Reasoning on Engineering Knowledge

Applications and Desired Features

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Agenda

Application:

- Introduction & Motivation
- Mapping Engineering Data
- Reasoning on Engineering Data

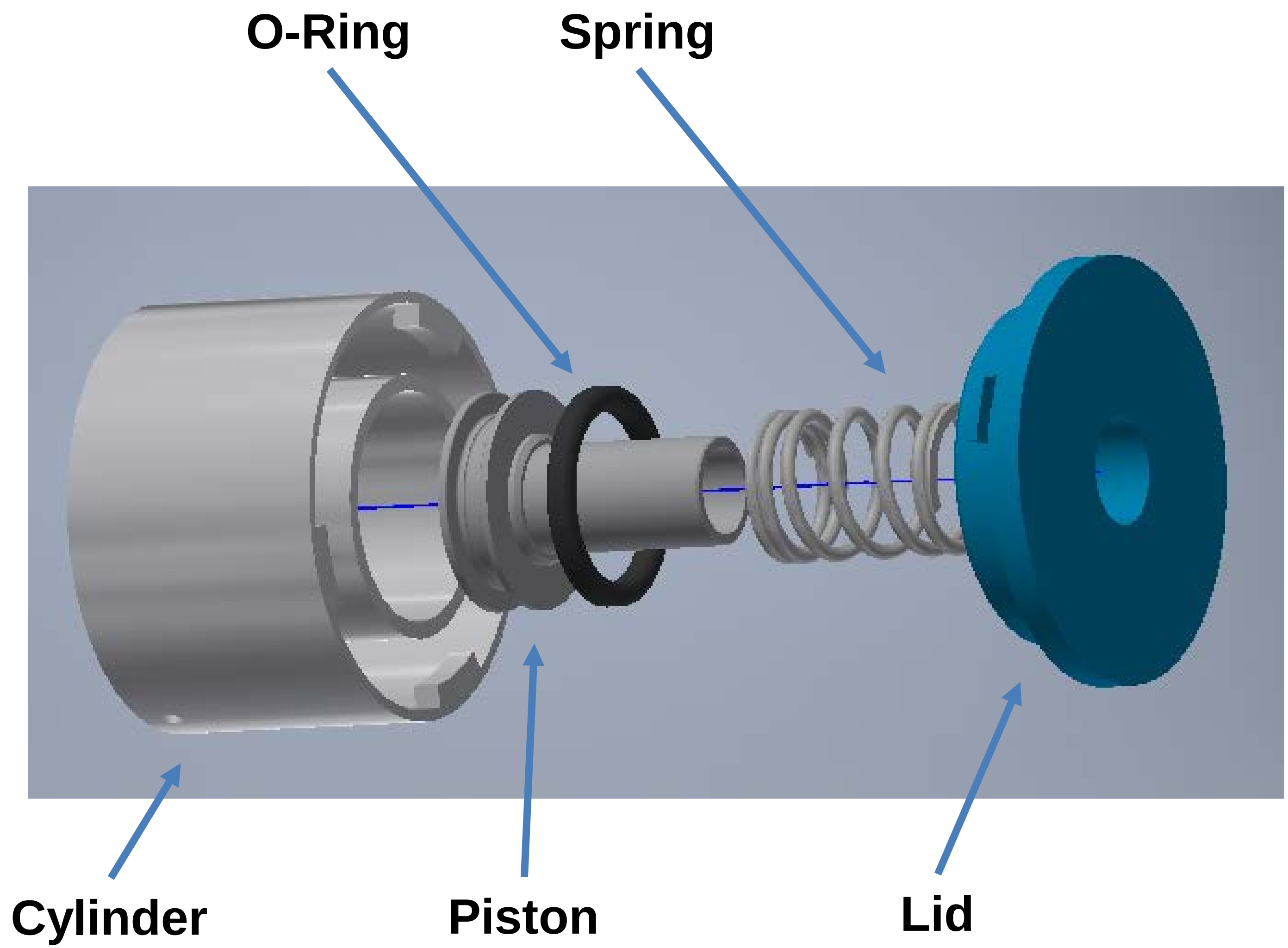
Desired Features:

- Desired Feature 1
- Desired Feature 2
- Desired Feature 3

The presentations´ mission:

Creating awareness in Semantic Web community for further potential of Semantic Web technologies in Engineering of automated production systems

Running Example - Product



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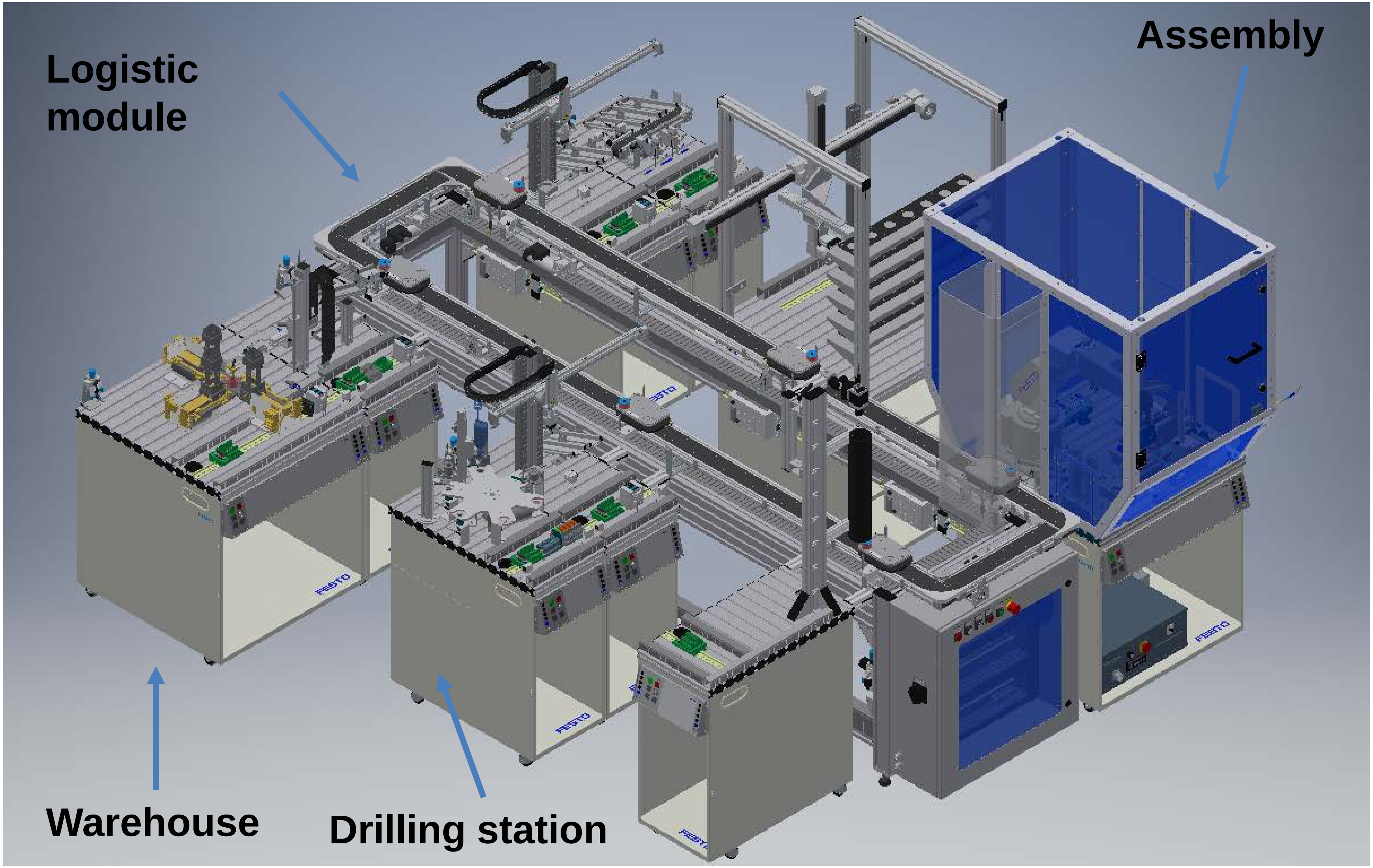
Running Example – Production System

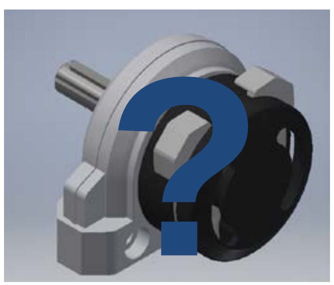


Introduction & Motivation

Market demand

- Increasing number of product variants

- Decreasing product life-cycles



- Decreasing lot sizes (-> 1pc.)
- Less re-occuring orders
- Low cost and high quality

