Semantics-related Challenges in Data Analytics Applications @ Siemens

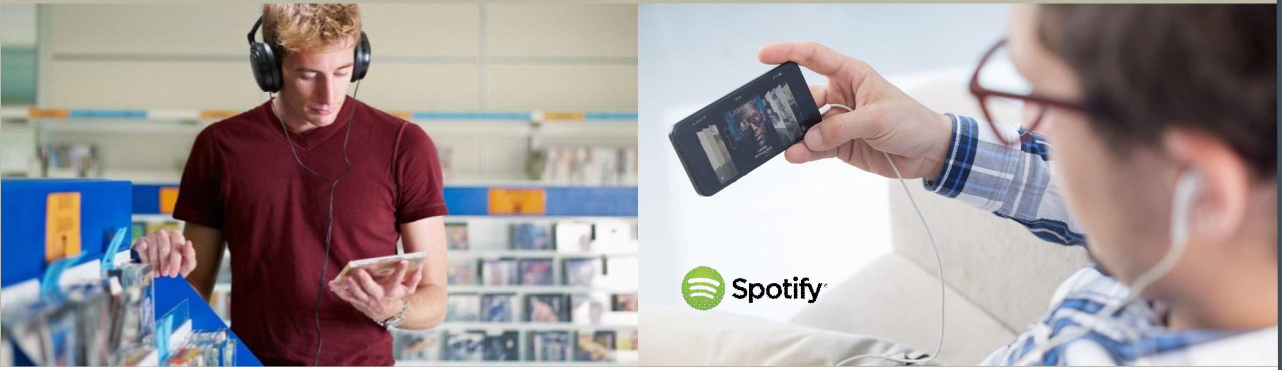
Stephan Grimm

Siemens Corporate Technology

Digitalization changes everything

From record store …

to streaming



From bookstore …

to e-book

From manual machine configuration…

to virtual commissioning

From fixed maintenance intervals…

to predictive maintenance

SIEMENS

SINALYTICS Platform powers Siemens Digital Services

Connectivity

300,000+
connected devices including wind turbines, buildings, trains

Know-how

- Product, domain and data science know-how
- Overall IT know-how with about **17,500** software engineers
- **160** Data Scientists

Sinalytics

Provides connectivity, advanced analytics and cyber security.

Advanced analytics

Creating new insights from smart data by leveraging world-class technologies

Customer outcomes

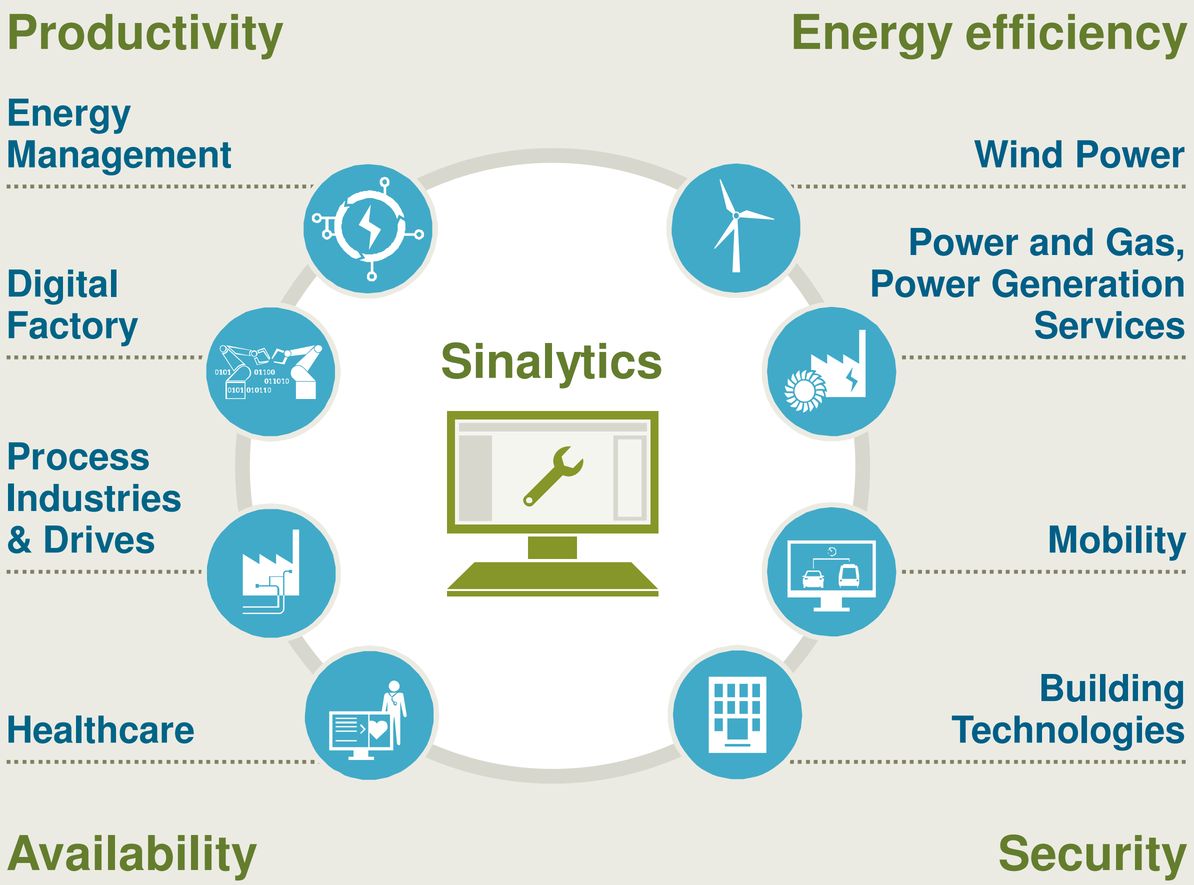
- Higher availability
- Lower costs
- Increased performance
- More security

SIEMENS

Sinalytics creates business proximity and benefits of scale

We build on common technology platforms ...

