Semantically Annotated Manufacturing Data to support Decision Making in Industry 4.0: A Use-Case Driven Approach

Stefan Schabus[1] & Johannes Scholz[2]

[1]Infineon Technologies Austria AG

[2]Graz University of Technology
Institute of Geodesy – RG Geoinformation

Email: johannes.scholz@tugraz.at
Web: http://johannesscholz.net || www.ifg.tugraz.at

Table of Contents

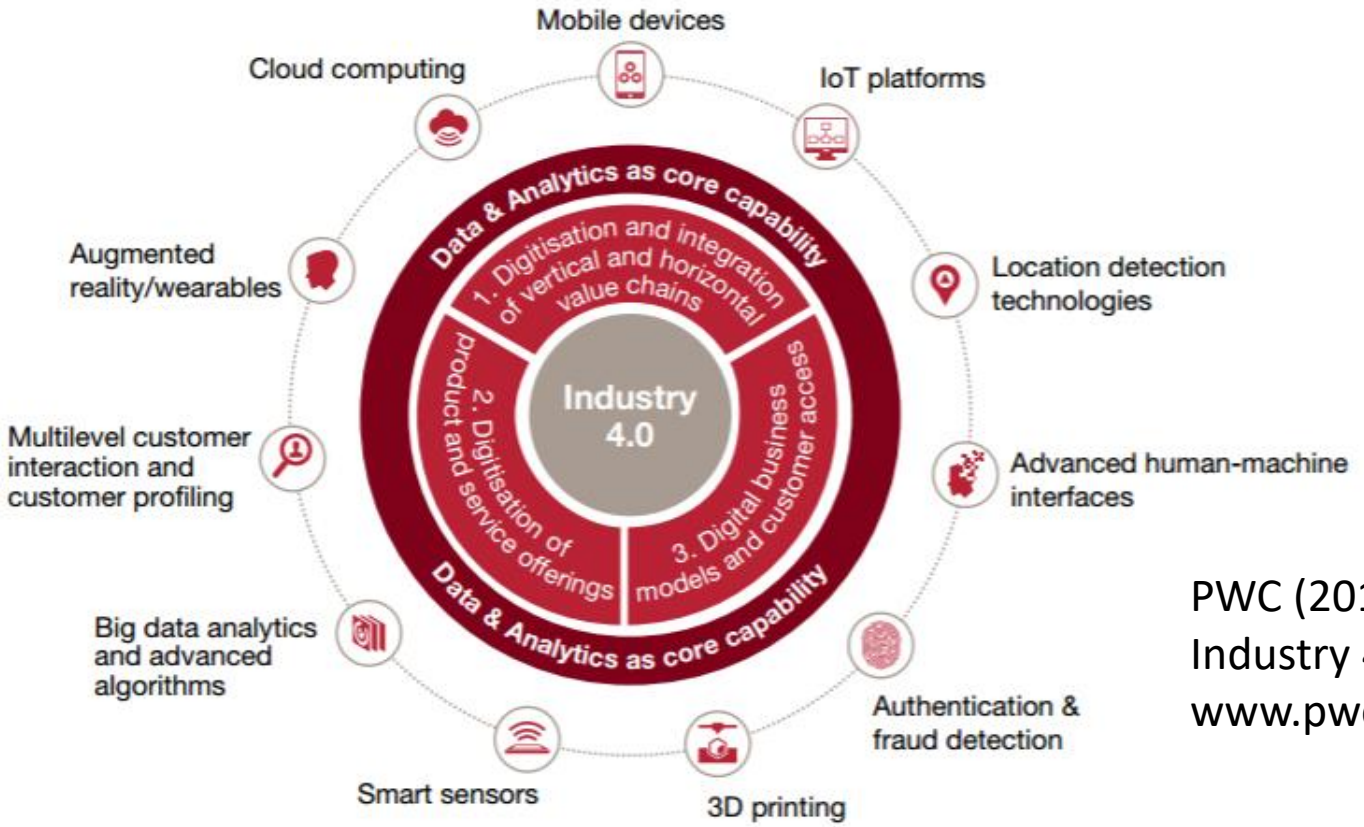
Introduction

- Manufacturing Industry
  - Focus on competitiveness of manufacturing processes as global markets are increasingly competitive
  - Strategies to increase productivity, efficiency and to realize cost savings

PWC (2016): 2016 Global Industry 4.0 Survey. Web: www.pwc.com/industry40

Introduction

- Industry 4.0
  - Digitizing in manufacturing includes cyber-physical systems, Internet of Things and Cloud Computing (Hermann, Pentek & Otto, 2016)



PWC (2016): 2016 Global Industry 4.0 Survey. Web: www.pwc.com/industry40

Introduction

- Semantic Interoperability ?
  - Currently a great variety of different IT-systems create large data volumes.
  - Integrated analysis of data sets requires syntactic and semantic interoperability!

