AI-Driven Consistency of SysML Diagrams

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Outline

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Introduction

Consistency in UML/SysML Models

- Not really a new research issue!

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  - Unequivocal, algorithmically verifiable
  - Address a wide spectrum of inconsistencies

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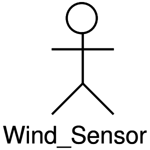

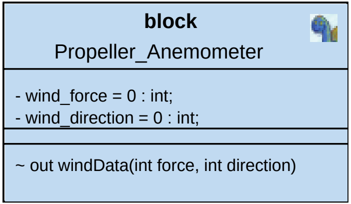

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Introduction

AI for MDE

- Maybe you've heard about LLMs?

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Our idea

- Blend formal rules and LLMs in symbiosis to detect and correct internal and cross-view inconsistencies
  - Generate consistent diagrams from a textual specification
  - Enhance the consistency of input diagrams

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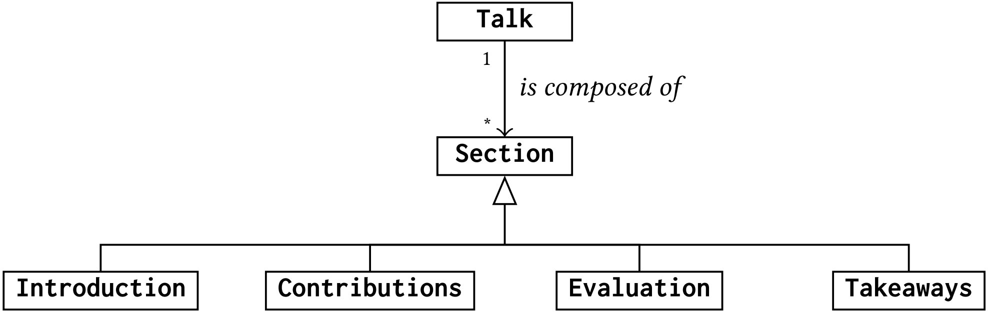
Talk
1
is composed of
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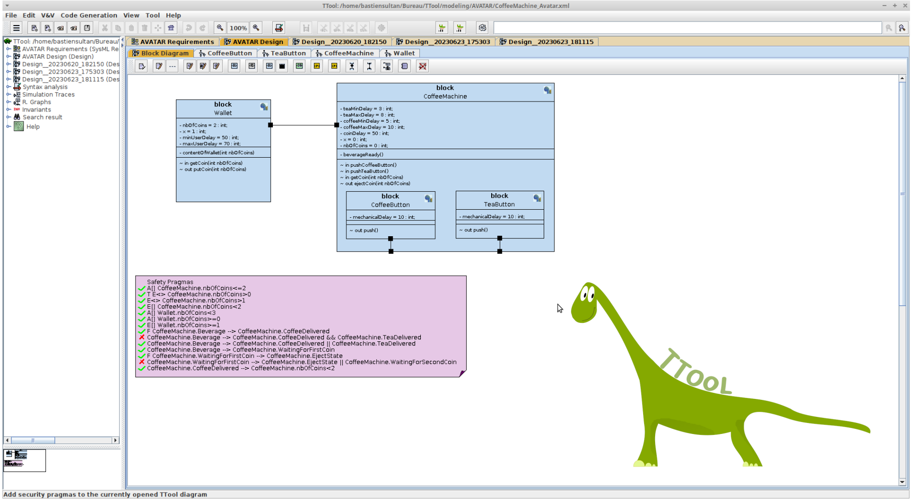
Section
Introduction
Contributions
Evaluation
Takeaways