- Latest technology for all Siemens businesses
- Reduction of technical complexity in the company
- Leveraging synergies through scaling
- Faster development



…and use the customer proximity of our operating units to develop applications

- Know-how regarding large installed bases of products and systems
- Deep know-how of customer processes and challenges
- Many existing applications that already generate value for our customers

SIEMENS

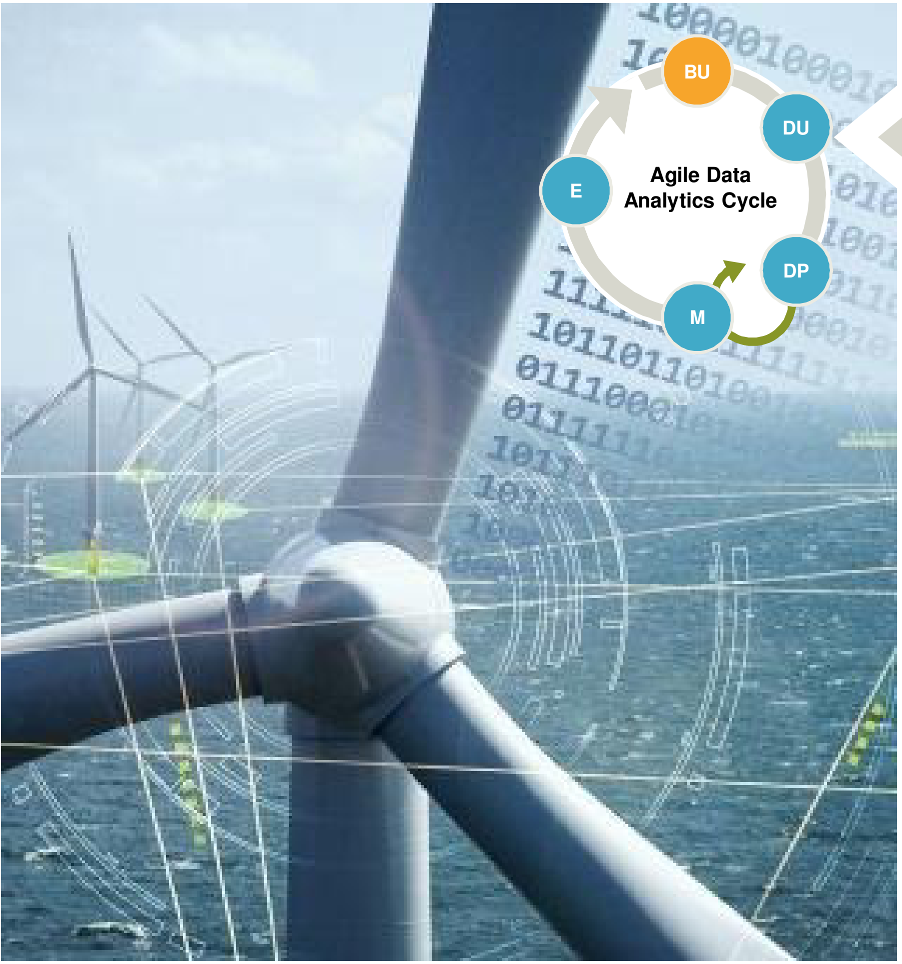
Siemens Mobility Services – Predictive Maintenance requires analysis of massive amounts of data

- Trains are fitted with **hundreds of sensors** to monitor critical parameters
- Each sensor can produce massive amounts of data
- Predictive patterns must be discovered for individual parts
- Finding clusters of signals which are jointly predictive for failures requires interactive analysis of all data

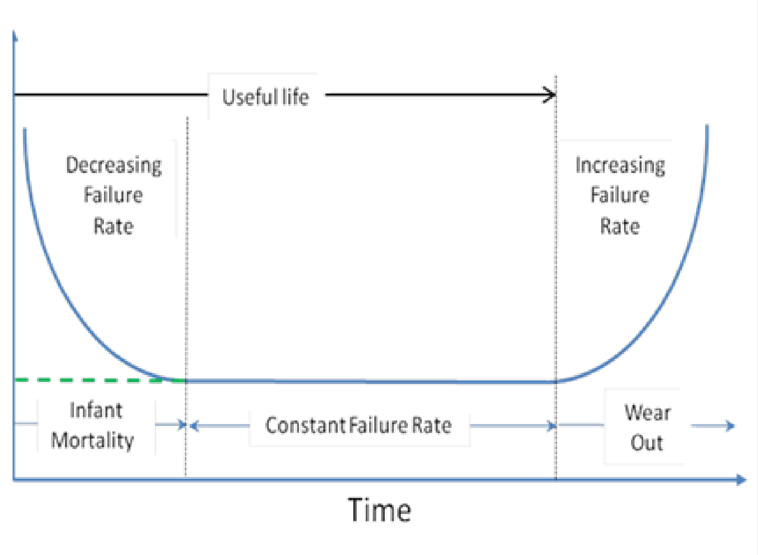
Illustration only

Siemens Wind Power Service – Business Understanding

SIEMENS



- Replacing main components is extremely costly, especially offshore
- Unknown failure modes, e.g., infant mortality, constant failure rate, wear out
- Objectives:
  - Predict risks of parts to fail
  - Identify root causes of failures