Resulting issues

- Fact: Production systems usually have a longer life-cycle than products have
- Resulting issue: Total product variance over a production systems´ life-cycle is unknown at design time
- Fact: Adaption to product changes requires to check system functionality against product requirements
- Resulting issue: Since lot size is decreasing and orders are less re-occuring, costly manual adaption is not profitably anymore

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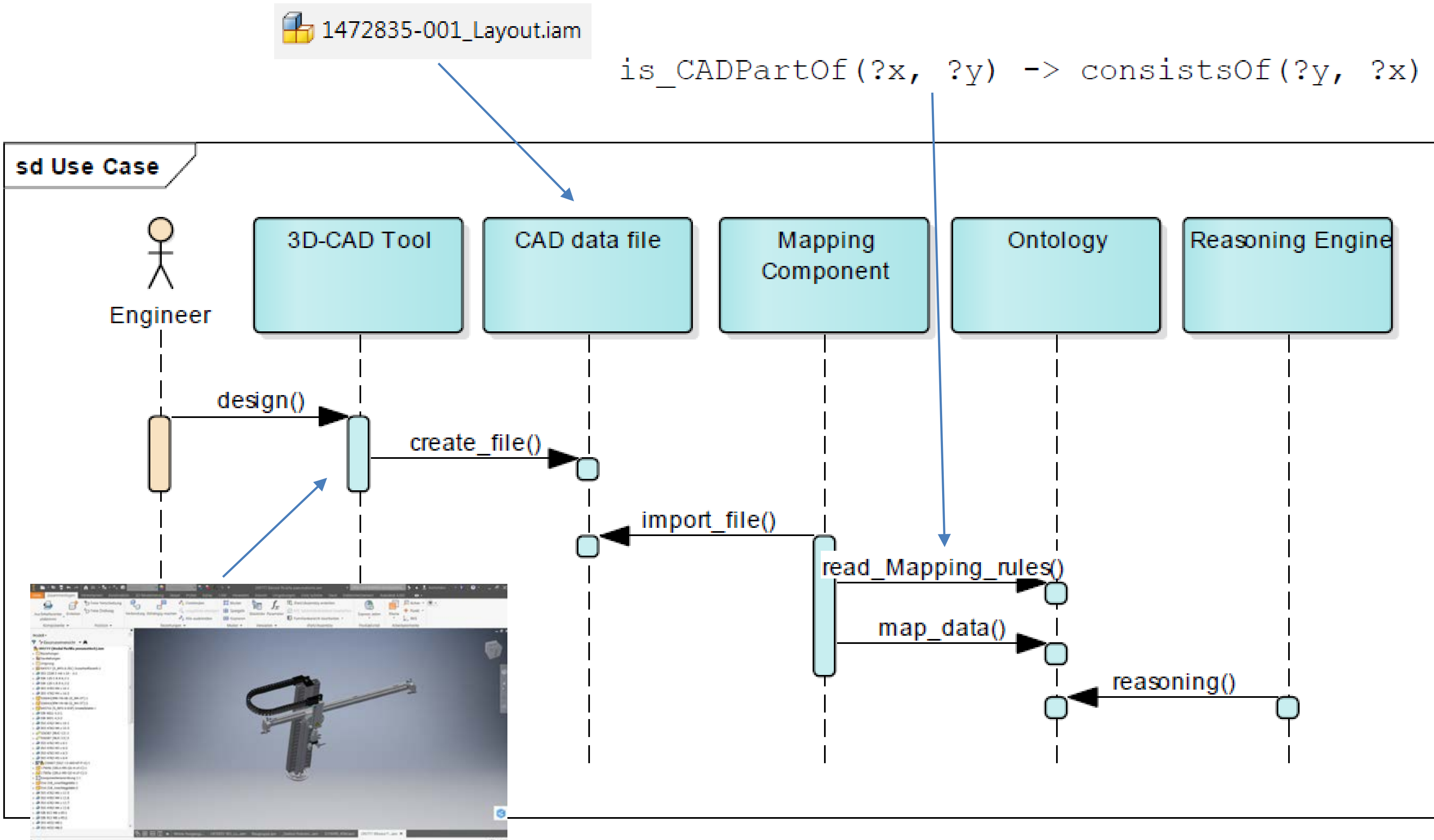
Approach

