Identifying Inconsistencies in the Design of Large-scale Casting Systems – An Ontology-based Approach

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Why Information Inconsistencies emerge

During the Development of large-scale automated Production Systems (aPS):

– Large number of disciplines involved

– Domain-specific tools, modeling languages and documents applied

– Large numbers of unstructured text-based documents

– More frequent information changes

Source: SMS Group

Requirements on inconsistency management approaches:

– Unified and formalized information representation from unstructured data sources – *R1*

– Identifying multiple types of inconsistencies within and across engineering domains – *R2*

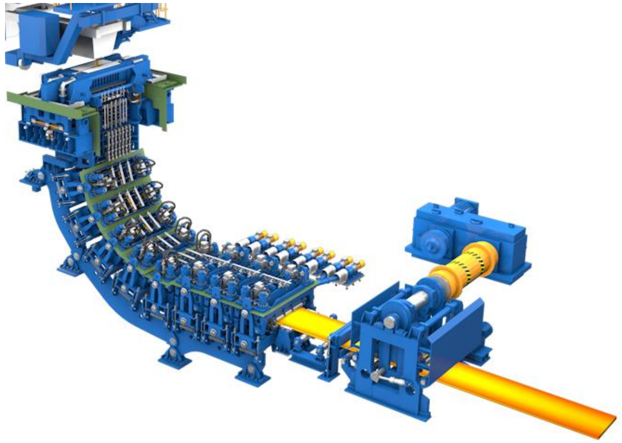
– (Semi-) automatic inconsistency-checking processes – *R3*

– Flexible to information changes – *R4*

Industrial-scale Application Example

Continuous steel-casting system

- relatively low production costs and high product quality compared to traditional casting system
- **rollers** along the casting line squeeze the molten steel into a continuous strand
- casting lines are divided into several **segments**, which are equipped with a water-air secondary cooling system to solidify the steel.



Source: SMS Group

System engineer
Design the general architecture of the casting system and define the general parameters of the system → Main casting plan

Structural engineer
Design the geometric structure of the casting system, e.g., roller layout → Roller plan

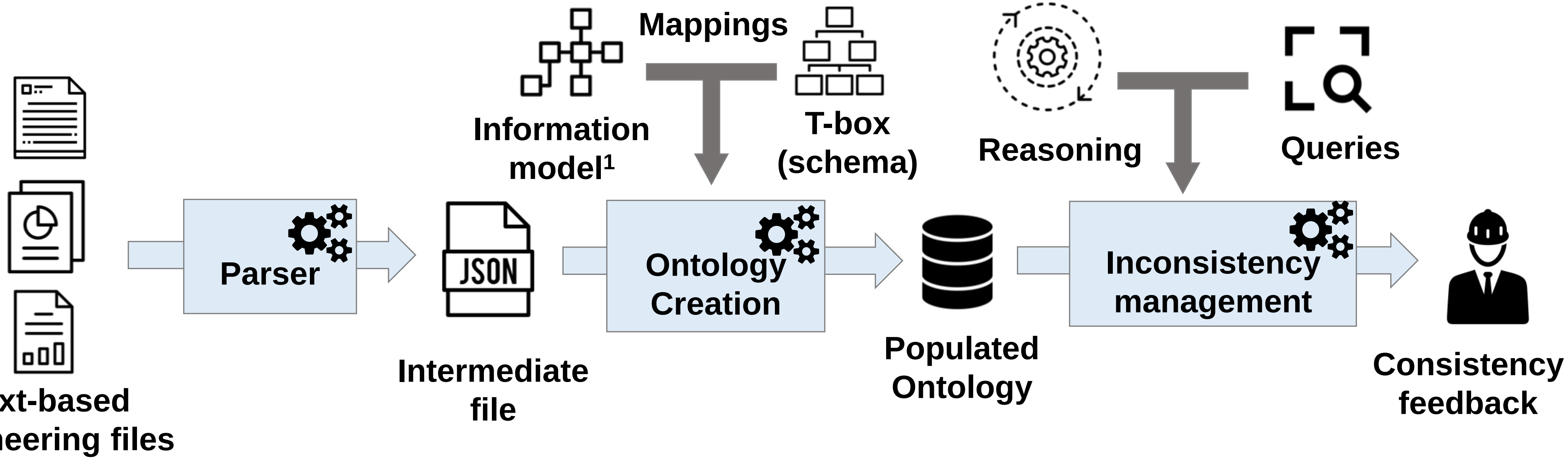
Thermal engineer
Calculate the thermal parameter of the cooling system → Force calculation report