Siemens Digital Services powered by Sinalytics – Example: Optimization of gas turbine operation

Powered by Sinalytics

SIEMENS

Energy System
– Market drivers
– Customer needs
– Product cycles

Gas Turbines
– Mechanical Engineering
– Thermodynamics
– Combustion chemistry
– Sensor properties

Autonomous Learning
– Neural Networks
– Smart Data Architecture processes data from 5,000 sensors per second

Results

Reduced NOx Emissions

Extension of service intervals

Domain know-how + **Context know-how** + **Analytics know-how** = **Customer value**

Siemens

Semantic technologies driving development from description of past to decision support and autonomy

Value and Complexity

Act

Analyze

Inform

Descriptive	Diagnostic	Predictive	Prescriptive
What happened?	Why did it happen?	What will happen?	What shall we do?

Examples

Knowledge graphs from heterogeneous data sources

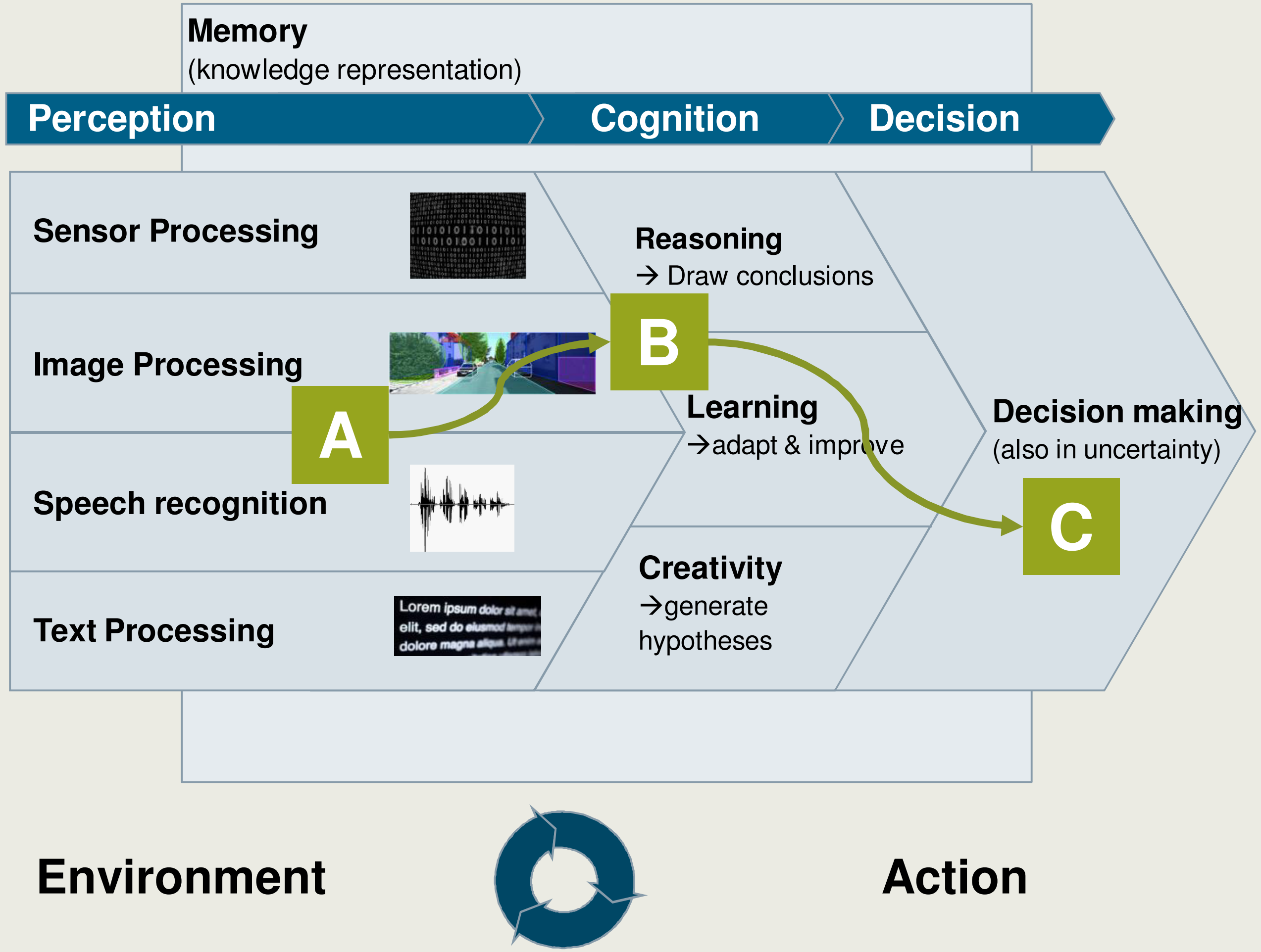
Ontology based data access and analytics
Symbolic reasoning with rules and ontologies

