# SMAPSS Ontology Evaluation

## What is an Ontology?

Ontologies are a widely used method for representing knowledge. Therefore, knowledge is expressed in semantic statements and stored digitally. An ontology consists of classes (objects), attributes, and relationships representing a domain's knowledge. Besides humans, machines can also understand the concepts defined within the ontology and process the content and interpret new knowledge. Moreover, it can be used to infer, querying the specific knowledge about a domain across heterogeneous systems. For example: 'Human' can be considered as a subclass of 'Animals', and 'Animals' is the subclass of 'Living Organism'.

These concepts can be further provided with a relationship. These relationships are called *Object Property*. For example: 'Humans' 'eats' 'Apple' where 'eats' is an Object Property.

The property of a concept is called *Data Property*. For example, an 'Apple' is a concept that is a subclass of 'Fruit', then the Data Property of Apple can be considered as 'Nutritional Content', which is 'Vitamin A' or the size, shape etc.

## What is the benefit of an Ontology?

Apart from having a shared conceptualization of the concepts and their relationship, using ontologies, we can have a mechanism where we can get new information out of the already existing concepts and their relationship. For example, 'Humans' eat 'Apple' and 'Apple' 'Nutritional Content' is 'Vitamin C'. Therefore, using the chain connection between Humans and the nutritional content of the apple. We can infer that a human who eats an apple gets Vitamin C.

## Use of an Ontology in a production environment:

Using ontologies in a production environment is a relatively new research field. As described above, the goal is to store knowledge about an organization and its processes and enable workers to share and extract new knowledge.

## Use of an Ontology in the project DAMOKLEZ:

In the research project DAMOKLEZ, an ontology has been developed to store knowledge about deviations between a simulation model and its real production system. The goal is to fasten and support the process of knowledge extraction from a knowledge worker who works on the shop floor of the production system to the simulation expert, who needs to adjust the parameters of the simulation model according to the current deviation.

## Your background

### In which industry is your company mainly active?

- ☐ Automotive/ motor vehicle manufacturers
- ☐ Mechanical and plant engineering
- ☐ Supply industry
- ☐ Consulting
- ☒ Research
- ☐ Other: Klicken oder tippen Sie hier, um Text einzugeben.

### What is your experience with the tools/activities mentioned below?

| | Not at all | No | Some what | Yes | Definitely yes | No statement |
|---|---|---|---|---|---|---|
| Are you involved in engineering tasks? | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ |
| Do you have experiences in production systems? | ☐ | ☐ | ☒ | ☐ | ☐ | ☐ |
| Do you work with data from production systems? | ☐ | ☒ | ☐ | ☐ | ☐ | ☐ |
| Do you work with simulation models? | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ |
| Have you heard about ontologies before? | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ |
| Have you worked with ontologies in the past? | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ |
| Have you used a Knowledge Management System before? | ☐ | ☐ | ☒ | ☐ | ☐ | ☐ |

Figure 1 represents the first-level concepts of the ontology. As mentioned in the figure, each class related to a process, product, deviation, or organization is colored respectively. Various concepts are not mainly related to a specific concept but can represent different knowledge for different concepts.

**Please look at the Simulation Model and Automated Production System Synchronisation (SMAPSS) ontology. The picture presents the first level of the ontology concept, which presents the general structure of an organization with a strong focus on the described task. Please answer the questions with 'strongly disagree', disagree', 'neutral', 'agree', 'strongly agree'.**

