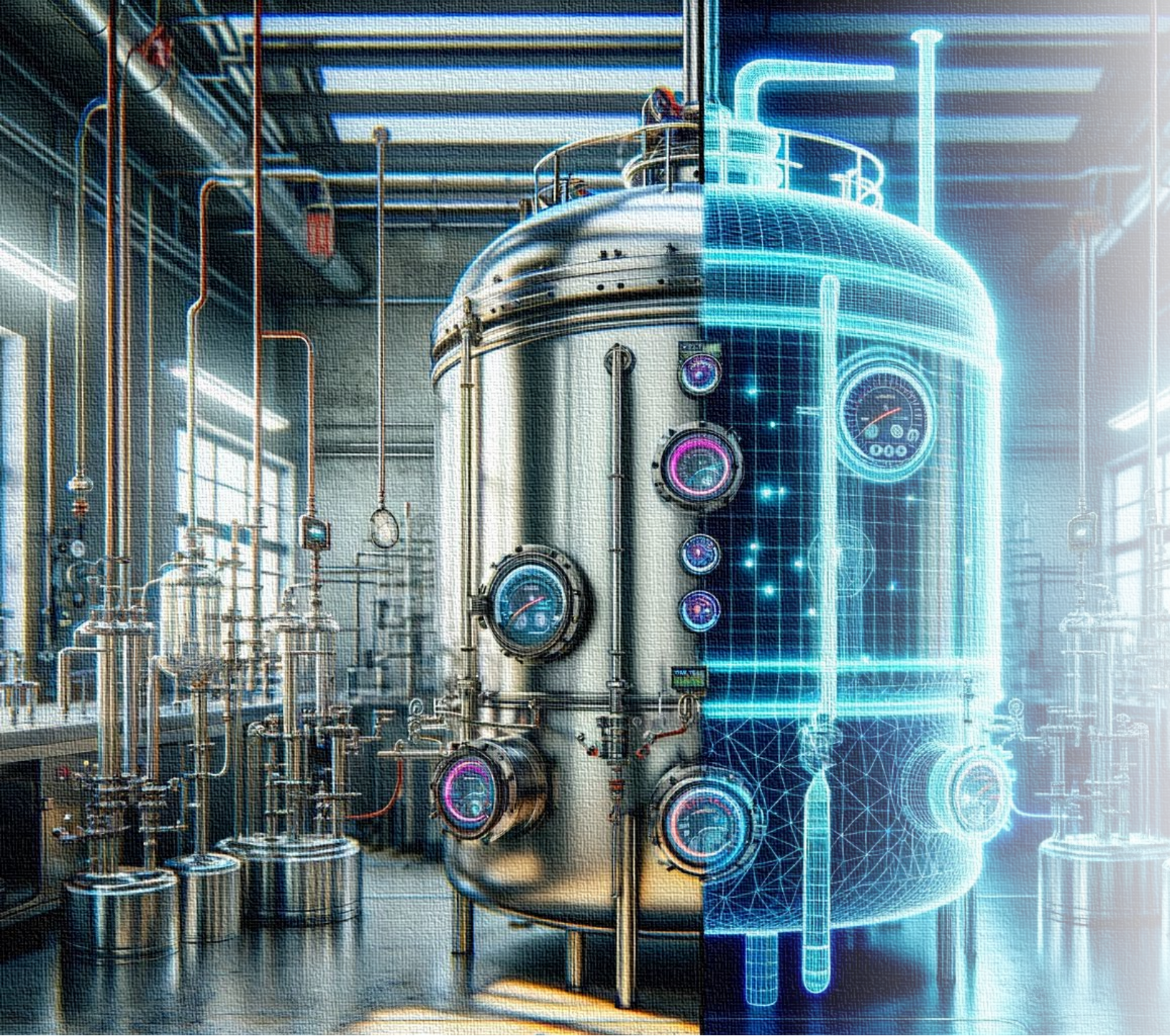


GRAN SASSO SCIENCE INSTITUTE

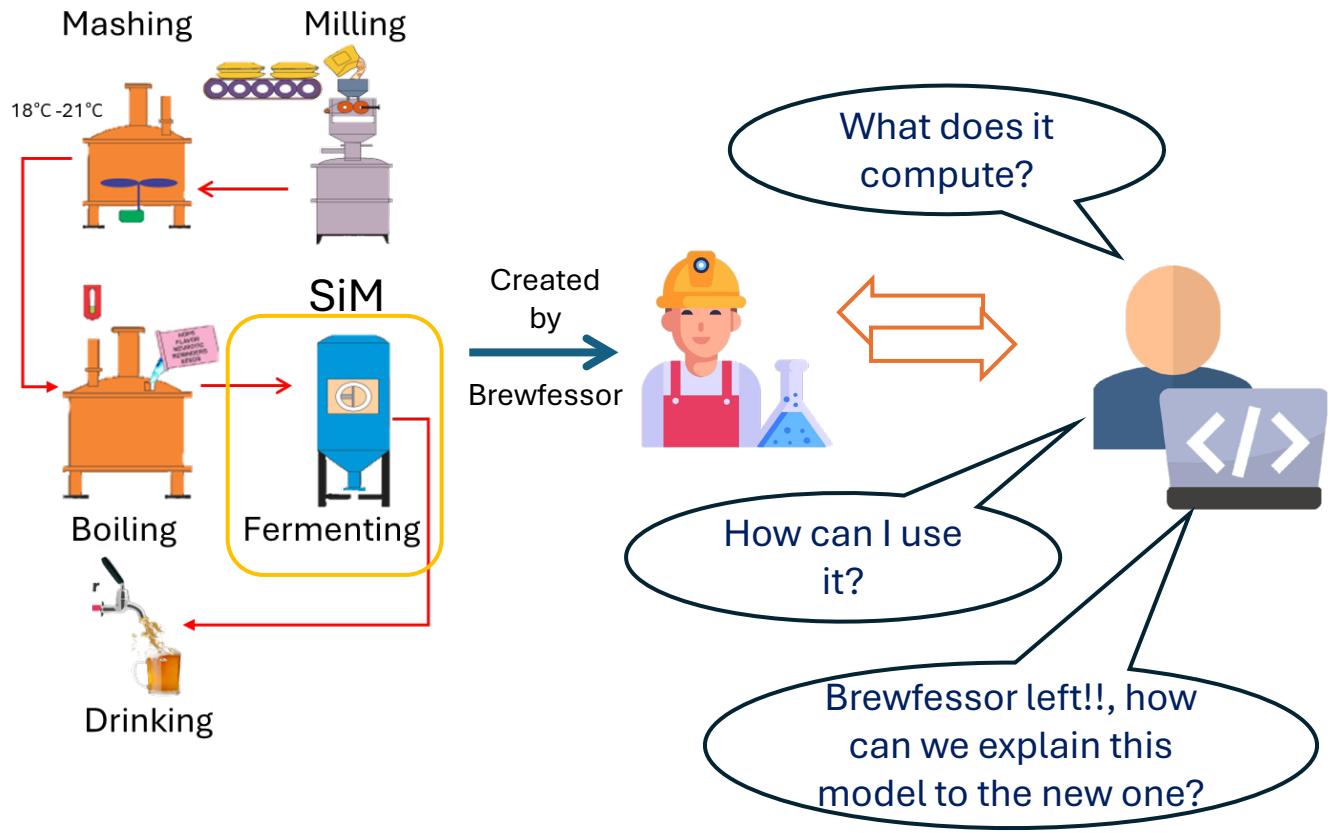
EINDHOVEN UNIVERSITY OF TECHNOLOGY

Towards a collaborative approach for digital twin simulation models' comprehension

Arianna Fedeli & **David Manrique Negrin**

Motivation & research gap

Task: Improve beer quality by a DT of the beer fermentation process



Challenges:

1. Capability comprehension
2. Effective use of Simulation Model (SiM)
3. Knowledge transfer

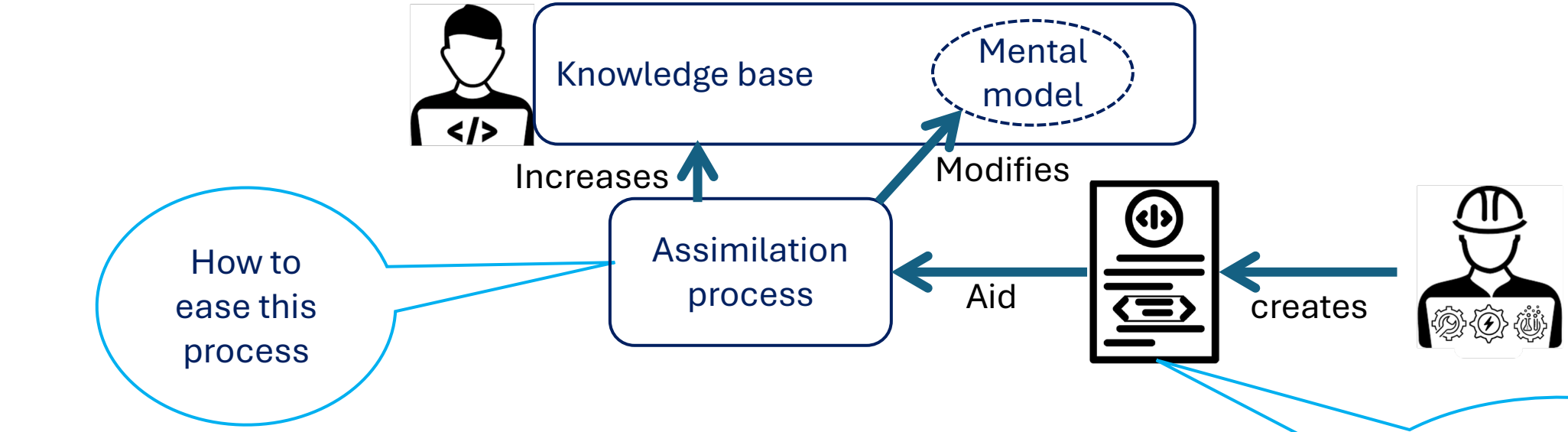
Research question

How can we **enhance** the **effectiveness** and efficiency of **knowledge transfer for SiM** to reduce the development time of **DTs**?

