University of Stuttgart
Institute of Industrial Automation
and Software Engineering

Capability modelling of production system using machine tool as an example

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Outline

Motivation

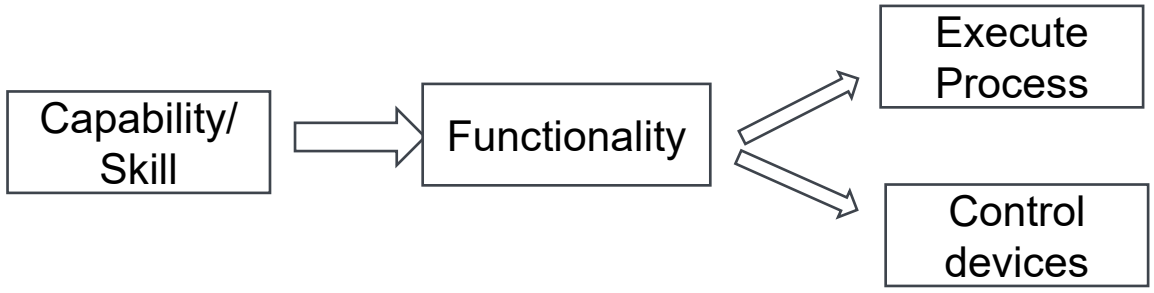
Systematic Literature review

Evaluation

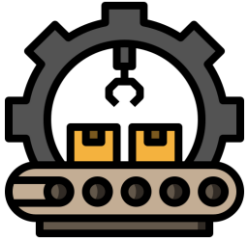
Experiment

Results and discussion

Motivation



Essential parts of capability/skill modelling



Production System

- Requirements
- Production process
- Skills of machine
- Derive actions
- Human-machine interface / external system (MMI)
- Skill execution

Outline

Motivation

Literature review

- Paper collection and Meta analysis
- Identify the motivation and requirements
- Modelling approaches
- Evaluation