- Approach followed in this paper
  - Manufacturing data with “added” semantics & spatial information
  - Enables integrated analysis of heterogeneous manufacturing datasets
  - Integration and analysis is done in a spatial Graph database
  - Proof of concept: two use-cases in a semiconductor company

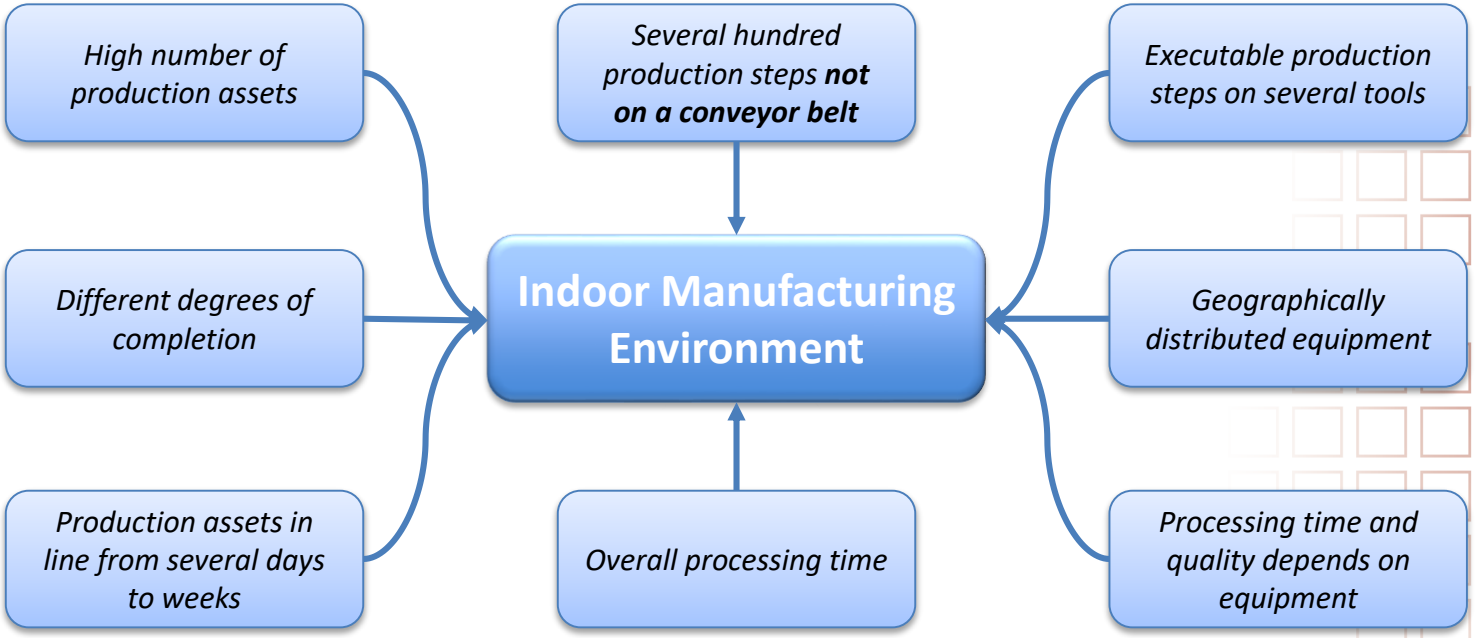
Indoor Space – Semiconductor Manufacturing Facility

- Semiconductor company from above
  - Four (five) manufacturing halls
  - Manufacturing halls are located on different vertical levels (i.e. vertical transportation necessary when changing a hall)

Indoor Space – Semiconductor Manufacturing Facility

Indoor Space – Semiconductor Manufacturing Facility

- **Characteristics** of the indoor manufacturing environment under review:



- **Production assets move several kilometres** in a complex process chain.