Outline

Some context – TTool



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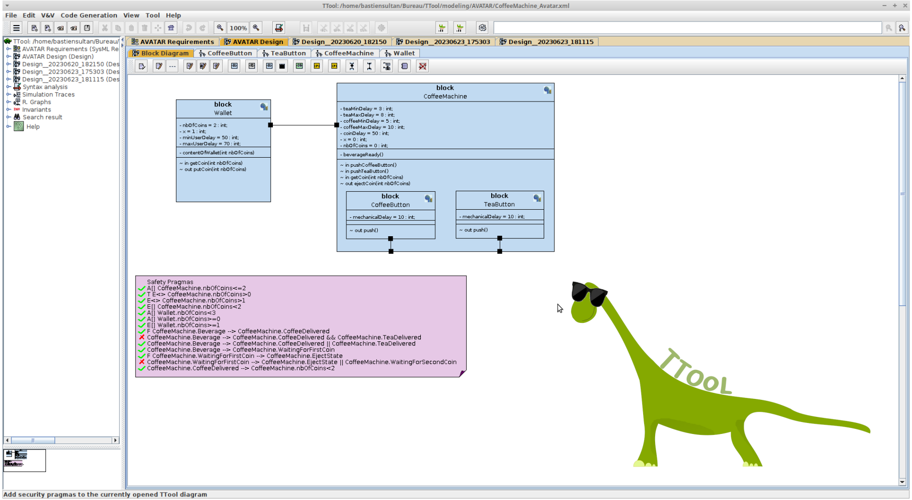

Contribution overview

Our contribution in a nutshell

- Applicable to any SysML diagram but the paper focuses on UCD/BD consistency

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- Applicable to any SysML diagram but the paper focuses on UCD/BD consistency
- Sets of formal consistency rules, both internal (UCD and BD) and external (crossed consistency UCD/BD)
  - You can find them in the paper if you like first-order logic :-)
- Consistency handling methodology blending formal rules and LLMs, and GPT-based implementation in TTool

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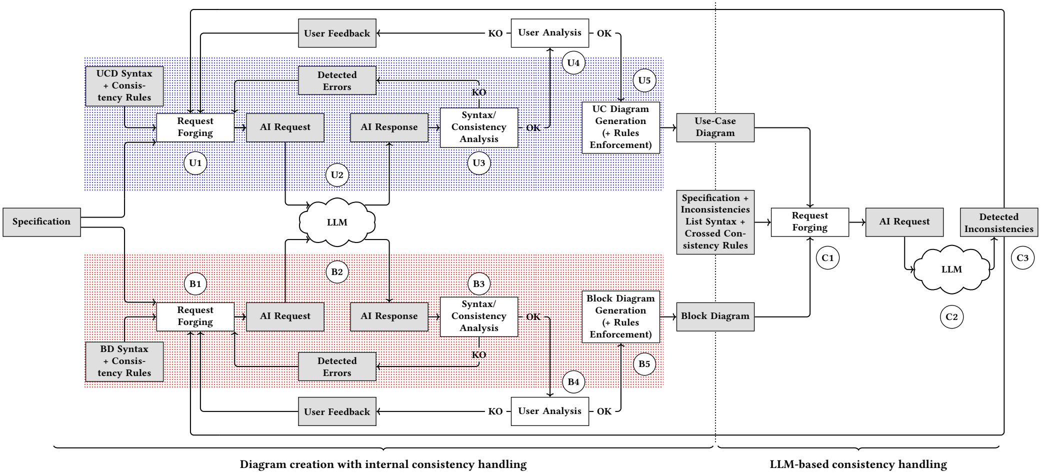

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Focus on LLM-based inconsistency detection – generated LLM prompts

Textual diagram description

```
actors: User Propeller_Anerometer ...
Use cases: Define_PositionAndCourse ...
Connections: include(Activate_BowThrusters, Maintain_SetPosition ...
```

Inconsistencies list syntax

```
When you are asked to identify all  the relevant incoherencies between
    two diagrams, return them as a JSON specification formatted as
    follows:
{incoherencies: [{ \"diagram\" :\"diagram1 or diagram2\", \"description\
    ": "description of the incoherency\"}..."]};
```