Evaluation

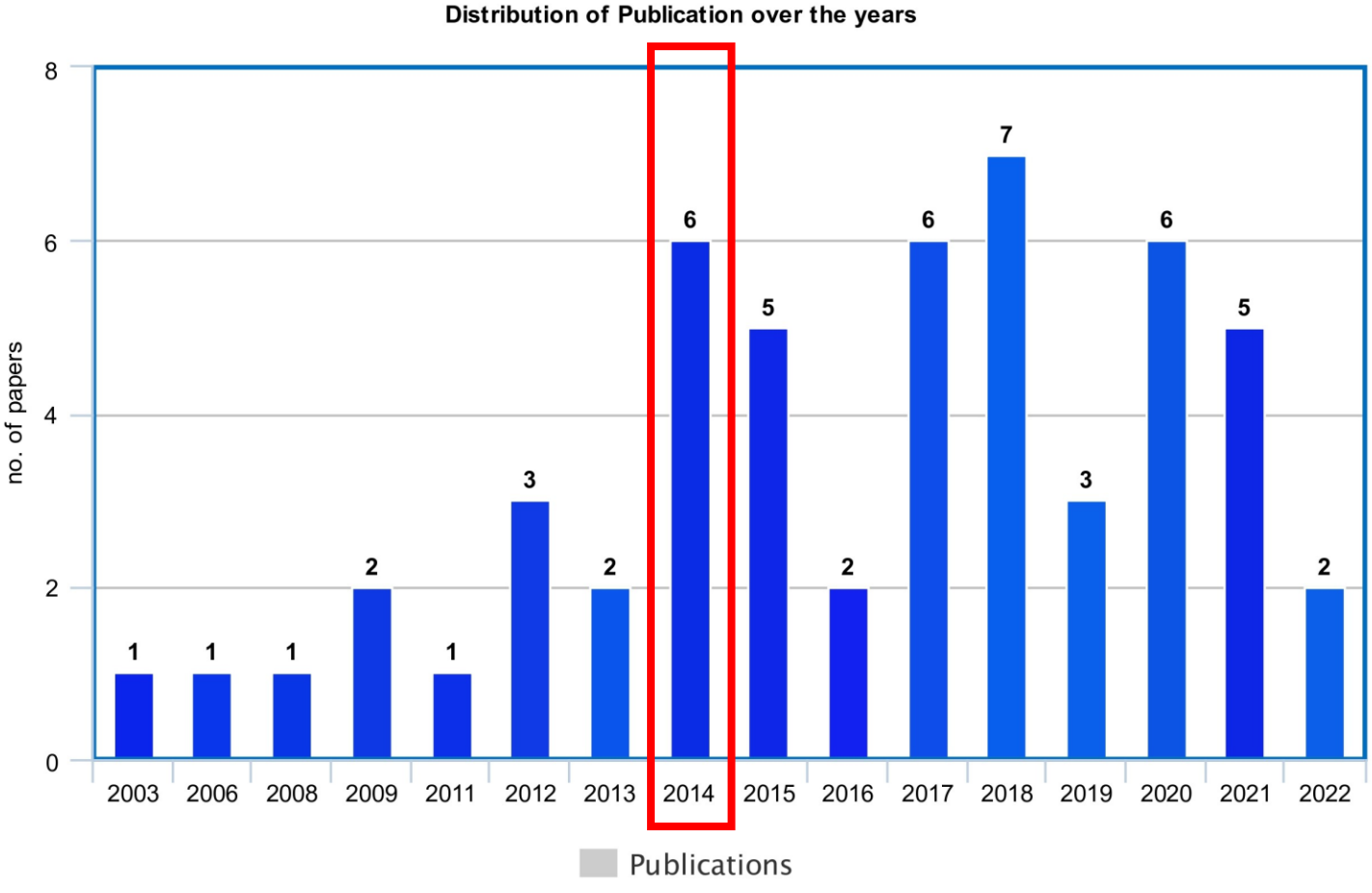
Experiment

Results and discussion

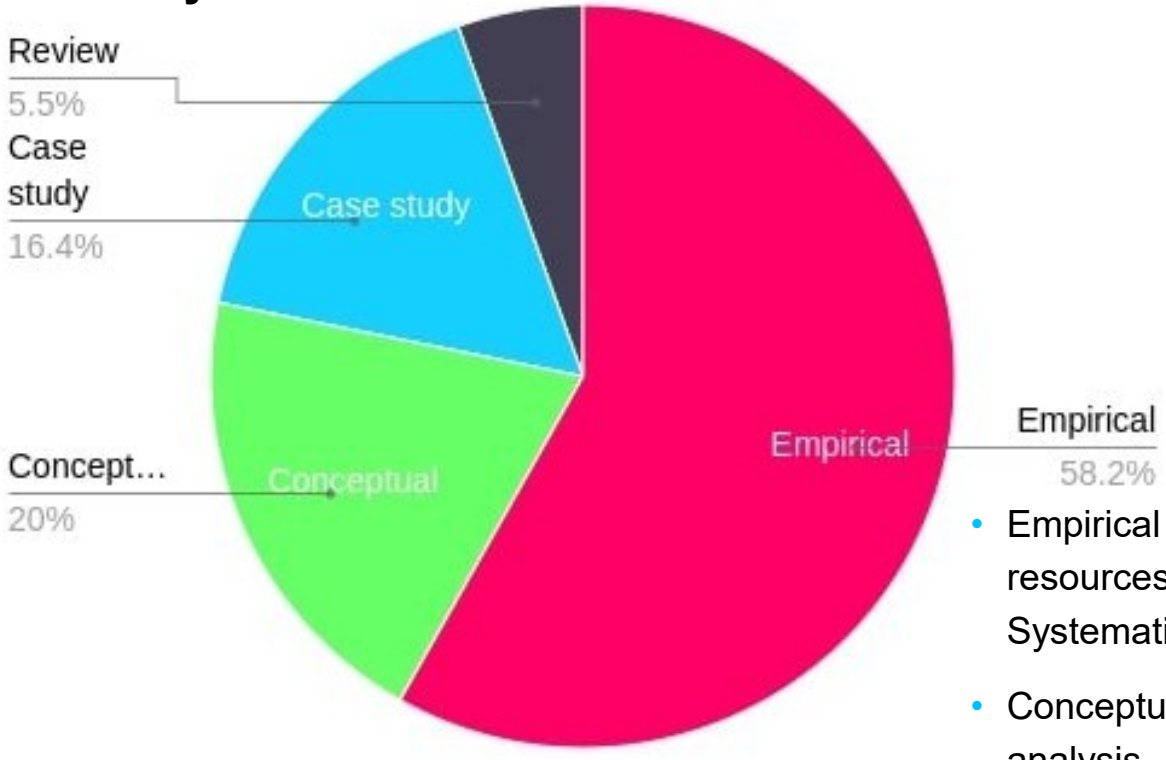
Paper Collection

- Different combination of keywords.
- Key Words: Capability modelling, Skill modelling, In Industrial automation, In production system, In manufacturing industry
- Database:
    1. IEEE Xplore
    2. Springer Link
    3. Science direct
    4. Semantic scholar
    5. ResearchGate
    6. Google Scholar
- Overall 57 related papers found

