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Towards Modeling the Structure of Product Dependencies in Supply Networks to Identify Bottlenecks Among Suppliers

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Agenda

1. Motivation
2. Supply Network Graph Model
3. Ontology
4. Limitations and Conclusion

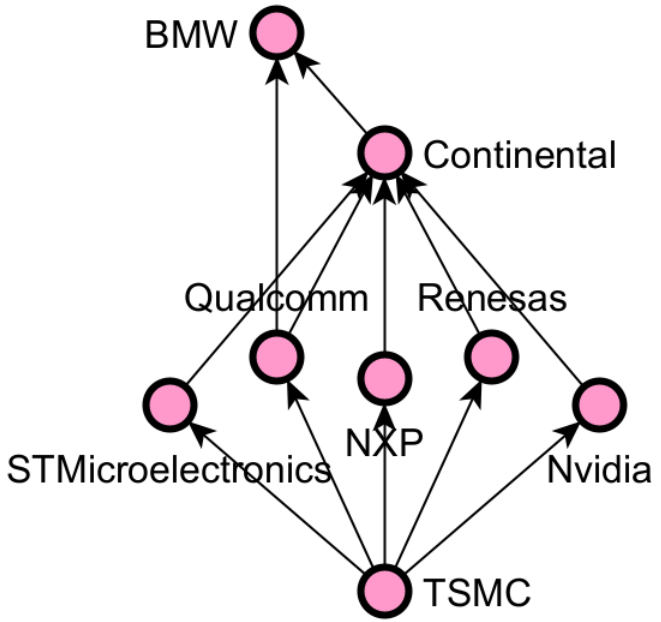
Motivation

- Global **chip shortage** in 2021 forced car manufacturers to halt production
- One reason were **bottlenecks in the supply networks** of microchips

- Bottlenecks are suppliers with the **highest loss contributions** in consequence of a **disruption**, resulting in a high **dependency**
- Disruptions in supply networks **increase(d)**

- Bottlenecks occur due to the **structure** of supply networks

➢ Provide a **graph model representing the structure of supply networks** as a basis for network metrics to identify bottlenecks

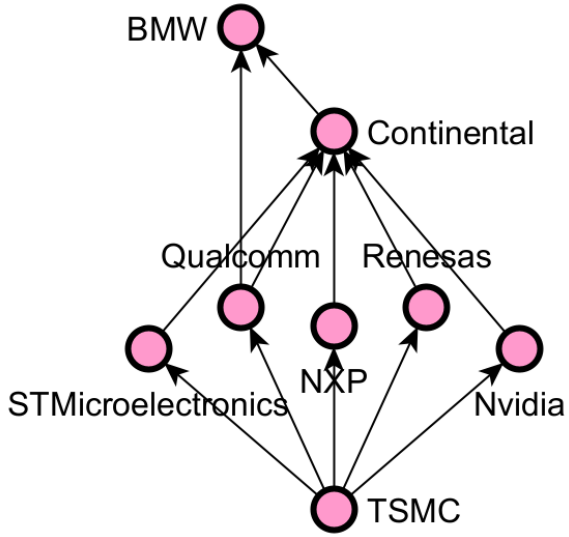


TSMC as a bottleneck in BMW's supply network.

