

FRAMily Meeting & Workshop 2026, Munich
Paul Weber

Ideas from an ongoing research project:

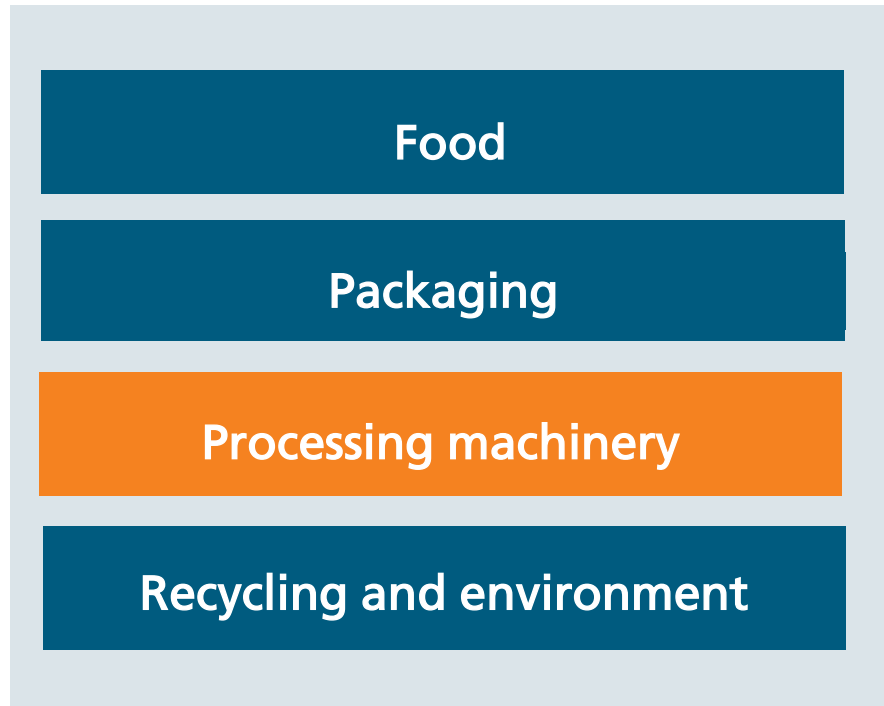
**Ontological FRAM-based modeling of food
production processes to support operators**

Who am I?

- **studying mechanical engineering @ Dresden University of Technology** | 2012 - 2018
 - focus: Processing and packaging machines
- **Research assistant @ Fraunhofer IVV Dresden** | since 2018
 - member of the team "Assistance Systems"
 - research interest: Formalization of knowledge for machine operation



Team “Assistance Systems”



Agenda

1. Domain background

2. Goals and methods

3. Preliminary results

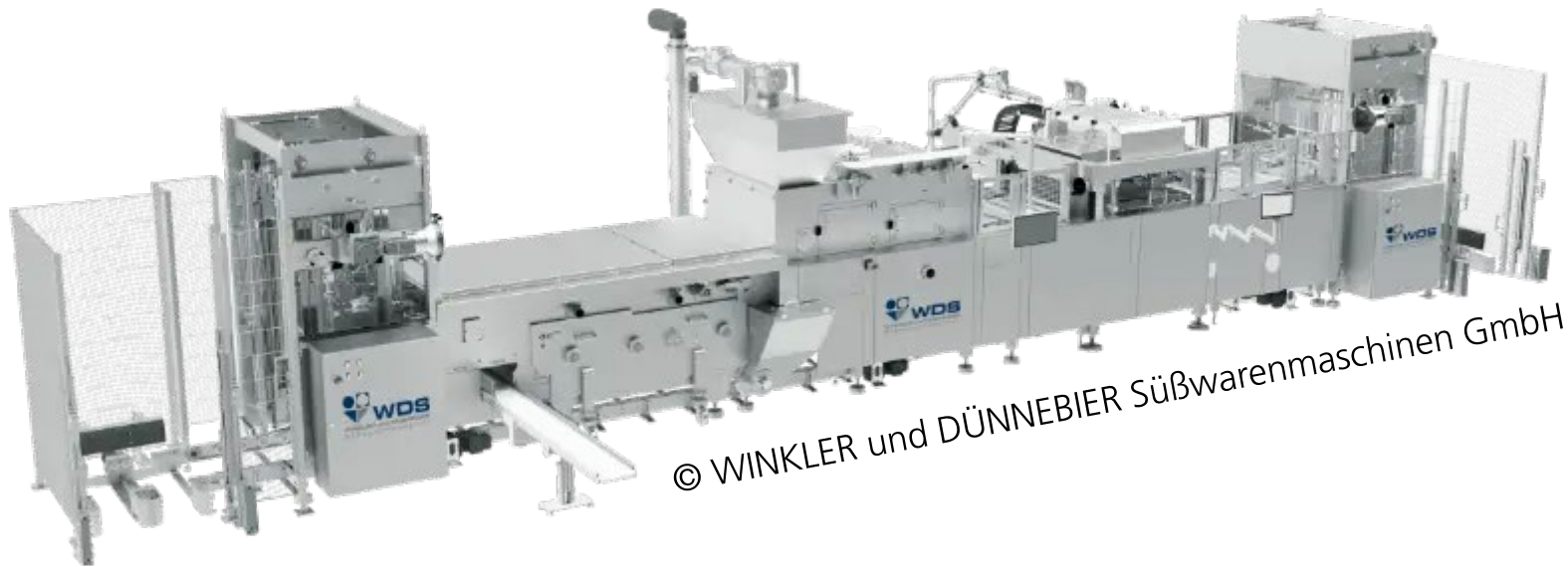
FRAM based modeling conventions

Current Ontology draft

4. Discussion and Outlook

Background

Challenges in operating processing machines in food production



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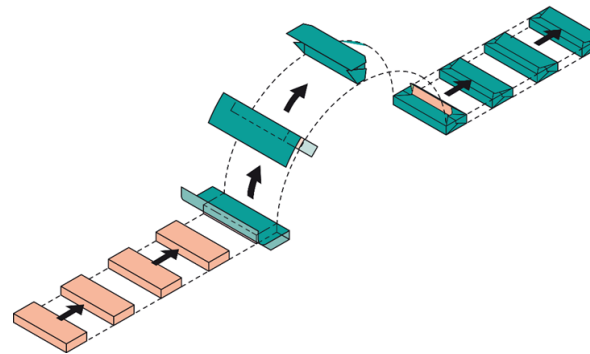