Meta Analysis



Meta Analysis

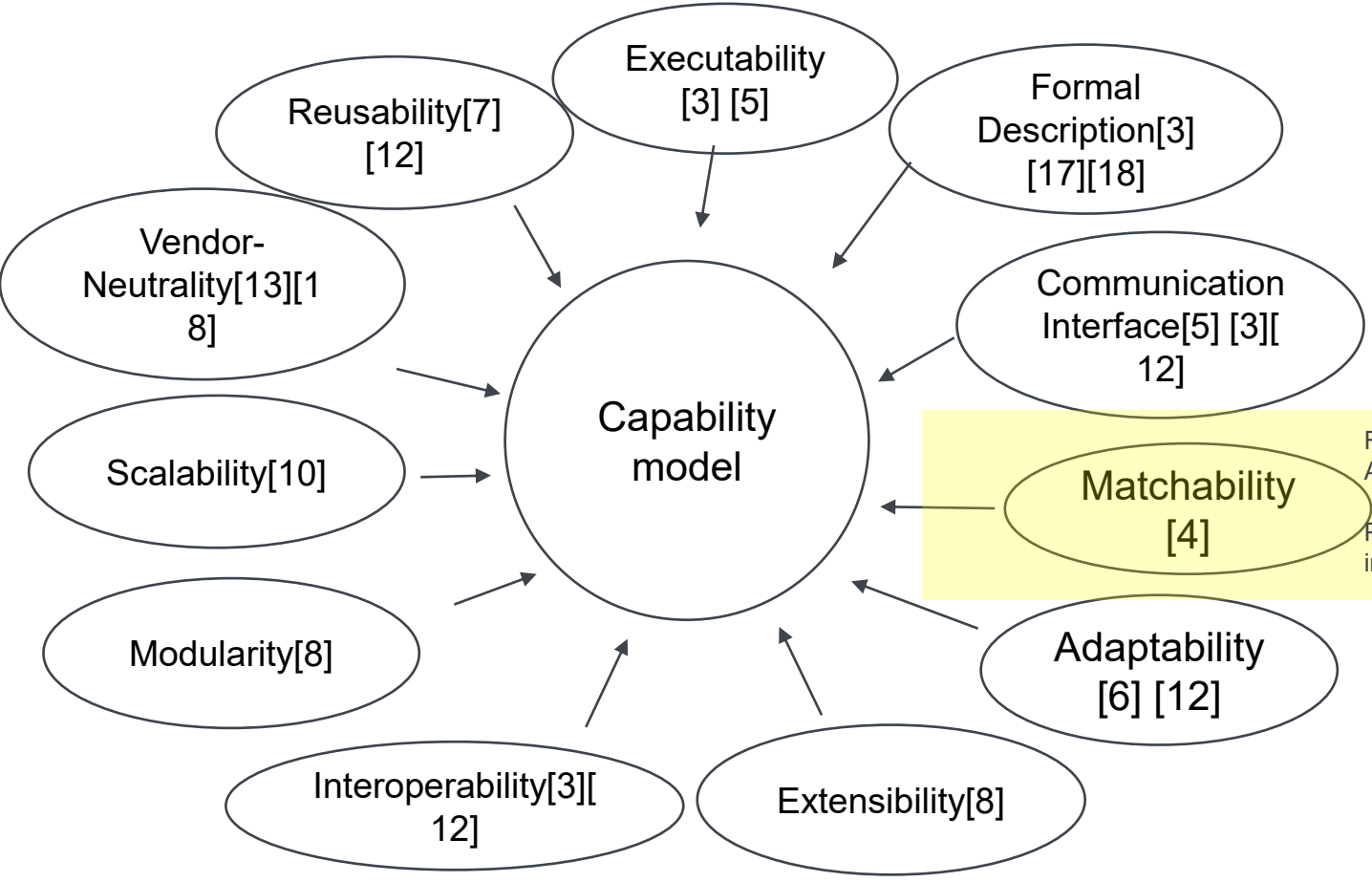


- Empirical experiment based on existing resources (Observational or practical) – Systematic observation
- Conceptual – Systematic review and meta analysis
- Case study – Better understanding of a process
- Review – Critical article or report

Related topics around the skill/capability modelling

- Integration of Industry 4.0 Technologies [3] [10]
- Implementing digital twins [5]
- Data-Driven Decision Making [4]
- Flexibile and Adaptable [6]
- Interaction with the other system [3]

Motivation and Requirements



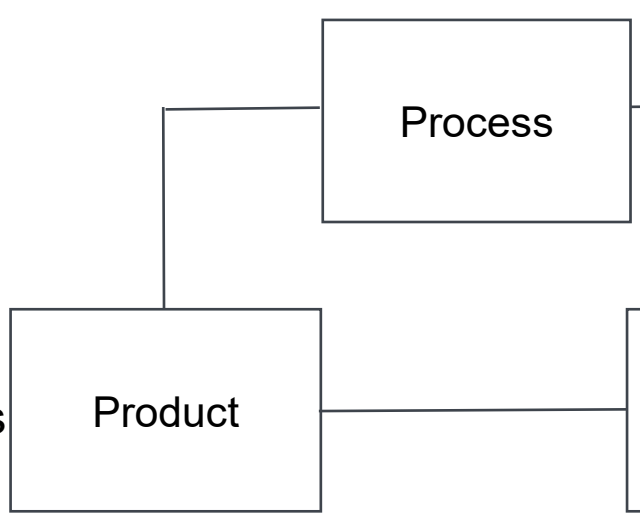
Required:
Abstract task requirements of process

Provided :
implementable functionalities of machines

The 4 dominant skill modeling approaches

Modelling approach(1/4)

Products, Process, Resource (PPR) (in early 2000s) [8] [9] [10]



