Reasoning in Situation-aware Applications

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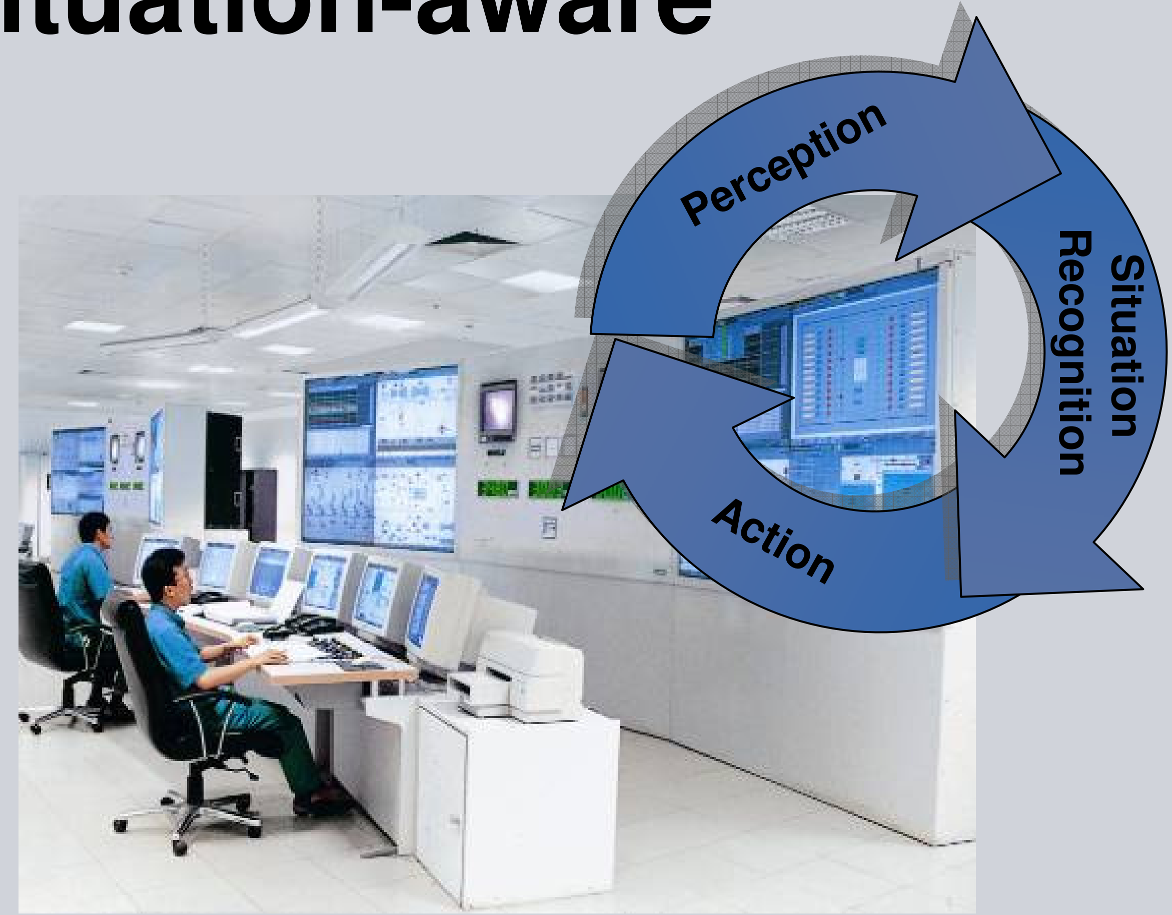

Application Areas of Situation-aware systems

Monitoring of complex technical systems for proactive maintenance and diagnostics

Examples:

- Maintenance of railroad infrastructures
- RFID-based incident management in production and logistics

Monitoring of human behavior to recognize critical situations

Examples:

- Surveillance
- Ambient Assisted Living

Fossil Power Generation

Renewable Power Generation

Power Transmission

Power Distribution

Water Technologies

Lighting (OSRAM)