Modeling & Storing Manufacturing Data

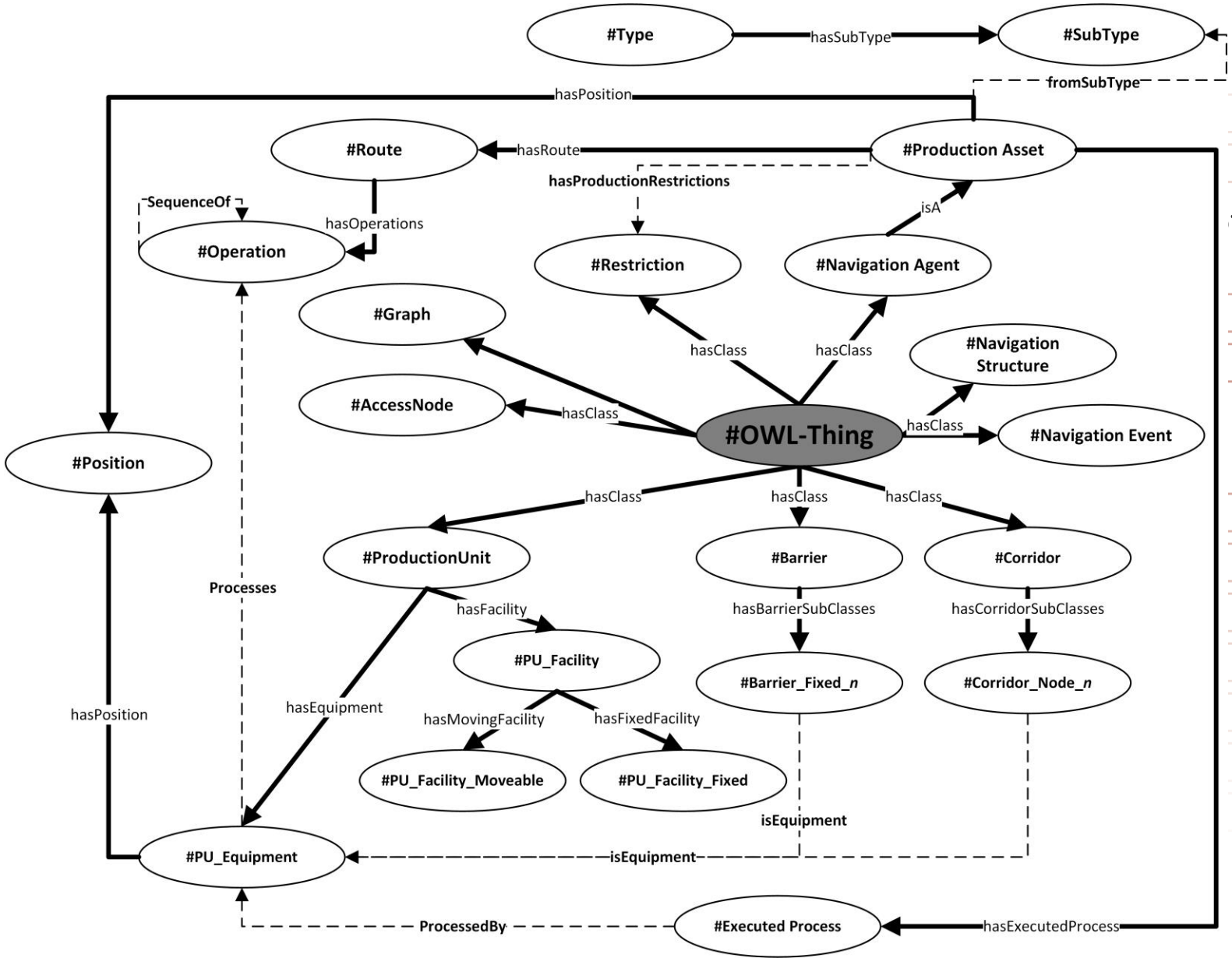
Spatial-temporal Ontology

- Ontology:
  - Specification of a conceptualization (Gruber, 1993)
  - Description of concepts and relationships existing in a universe of discourse (Uschold & Gruninger, 1996)

- Ontology for manufacturing data
  - Based on an indoor space ontology (Scholz & Schabus, 2014)
  - Top level classes: Navigation Agents, Corridors, Graph, Production Unit
  - Spatial information
    - stored in classes position and graph
  - Temporal component
    - Historical information on production assets (spatial information [trajectory], sequence of manufacturing operations)