- Abstract skills
- Production process
- Sub-process

- Input elements
- Output elements
- Other product

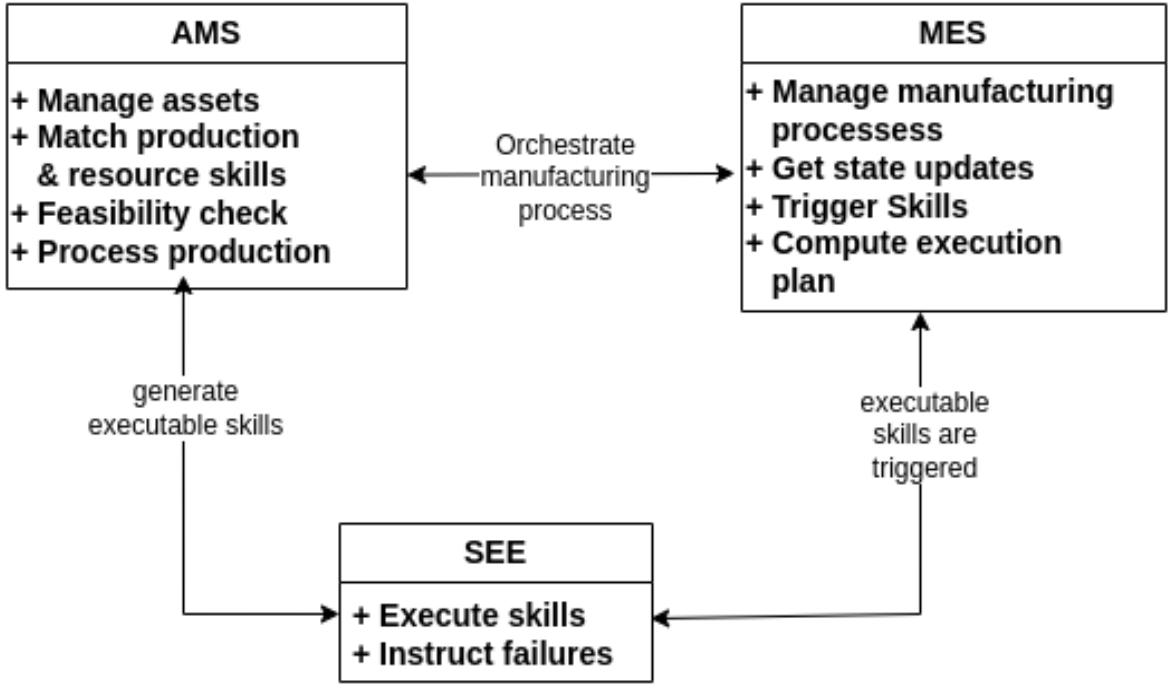
- Engaged entity
- Handle products
- Carry out operation

- Implementable in combination with AutomationML, OPC UA [9][10]

Modelling approach(2/4)

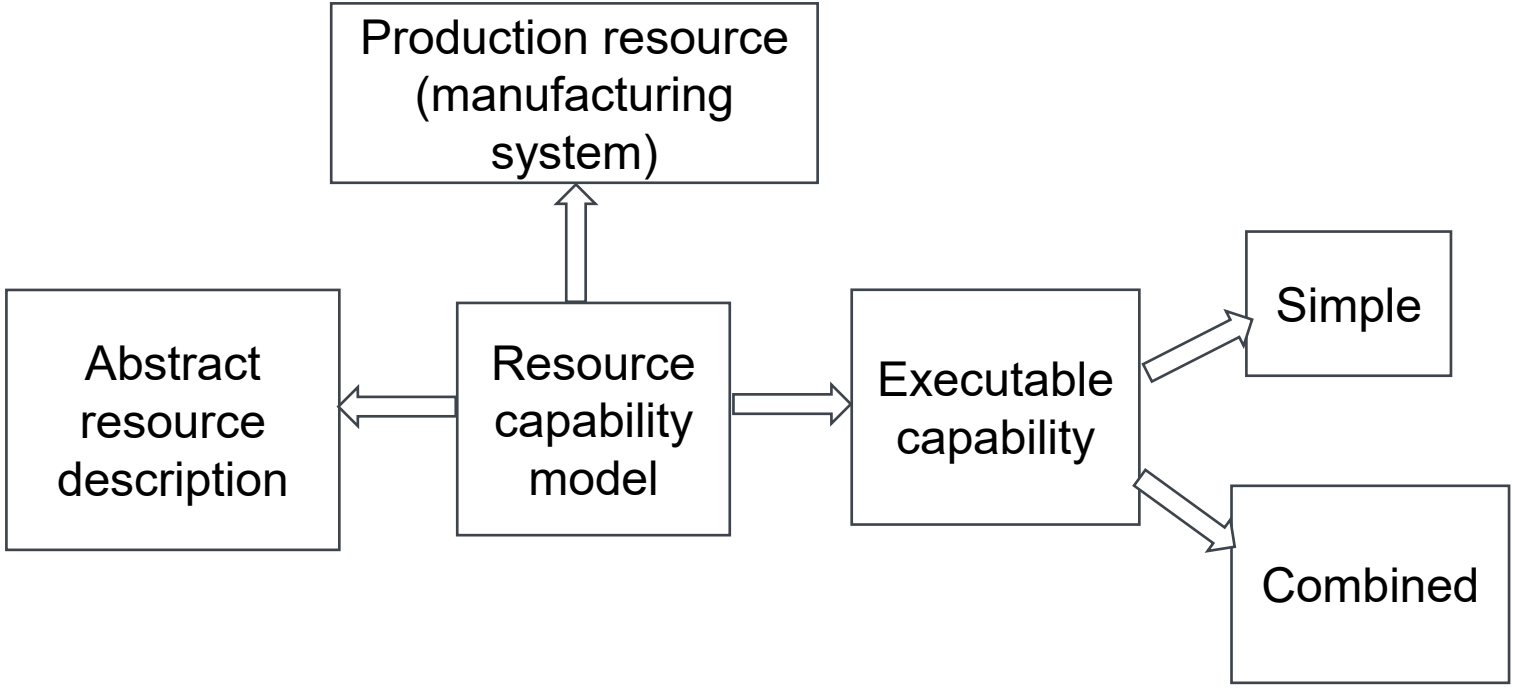
SkillPro (2012 - 2015) [11][12]