SiM: Simulation Model

SiMs' comprehension method

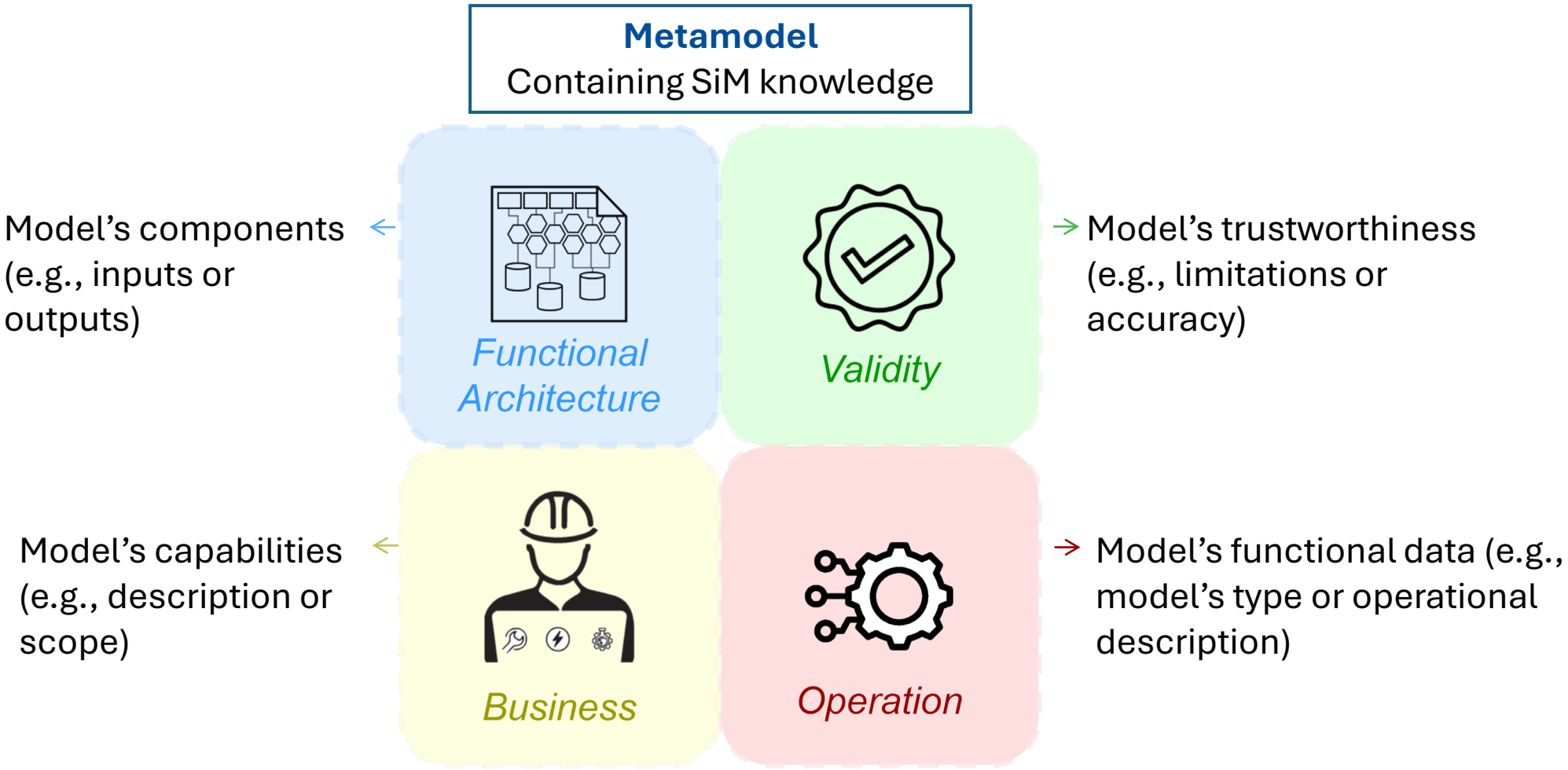
Background – Knowledge transfer for SiM



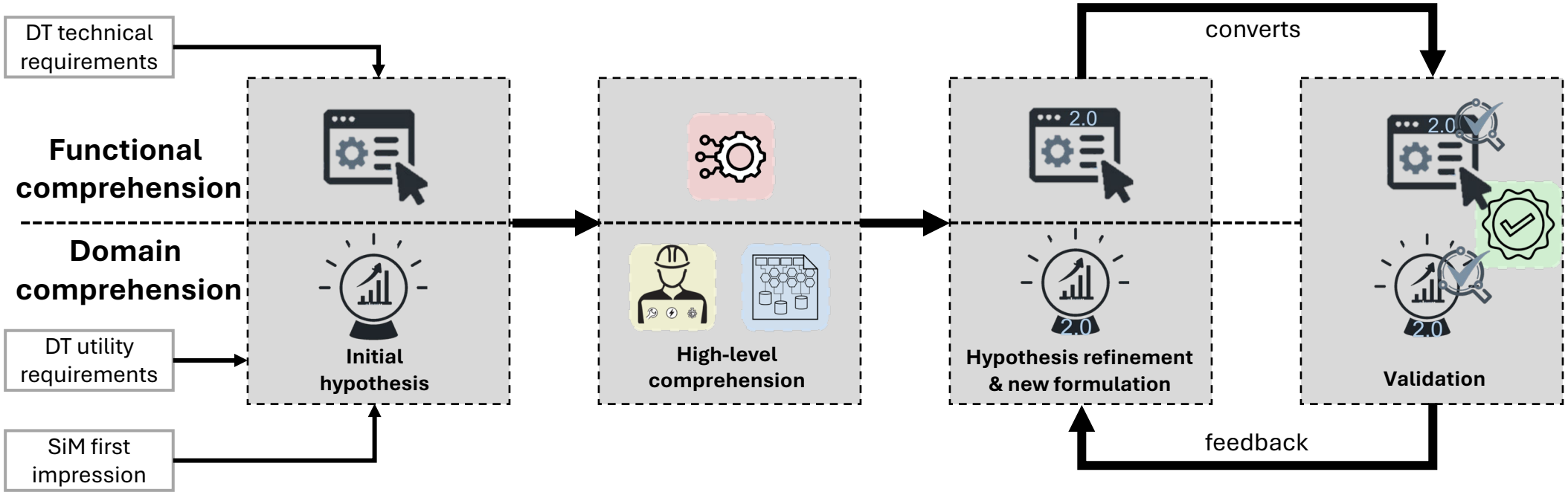
Procedure to accelerate assimilation
Leveraging the metamodel