Modeling & Storing Manufacturing Data

Spatial-temporal Ontology



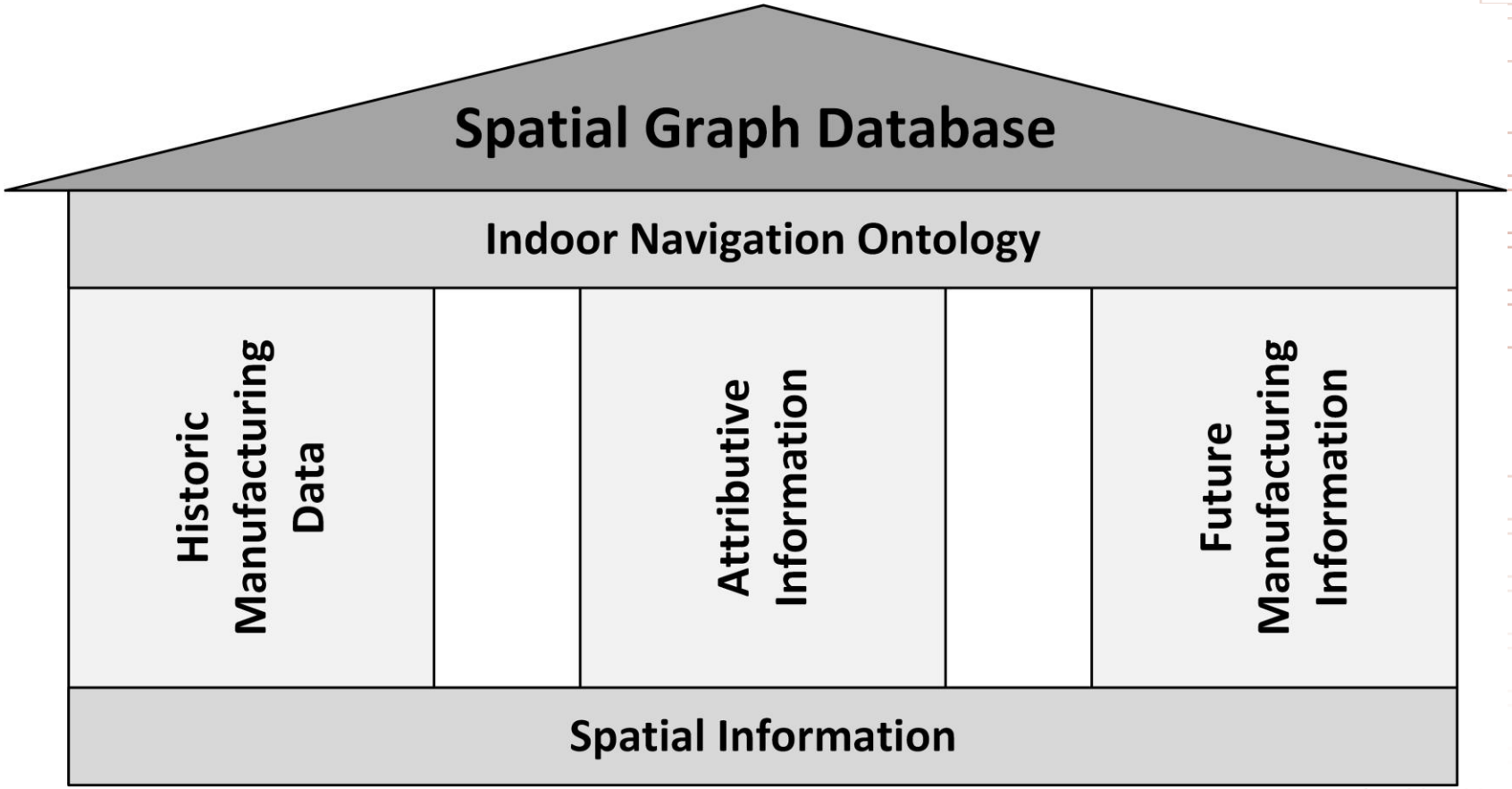
Modeling & Storing Manufacturing Data
Graph Database :: Storage and Analysis

- Graph Database:
  - Database management system that is capable of creating, reading, updating, and deleting data in form of **graphs in a database** (Robinson, Weber & Eifrem, 2015)
  - Graph DBs became popular: Facebook Open Graph, Google Knowledge Graph, Twitter FlockDB (Miller, 2013)

- Approach:
  - Migration of spatial-temporal ontology – as OWL – into the graph database
  - Migration of manufacturing data and add their semantic annotation