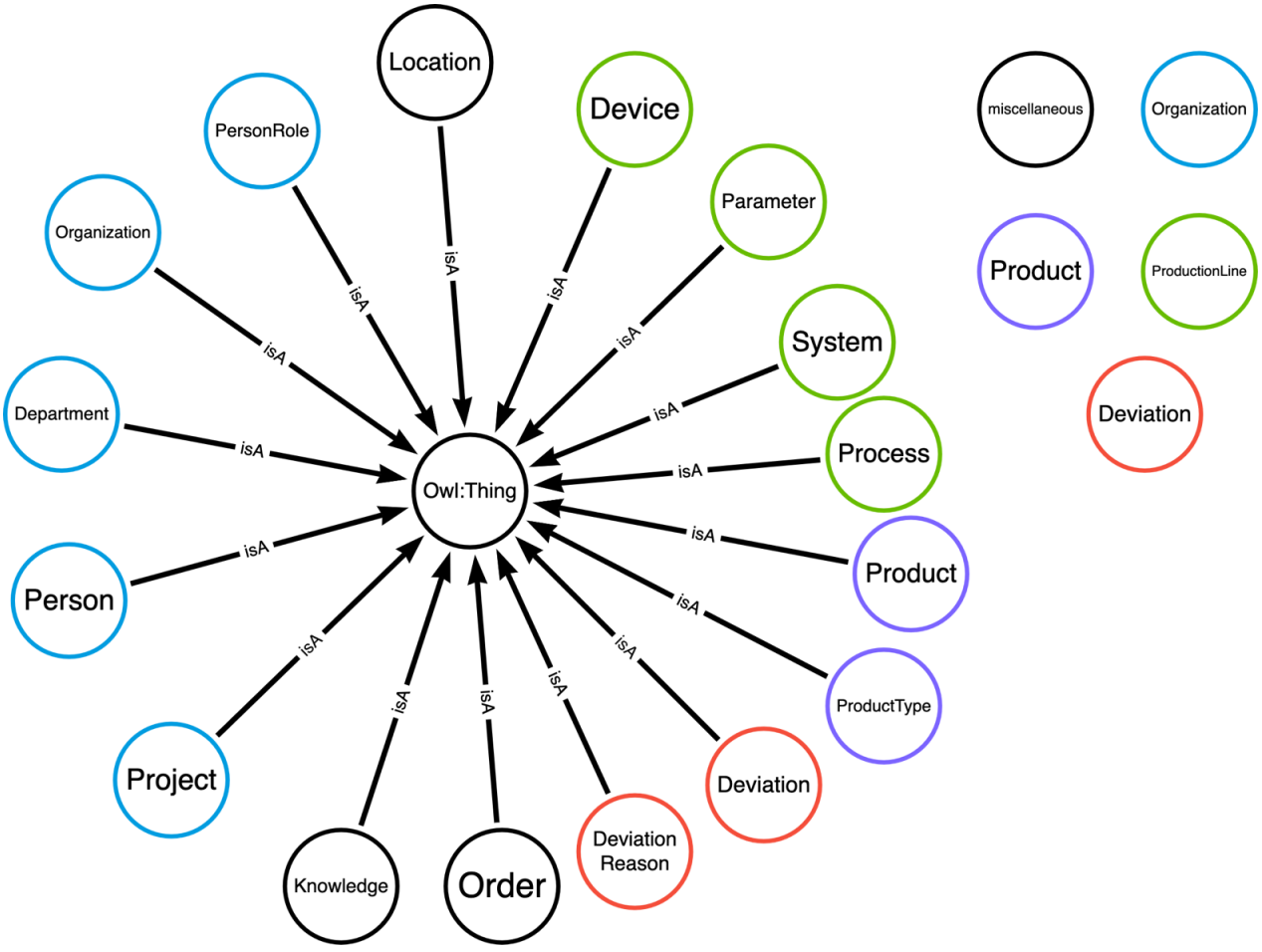


Fig 1: Ontology first level concepts

1. Do you think the concepts defined in ontology contradict each other?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

2. Do you think concepts defined in the ontology covers the most relevant information about assembly line manufacturing plants?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☒ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

3. Do you think some of the concepts are useless?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

4. Do you think there is clarity with the naming of the concepts?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☐ agree | ☒ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

5. Do you think these concepts can be used for other manufacturing companies?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☒ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

The above figure 1 represents the main class or the concepts used to store information and knowledge about different aspects of the industry with an automated production system. On the other hand, this section presents the subclasses for the main classes described above.

The class *DeviationReasons* is used to classify the different reasons for deviation of a production system and its simulation model. It consists of the so-called *5 M's* described in a paper by GALASKE ET AL. (2015) [1]. The 5 M's consist of Material, Method, Mileu, Manpower, Machine [1]. Moreover, we have added one more class named *UnknownDeviation* to the deviations that do not have any factual information about the origin.