Metamodel
Containing SiM knowledge

Overview of the method



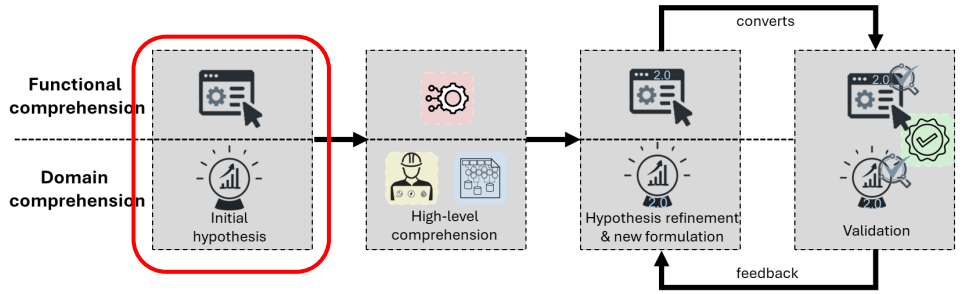
Overview of the method



Procedure to accelerate assimilation
Leveraging the metamodel

Procedure example

Initial hypothesis



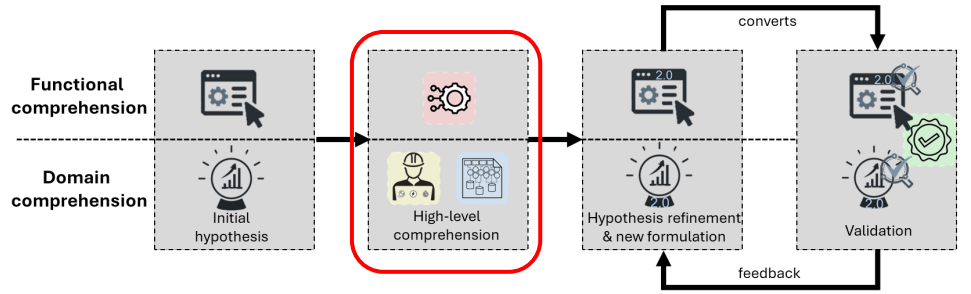
Initial information

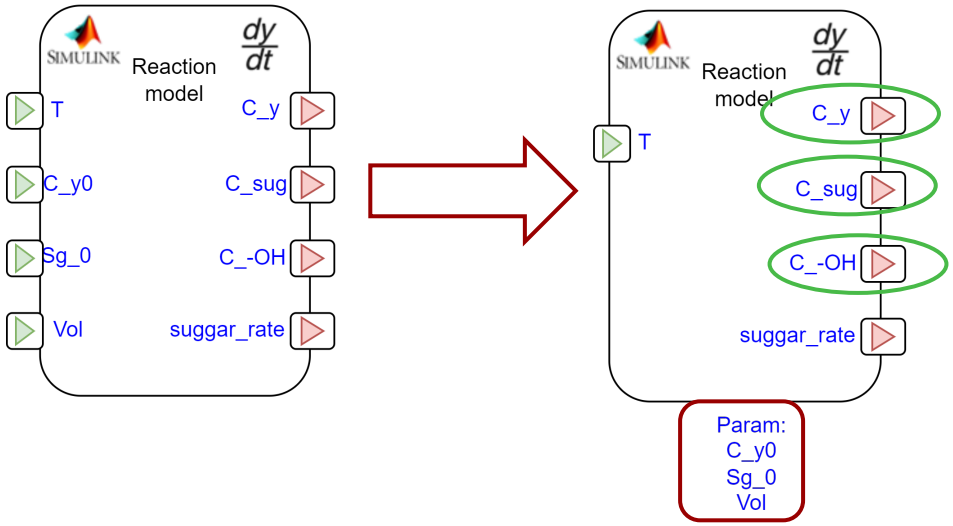
- **Model name**: Reaction_model
- **Utility req**: DT predict *future alcohol* content at *any starting* point (e.g., t = 0, t = 5 days).
- **Technical req**: DT uses *sugar content* as *sensor* data.

Initial hypothesis

- **Capability expectation** : Model *computes alcohol* content *using sugar* content *data*.
- **Operational expectation**: Model is *time-dependent* (e.g., ODE type) & time can be *configured*.

Procedure example
High-level comprehension





Operation

- **Model type**: ODE
- **Execution engine**: Simulink
- **Operational description**:
  - Sg_0 , C_{y0} & Vol set in Sim starts.
  - Set time period.