Background

Challenges in operating processing machines in food production



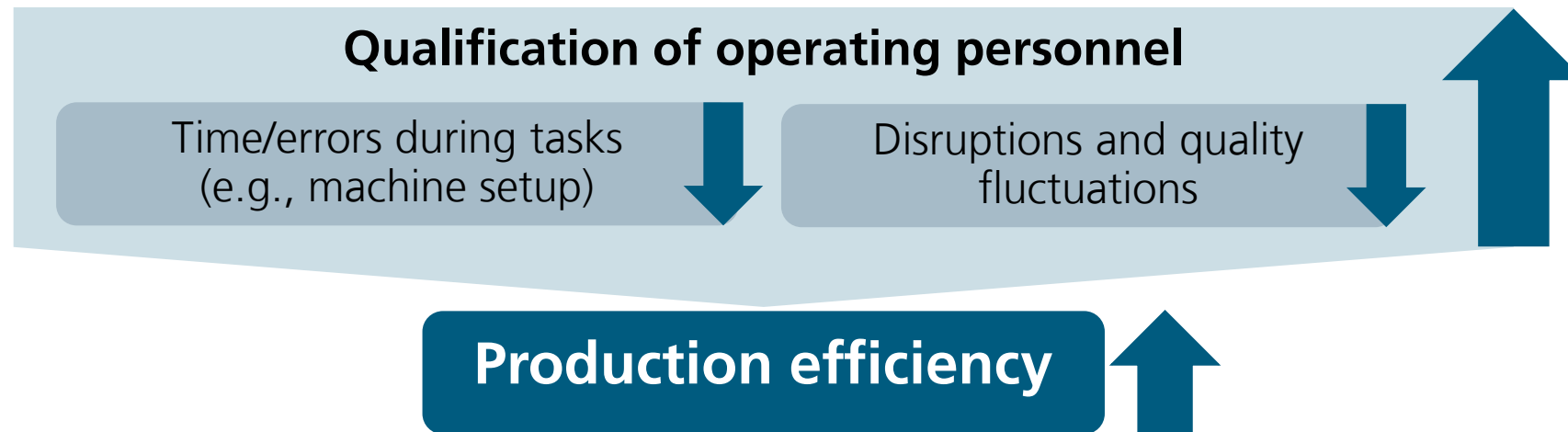
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Background

Challenges in operating processing machines in food production

What has happened here? (symptom)
Why has it happened? (cause)
How can I fix the cause?



Background

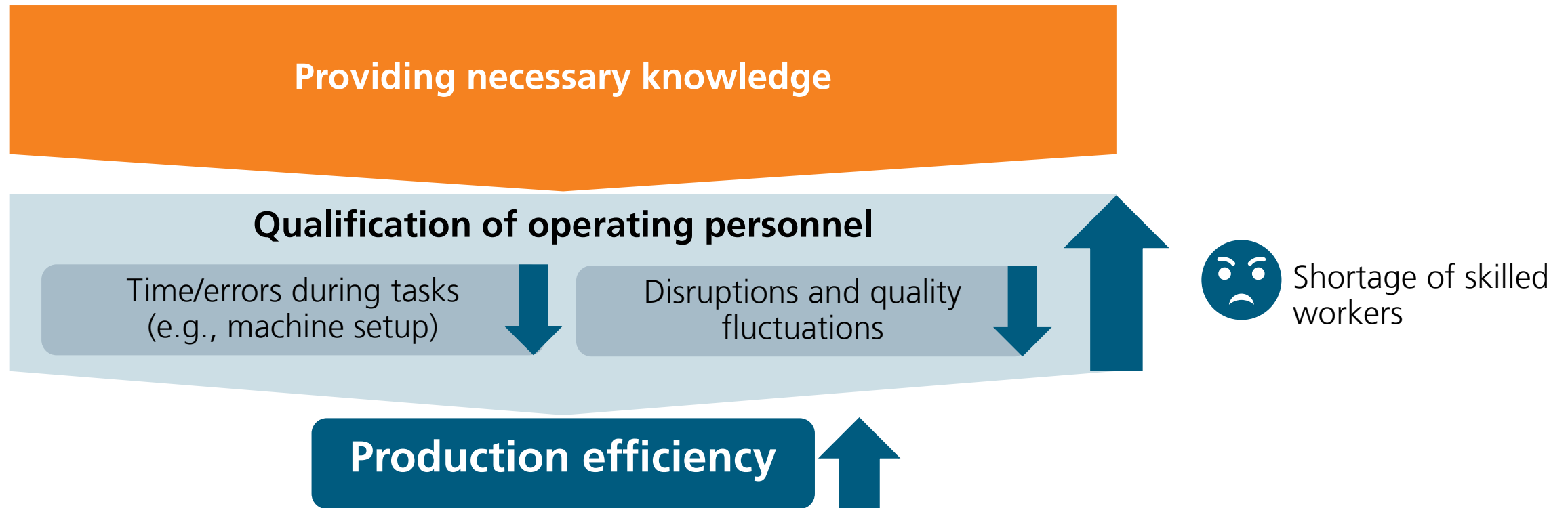
Challenges in operating processing machines in food production

incorrect parameter settings in a chocolate molding machine can cause deviations in product geometry, leading to faults in subsequent packaging machines



Background

Challenges in operating processing machines in food production



Background

Challenges in operating processing machines in food production

Providing necessary knowledge =
operator support systems should help to make such relationships
understandable

HOW?

How to model these relations?

How to translate them into usable visualizations for operators?

Goals and methods

Research project MoCa-Dia

Funded by



Deutsche
Forschungsgemeinschaft
German Research Foundation

Modeling and visualizing causal relationships in process chains [MoCa-Dia]

How to model these causal relations?



How to translate them into usable visualizations
for operators?



Chair of Engineering Psychology
and Applied Cognitive Research

Goals and methods

Requirements for the modeling

- faults and deviations result from interactions between technical, human, organizational, and environmental factors

→ **functional interactions should be visible**

→ **use FRAM as basis**

- higher abstraction improves diagnosis and flexible problem-solving

→ **should support navigation between abstraction levels** (e.g., for functions and symptoms)

→ **reuse of ideas of Abstraction/Agency Framework¹**

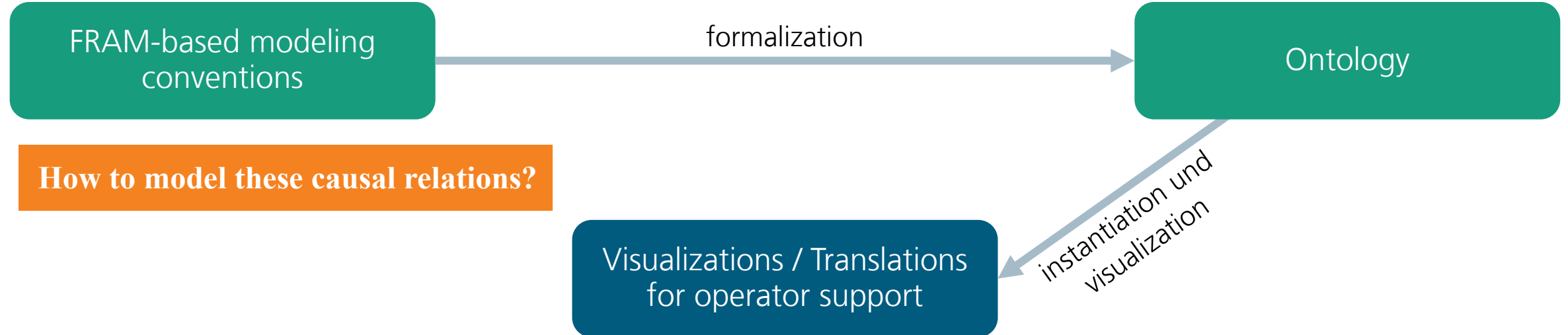
- include observable symptoms

→ **integrate, hierarchically organize characteristics for diagnosis as enhancement**

¹Patriarca, R., Bergström, J., & Di Gravio, G. (2017). Defining the functional resonance analysis space: Combining Abstraction Hierarchy and FRAM. *Reliability Engineering & System Safety*, 165, 34–46.