- Support production system adaption by providing a skill description
- Skill description represents HW&SW information that eases the check against product requirements
- Skill description contains information on system structure and behavior so that identifying components that need change is eased
- Use of Semantic Web technologies for modeling and reasoning on engineering data
- First step: only focus on kinematic skills

Requirements

- Production systems are often engineered customer specific:
  - Existing engineering data has to be used (3D-CAD, electrical CAD, PLC code)
  - No manual creation of models
- A production system usually consists of modules of different suppliers (e.g. FESTO, Siemens, Bosch, …): Same structure and behavior has to result in the same skill
- Approach has to cope with partially incomplete information:
  - Kinematics might not be modeled
  - PLC code might be incomplete
  - …

Mapping Engineering Data I



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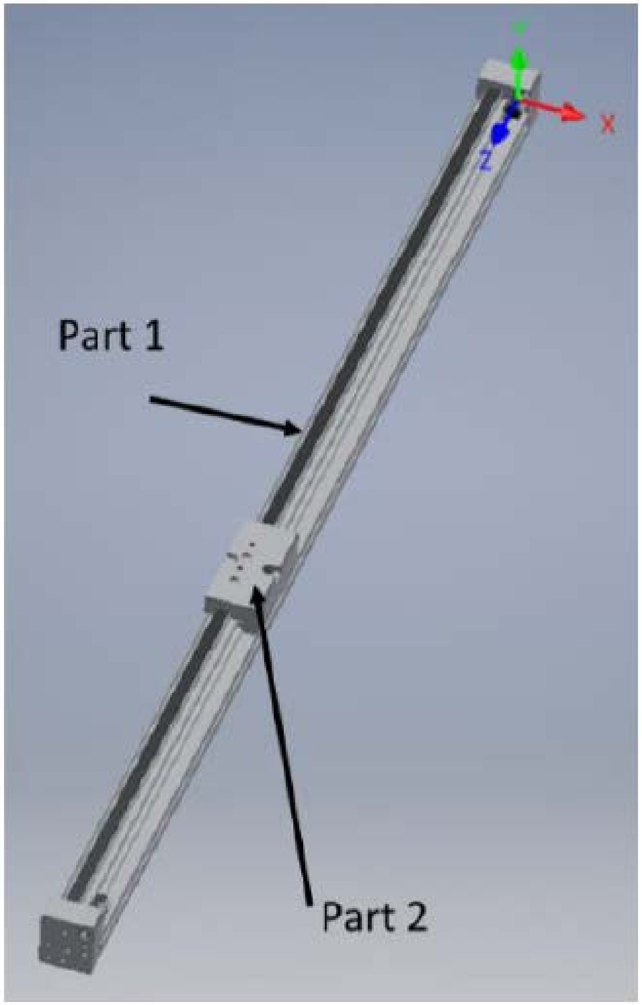
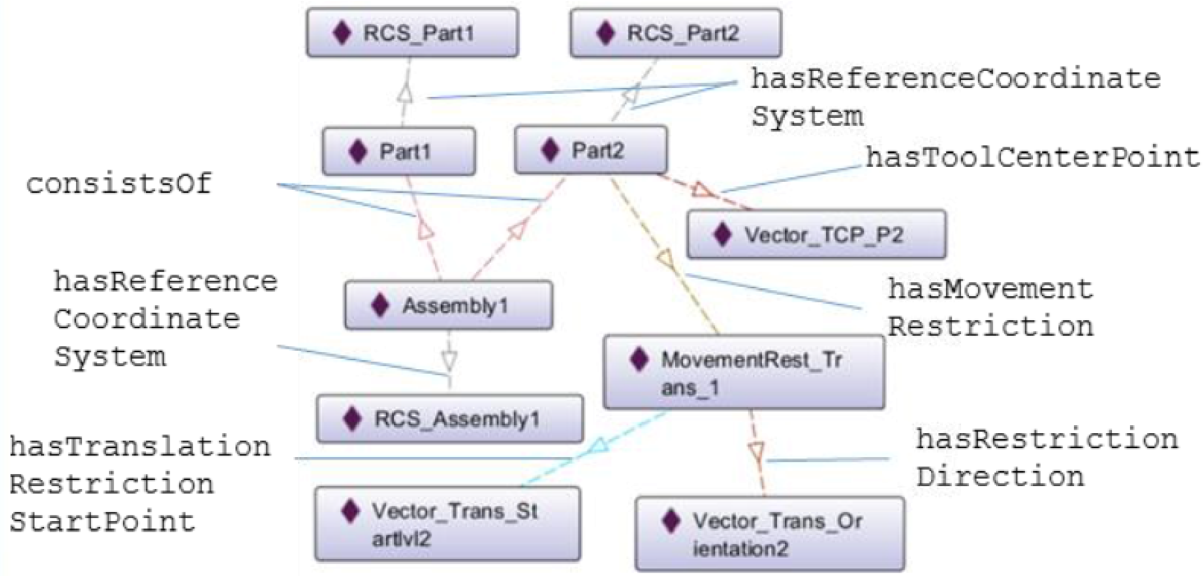
Mapping Engineering Data II