**Please consider the below (Simulation Model and Automated Production System Synchronisation) SMAPSS ontology second-level concept for a deviation reason and answer whether you 'strongly disagree', 'disagree', 'neutral', 'agree', or 'strongly agree' with the defined concepts.**

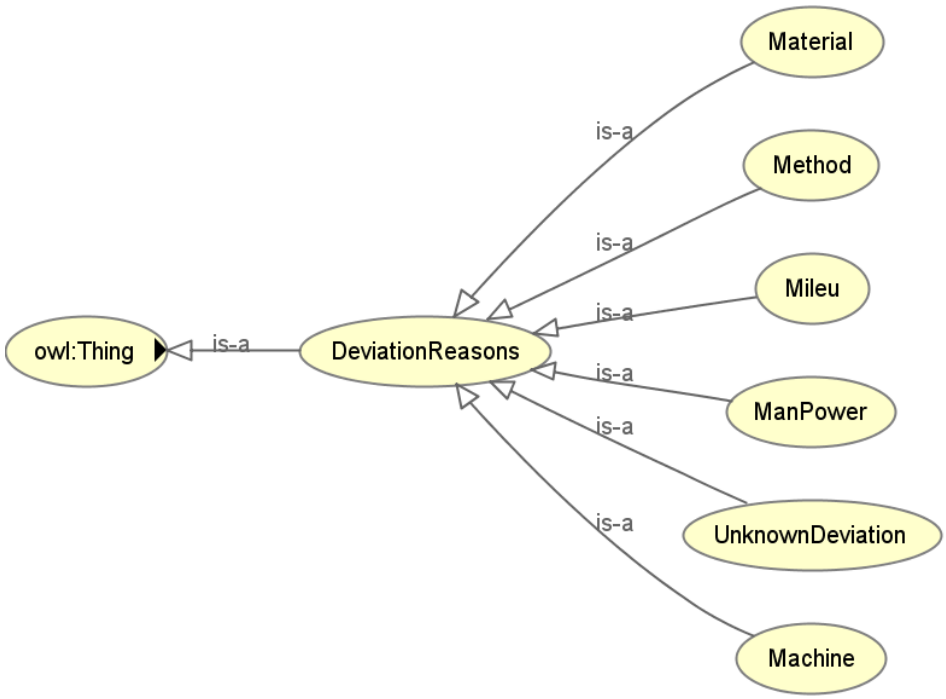


Fig 2. Sub concepts for DeviationReason class

1. Do you think the concepts defined in ontology contradict each other?

| ☐ strongly disagree | ☐ disagree | ☒ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | The reasons appear to be "soft", i.e. there is no clear categorization. E.g.: What's the DeviationReason if a Machine is operated in a wrong manner? Machine or Man? | | | |

2. Do you think concepts defined in the ontology cover the most relevant information about assembly line manufacturing plants?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Shouldn't there be different types of deviations? E.g. random or systematic deviations. | | | |

3. Do you think some of the concepts are useless?

| ☐ strongly disagree | ☐ disagree | ☒ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | See 1. | | | |

4. Do you think there is clarity with the naming of the concepts?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☐ agree | ☒ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

5. Do you think these concepts can be used for other manufacturing companies?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☒ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

The ontology class *Process* describes the different types of processes in an automated production system. The subclasses of *Process* have been defined using the classification of manufacturing processes defined in the paper by SORENSEN ET AL. (2018) [2]. The actual classification consists of more concepts, but for the Project DAMOKLEZ we have used the main concepts that are relevant to our purpose.

**Please consider the SMAPSS ontology below for the second-level concepts of *Process* and answer the questions whether you 'strongly disagree', 'disagree', 'neutral', 'agree', or 'strongly agree' with the defined concepts.**