Mobility

Solutions for Industry

Healthcare

IT Solutions and Services

Building Technologies

Situation-aware Applications: Architectural Blueprint

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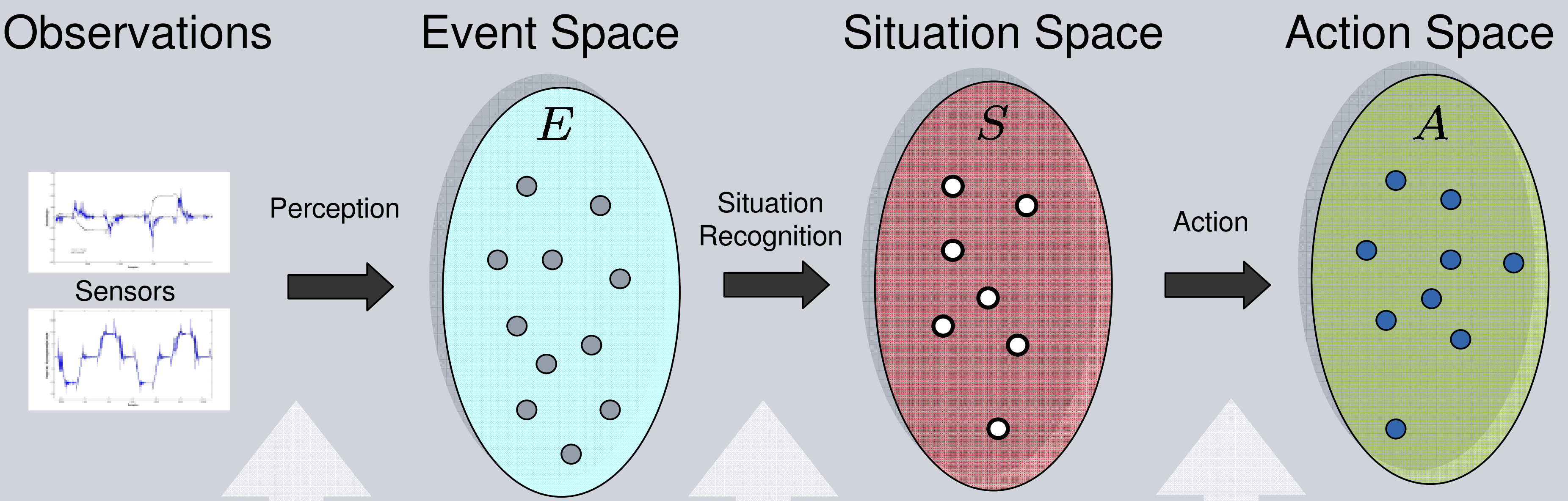

Observations

Event Space

Situation Space

Action Space

Sensors

Perception

E

Situation Recognition

S

Action

A

Which events are observed by a sensor?

Which situations can be identified by a set of observed events?

Which actions have to be executed in a certain situation?