3D CAD example



Mapped individuals



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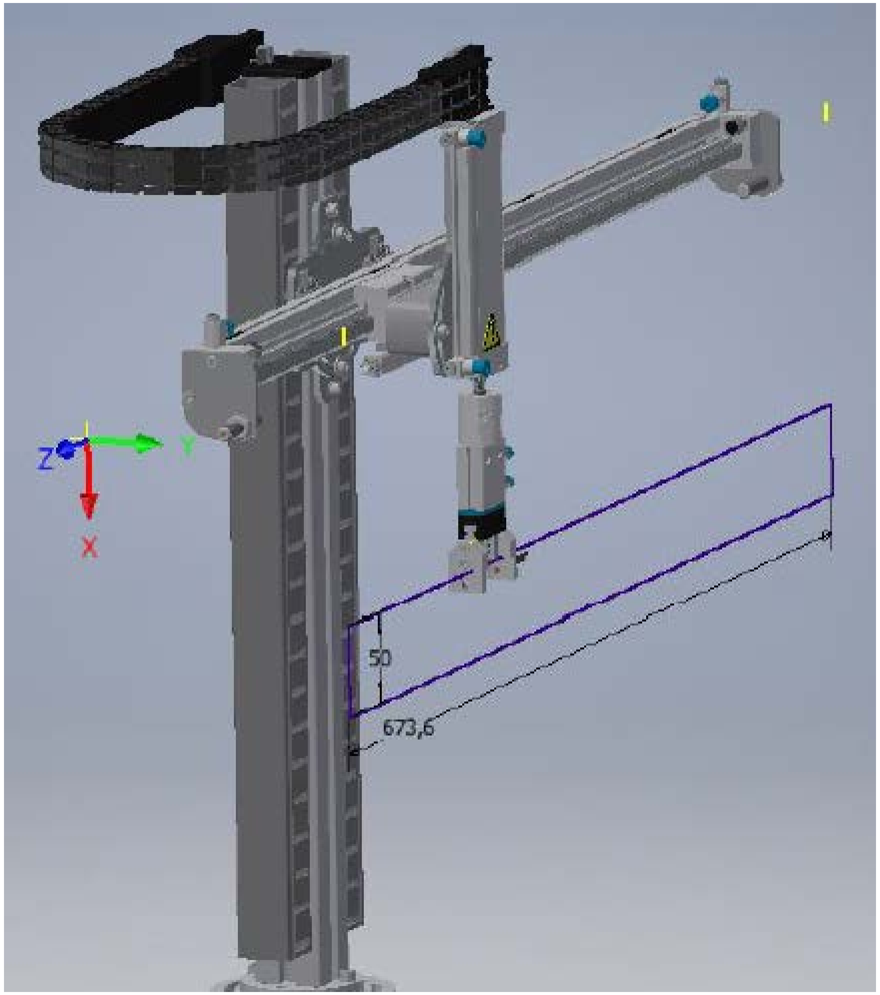
- Reasoning is necessary, since needed information is only implicitly in engineering data
  - Only kinematic of single assemblies
  - No combined kinematics
- SWRL has been choosen to model knowledge on combination of kinematics
- Reasoning Target: Inference of the overall kinematic, based on the combination of „primitive“ kinematics