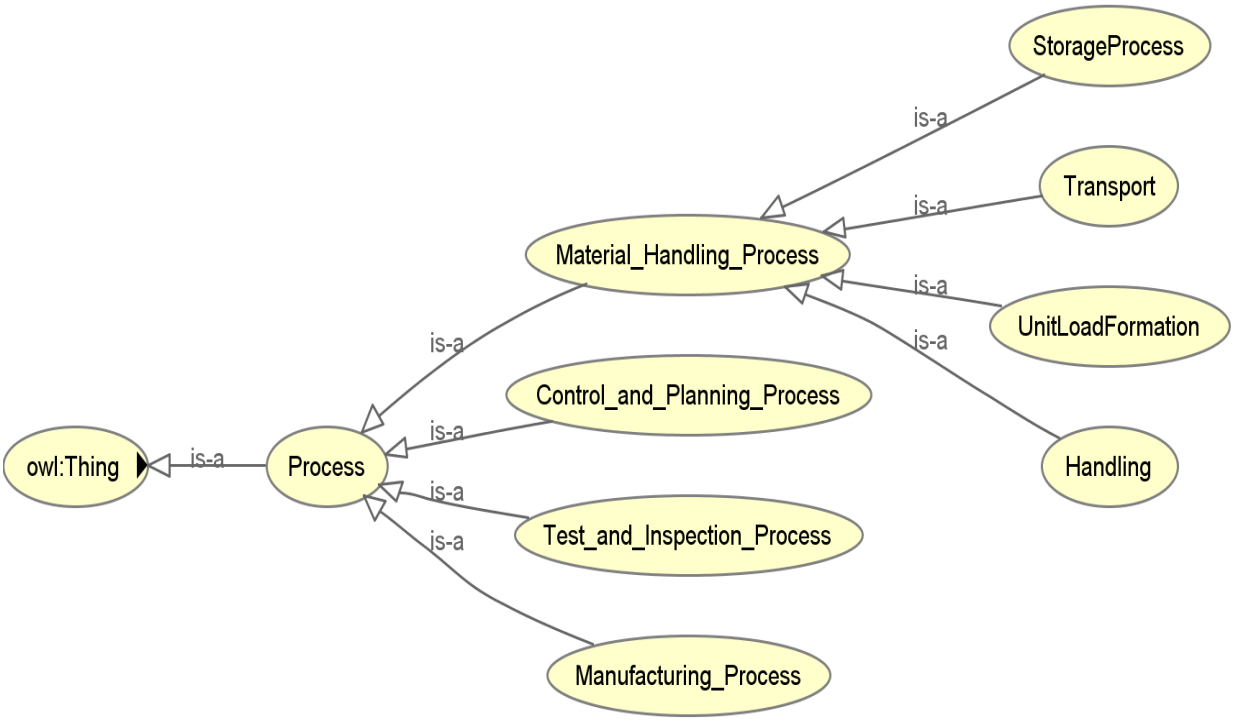


Fig 3. Subconcepts for Process class

1. Do you think the concepts defined in ontology contradict each other?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

2. Do you think concepts defined in the ontology cover the most relevant information about assembly line manufacturing plants?

| ☐ strongly disagree | ☐ disagree | ☒ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

3. Do you think some of the concepts are useless?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

4. Do you think there is clarity with the naming of the concepts?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☒ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

5. Do you think these concepts can be used for other manufacturing companies?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Quite specific taxonomy | | | |

*Product_Type* describes the type of product which goes into a process or leaves a process. Our generic ontology has three sub-categories that are *Final_Product*, *Raw_Material,* and *Intermediate_Goods*.

**Please consider the SMAPSS ontology below for the second-level concepts of *Product_Type* and answer the questions whether you 'strongly disagree', 'disagree', 'neutral', 'agree', or 'strongly agree' with the defined concepts.**

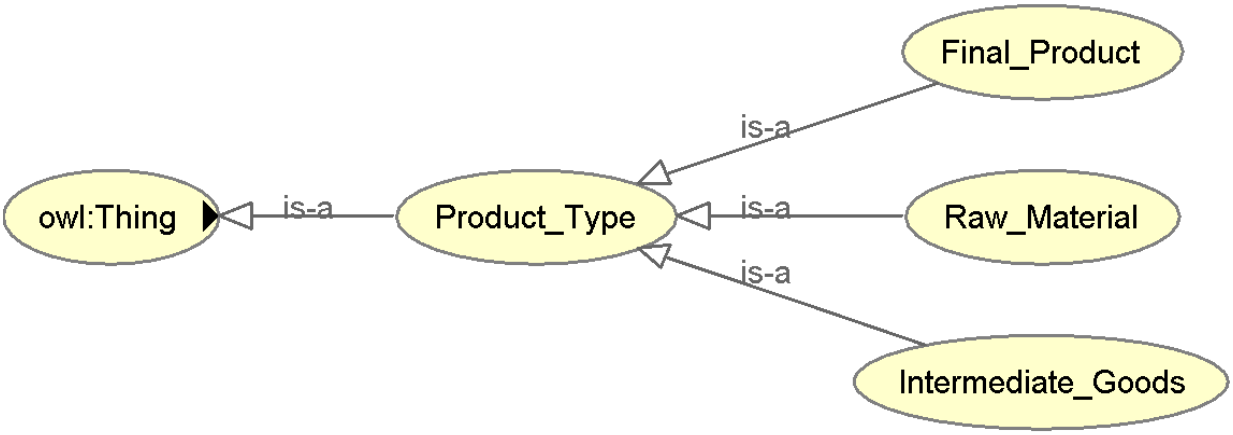


Fig 4. Subconcepts for Product_Type Class

1. Do you think the concepts defined in ontology contradict each other?

| ☐ strongly disagree | ☐ disagree | ☒ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Subtype depends on point of view | | | |