- Combination of cyber physical asset and skills
- Plug and produce
- Implementable with AutomationML



Modelling approach(3/4)

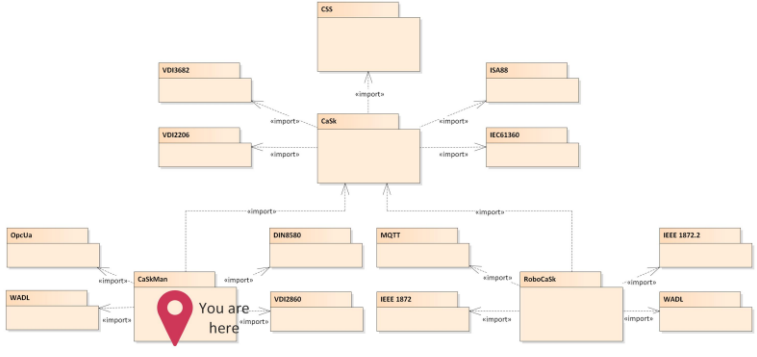
Resource capability model (2016) [14][15]



Only demonstrated on academic research [15], no implementation found.

Modelling approach(4/4)
Ontological modelling (2020 and continuing) [17][18][19]

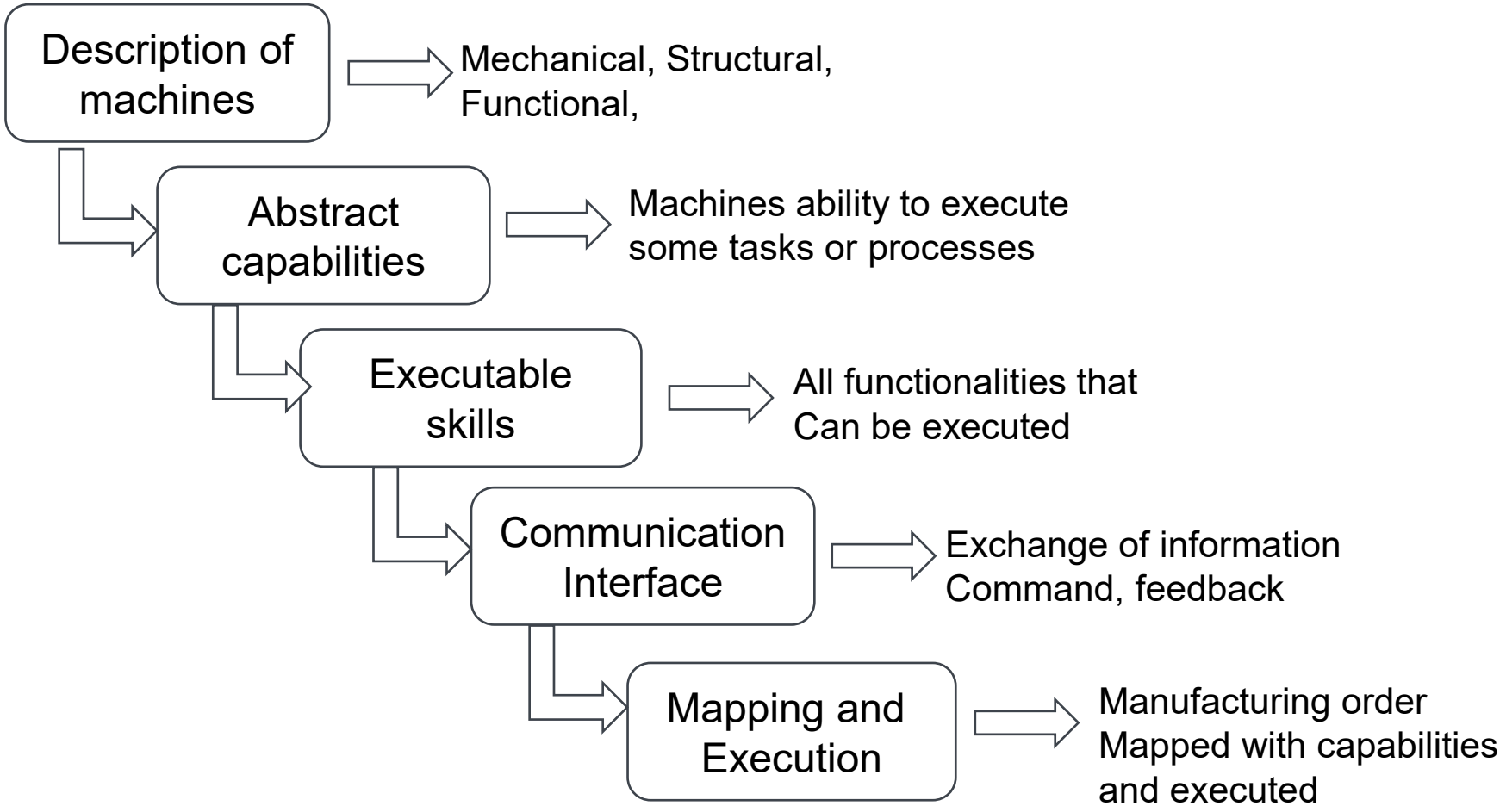
- Provides framework to define and design capabilities.
- This model uses Semantic web technologies.
- Covers - Resources, processes, capabilities, and constraints of production systems.
- Capability model using Web Ontology Language (OWL)
- Formal and machine-interpretable descriptions
- Can be mapped to other entities.
- Can be used as both conceptual and executable