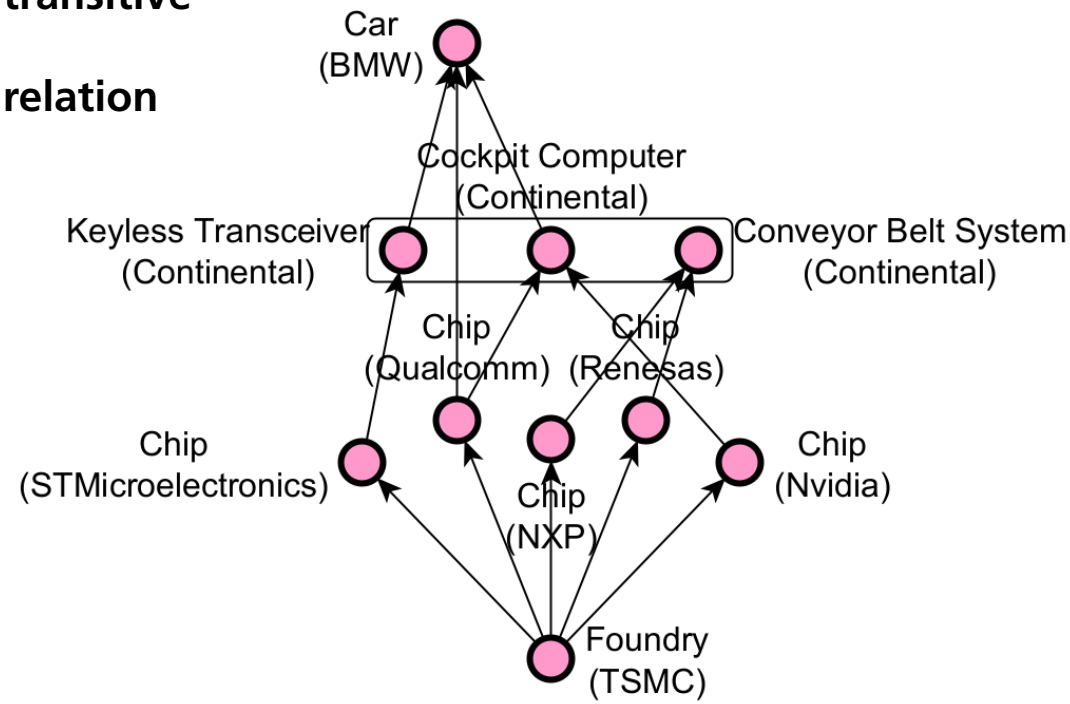
Choice of Supply Network Graph Model 1/2

- One could model the graph of a supply network through **enterprises**
- The dependency relationships between enterprises are **not (entirely) transitive**

➢ Model graph of supply network through **products and their supply relation**



Enterprise supply network.



Product supply network.

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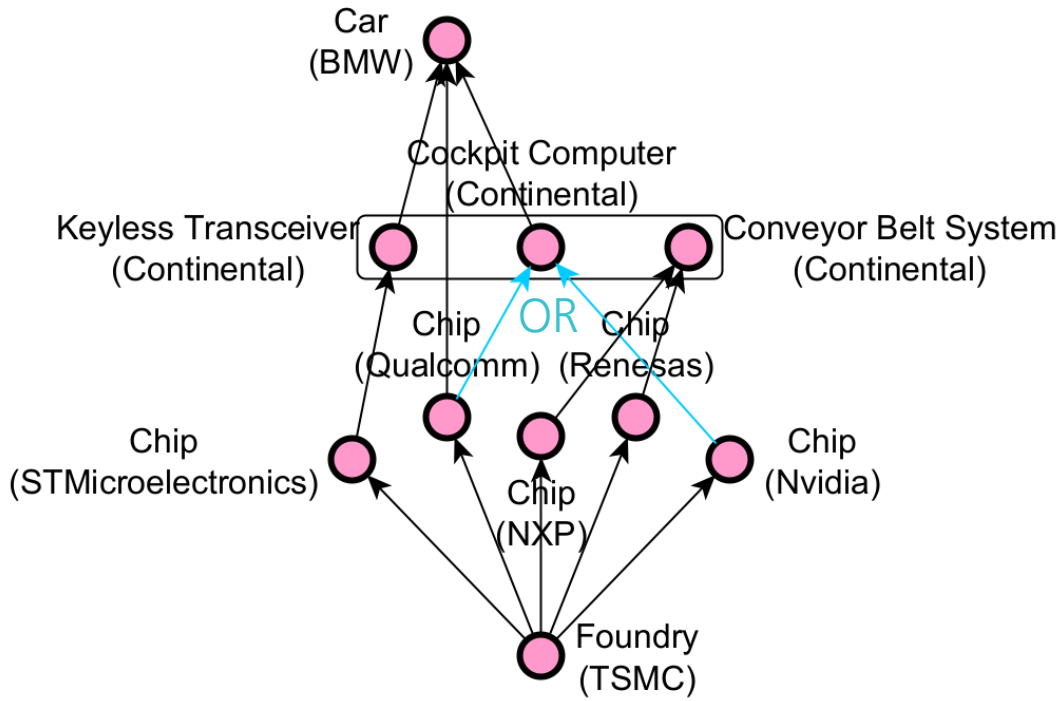
Choice of Supply Network Graph Model 2/2

