Product/ion-Aware Modeling Approaches that Support Tracing Design Decisions

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Application Context

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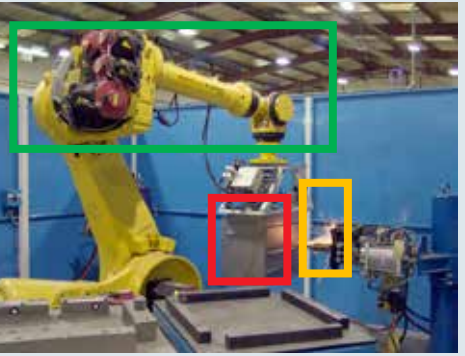
- Industry Partner: Large-scale Austrian engineering company with focus on engineering and construction of highly automated and high-speed discrete manufacturing systems.
- Multi-disciplinary (mechanical, software, electrical engineering).
- Highly complex production lines.
- Design decision consist of a scope, possible and concrete outcomes as well as rationales.
- Example: “Fragile Product” – Limited transportation speed as a parameter.

Context: Product – Process - Resource (PPR)[1]



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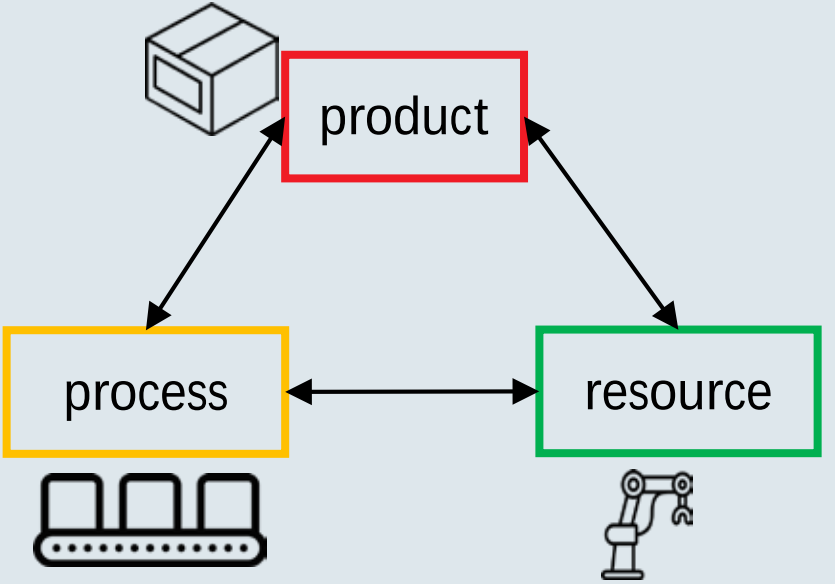
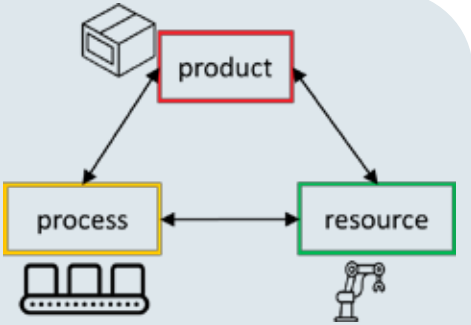


[1] Schleipen, M., Lüder, A., Sauer, O., Flatt, H., & Jasperneite, J. (2015). Requirements and concept for plug-and-work

Related Work: Product & Process Modeling

Product modeling

- Focus on describing structures, assemblies and characteristics of products.
- Example solutions: Spread Sheet tools like MS Excel, Product Lifecycle Management Tools, House of Quality.