Business

- **Capability** – *predicts alcohol*, yeast & sugar content during beer fermentation
- **Scope**: blond beer

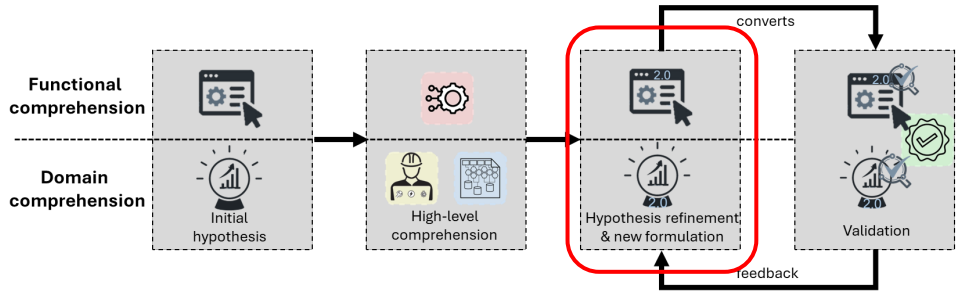
Functional Architecture

- **Inputs** – Wort Temperature
- **Outputs** – C_{EtOH}, C_y & C_{sugar}
- **Parameters**:
  - Sg_0 (initial relative density),
  - C_{y0} (initial yeast content) &
  - Vol batch volume

Procedure example

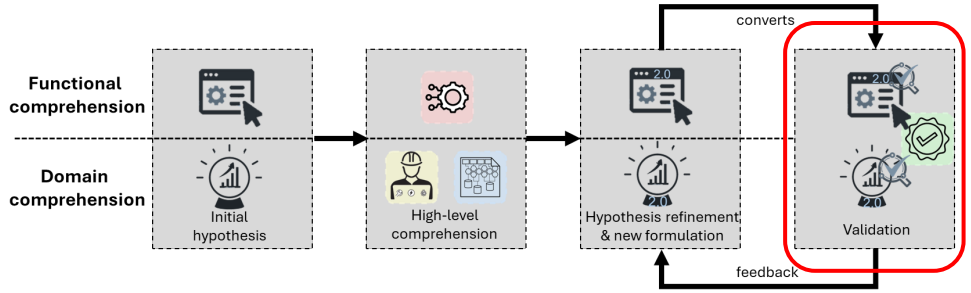
Hypothesis refinement & new formulation

- **Capability expectation** : Model computes alcohol content (C_{EtOH})using sugar content data by setting Sg_0 param.
- **Operational expectation**: Model is ODE type, time can be configured, by setting values of Sg_0, S_{y0} & the time period (e.g., 5 days).



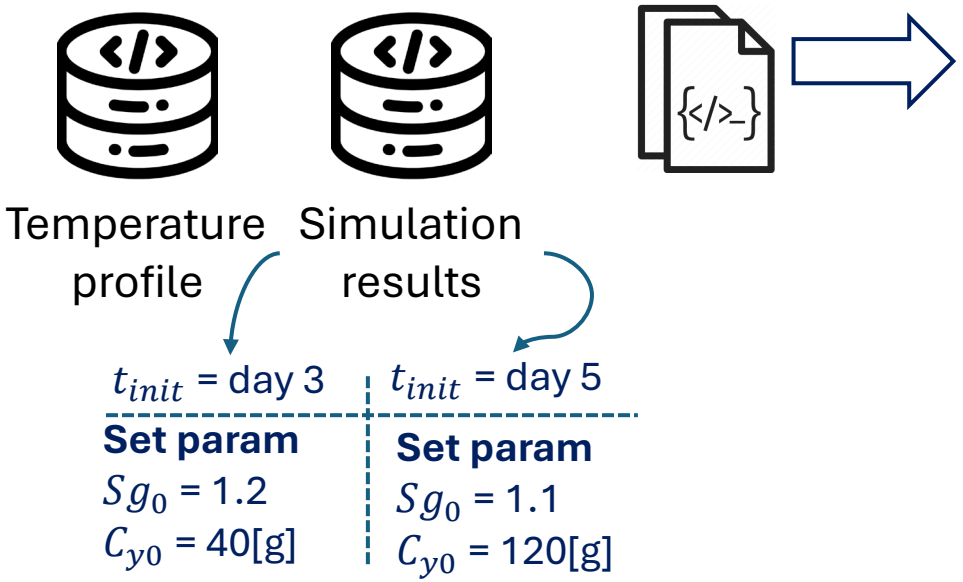
	Exp 1	Exp 2
Configure	t_{init} = day 3 t_{period} = 11 days	t_{init} = day 5 t_{period} = 5 days
Set param	Sg_0 = ? C_{y0} = ?	Sg_0 = ? C_{y0} = ?