[17] [18]

The commonality of these approaches

How to model the machine functionality into a skill

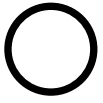
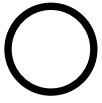


Evaluation of various methods with defined criteria

Evaluation criteria

1. Adapt to changing requirements(Adaptability).
2. The model should be based on industry standards.
3. Integrate information from different sources. (interoperability)
4. Skills can be invoked by external system /API (Connectivity)
5. Skill model - descriptive model or a executable model(executability)

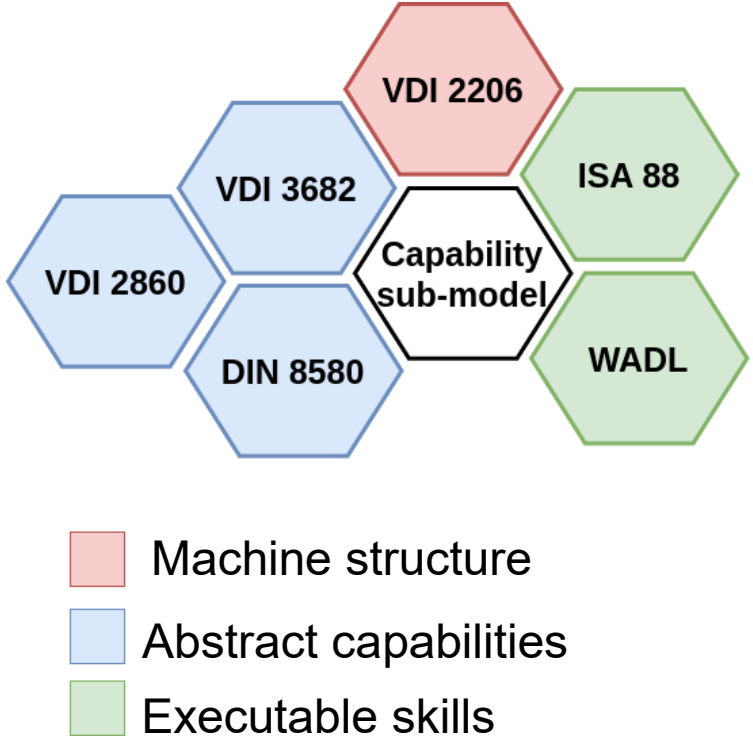
Evaluation

Approaches / Requirements	PPR model	SkillPro	Resource Capability model	Ontological model
Adaptability				
Based On standards				
Interoperability				
Connectivity				
Executability				

Experimenting with the selected approach

Experiment with Ontological Modelling [18][19]

- Ontological modelling is preferred
- The model is based on Ontological Design Patterns(ODP).
- Can be created and maintained separately.