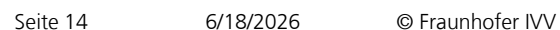
Ontology of FRAM based modeling conventions

Role of Ontology in our research project



Knowledge Elicitation and iterative modeling

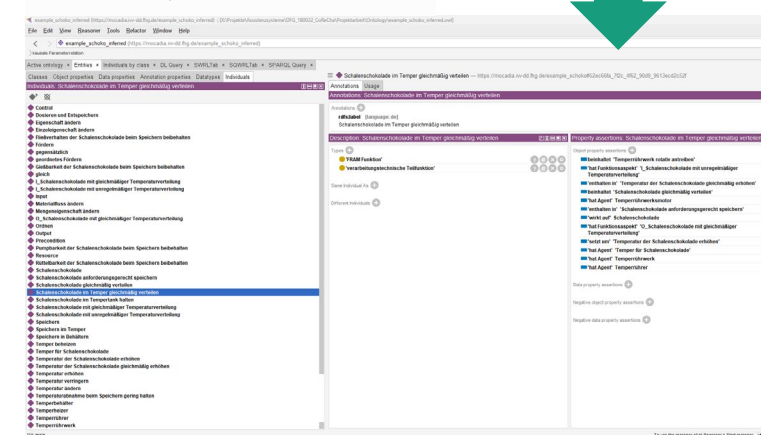
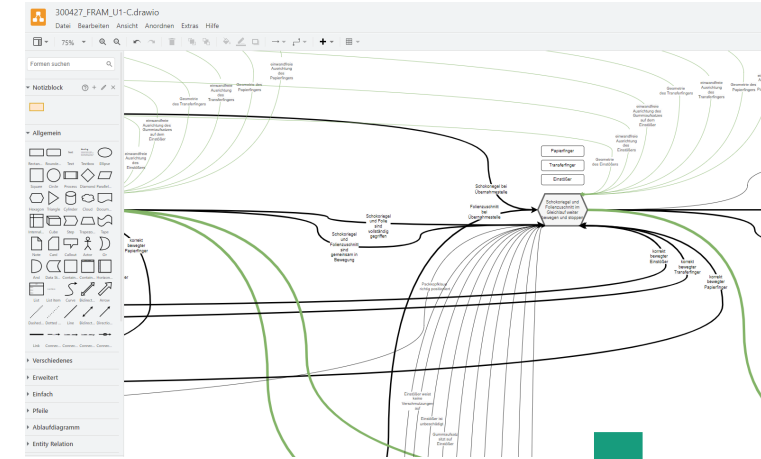
- [illegible]



Goals and methods

Knowledge Elicitation and iterative modeling

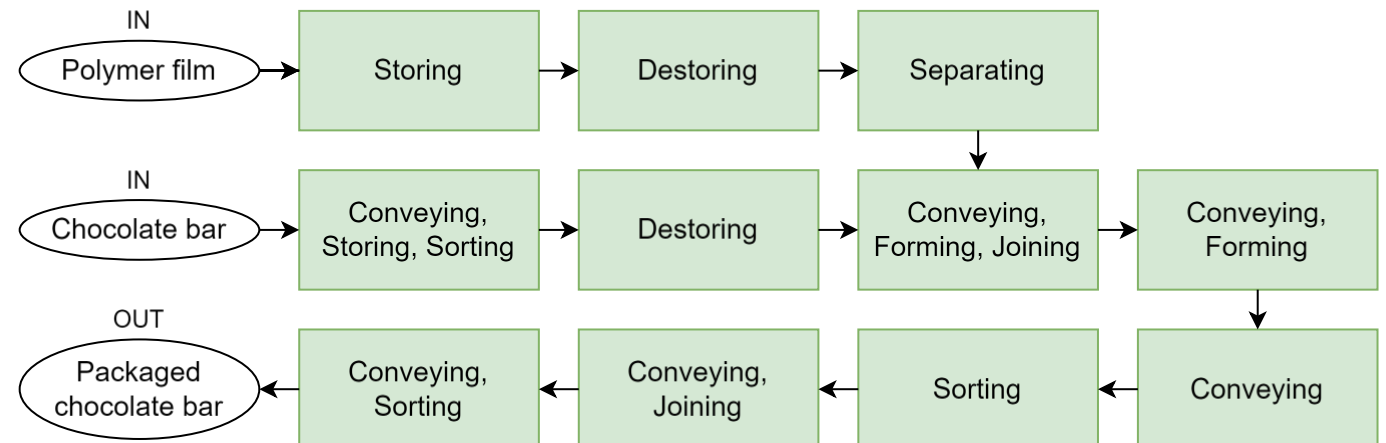
- development of FRAM models for fault diagnosis in food processing based on two processes: chocolate molding and packaging
- Knowledge elicitation through operator interviews and process observations
→ results: causal diagrams and fault classification lists
- based on that: FRAM models created with draw.io
- iterative refinement of model drafts with a machinery expert and researchers of TU Dresden
- creation of ontology-based model representations using Protégé
- validation of instantiated process ontologies with ontology reasoner



FRAM based modeling conventions

Initial layout of the models is based on the respective IMP

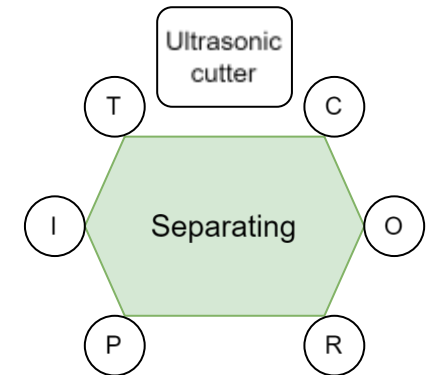
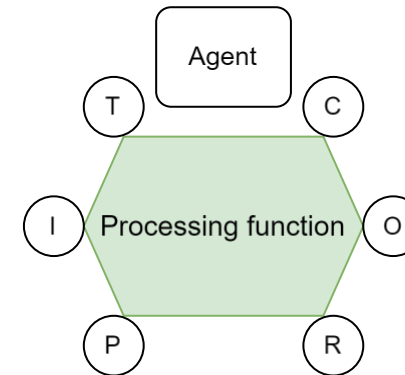
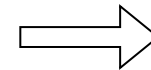
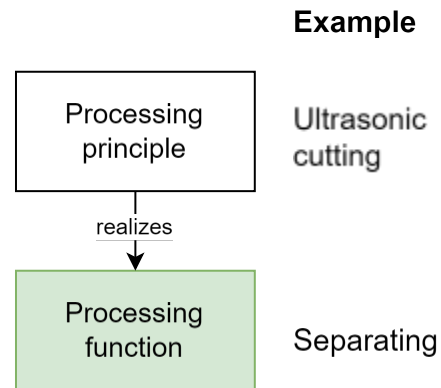
- Inner machine process (IMP)
represents the flow of
material within a machine
 - based on processing
functions