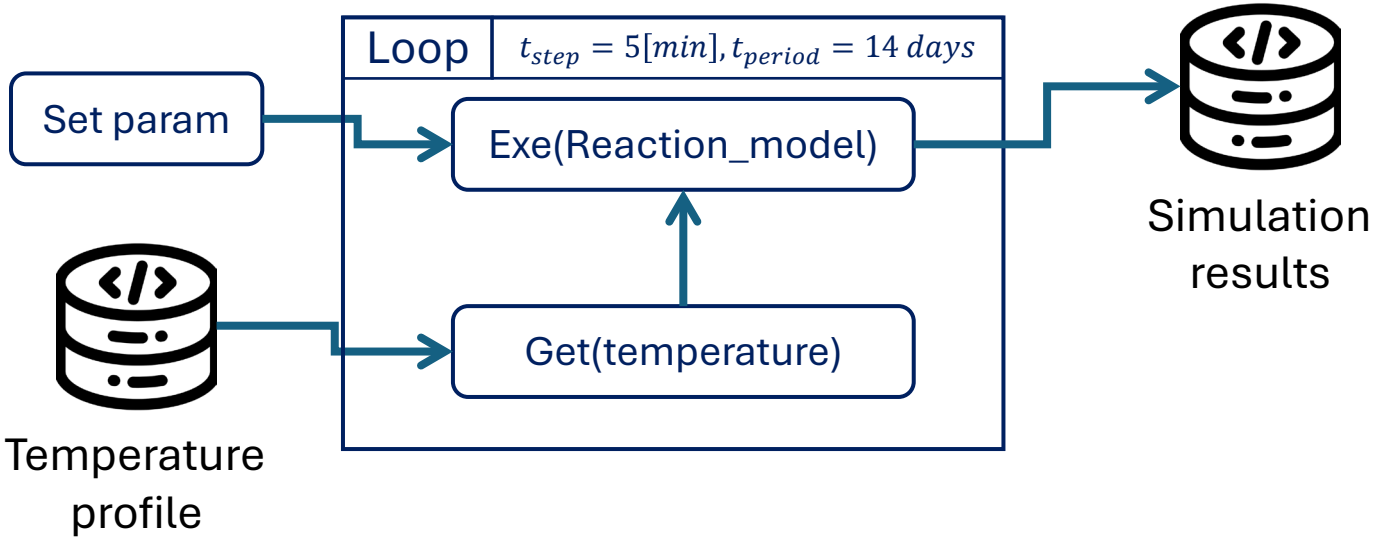
Procedure example
Validation



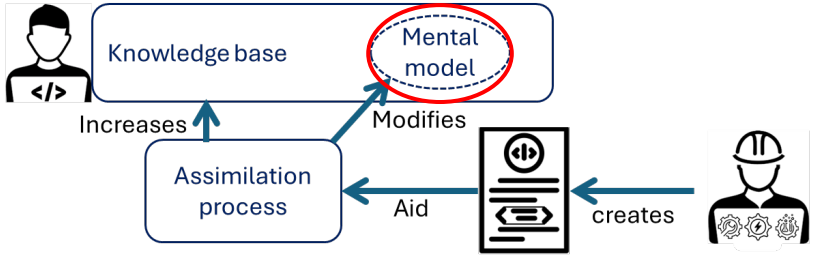
Validity

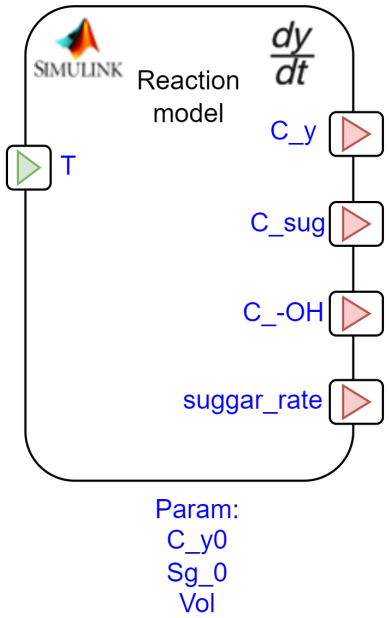
- **Limitations:** $t_{step} > 5\ min$
- **Accuracy:** $C_{EtOH} \pm 5\%$; C_y = unknown
- **Test doc**





