Semantics-related Challenges in Data Analytics Applications @ Siemens

Stephan Grimm
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
SINALYTICS Platform powers Siemens Digital Services

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

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

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

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

Productivity
- Energy Management
- Digital Factory
- Process Industries & Drives
- Healthcare

Energy efficiency
- Wind Power
- Power and Gas, Power Generation Services
- Mobility
- Building Technologies

Availability

Security

...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 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
Siemens Wind Power Service – Business Understanding

- 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

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

Value and Complexity

Inform

Descriptive
What happened?

Diagnostic
Why did it happen?

Predictive
What will happen?

Prescriptive
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

Memory (knowledge representation)

Perception
- Sensor Processing
- Image Processing
- Speech recognition
- Text Processing

Cognition
- Reasoning → Draw conclusions
- Learning → adapt & improve
- Creativity → generate hypotheses

Decision
- Decision making (also in uncertainty)

Environment Action

Example

Device Service Automation

Remote diagnostic centers
- Monitoring
- Root cause analysis
- Predictive maintenance
- Reports
- Global service products

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
Perception: Connecting Industrial Knowledge (Sources)

Data Sources
- Static aspects: 
  - R&D data
  - Engineering data
  - Plant data
- Dynamic aspects: 
  - Service data
  - Monitoring data

Relational Learning (e.g. via Tensor Factorization)

Pattern Sequence Mining (e.g. via PrefixSpan)
- Build in-depth prefixes
  - ROOT
  - Not frequent
  - AA
  - AB

Examples for automated graph construction

Industrial Knowledge Graph
Knowledge fusion into one coherent semantic model

Examples for automated graph construction

Data Sources Industrial Knowledge Graph
R&D data
Engineering data
Plant data
Service data
Monitoring data

Static aspects
Dynamic aspects

Stations for R&D
Engineering
Plant
Service
Monitoring

Examples for automated graph construction

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

Data Sources

- R&D data
- Engineering data
- Plant data

- Service data
- Monitoring data

Industrial Knowledge Graph

Ontology-based Data Access

- Examples
  - SAP
  - TIBCO
  - KNIME
  - R
  - Teradata Aster

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Semantic knowledge fusion and reasoning for integrated diagnostics

Problem: high analysis effort due to lack of uniform data models

- BSX-TC3562-XE01
- BSX-TMP12A-XE01
- BSX-TICCFB1-XE01
- MS-XC255-X12
- BSX-TC3562-XE01
- BSX-TC3562-XE01
- MRR-T8901-8462
- CRR-M8393-9272
- "Ignitor on"

Queries:

1. Query1: DC1, DB X1, TY2
2. Query2: DC2, DB X2, TY2
3. Query3: DC2, DB X2, TY4

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Sensor types, turbine structure, site configurations, measurable quantities, Processes

Normal start?
Query

Analytics

Domain ontology

Semantic mapping

Sensor types, turbine structure, site configurations, measurable quantities, Processes

Analytics

examples

* FP7-318338 - http://optique-project.eu/
Abstraction Enables Uniform Solutions (EU funded Project Optique*)

Sensor types, turbine structure, site configurations, measurable quantities, Processes

Query

Analytics

Normal start?

Semantic mapping

Domain ontology

NLP & Deep Learning

Indexing

Digipen

Observation sheet (hypothetical)

Free-text Docs

Inspections

Images + Text

Remote monitoring example:
Semantics in the wider ecosystem

Abstraction Enables Uniform Solutions (EU funded Project Optique*)

Semantics in the wider ecosystem

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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


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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**

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Decision: From Unified Insights to Actions

Service Activity Planning

Reduced time for service engineers

Higher flexibility & resilience

Increased availability & efficiency

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

5. Inferred action: Shutdown

Scheduling of actions

Optimization
Minimize service costs and downtimes considering side constraints / sequences

Scheduled Downtime

Order/ship air intake filter
Check air intake filter
If damaged: replace air intake filter
If negative: aerodynamic wash
If problem persists: Consider full inspection

Inferred action: Shutdown
Key Challenges related to Semantics for Data Analytics

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
- 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
- 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