FRAM based modeling conventions

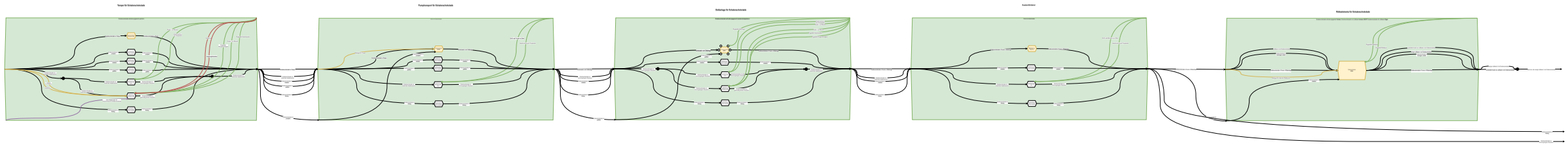
Initial layout of the models is based on the respective IMP

- Inner machine process (IMP)
represents the flow of
material within a machine
 - based on processing
functions
- processing functions as
FRAM functions
- subfunctions for further
specification



FRAM based modeling conventions

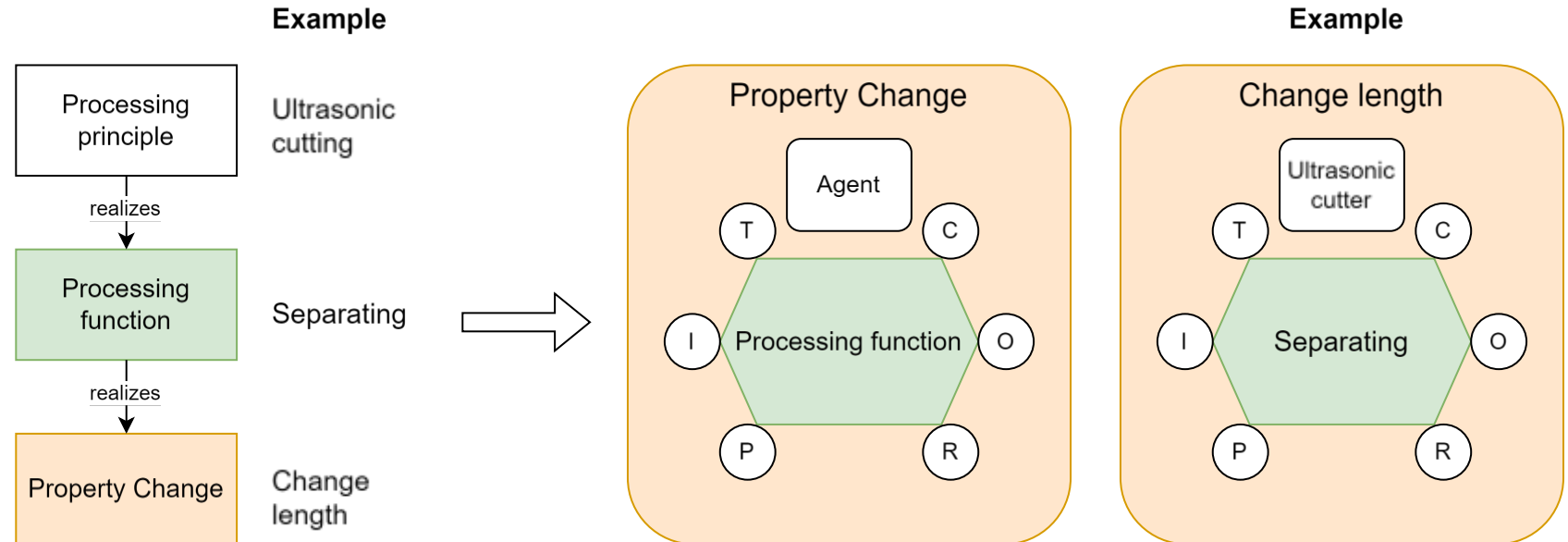
Initial layout of the models is based on the respective IMP



FRAM based modeling conventions

Property changes of a good linked to the functions

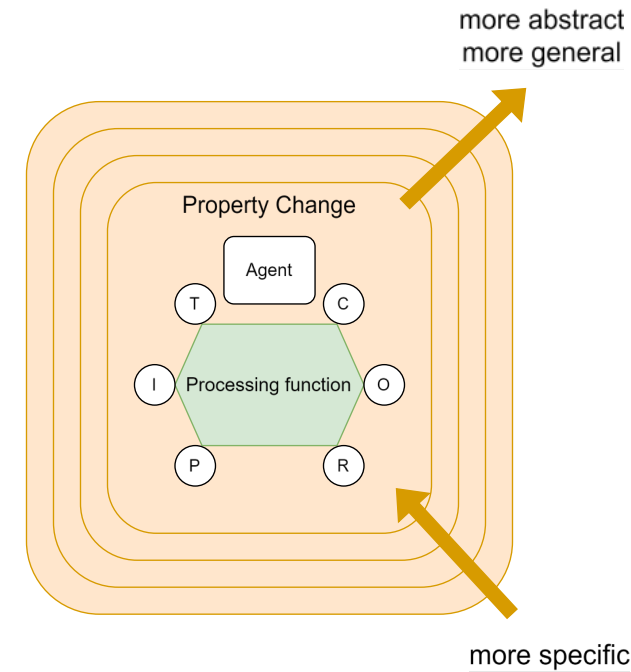
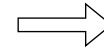
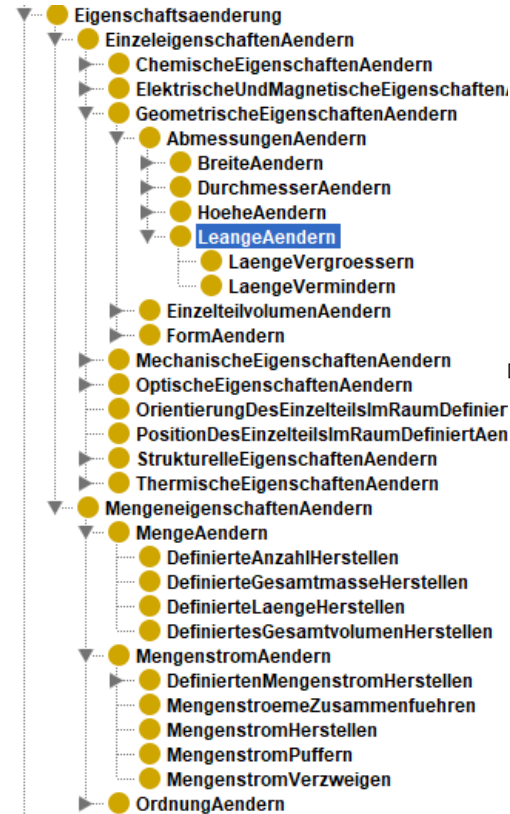
- property changes describe effects achieved by executing the functions
- enables clustering of the FRAM model