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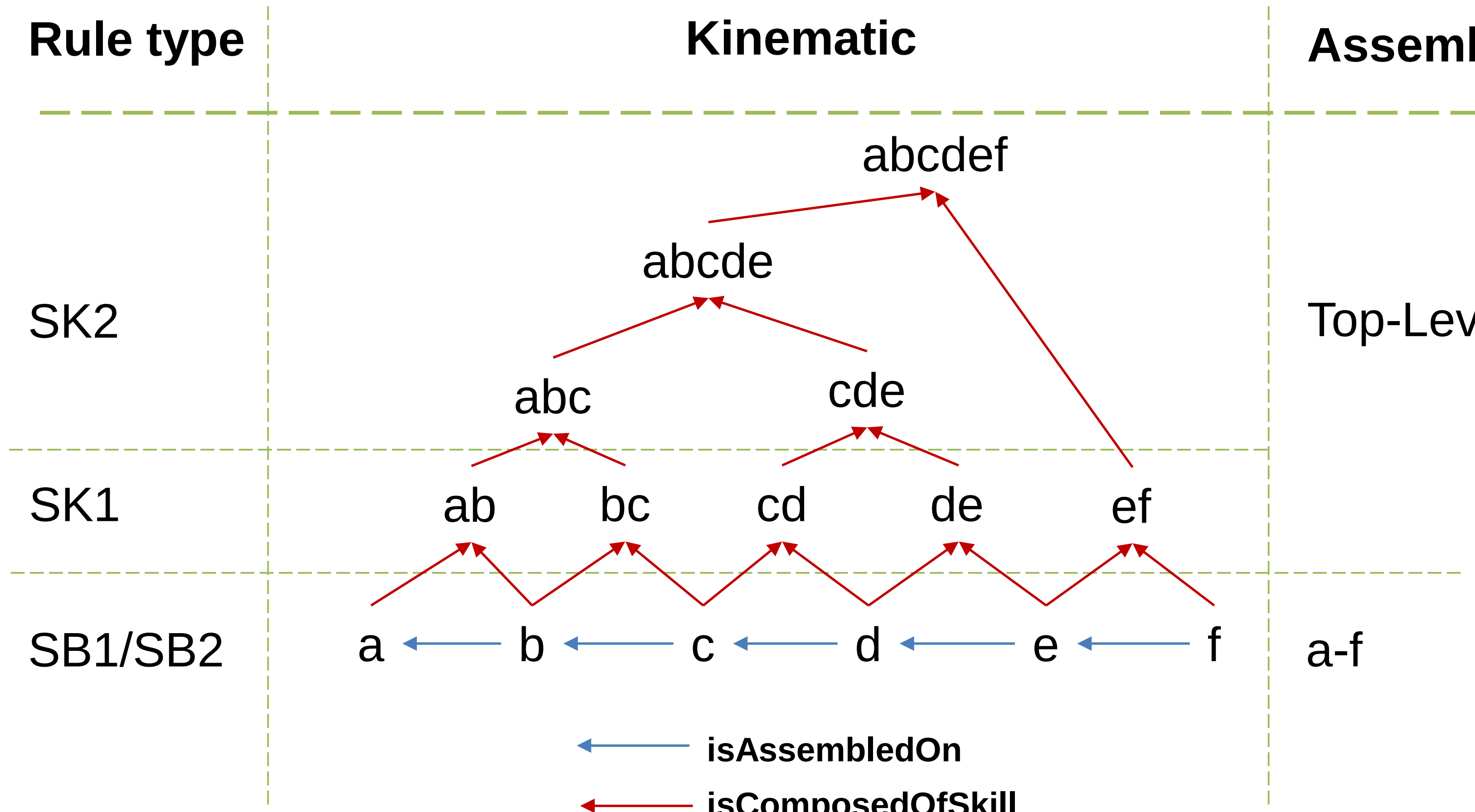
example on rule combination



Desired Feature 1

Creating Individuals

- The first desired feature seems easy: creating individuals with SWRL
- Creating individuals becomes necessary at various points, since knowledge is not only connected in another way:
  - A kinematic is not existing in engineering data -> create individual
  - The kinematics´ vectors do not exist in engineering data -> create individual
  - …
- There already exists a syntax through the SWRL Extensions built-in library
- Unfortunately this extension is not supported by any "of-the-shelf" reasoner