AI Planning based on expressive background knowledge

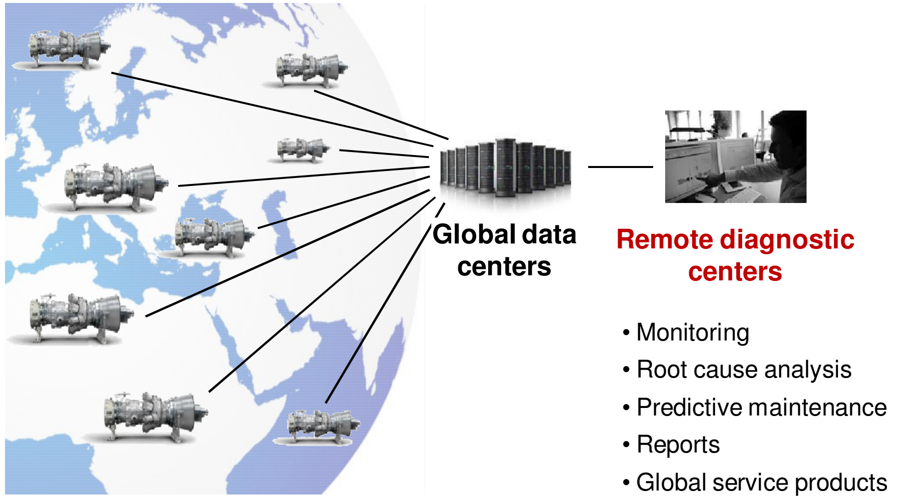
Expressivity of semantic models

Combine AI Techniques in Cognitive Systems to make machines intelligent

SIEMENS



Example **Device Service Automation**



A **Deep learning for object recognition and labeling in service reports**

B **Semantic knowledge fusion and reasoning for integrated diagnostics**

C **Automated planning of maintenance service and activities**

A

Perception: Connecting Industrial Knowledge (Sources)

SIEMENS

Data Sources

Static aspects

R&D data

Engineering data

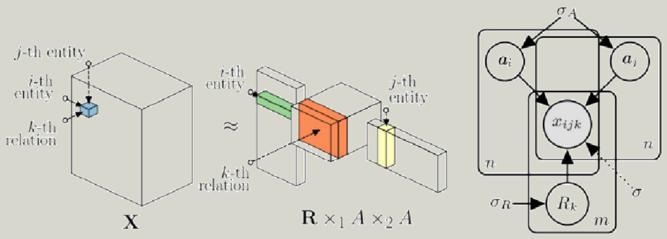
Plant data

Dynamic aspects

Service data

Monitoring data

Relational Learning (e.g. via Tensor Factorization)

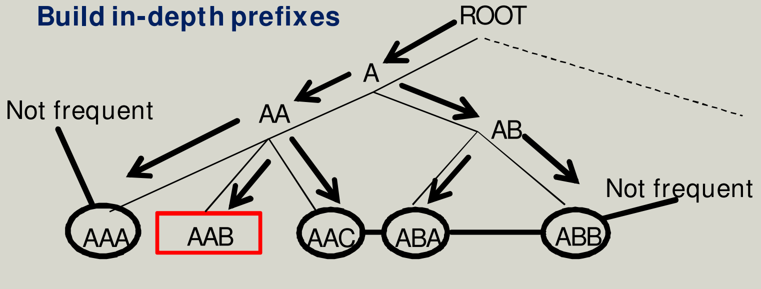


Tresp, Nickel. Tensor Factorization for Multi-Relational Learning, ECML, 2013

Information extraction

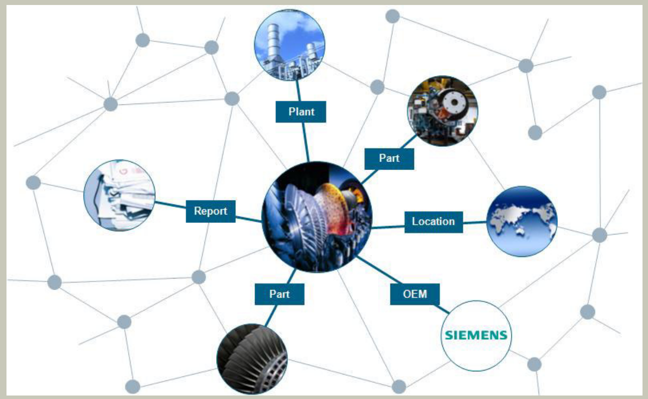
(e.g. Natural Language Processing)

Pattern Sequence Mining (e.g. via PrefixSpan)



Industrial Knowledge Graph

Knowledge fusion into one coherent semantic model



Examples for automated graph construction

B Cognition: Enable Intuitive End User Access to Industrial Data

Data Sources

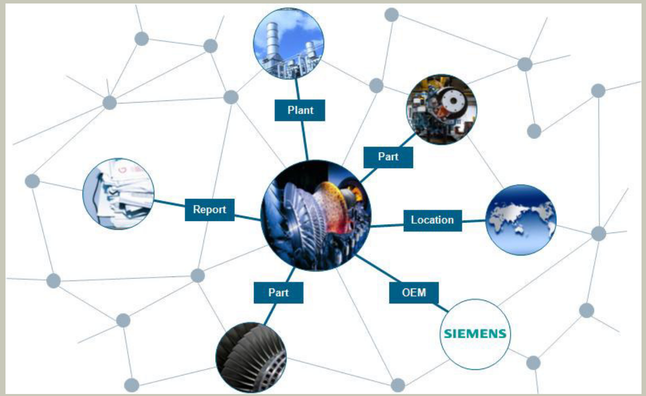
Static aspects

- R&D data
- Engineering data
- Plant data

Dynamic aspects

- Service data
- Monitoring data

Industrial Knowledge Graph



Ontology-based Data Access

Normal start?