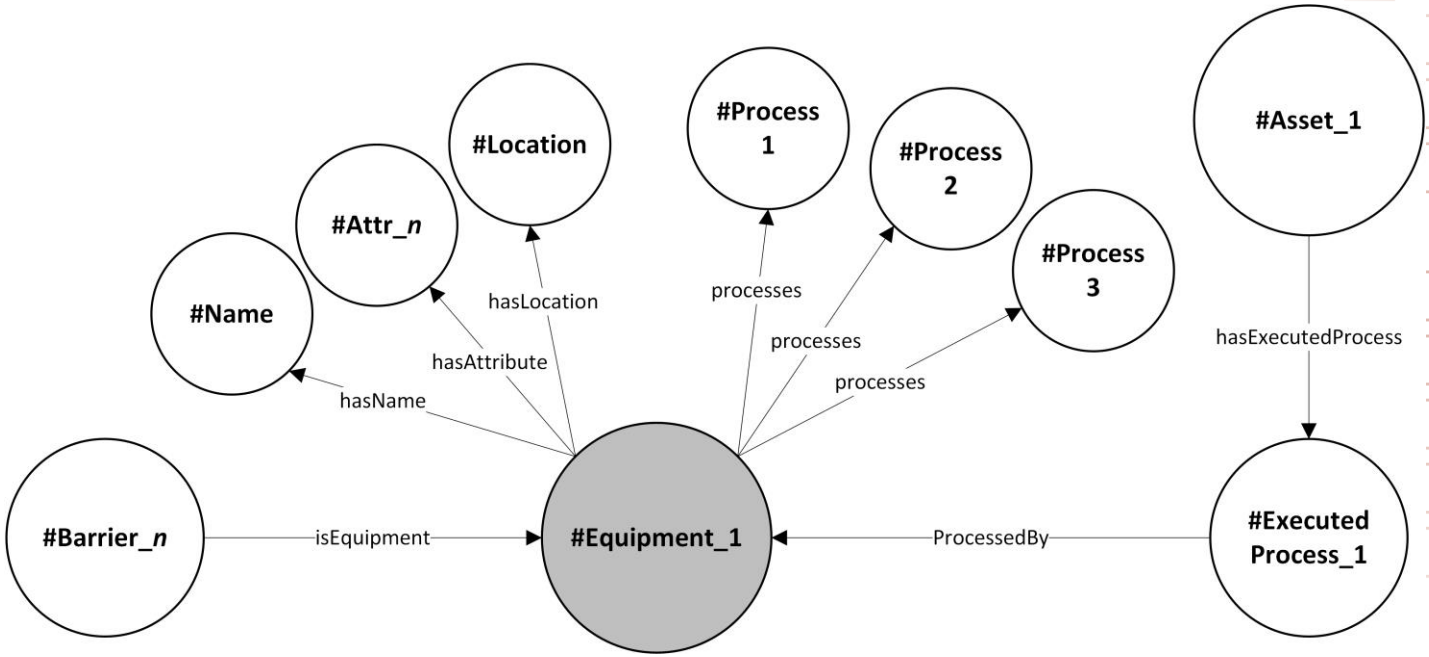
Modeling & Storing Manufacturing Data

Graph Database :: Storage and Analysis



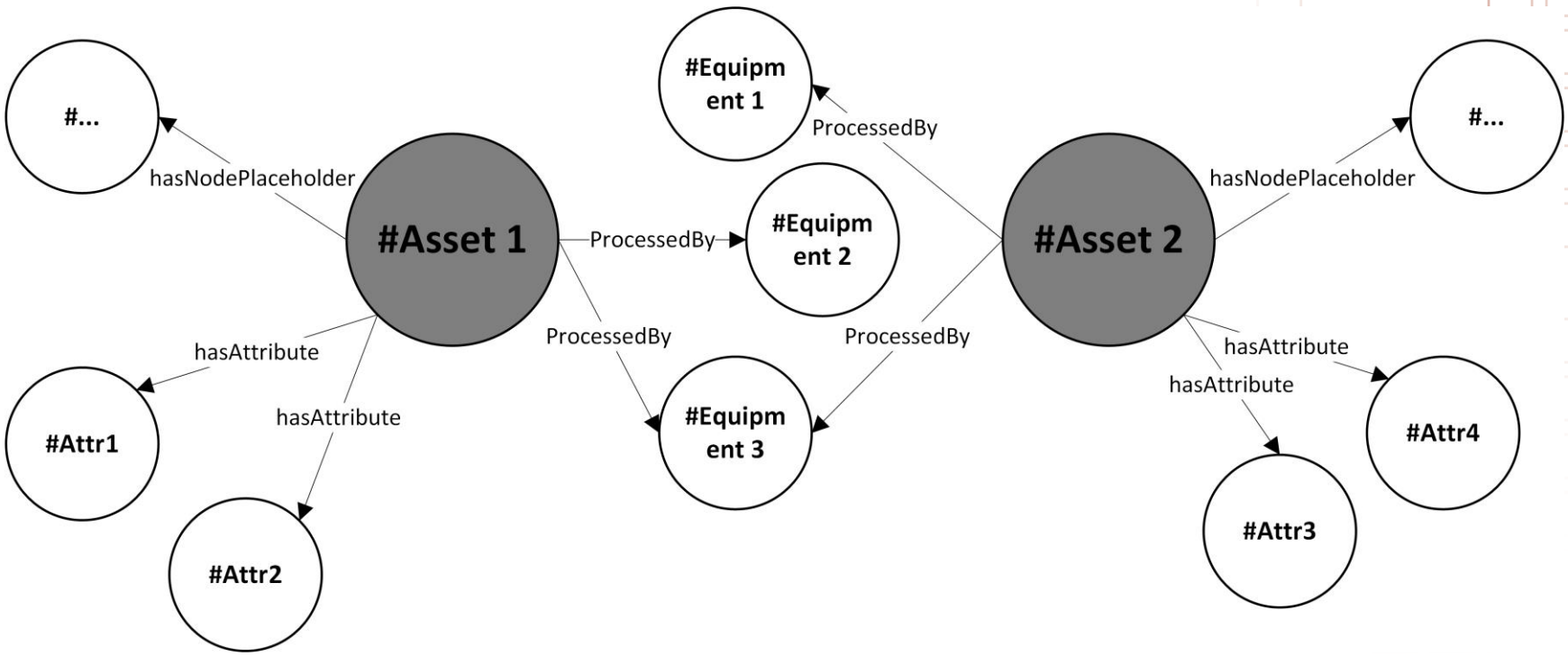
Modeling & Storing Manufacturing Data
Graph Database :: Storage and Analysis