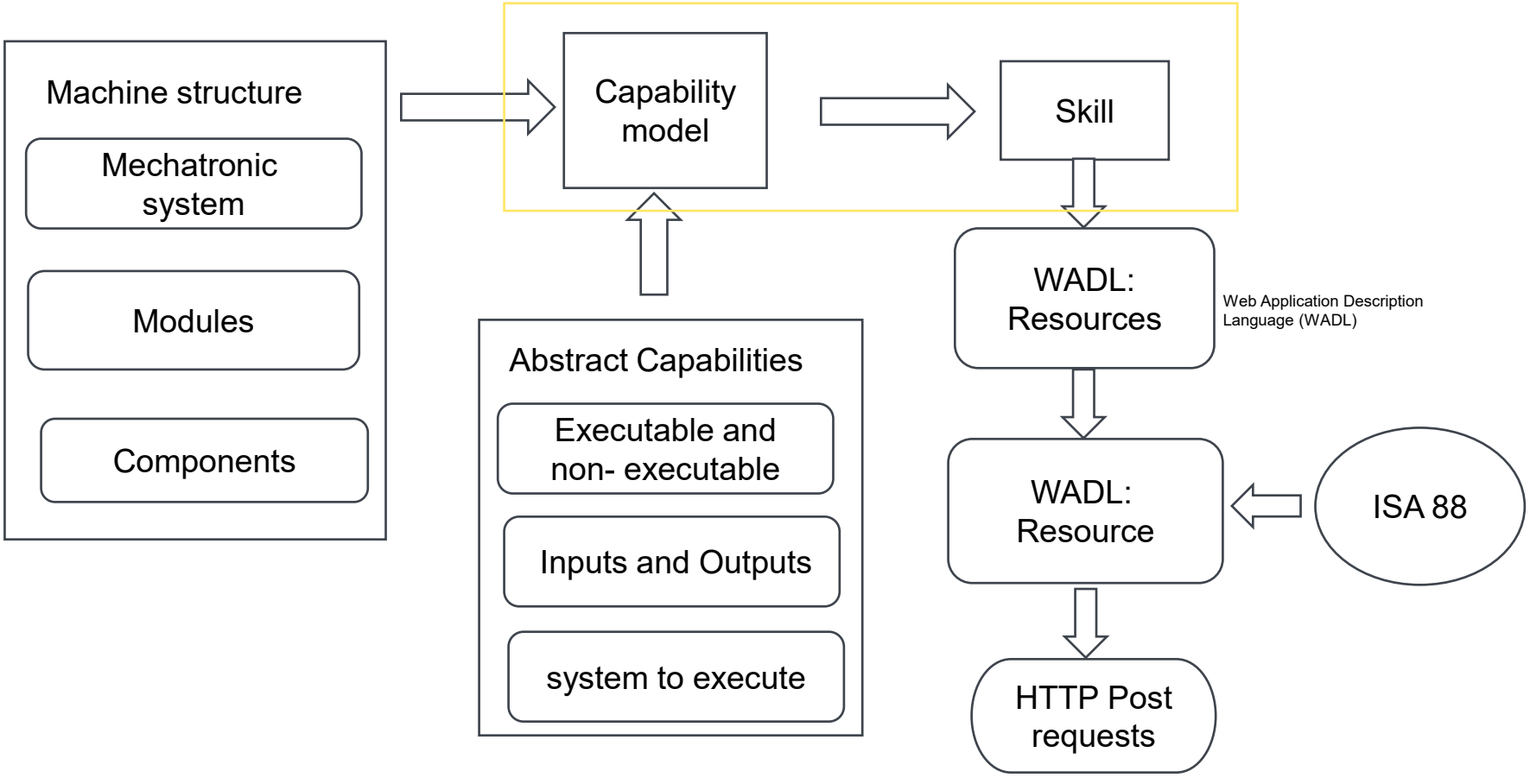
Experimenting depth

- **Description of machines** → Mechanical, Structural, Functional,
- **Abstract capabilities** → Machines ability to execute some tasks or processes
- **Executable skills** → All functionalities that Can be executed
- **Communication Interface** → Exchange of information Command, feedback
- **Mapping and Execution** → Manufacturing order Mapped with capabilities and executed