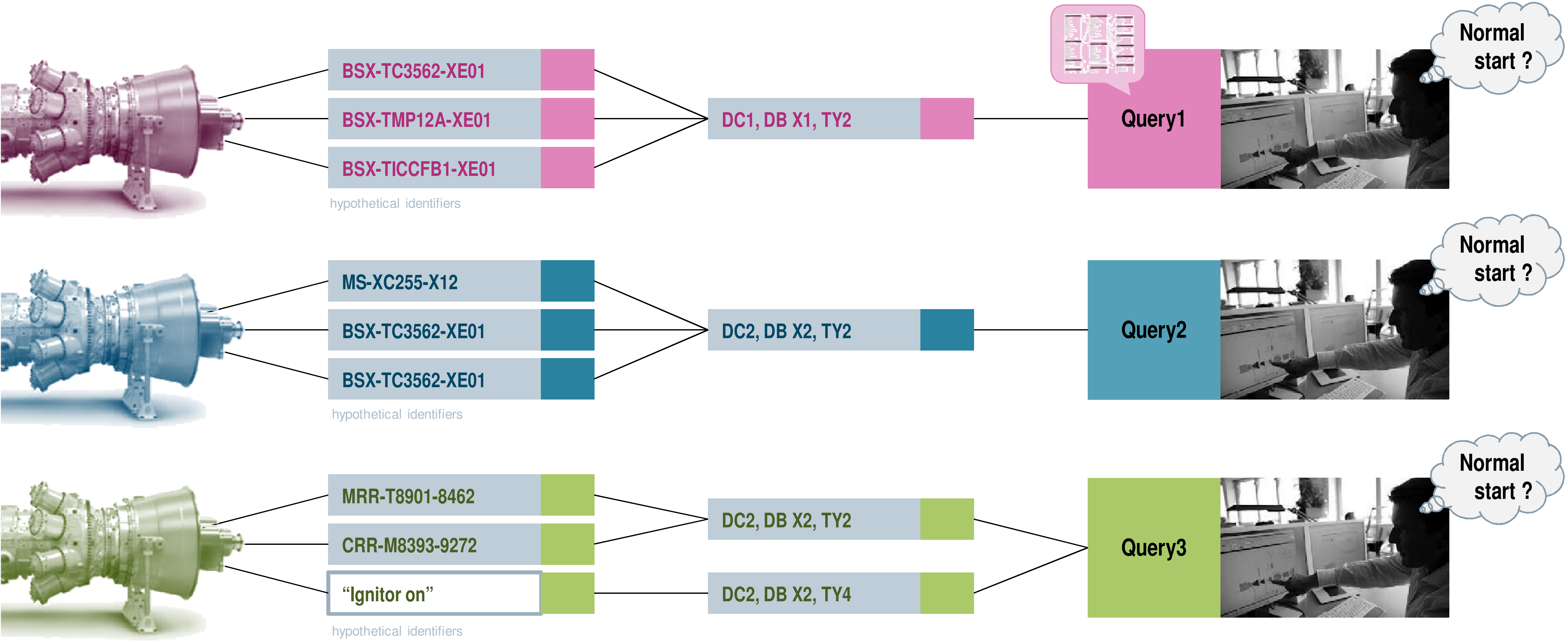
Query

Analytics

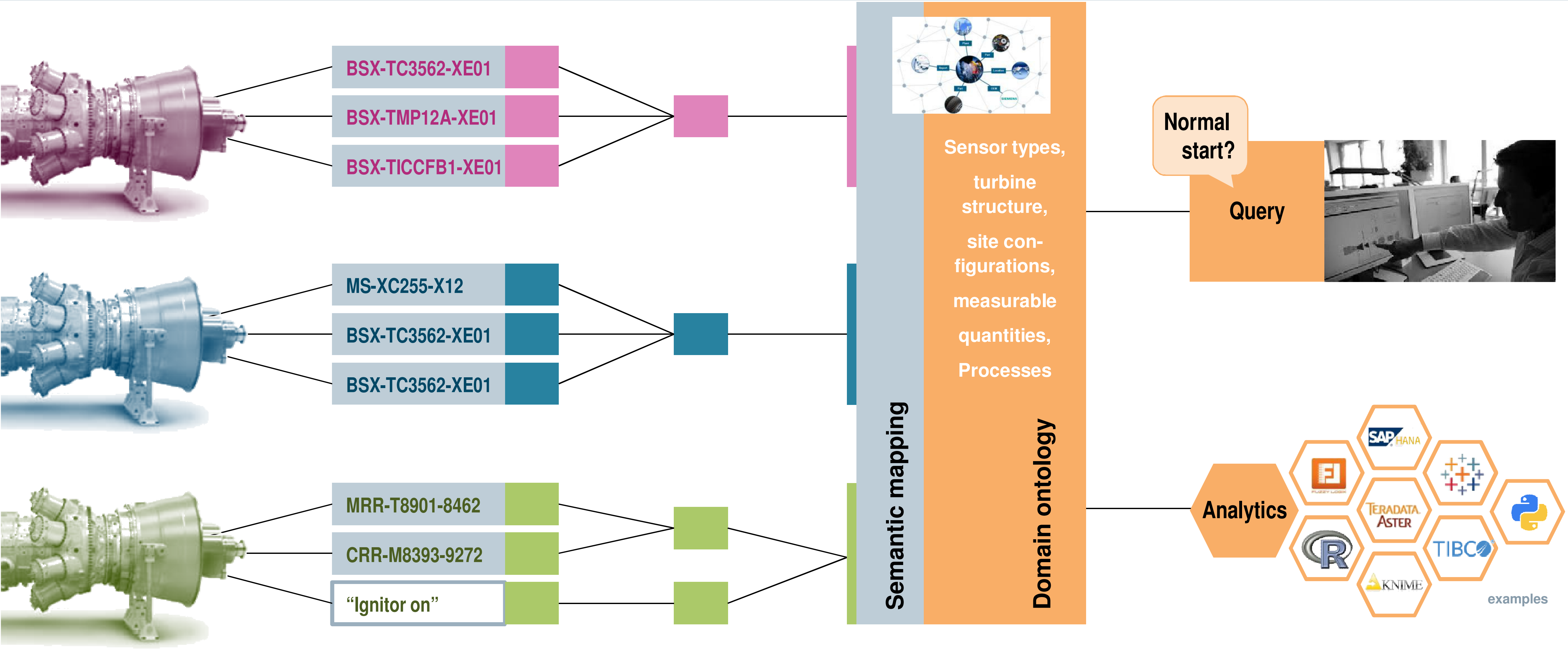
examples

B

Semantic knowledge fusion and reasoning for integrated diagnostics
Problem: high analysis effort due to lack of uniform data models