- Graph Database examples:
  - Visualization of a single manufacturing equipment



Modeling & Storing Manufacturing Data
Graph Database :: Storage and Analysis

- Graph Database examples:
  - Visualization of two production assets



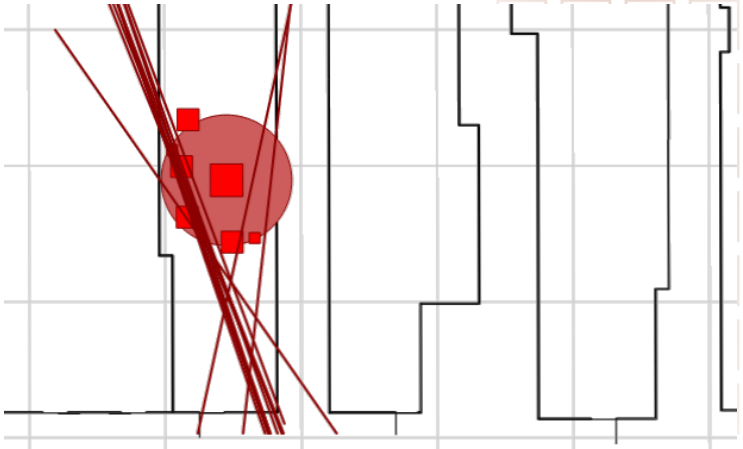
Analysis of Manufacturing Data
Use Case #1 : Incident Analysis

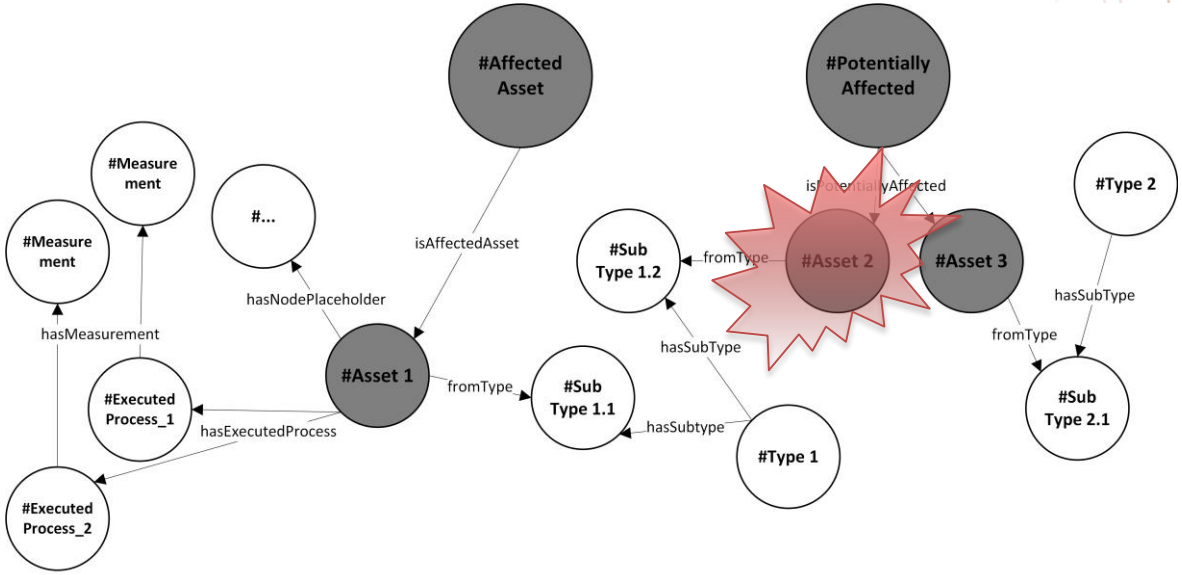
- Incident
  - "an unplanned, undesired event that hinders completion of a task and may cause injury or other damage" (NRMC, 2016)
  - Does not disrupt the system as a whole
- Incident analysis:
  - Process of finding production assets that are similar to assets having quality issues.