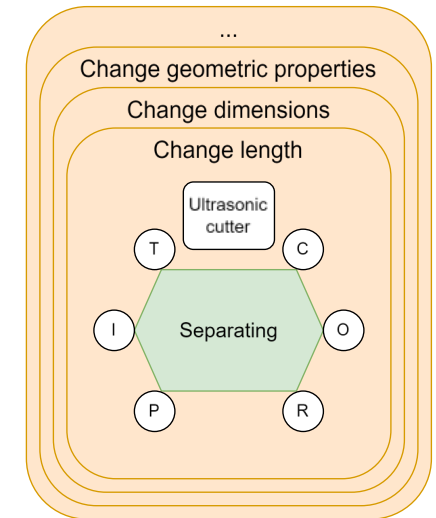
FRAM based modeling conventions

Property changes of a good linked to the functions

- property changes describe effects achieved by executing the functions
- enables clustering of the FRAM model
- hierarchical structure of property changes allows adaptive clustering



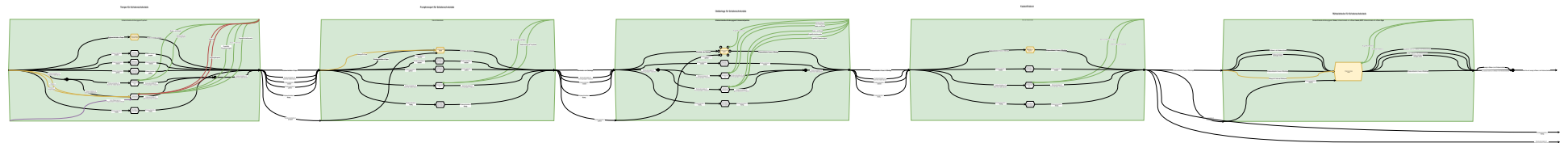
Example



FRAM based modeling conventions

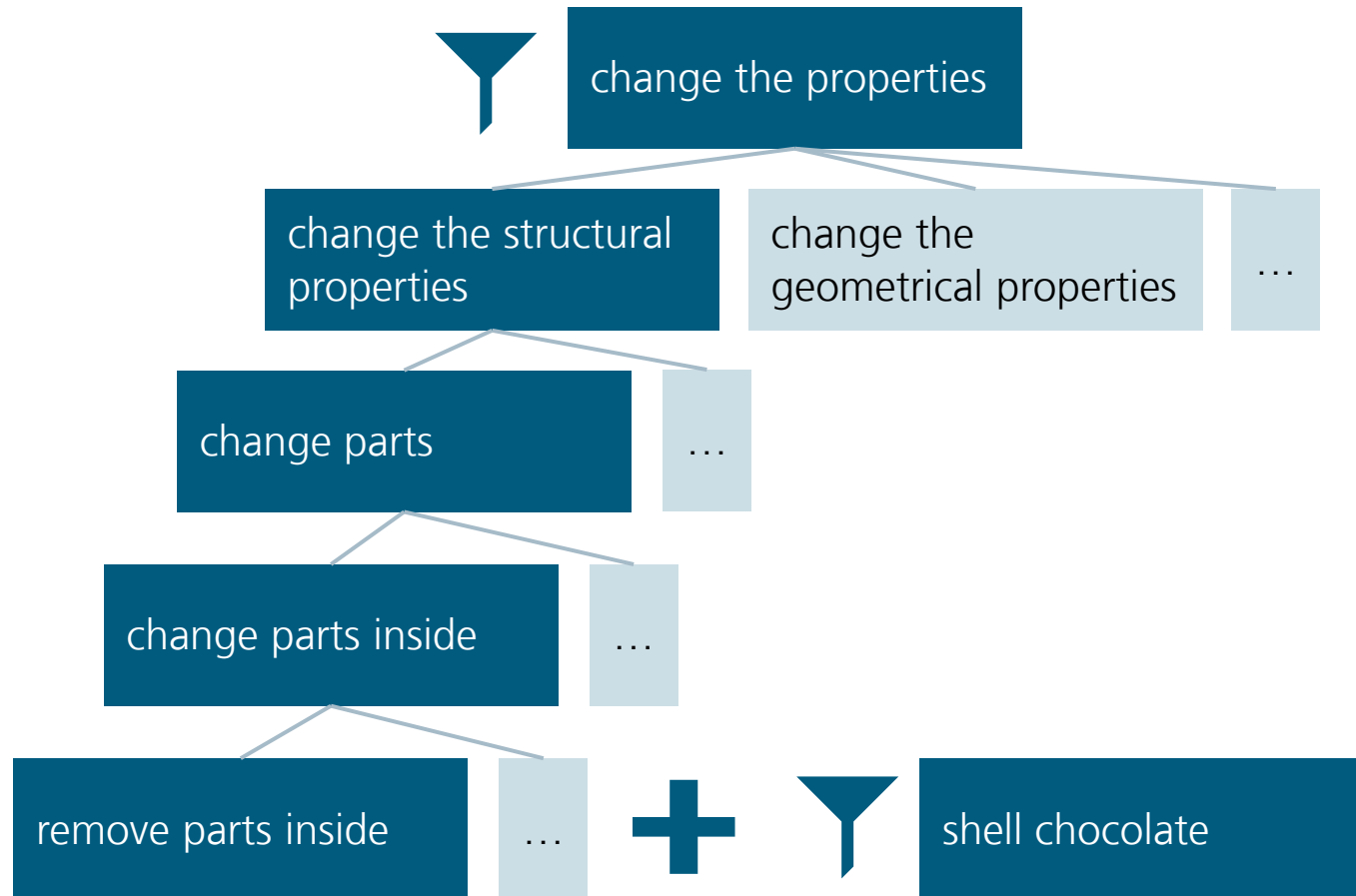
Property changes of a good linked to the functions

What functions could cause things to be added or removed from the shell chocolate?