End result





Parameters set at start of simulation

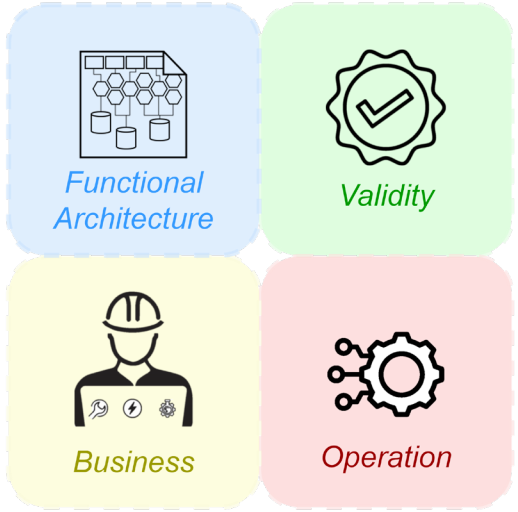
- **Capability:** Model computes alcohol content (C_{EtOH})using sugar content data by setting Sg_0 param. Accuracy of yest prediction is unknown.
- **Operational expectation**: Model is ODE type, time can be configured, by setting values of Sg_0, S_{y0}& $time_{period}$. Min $t_{step} = 5[min]$.

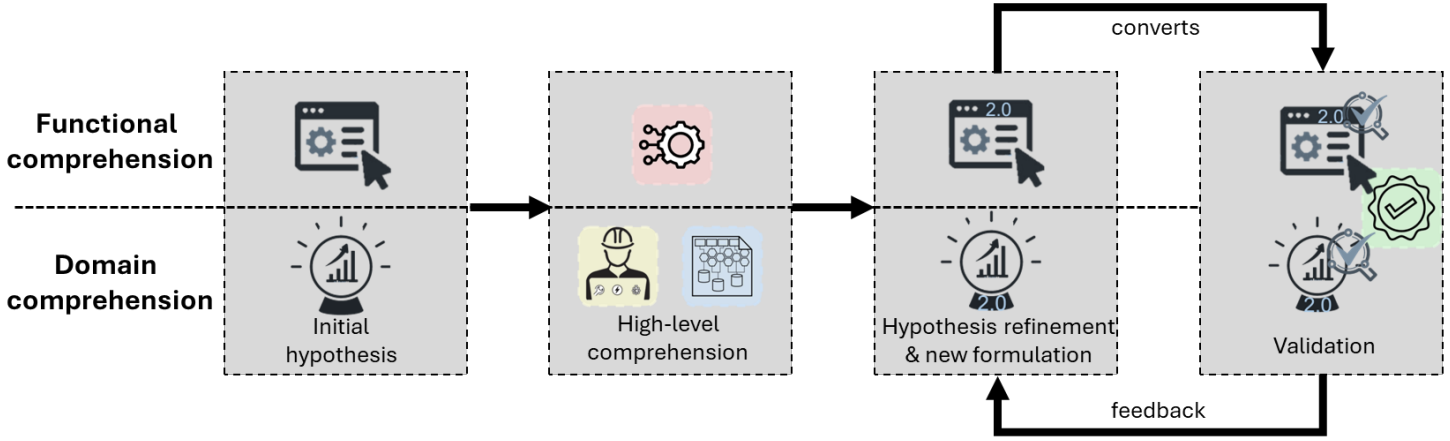
Conclusions

RQ How can we **enhance the effectiveness** and efficiency of **knowledge transfer for SiM** to reduce the development time **in DTs**?

Metamodel as a Knowledge Container: The metamodel *encapsulates* the expertise and *knowledge* of modelers.

Guided Assimilation Process: Utilizing the metamodel and its components helps *users understand* the model's *capabilities* & learn *how* to effectively apply it.





SiM: Simulation Model

SiMs' comprehension method

Future work

- **Enhance SiM evolution** by introducing DIKW Pyramid model.
- **Introduce virtual assistant** using LLMs to aid the model's engineer in SiM metamodel instantiation & user in querying SiM model & follow process.
- **Conduct user testing to evaluate approach** by comparing rate of SiM comprehension between standard approach and our approach.

Thank you

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