- Use Case: "Detection of potentially affected assets of an malfunctioning air cleaning"
  - Spatial analysis
  - Determination of similarities

Analysis of Manufacturing Data
Use Case #1 : Incident Analysis

- Use Case: “Detection of potentially affected assets of an malfunctioning air cleaning”
  - Detect trajectories of production assets crossing the incident area
  - Detect similarities



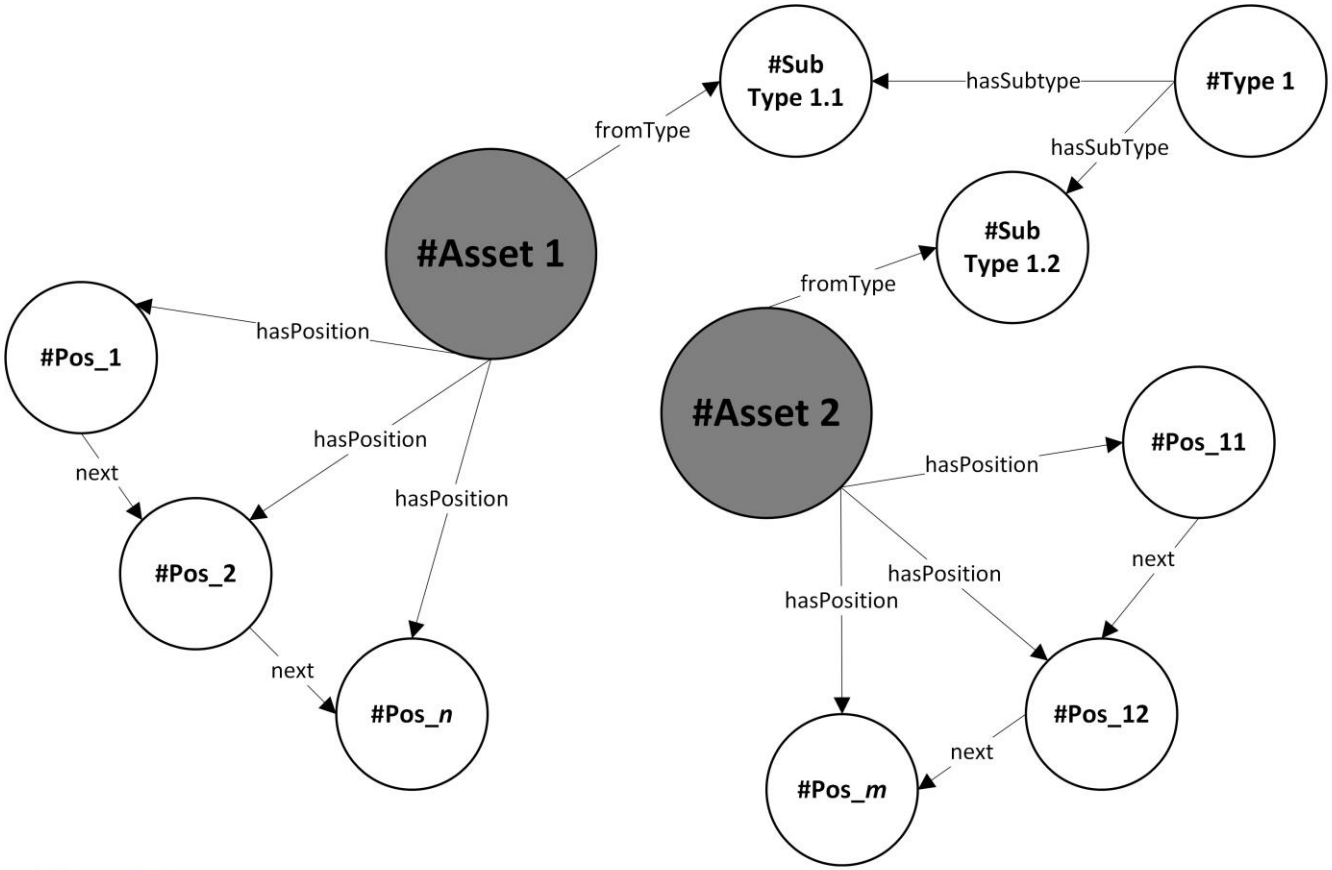


Analysis of Manufacturing Data
Use Case #2 : Bottleneck Analysis

- Bottleneck
  - Capacity of manufacturing equipment for a specific task is lower than the inflow of assets to be processed
  - Assets need to be stored in shelves, and have to “wait”