2. Do you think concepts defined in the ontology cover the most relevant information about assembly line manufacturing plants?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | It would make sense to account for differnt roles a product can play in different processes. E.g. a piece of sheet metal can be a "formed part" in a forming process, but a "joining partner" in an assembly process. | | | |

3. Do you think some of the concepts are useless?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☒ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Subtypes are questionable; "Final Product" (=last output) or "Raw Material" (=first input) can be inferred from the topology of a process chain | | | |

4. Do you think there is clarity with the naming of the concepts?

| ☐ strongly disagree | ☐ disagree | ☒ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Product_Type should just be named Product | | | |

5. Do you think these concepts can be used for other manufacturing companies?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | See 1, 2 | | | |

Device concepts have been defined to represent all the devices used, or that can be used within an automated production system. To define Device's subclasses, we have used the paper by CHENG ET AL. (2016) [3]. The sub-classes are again project-specific and can differ between different kinds of projects. Please refer to Figure 5. In the SMAPSS Ontology.pptx document for the representation of the subclasses of Device concept.

**Please consider the SMAPSS ontology below for the second-level concepts of *Device* and answer the questions whether you 'strongly disagree', 'disagree', 'neutral', 'agree', or 'strongly agree' with the defined concepts.**

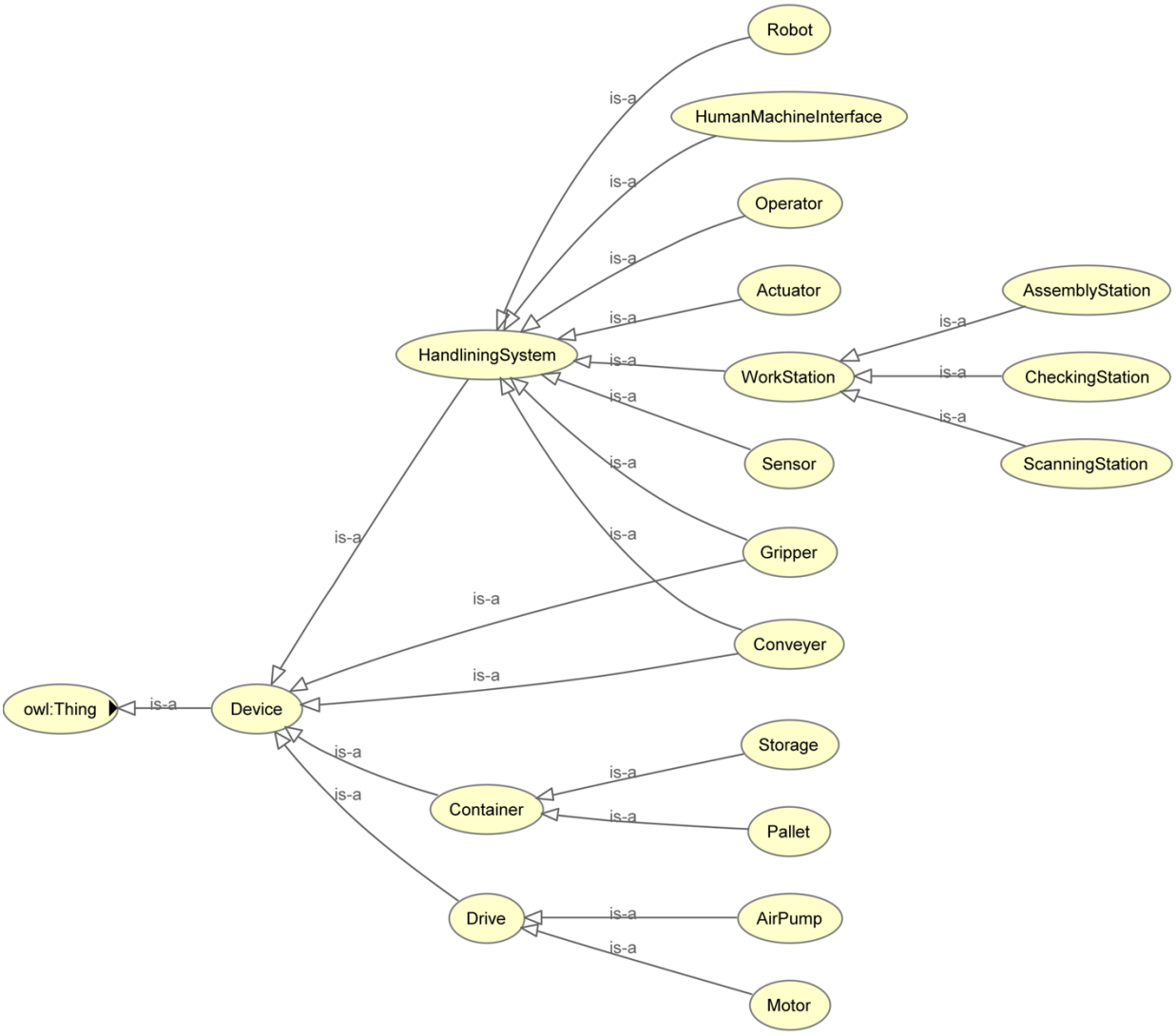


Fig 5. Subconcepts for Device Concept

1. Do you think the concepts defined in ontology contradict each other?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☒ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Subtypes of HandlingSystem appear to be arbitrary | | | |

2. Do you think concepts defined in the ontology cover the most relevant information about assembly line manufacturing plants?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☒ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

3. Do you think some of the concepts are useless?

| ☐ strongly disagree | ☐ disagree | ☒ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Intention behind subtypes unclear | | | |

4. Do you think there is clarity with the naming of the concepts?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | See 1; HandlingSystem and its subtypes don't match | | | |

5. Do you think these concepts can be used for other manufacturing companies?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☒ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

As mentioned earlier, the relationship between the classes can be described using object properties. Therefore, in figure 6 of the SMAPSS Ontology.pptx file, we have represented the relationships between the classes. The arrow from where it starts is the domain concept; the arrow pointed toward a class is the range concept.

Furthermore, the relationship or the object property between the concepts is represented using '-relationship'. For example, a deviation named '*DeviationID XXX*' which occurred in a process named '*Process1*' can be stored in our knowledge base, which satisfies the rules mentioned in Fig 6. Therefore, the stored knowledge will be in the form of '*Process1*' '*hasDeviation*' '*DeviationID XXX*'. Similarly, for different use-cases, we can use the defined object property.