Simulation engineer
Simulate the entire casting process and calculate the driving forces on rollers. → Cooling plan

Ontology-based Framework for Inconsistency Identification

Core elements of the framework

- Information extraction from texted-based engineering files
- Reusable upper structure and terminological components of the knowledge base
- Inference relations between engineering documents, parameters and physical plant objects
- Queries for multi-type of inconsistencies

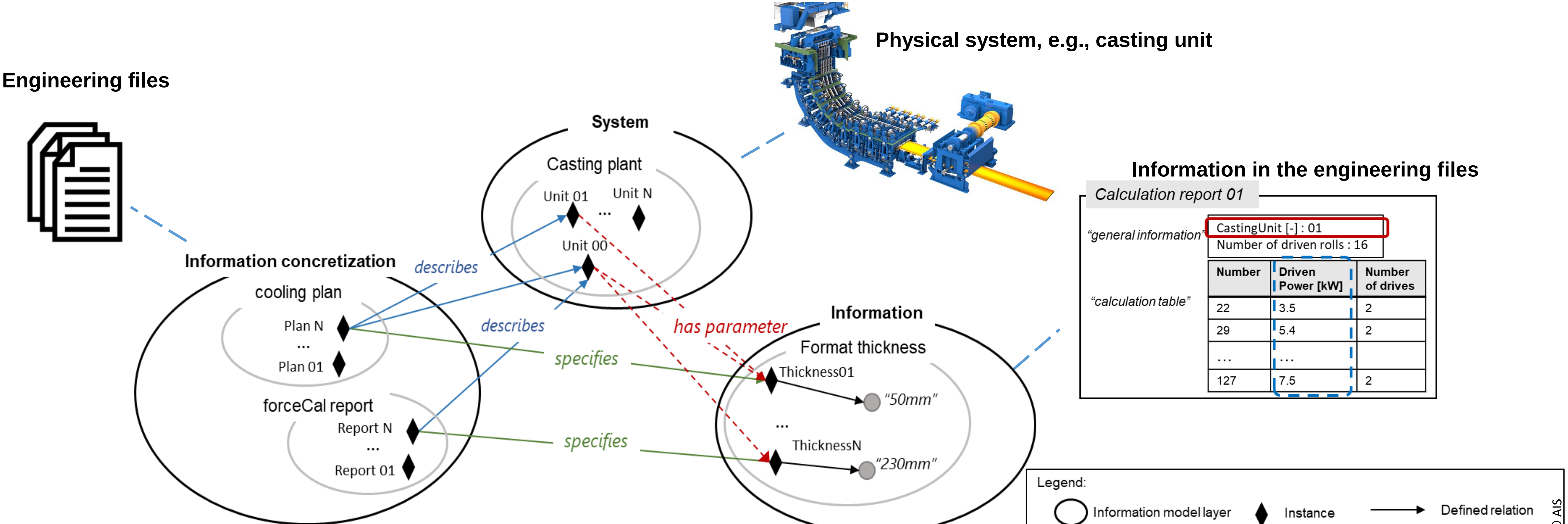


1.F. Ocker, B. Vogel-Heuser, M. Seitz, and C. J. Paredis, “A Knowledge Based System for Managing Heterogeneous Sources of Engineering Information,” IFAC-PapersOnLine, vol. 53, no. 2, pp. 10511–10517, 2020.

Inconsistency case

Reasoning-based Cross-domain Inconsistency Checking

- assigning the file data automatically to the corresponding physical elements via reasoning
  →resilient to information changes
- checking the consistency of the overall plant parameter
- inconsistencies can be traced back to the engineering documents



Property chain:
has_parameter= Inverse(describes)+specifies

Summary and Outlook

What did we do?

- Information extraction from unstructured or semi-structured engineering documents via parser (*R1*)
- Workflow design for automatic inconsistency checking (*R3*)
- Intra- and inter-domain inconsistency identification (*R2*)
- Applicability on real industrial production systems is proved
- Capability to deal with changes in information (*R4*)

What is next?

- Automatic mapping generation through text mining
- Consider graph-based documents as input
- Reduce the manual work through automatic or semi-automatic rule and query generation
- Integrating the framework to the engineering workflow management system → automatically trigger the inconsistency check process