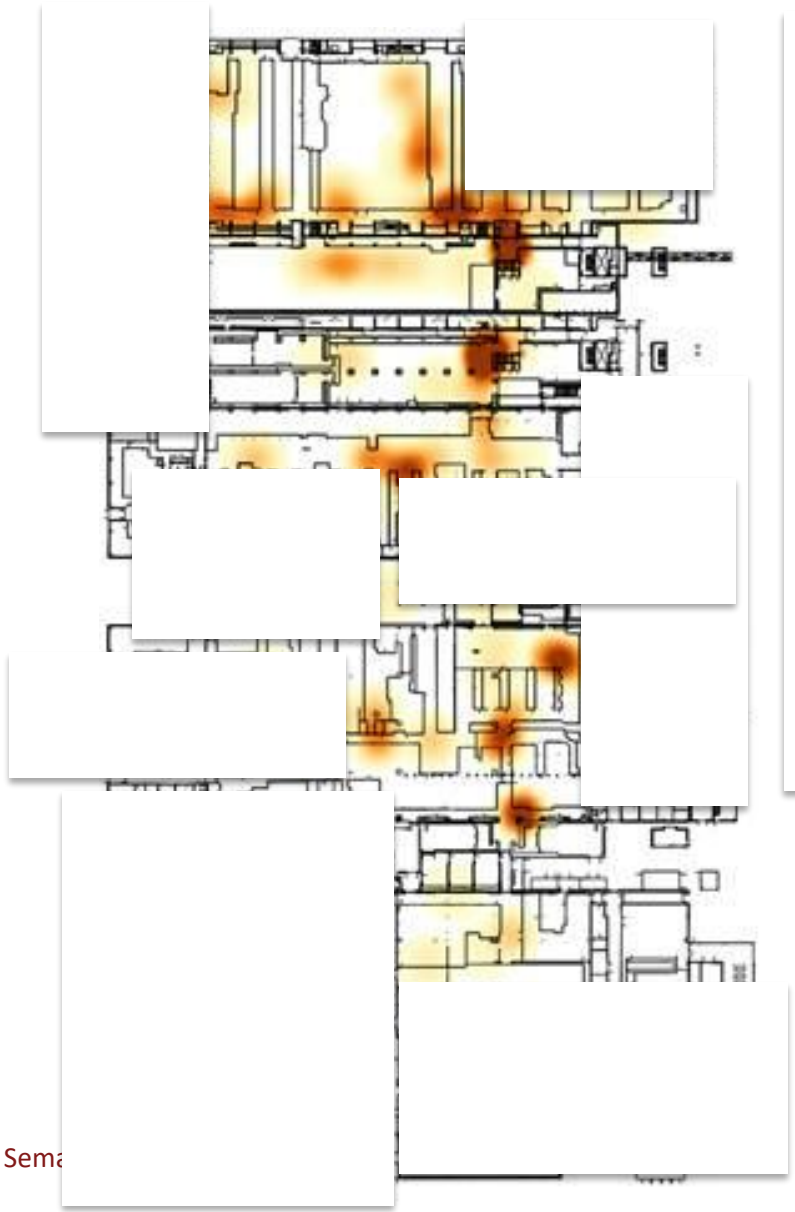
- Use Case: “Identification of Bottlenecks”
  - Detect assets with a “high” waiting time
    - Waiting time: time from being placed in a shelf and the start of the next manufacturing operation
  - Calculation of “normal” waiting time over a given historical time period (1-3 months)
  - Assets having a recent waiting time higher than 2-σ range are classified as “delayed”

Analysis of Manufacturing Data
Use Case #2 : Bottleneck Analysis




```
PSEUDOCODE:
-----------------------------------------------------------------------------------------------
MATCH    (ASSET)
WHERE    EXISTS(Asset)-[*]-(Asset)    AND
         DISTANCE(POINT(X), POINT(Y)) LESS THAN 10 METER AND
         (
             MATCH    (POSITION)
             WITH MEAN(POSITION.TIMESTAMP >= Current_TIMESTAMP - 1Month) AS WaitingTime_LongTerm
             WITH MEAN(POSITION.TIMESTAMP >= Current_TIMESTAMP - 2Hours) AS WaitingTime_Current
             WHERE WaitingTime_Current >= 2*StdDev(WaitingTime_LongTerm)
             RETURN POSITION
         )
RETURN ASSET.POSITION AS PotentialBottleneckArea
```

Analysis of Manufacturing Data
Use Case #2 : Bottleneck Analysis



Conclusion

- Manufacturing data and Industry 4.0
- Development of spatial-temporal ontology for manufacturing data
- Integration of ontology and manufacturing data in a graph database
- Integrated spatial and semantic analysis reveals patterns in manufacturing data >> decision support

Semantically Annotated Manufacturing Data to support Decision Making in Industry 4.0: A Use-Case Driven Approach

Stefan Schabus[1] & Johannes Scholz[2]

[1]Infineon Technologies Austria AG

[2]Graz University of Technology
Institute of Geodesy – RG Geoinformation

Email: johannes.scholz@tugraz.at
Web: http://johannesscholz.net || www.ifg.tugraz.at