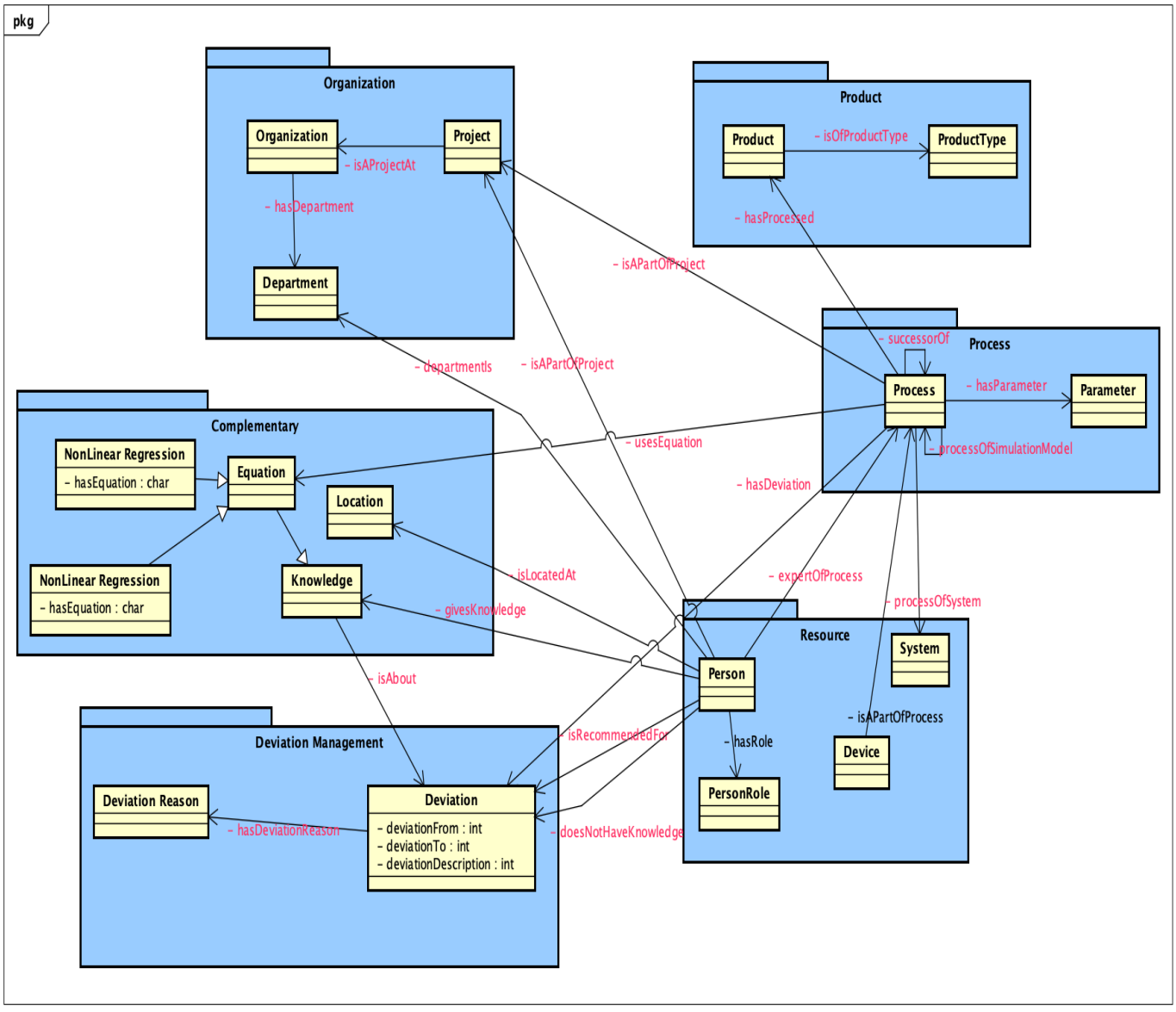


Figure 6. Ontology with their relationships and properties

**Please consider the SMAPSS ontology for the relationships and properties and answer the questions with 'strongly disagree', 'disagree', 'neutral', 'agree', 'strongly agree'.**

1. Do you think the relationships and the properties defined in ontology contradict each other?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

2. Do you think the relationships and the properties defined in the ontology covers the most relevant information about assembly line manufacturing plants?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☒ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

3. Do you think some of the relationships and the properties are useless?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

4. Do you think there is clarity with the naming of the relationships and the properties?

| ☐ strongly disagree | ☒ disagree | ☐ neutral | ☐ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Maybe a separation of the system level and metadata would make sense | | | |

5. Do you think these the relationships and the properties can be used for other manufacturing companies?

| ☐ strongly disagree | ☐ disagree | ☐ neutral | ☒ agree | ☐ strongly agree |
|---|---|---|---|---|
| Comment: | Klicken oder tippen Sie hier, um Text einzugeben. | | | |

## References

[1] Galaske, Nadia & Strang, Daniel & Anderl, Reiner. (2015). Process Deviations in Cyber-Physical Production Systems. https://www.researchgate.net/publication/283499328_Process_Deviations_in_Cyber-Physical_Production_Systems

[2] Sorensen, Daniel & Brunoe, Thomas & Nielsen, Kjeld. (2018). A classification scheme for production system processes. Procedia CIRP. 72. 609-614. 10.1016/j.procir.2018.03.021. https://www.researchgate.net/publication/326039294_A_classification_scheme_for_production_system_processes

[3] Cheng, Haibo & Zeng, Peng & Xue, Lingling & Shi, Zhao & Wang, Peng & Yu, Haibin. (2016). Manufacturing Ontology Development Based on Industry 4.0 Demonstration Production Line. 42-47. 10.1109/TSA.2016.17. https://www.researchgate.net/publication/311610072_Manufacturing_Ontology_Development_Based_on_Industry_40_Demonstration_Production_Line