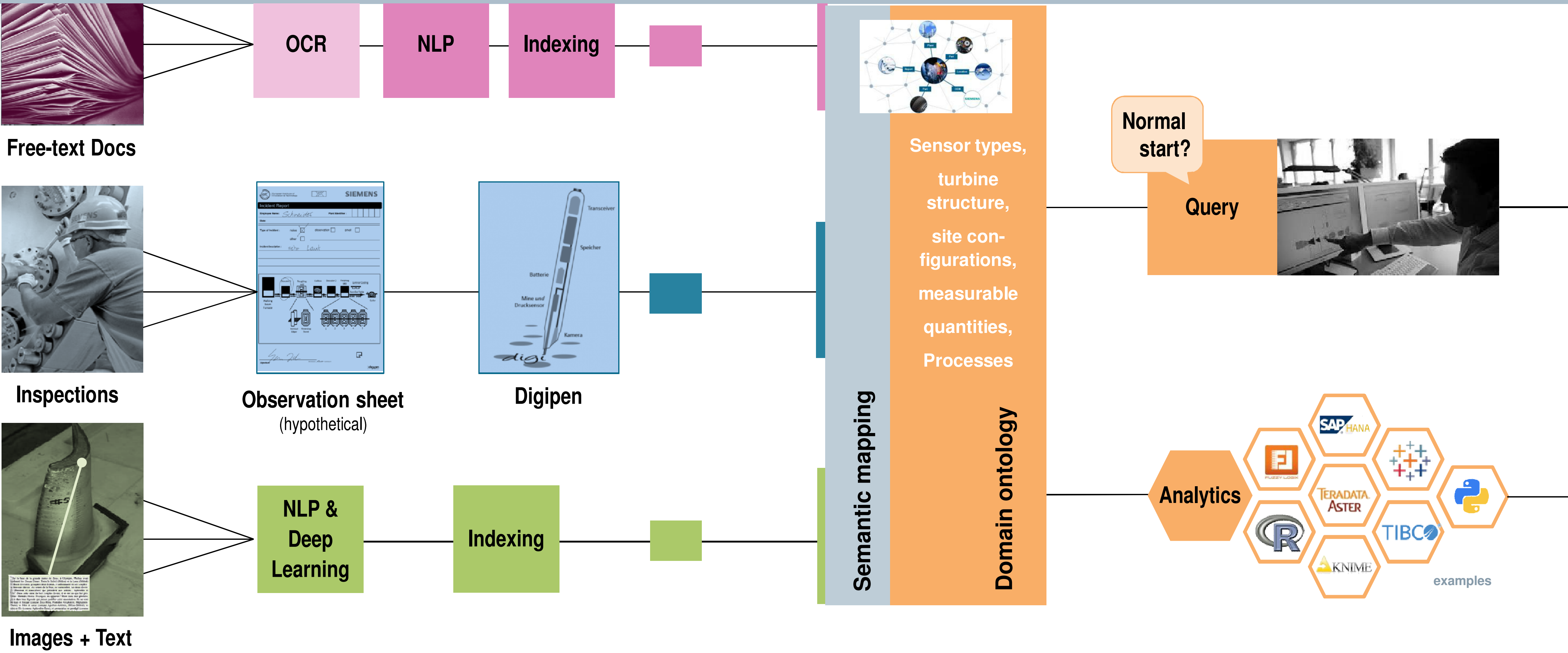


B Abstraction Enables Uniform Solutions (EU funded Project Optique*)



B

Abstraction Enables Uniform Solutions (EU funded Project Optique*)