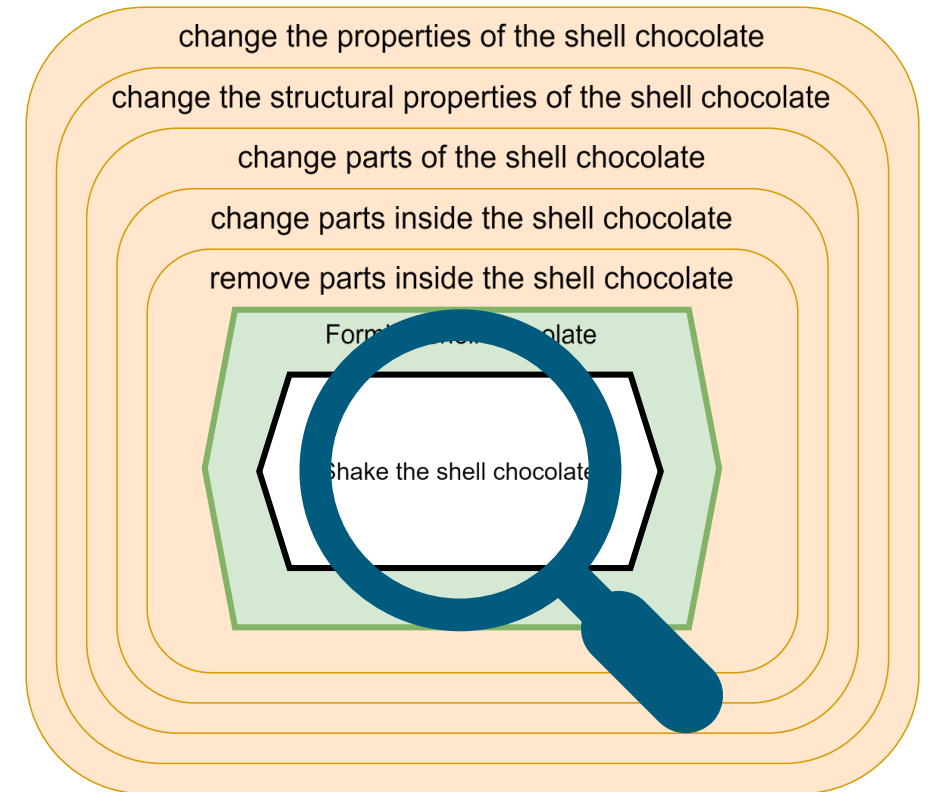


FRAM based modeling conventions

Property changes of a good linked to the functions



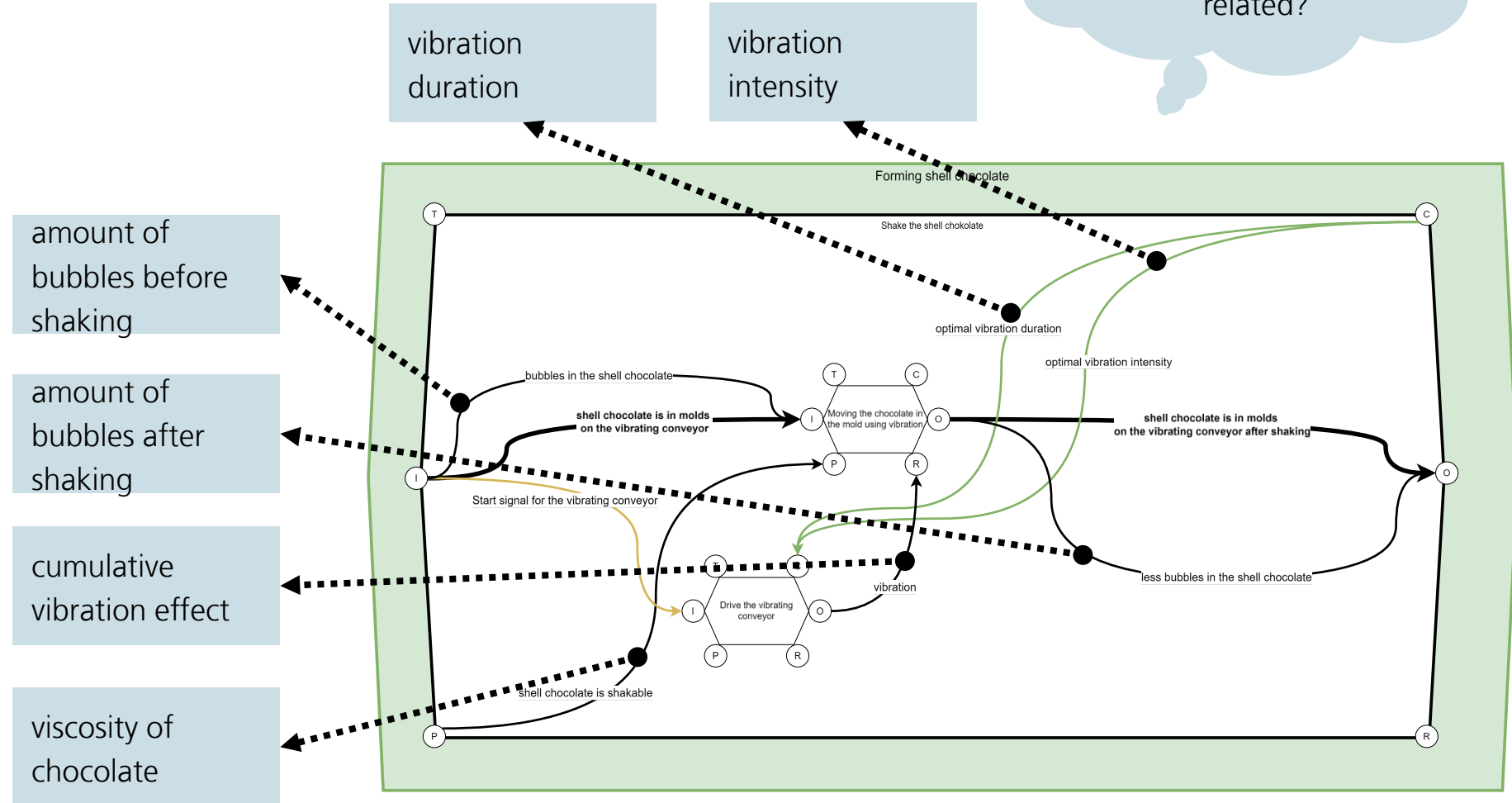
What functions could cause things to be added or removed from the shell chocolate?



FRAM based modeling conventions

Causal relationships between parameters

- Add parameters to function aspects (following the metadata approach)



Ontology of FRAM based modeling conventions

What is an Ontology?