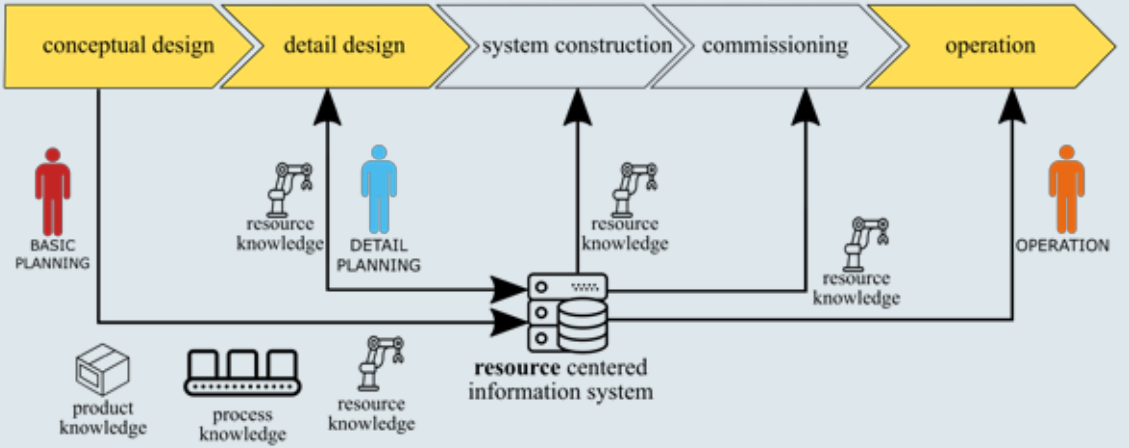
Process modeling

- Focus on describing relations, processes, and assembling sequences.
- Example solutions: BPMN 2.0, Petri Nets.

Resource modeling

- Focus on describing the structure and behavior of a production system.
- Example Solutions: UML Class Diagrams.

Engineering Process based on VDI/VDE 3695[2]



Key Goals:

- Identify promising modeling approaches that combine PPR concepts.
- Understand modeling capabilities to support tracing design decisions.

[2] VDI 3695: Engineering of industrial Plants, Evaluation and Optimization, Beuth Verlag Std., 2009.

Research Questions

RQ1. What **modeling approaches** - in industrial informatics and in business informatics - **combine process, product and resource modeling**?

?

Approach:

- Following an adapted literature survey complemented with interviews with domain experts.
- Analysis of 45 Papers regarding modeling languages and requirements.

RQ2. What are **PPR modeling capabilities** and **limitations** of modeling approaches that **combine process, resource, and product modeling**, as foundation for **tracing design decisions**?

?

Approach:

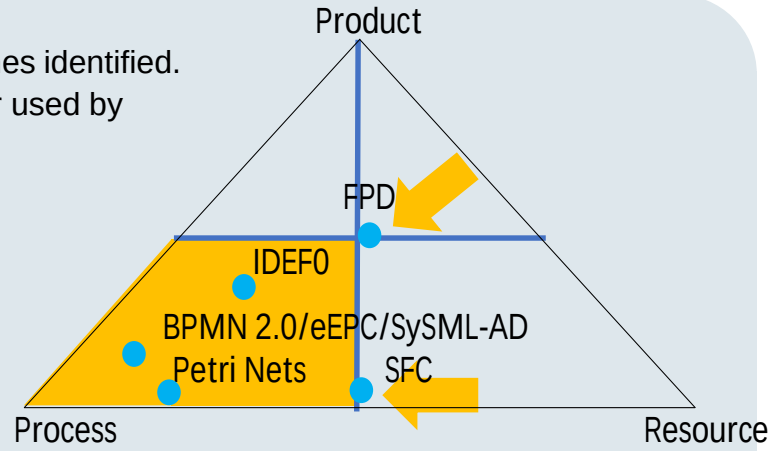
- Assessment of existing solutions against identified requirements.

RQ.1 - Results

- Seven graphical modeling approaches identified.
- Elicited from literature and known or used by domain experts.

Observations:

- Most of the approaches focus on one/two aspects of PPR.
- Focus on processes: IDEF0, BPMN 2.0, eEPC, SysML-AD, Petri-Nets.
- Fundamental PPR Capabilities: Formal Process Description (FPD).
- Process descriptions for resources: Sequential Function Charts (SFC).

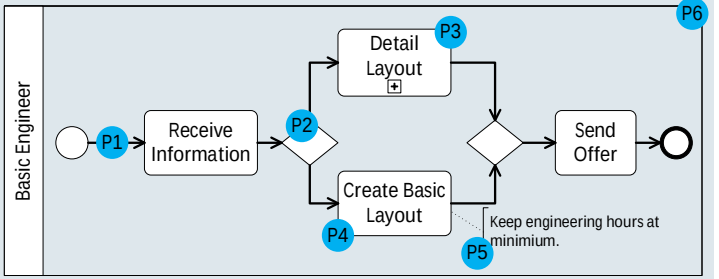


No “native” and visual PPR modeling approach.

RQ.2 – Results – Process Modeling Capabilities

- RQ.2: What are **PPR modeling capabilities** and **limitations** of modeling approaches that **combine process, resource and product modeling** as foundation for **tracing design decisions**?

- Which process modeling capabilities are needed?



- Basic elements for modeling process engineering knowledge.
  - P1 – Basic Workflow.
  - P2 – Logical operations (not present in FPD or IDEF0).
  - P3 – Meta-processes.
  - P4 – Tasks.
  - P5 – Comments (defined in BPMN but extensible for other approaches).
  - P6 – Organizational Responsibilities (Swimlanes available for BPMN and UML).