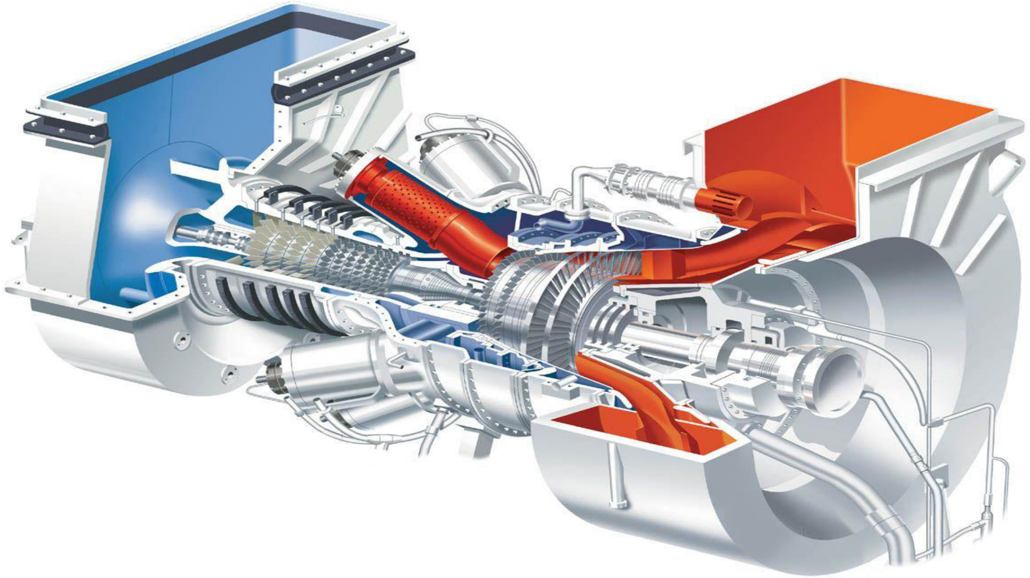


* FP7-318338 - http://optique-project.eu/

Fault Diagnostics with OWL 2 EL Reasoning

Power Plant Use Case

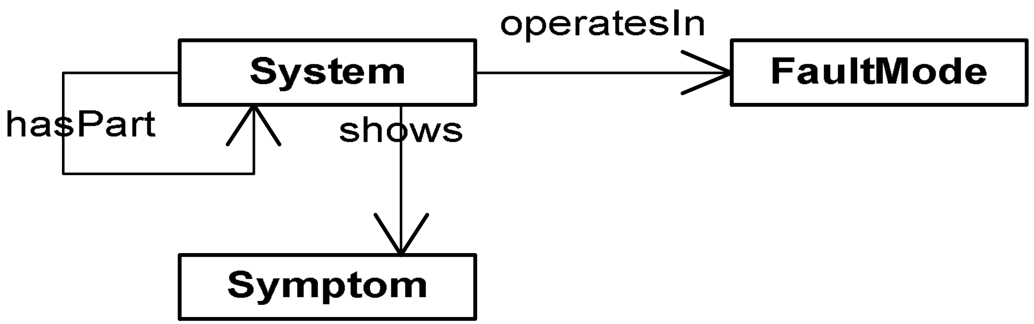
- Causality between symptoms and faults
- Location of phenomena in system
- Taxonomies of faults



Diagnostic Knowledge in OWL 2 EL

- Easy maintenance of diagnostic knowledge
- OWL 2 Profiles with faster computation on embedded, ressource-constrained devices

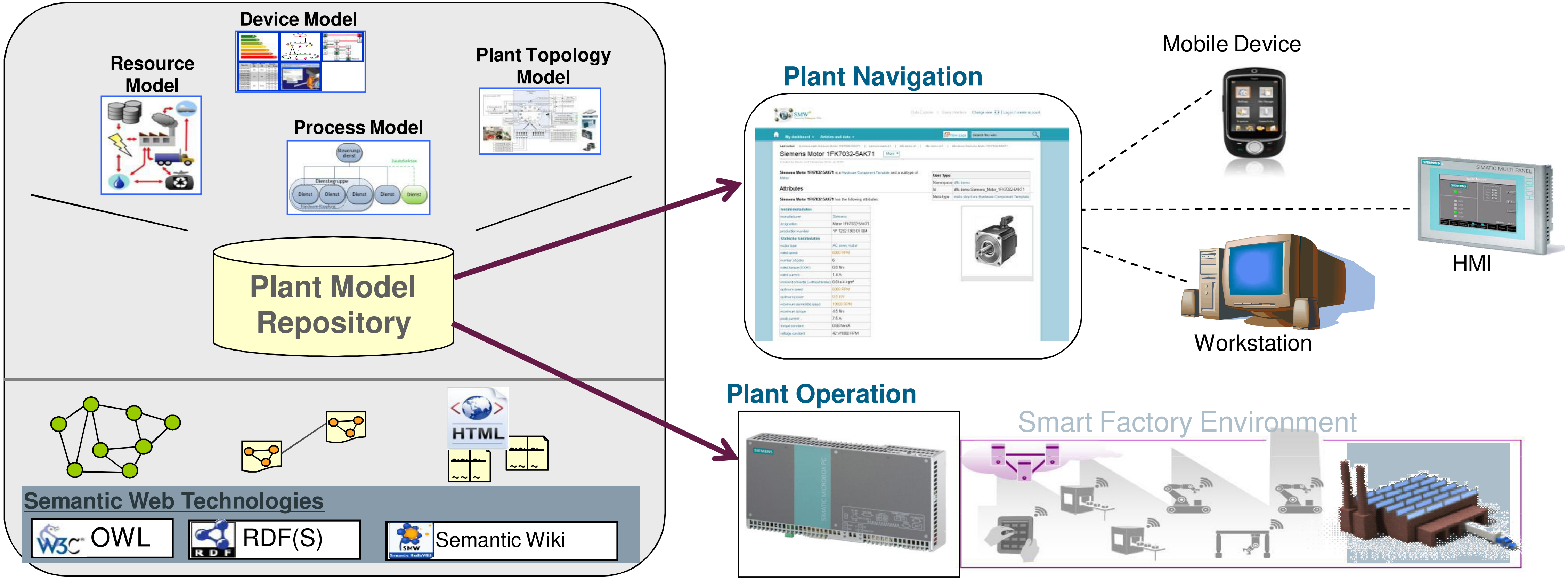
$$\overset{\text{Sys}}{Turbine} \sqcap \exists\, hasPart\,.(\overset{\text{Sys}}{Fan} \sqcap \exists\, shows\,.\overset{\text{Sym}}{Vibrations}) \sqcap$$
$$\exists\, hasPart\,.(\overset{\text{Sys}}{CombChamber} \sqcap \exists\, shows\,.\underset{\text{Sym}}{TempFluctuations})$$
$$\sqsubseteq \exists\, operatesIn\,.\overset{\text{Fault}}{CanFlameFailure}$$