Rule example

```
Assembly(?a),
hasReferenceCoordinateSystem(?a,?RCSa),
consistsOf(?a,?c),
Component(?c),
hasDegreeOfFreedomTranslational(?c,?DoF
T),
hasDegreeOfFreedomRotational(?c,?DoFR),
swrlb:add(?DoFSum,?DoFT,?DoFR),
swrlb:greaterThan(?DoFSum,0),
swrlx:makeOWLThing(?Kin,1) ->

movesRelativeTo(?c,?RCSa),
movementRestrictionDefinesMovementDescr
iption(?c,?Kin),
Kinematic(?Kin)
```

Desired Feature 2

Mathematical Operations

- Knowledge in the manufacturing domain is often based on mathematical descriptions like vectors
- In cases where this knowledge is processed or evaluated in a new context, mathematical operations need to be performed
- Example:
  - Every assembly provides a kinematic that has to be calculated
  - When combining these kinematics, mathematical operations are necessary in order to identify their type of kinematic (translation, rotation, planes, …)
  - Since every DataProperty of every vector has to be mentioned in a rule, these rules become very complex
- An easier way to handle mathematical operations within SWRL rules is needed, that is supported by an “off-the-shelf” reasoner

Equation example

- Extracting a translational kinematic out of CAD data:
  - SV = start vector
  - O = orientation vector
  - RS = restriction start vector
  - T = Tool Center Point vector
  - EV = end vector
  - S = vector pointing on start level
  - Alpha = scalar

$$\overrightarrow{sv} = \vec{T} + \left(\frac{\vec{O} \cdot (\overrightarrow{RS} - \vec{T})}{\vec{O} \cdot \vec{O}}\right)\vec{O};\ \overrightarrow{ev} = \vec{S} + \alpha\vec{O}$$

- Required basic math operations: 16

Desired Feature 3

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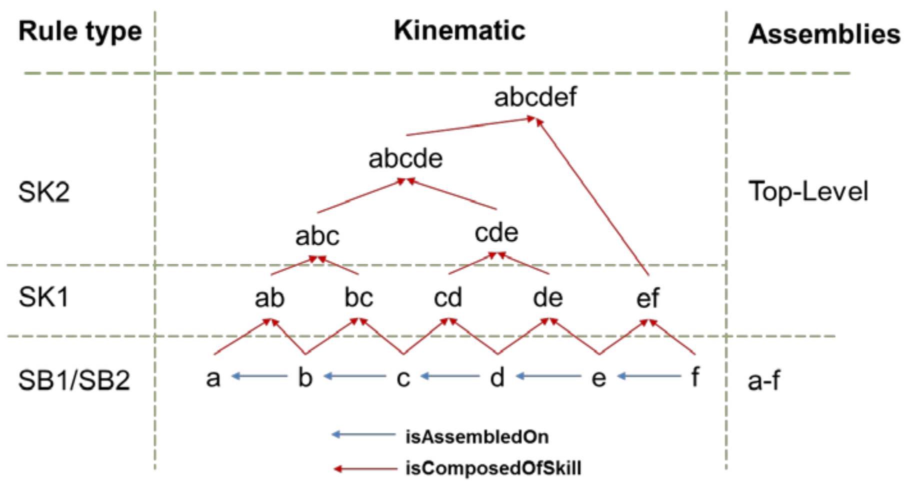
Defeasible reasoning

- Engineering methods are often based on an iterative procedure, since the overall task needs to be split in smaller tasks
- Handling iterative procedures in SWRL, requires defeasible reasoning, example:
  - Inferring a top level kinematic within one rule results in a too complex rule -> inference of single kinematics and combination of them
  - This requires defeasible reasoning, since only latest inferred kinematics should be considered for further inference
- Unfortunately, defeasible reasoning is not supported by any “off-the-shelf” reasoner
- The need for defeasible reasoning becomes even more apparent, when looking at what has to be done next