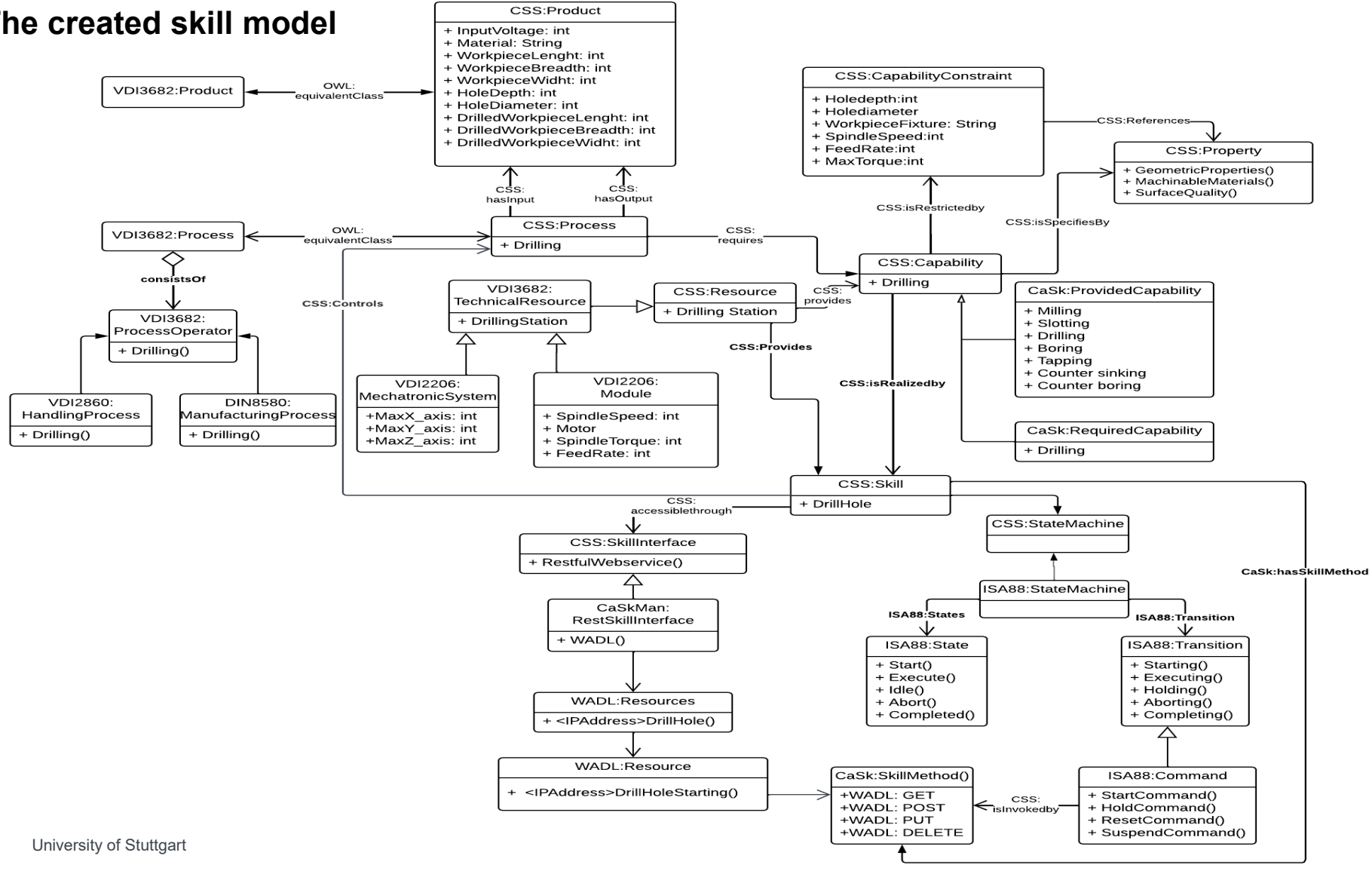
CMX 600V
Vertical Milling machine

- Datasheet
- Description from Manufacture Web
- User Manual

The essential part of the skill model



The created skill model



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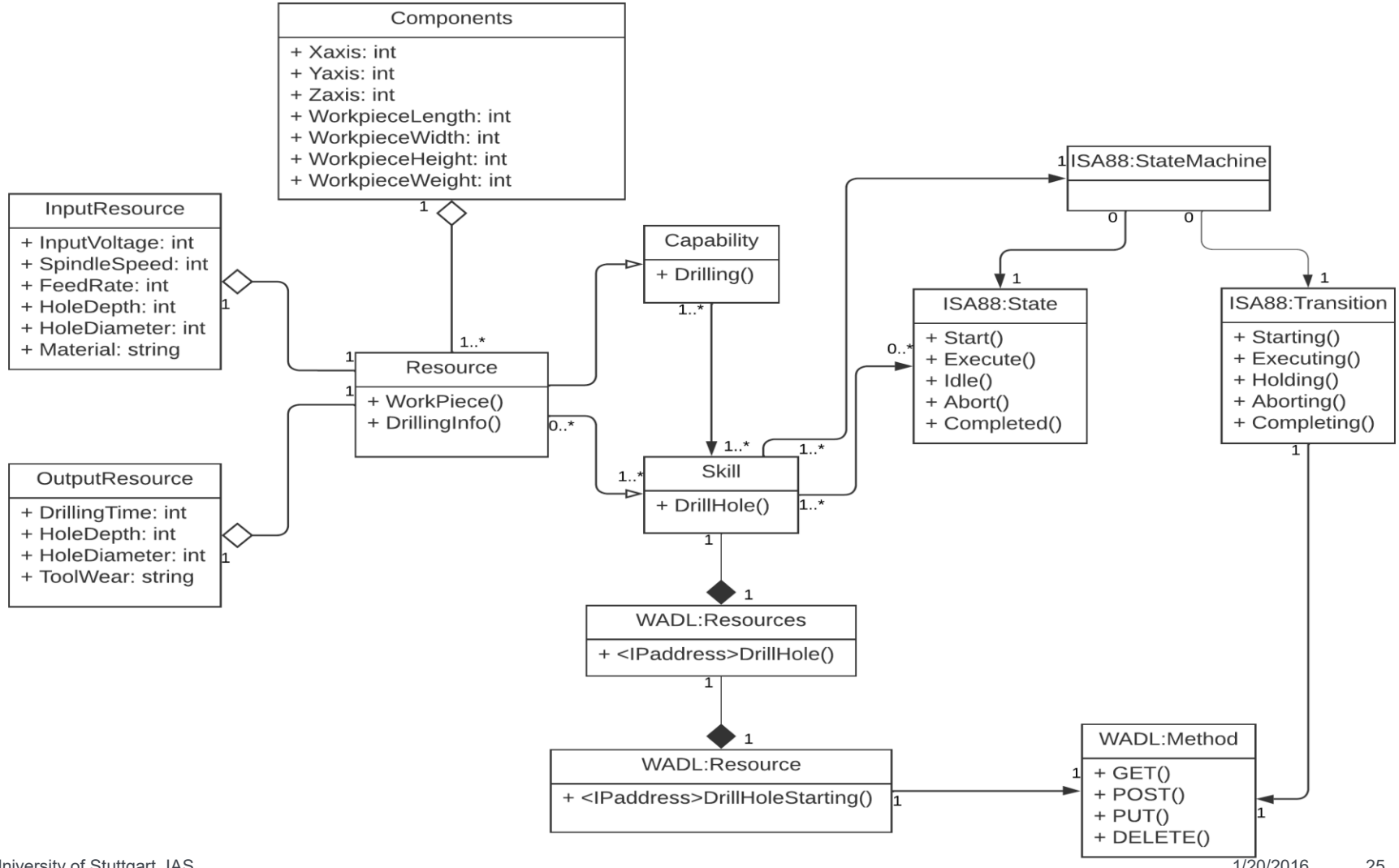

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Results and Conclusion

- Formal capability model is presented using ODP.
- Abstract capability and skill description.
- Alignment ontology to connect multiple contents.

Future Work

- Automatic skill description generation.
- Capability matching with manufacturing order.
- Feasibility check

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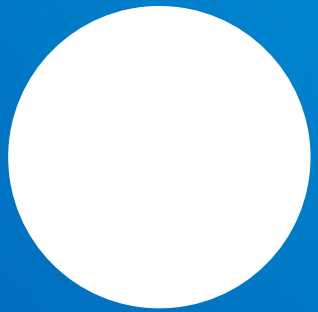
Thank you!



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