Support	Back Assembly	Back Frame
Gas Lift Column	Base Assembly	Support Plate, Star Base
Star Base	Base Assembly	Gas Lift Column, Casters
Casters	Base Assembly	Star Base



Elements and Relationships

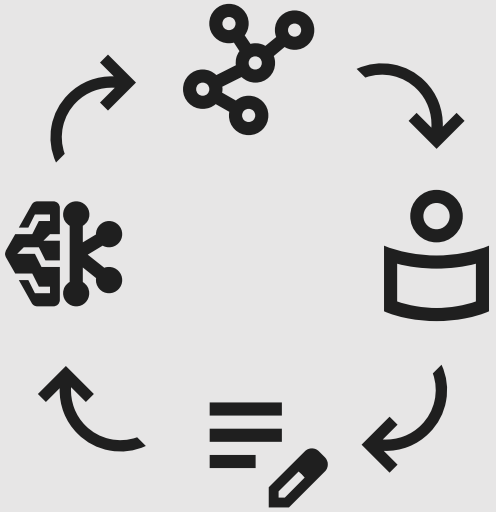
Precision – Are the elements/relationships in the resulting model present in the documentation?
Recall – Are the elements/relationships in the documentation present in the resulting model?
F1 – The harmonic mean of precision and recall values (from 0 to 1, 1 being the best performance)

Text	Element Precision	Element Recall	Element F1
University Text	7/7	7/7	1
Summer School Text	32/33	32/34	0.955
Chair Text	14/14	14/14	1

Text	Relation Precision	Relation Recall	Relation F1	Relation Type Accuracy
University Text	9/11	9/9	0.900	0.900
Summer School Text	41/51	41/48	0.828	0.927
Chair Text	18/20	18/22	0.857	0.636

What's Next?

Extending the Current Work



- Using better models – LLMs constantly improving
- Incorporating real world examples
- Human in the loop

Applicability to SysML V2

- Achieved final adoption by Object Management Group (OMG) on July 21st, 2025
- SysML V2 utilizes KerML (Kernel Modeling Language)
  - Metamodel-based language, moving away from UML
  - Defines elements, relationships, and formal semantics for SysML V2
- Opportunities to refine our approach to incorporate SysML V2 as commercial modeling software begins to integrate it

Challenges of Extending To SysML V2 Textual Notation

Lack of Training Data

- Most Coding LLMs have millions of code examples
- SysML V2 has little training data and uses a unique syntax.

Understanding Semantics

- Since the LLM is directly writing SysML V2, there is no layer to insert vocabulary that the LLM is more comfortable with
- The LLM must differentiate the SysML V2 vs the colloquial definitions

Repository Management

- SysML V2 is designed to be split among multiple files for large projects
- The model must identify which files to read and edit, and when to make new files.