[1] S. Grimm, M. Watzke, T. Hubauer, F. Cescolini, *Embedded EL+ Reasoning on Programmable Logic Controllers*, In Proceedings of the 11th International Semantic Web Conference, November 2012

B Semantic Plant Model Repository
Knowledge Graph Handling for Domain Experts

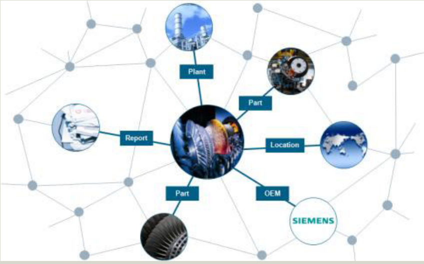
- Provide **integrated access** to plant models for user navigation and M2M communication
- **Plant model repository** based on **Semantic Web technology**



[1] L. Abele, S Grimm, *A knowledge-based Integration of Industrial Plant Models,* In Proceedings of the 39th conference of the IEEE Industrial Electronics Society, 2013

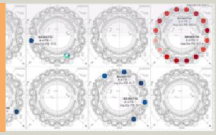
C Decision: From Unified Insights to Actions

Industrial Knowledge Graph



Wiki / Dashboard

Diagnostics



Service Planning

Service Activity Planning

Reduced time for service engineers	Higher flexibility & resilience	Increased availability & efficiency
Derive required actions	**Sequencing of actions**	**Scheduling of actions**

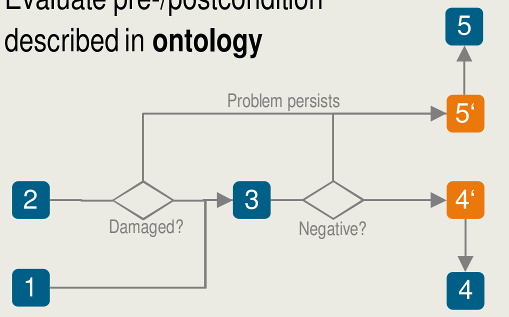
Derive required actions

Query required actions
"Air intake filter degradation or damage"

1. Order/ship **air intake filter**
2. Check **air intake filter**
3. If damaged: replace **air intake filter**
4. If negative: **aerodynamic wash**
5. If problem persists: Consider **full inspection**

Sequencing of actions

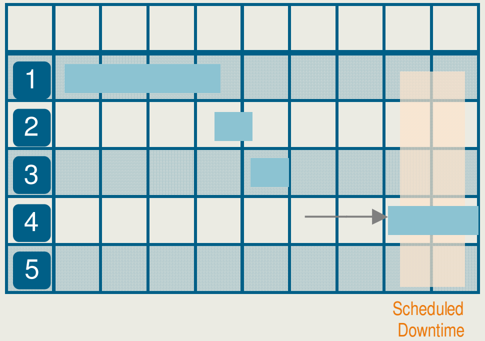
Classical AI Planning & Reasoning
Evaluate pre-/postcondition described in **ontology**



4' 5' Inferred action: Shutdown

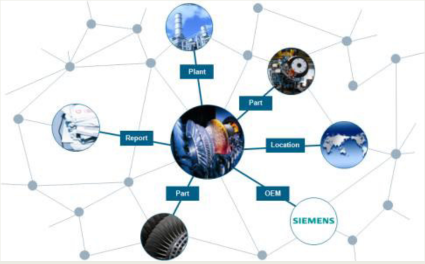
Scheduling of actions

Optimization
Minimize service costs and downtimes considering side constraints / sequences



SIEMENS

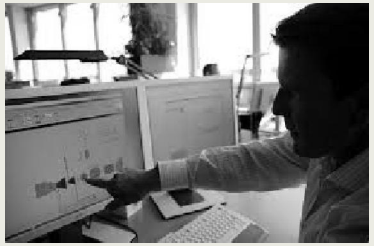
Key Challenges related to Semantics for Data Analytics



Capture internal domain knowhow

Build up Industrial Knowledge Graphs

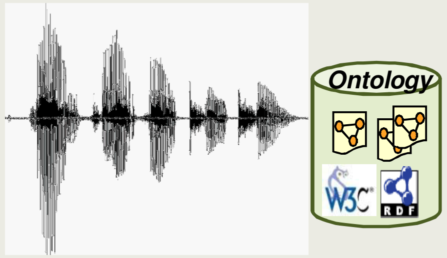
- Build and maintain company-internal domain ontologies for vertical businesses
- Establish semantic technologies as the means for meta/master data management
- Extract information from established tool portfolio in an automated way



Make technology accessible

Make Semantics Usable for Non-experts

- Build on intuitive and problem-oriented representation formalisms
- Provide tooling for domain model authoring
- Establish abstraction layers between formalisms and tooling



Support data analytics semantically

Combine Data Analytics with Semantics

- Semantically represent domain data models that are input to analytics tasks for easier access by analysts and decision makers
- Semantically represent analytical findings for further automated processing
- Semantically annotate analytics workflows to support analytical model management