RQ.2 – Results – Tracing of Design Decisions

Approach	A1: Product Assembly	A2: Process Modeling	A3: Resource modeling	B1: Hierarchy Modeling	B2: PPR Relations	B3: Consistency Expressions
	Criteria for Tracing Design Decisions with PPR.					
BPMN 2.0	Partially	Yes	Partially	Partially	Partially	No
eEPC	No	Yes	No	No	No	No
FPD	Yes	Yes	Yes	Partially	Yes	No
IDEF0	Partially	Yes	Partially	Partially	Partially	No
Petri nets	No	Yes	No	No	No	No
SFC	No	Yes	No	No	No	No
SysML-AD	Partially	Yes	No	Partially	Partially	No

RQ.2 – Results – Process Modeling Support

Approach	A1: Product Assembly	A2: Process Modeling	A3: Resource modeling	B1: Hierarchy Modeling	B2: PPR Relations	B3: Consistency Expressions
	Criteria for Tracing Design Decisions with PPR.					
BPMN 2.0	Partially	Yes	Partially	Partially	Partially	No
eEPC	No	Yes	No	No	No	No
FPD	Yes	Yes	Yes	Partially	Yes	No
IDEF0	Partially	Yes	Partially	Partially	Partially	No
Petri nets	No	Yes	No	No	No	No
SFC	No	Yes	No	No	No	No
SysML-AD	Partially	Yes	No	Partially	Partially	No

RQ.2 – Results – Consistency Checking Support

Approach	A1: Product Assembly	A2: Process Modeling	A3: Resource modeling	B1: Hierarchy Modeling	B2: PPR Relations	B3: Consistency Expressions
	Criteria for Tracing Design Decisions with PPR.					
BPMN 2.0	Partially	Yes	Partially	Partially	Partially	No
eEPC	No	Yes	No	No	No	No
FPD	Yes	Yes	Yes	Partially	Yes	No
IDEF0	Partially	Yes	Partially	Partially	Partially	No
Petri nets	No	Yes	No	No	No	No
SFC	No	Yes	No	No	No	No
SysML-AD	Partially	Yes	No	Partially	Partially	No

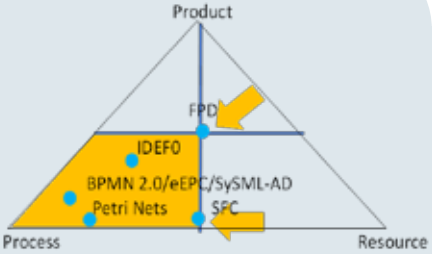
RQ.2 – Result – Formal Process Description

Approach	A1: Product Assembly	A2: Process Modeling	A3: Resource modeling	B1: Hierarchy Modeling	B2: PPR Relations	B3: Consistency Expressions
	Criteria for Tracing Design Decisions with PPR.					
BPMN 2.0	Partially	Yes	Partially	Partially	Partially	No
eEPC	No	Yes	No	No	No	No
FPD	Yes	Yes	Yes	Partially	Yes	No
IDEF0	Partially	Yes	Partially	Partially	Partially	No
Petri nets	No	Yes	No	No	No	No
SFC	No	Yes	No	No	No	No
SysML-AD	Partially	Yes	No	Partially	Partially	No

Summarized Results

RQ.1: Available modeling approaches to support PPR?

- Seven modeling approaches have been investigated.
- FPD supports basic PPR concepts that could be extended.
- However, no „native“ and visual PPR modeling language.



RQ2. Capabilities and limitations for tracing design decisions based on PPR modeling capabilities?

- No modeling approach meets all identified requirements.
- In the evaluation context, FPD provides a promising starting point, however,
  - Need for extensions
  - Hierarchy modeling only implicitly possible.
- No approach allows modeling consistency expressions!

Limitations, Conclusions, and Future Work

Limitations

- Focus on process-centered modeling.
- Focus on a selected set of modeling language approaches.
- Requirements definition driven by industry partner, i.e., they are domain specific.

Conclusion

- Domain experts depend on design decisions from earlier phases.
- Design decisions currently hard to trace throughout engineering roles and phases.
- Formal Process Descriptions (FPD) represent a promising starting point (including some limitations).

Future Work:

- Extend FPD for hierarchy and consistency modeling.
- Consideration of additional modeling approaches and requirements.
- Secure the engineering process for IPR concerns.

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