Focus on LLM-based inconsistency detection – generated LLM prompts

Rules

```
# Respect: In a block diagram, the blocks representing actors as defined
    in the use case diagram must bear identical names to their
    corresponding use cases.

# Respect: In a block diagram, blocks representing actors from the use
    case diagram must not be connected together.

...
```

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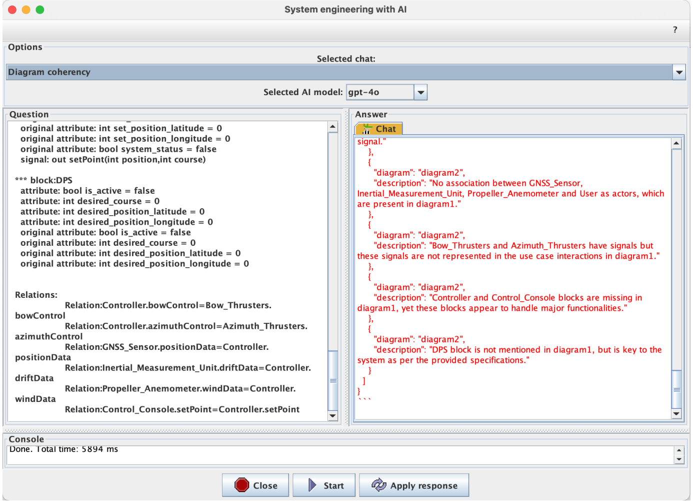
Focus on LLM-based inconsistency detection



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In practice

Test setup

- Three different systems: an automotive braking system, a space-based system, and ship dynamic positioning system
- All specifications, diagrams and results: Zenodo archive[a]
- Evaluation on model generation (UCD, BD), inconsistency detection, inconsistency correction
- Use GPT 4 as underlying LLM for inconsistency detection and correction

[a] https://doi.org/10.5281/zenodo.11962707

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Results

System	Test	Diagram	Inconsistencies detected: Internal	External	Errors	Total	Inconsistencies corrected: Internal	External	Total
Automated braking	BD1 vs UCD1	*BD1*	1	2	0	3	1	2	3/3
		UCD1	0	0	0	0	0	0	—
	BD1 vs UCD2	*BD1*	0	1	0	1	0	1	1/1
		UCD2	0	3	0	3	0	2	2/3
	BD2 vs UCD1	*BD2*	5	1	1	6	4	1	5/6
		UCD1	0	1	1	1	0	1	1/1
	BD2 vs UCD2	*BD2*	4	2	0	6	3	1	4/6
		UCD2	2	2	0	4	2	2	4/4
Dynamic positioning system	BD1 vs UCD1	*BD1*	1	1	0	2	1	0	1/2
		UCD1	0	0	1	0	0	0	—
	BD1 vs UCD2	*BD1*	2	2	0	4	2	1.5	3.5/4
		UCD2	2	0	0	2	0	2	2/2
	BD2 vs UCD1	*BD2*	1	0	0	1	1	0	1/1
		UCD1	1	1	0	2	1	1	2/2
	BD2 vs UCD2	*BD2*	3	0	1	3	3	0	3/3
		UCD2	0	0	1	0	0	0	—
//									
Total			36	33	6	69	30	30.5	60.5/69

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Takeaways

Pros

- Blending is cool! Significant model improvements derived from the integration of the rule-based and LLM-based approaches
- High automated correction rate for LLM-detected inconsistencies: between 50% and 100% per diagram, averaging at 87%

Limits and improvement directions

- With cross-diagram consistency rules, the LLM tends to exclusively focus on these rules → the user can opt to use them or not
- Correction rate is not at 100% for LLM-detected inconsistencies
- Extension to other diagrams, to other tools (cross-tool consistency ?)
- Possibility to support user-defined rules

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Questions?

AN OPEN SOURCE TOOLKIT PROVIDED BY:

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Latest version of TTool includes what has been presented in the paper. . . and much more! `ttool.telecom-paris.fr`

All evaluation results (including models) are available on our public Zenodo repository