- The **relation between a product and its enterprise** enables to identify suppliers
- **Alternative products** affect dependencies

➢ Model **knowledge graph** of supply network with an **ontology**



Alternative products in a supply network.

Ontology Methodology 1/3

Comparison with ontology with the greatest overlap of scope from related work (PRONTO [1])

- Make ontology **usable for a wider audience** beyond ontologists
- Reduce **amount and complexity of data** required

➢ Particular focus on **conciseness** (minimal number of vocabulary terms and avoidance of redundancy)

[1] M. Vegetti, H. Leone, G. Henning, PRONTO: An ontology for comprehensive and consistent representation of product information, Engineering Applications of Artificial Intelligence 24 (2011) 1305–1327. doi:10.1016/j.engappai.2011.02.014.

Ontology Methodology 2/3

Competency questions

Support the identification of bottlenecks among suppliers by providing data on a supply network

- How many derivational dependency paths from a product to another certain product are there in a supply network?
- How many/much of a certain product does the creation of a product require across the supply network?
- Which enterprise sells a certain product in the supply network?

Ontology Methodology 3/3

Modeling requirements

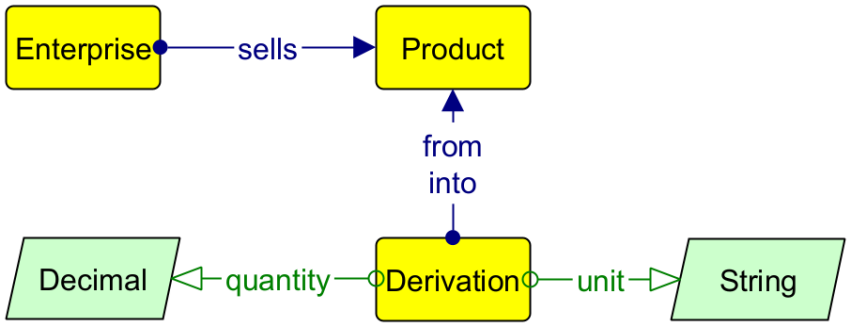
- Provide a representation of products that are available for (potential) customers.
- Provide a representation of the enterprise that sells a product.
- Provide a representation of derivational dependencies between products of different enterprises, specifically all dependencies where a product is (partially) consumed in the process of creating another product.
- Provide a representation of the quantity of a dependency.
- Provide a representation of a derivational dependency being split between alternative products.