Inference of top level kinematic



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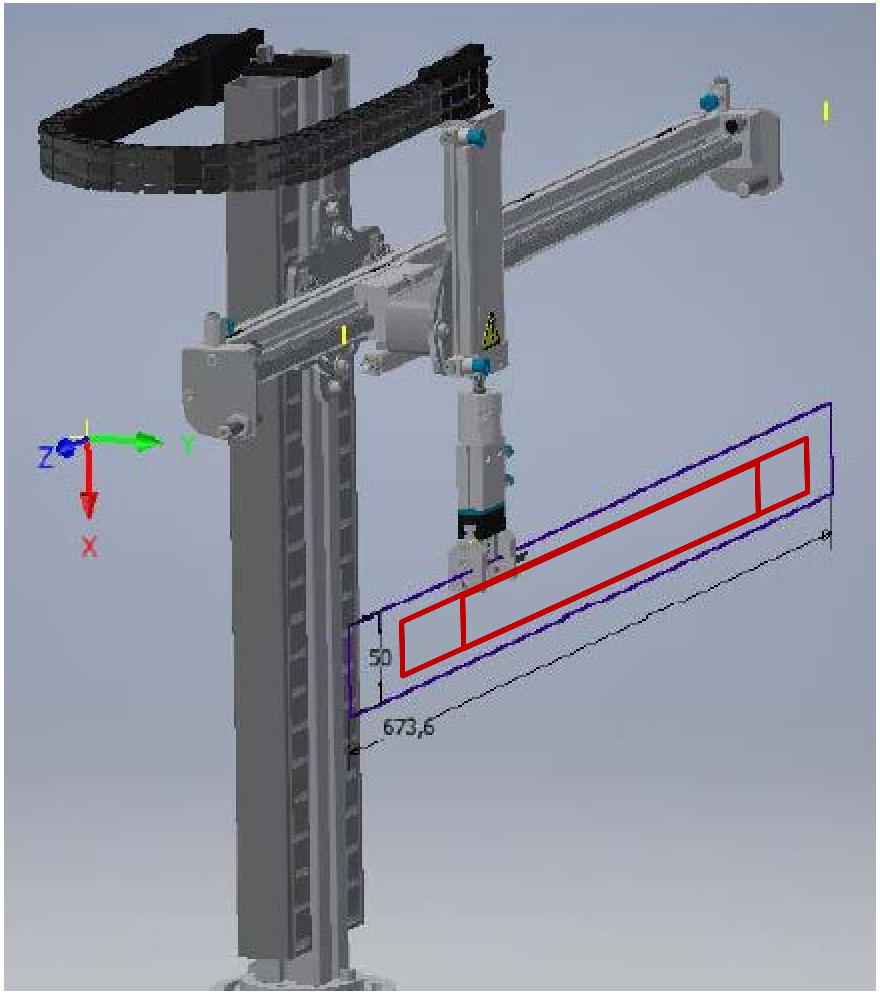
Desired Feature 3

Defeasible reasoning

- After having inferred the kinematic, other data formats have to be mapped in OWL and their restrictions on the skill have to be inferred:
  - E-CAD e.g.: Properties of drives and sensors
  - PLC e.g.: Programmed behavior

- Other data formats than 3D-CAD might restrict the inferred knowledge, example:
  - PLC: Kinematic may show greater movement areal than sensors and drives do allow based on PLC program
  - E-CAD: Chosen drives and sensors restrict possible endpoints due to resulting forces or their structure

Skill example

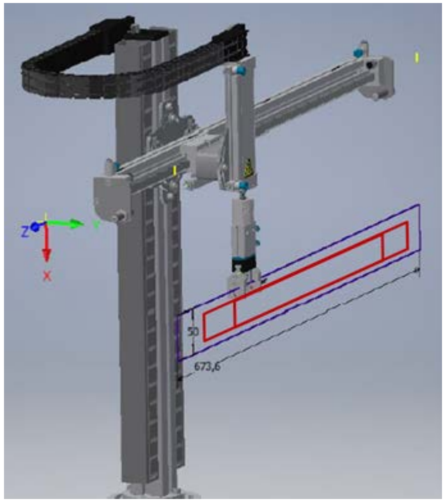


Conclusion

- Semantic Web technologies provide a great potential in handling upcoming changes in future manufacturing
- Manufacturing skill descriptions can be extracted from engineering data
- Providing a few features by an "off-the-shelf" reasoner would even enhance the potential

Desired Features

- Creating individuals within SWRL
- Support of complex math operations in SWRL
- Defeasible reasoning



Thank you for your attention