- How to reuse the modeling elements?
- formalizing them via an **Ontology**

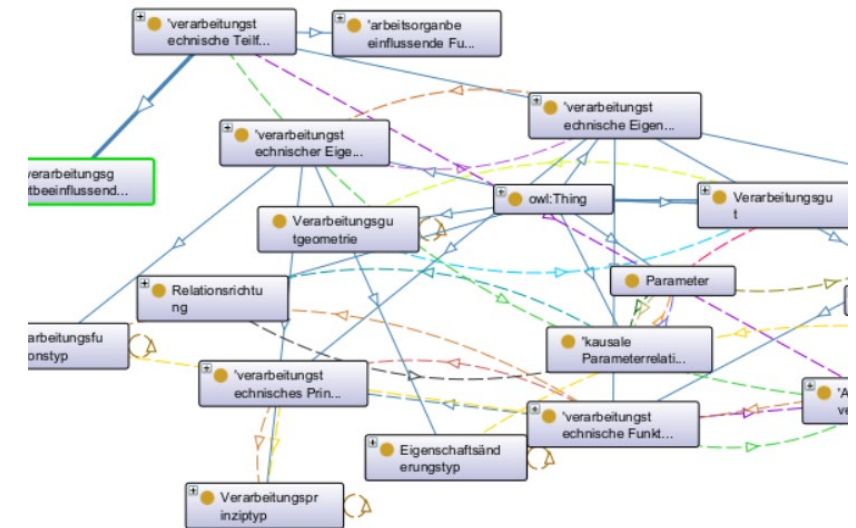
Ontology of FRAM based modeling conventions

What is an Ontology?

Tom Gruber: *An explicit specification of a conceptualization.*¹

My short interpretation:

- machine readable model of things and relations between them in a domain
- makes things explicit
- **standardized language for model construction and interpretation**

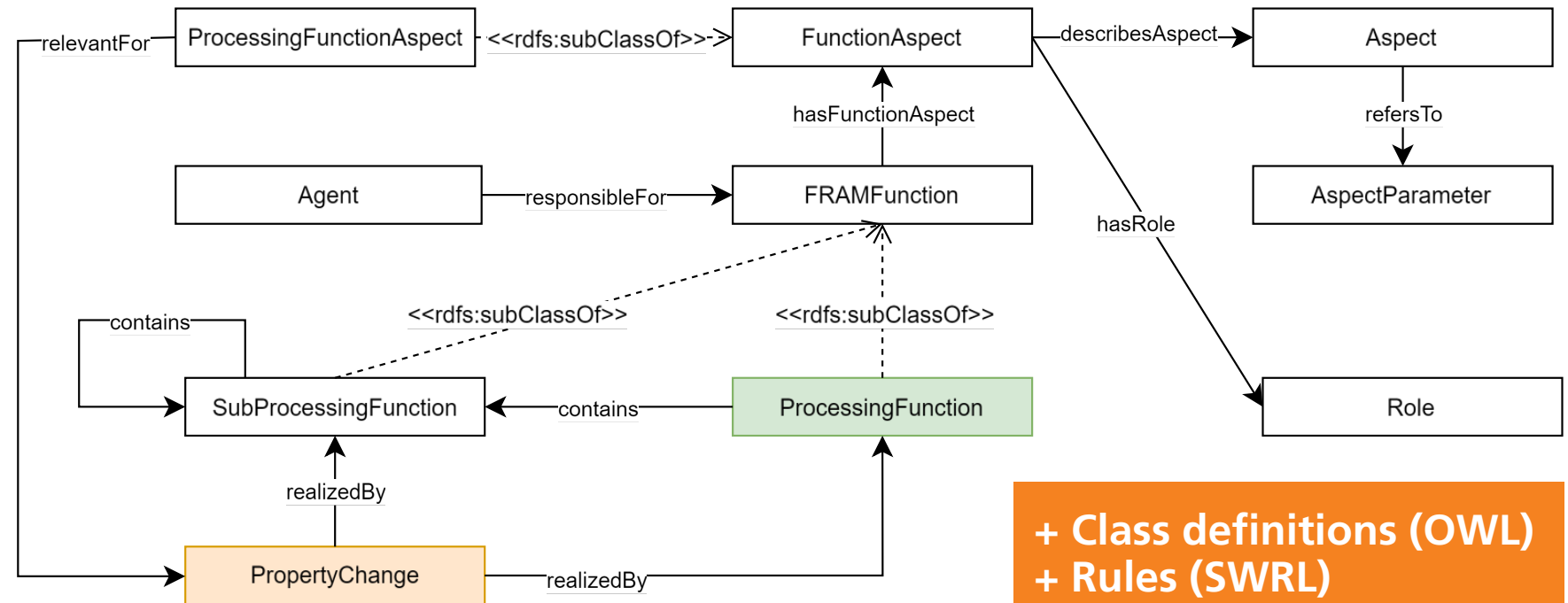
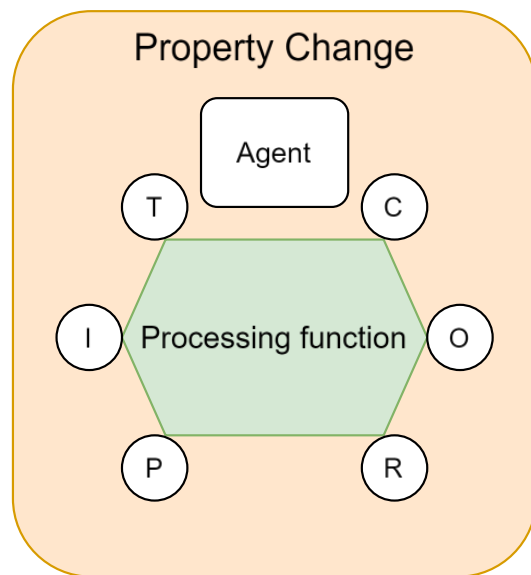


¹ Gruber, T. R., *A Translation Approach to Portable Ontology Specifications*. *Knowledge Acquisition*, 5(2):199-220, 1993. See also *What is an Ontology?* <http://www.wksl.stanford.edu/kst/what-is-an-ontology.html>

Ontology of FRAM based modeling conventions

Core concepts

Core concepts = Classes + object properties (relations between instances)



+ Class definitions (OWL)
+ Rules (SWRL)

Ontology of FRAM based modeling conventions

Instantiation and reasoning

The screenshot shows the Protégé ontology editor interface. The main window displays the concept 'increase temperature of shell chocolate gradually' with its URI. The 'Annotations' tab is active, showing two labels: 'increase temperature of shell chocolate gradually' (English) and 'Temperatur der Schalenschokolade gleichmäßig erhöhen' (German). The 'Description' tab shows the description 'increase temperature of shell chocolate gradually'. The 'Types' tab shows the type 'sub processing function'. The 'Property assertions' tab shows several assertions, including 'contains apply heat to the shell chocolate', 'contains distribute the shell chocolate evenly in the temper', and 'contained in store shell chocolate according to specifications'.