Ontology Considerations

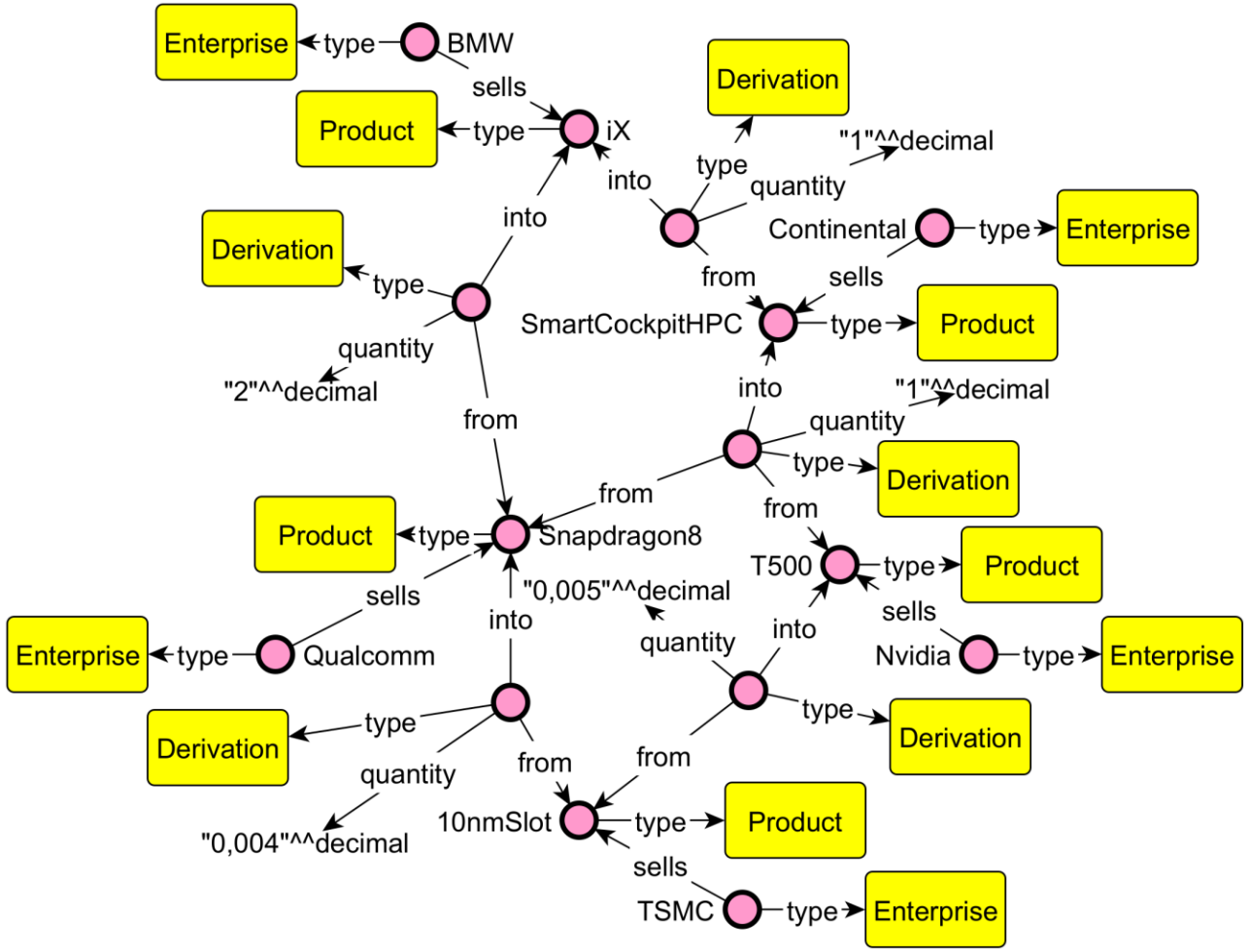
Abstraction levels of the product class from related work

- Product model vs. product instance (“a BMW iX“ vs. “that blue BMW iX over there in the corner”)
- Product vs. product class (“BMW iX” vs. “car”)
- Product vs. product group/family (“BMW iX, superior edition, 1.8 TDI, …” vs. “BMW iX”)

Ontology Result



Resulting ontology after considering concepts from related work.



Instance data for a part of BMW's iX supply network.