Annotations: increase temperature of shell chocolate gradually

Annotations:

- rdfs:label** [language: en]
increase temperature of shell chocolate gradually
- rdfs:label** [language: de]
Temperatur der Schalenschokolade gleichmäßig erhöhen

Description: increase temperature of shell chocolate gradually

Property assertions: increase temperature of shell chocolate gradually

Types

- 'sub processing function'

Same Individual As

Different Individuals

Object property assertions

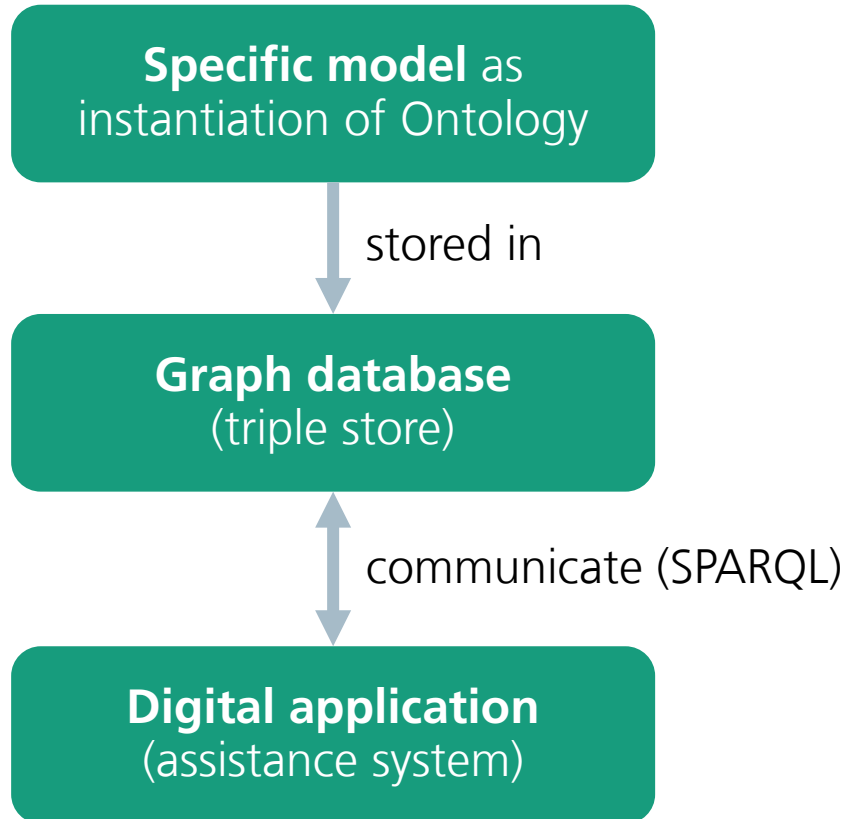
- contains 'apply heat to the shell chocolate'
- contains 'distribute the shell chocolate evenly in the temper'
- 'contained in' 'store shell chocolate according to specifications'
- contains 'distribute the shell chocolate evenly in the temper'
- contains 'heat the temper'
- contains 'implement heat transfer in shell chocolate'
- contains 'drive the temper agitator rotatively'



inferred
relationships (based
on definitions and
rules)

Ontology of FRAM based modeling conventions

Querying the instantiated ontology



Show all processing functions that fulfill the property change
"increase temperature of the shell chocolate"!

PREFIX fram: <https://mocadia.ivv-dd.fhg.de/core#>

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>

SELECT DISTINCT ?processingfunction

WHERE {

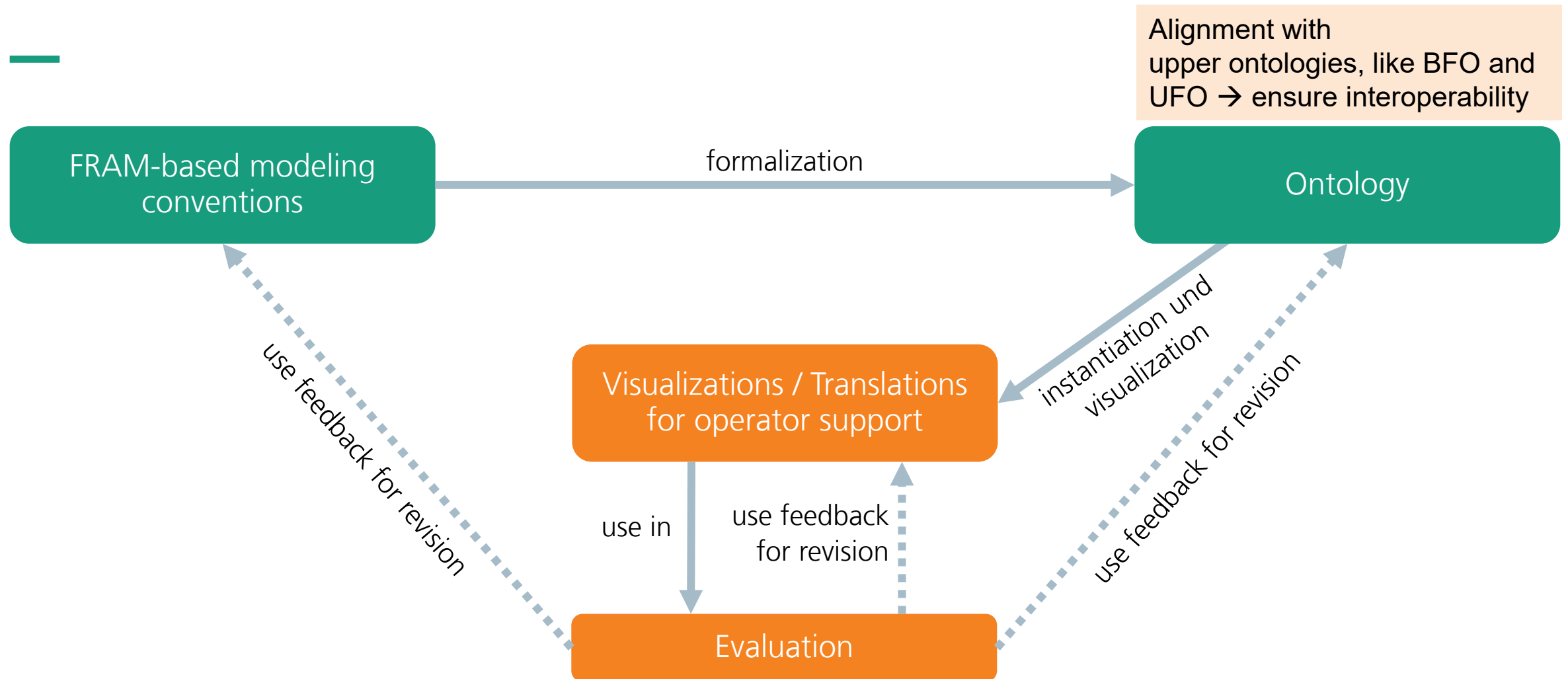
 ?processingfunction rdf:type fram:ProcessingFunction.

 ?propertychange fram:realizedBy ?processingfunction ;
 rdfs:label "increase the temperature of the shell
 chocolate"@en

}

→ store shell chocolate according to specifications

Outlook



Thank you very much for your interest!

Contact

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