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Ontology Evaluation 1/2

Concise ontology

Metric	Our ontology	PRONTO
Number of classes	3	35
Number of relationships	3	43
Number of leaf classes	3	25
Number of root classes	3	10
Relationship richness	$3/3 = 1.0$	$17/43 = 0.4$
Inheritance richness	$0/3 = 0.0$	$26/35 = 0.74$
Depth of subsumption hierarchy	0	3
Attribute richness	$2/3 = 0.67$	$6/35 = 0.17$

Metrics regarding ontology complexity compared with PRONTO .

Ontology Evaluation 2/2

Competency questions

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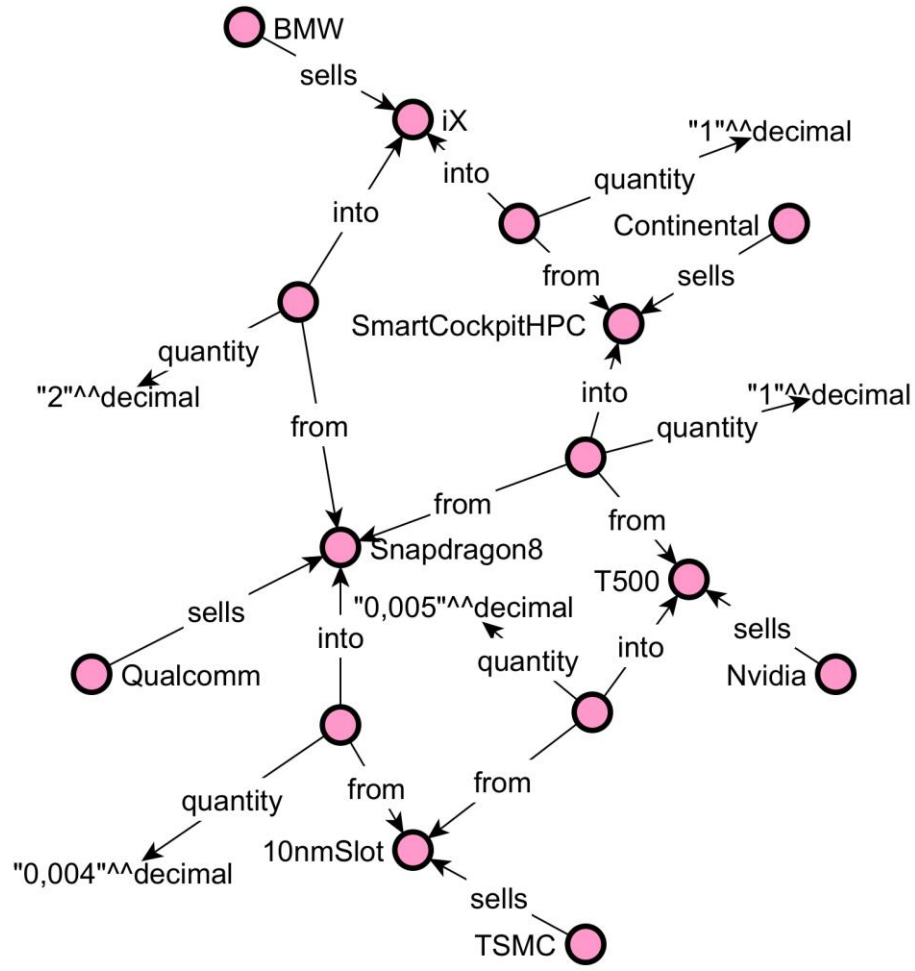

Limitations

- The expressiveness of our concise ontology is naturally limited compared to heavyweight ontologies like PRONTO
- The paper does not answer which network metrics to use for identifying bottlenecks
  - How to execute the calculation of metrics (with queries)?
  - How to weight and aggregate weights regarding alternative products?
  - How to determine weights if a product is only occasionally required for a variant?
  - How to consider overlapping supply networks?

Conclusion

- Ontology representing supply networks of products with derivational dependencies between them to identify bottlenecks among suppliers
- The ontology is concise and considers various concepts and definitions from existing ontologies
- Compared the ontology to PRONTO, an ontology with a similar scope

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