Reasoning based on Semantic Models

Example: Proactive Maintenance for Complex Industrial Processes

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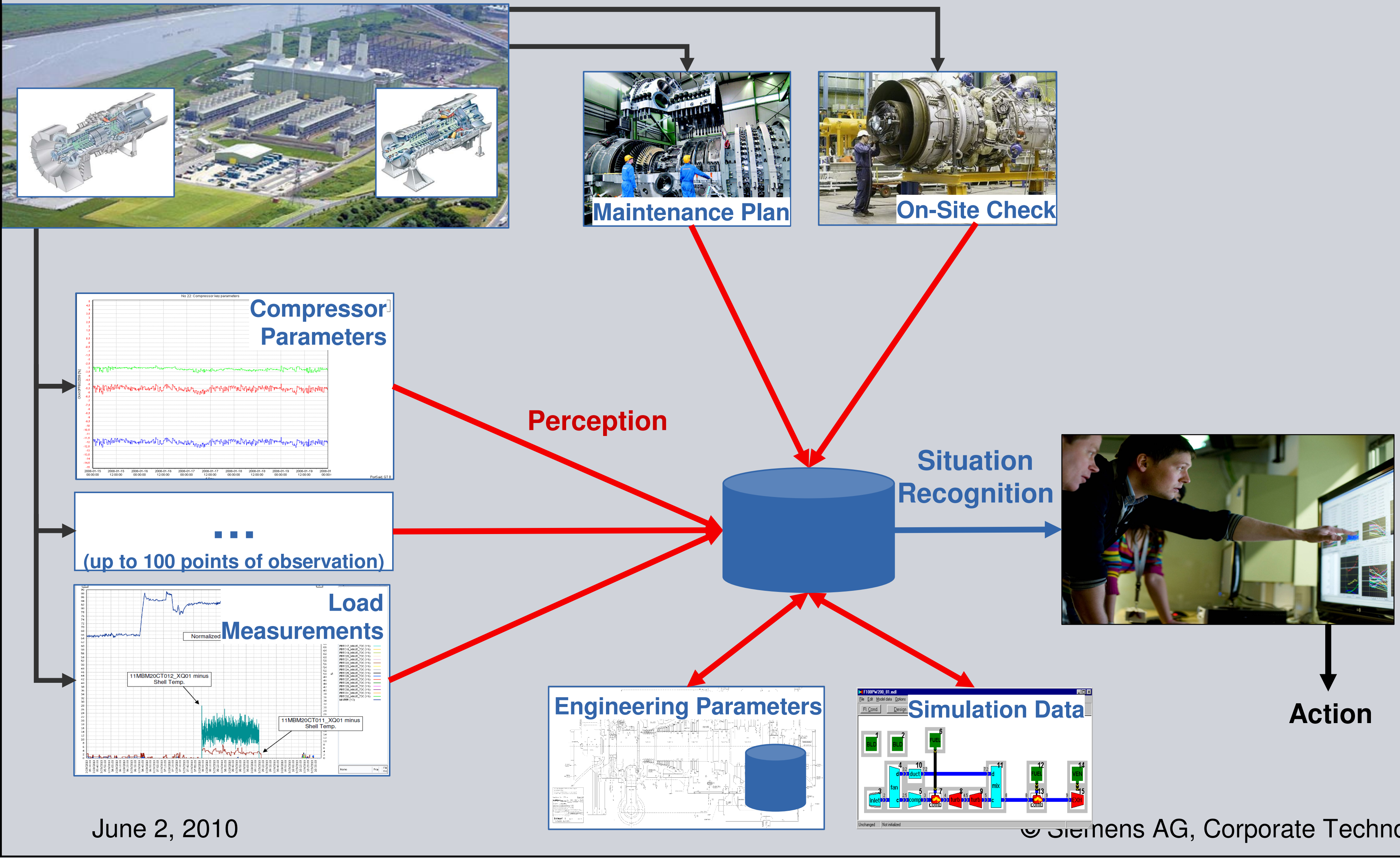

Maintenance Plan

On-Site Check

Compressor Parameters

...

(up to 100 points of observation)

Load Measurements

Perception

Situation Recognition

Engineering Parameters

Simulation Data

Action

Normalized
11MBM20CT012_XQ01 minus Shell Temp.
11MBM20CT011_XQ01 minus Shell Temp.

Situation-aware Applications: Challenges for Semantic Technologies

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Situation Recognition Algorithms for Event Streams

- Efficient situation understanding for stream data necessary
- Situations depend on temporal as well as causal relations between events

Distributed Situation Recognition

- Events come from various sources and locations
- Processing and communication in real time

Intelligent Sensors with Situation Recognition “on board”

- Situation understanding algorithms are executed embedded on device/sensor
- Tractability on resource restricted hardware

Towards “on-board diagnostics”

Situation Specification: Event Correlation Language

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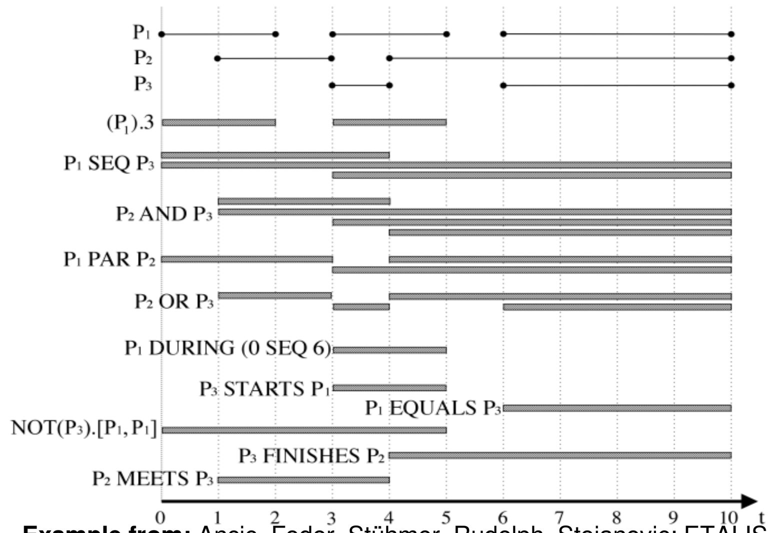
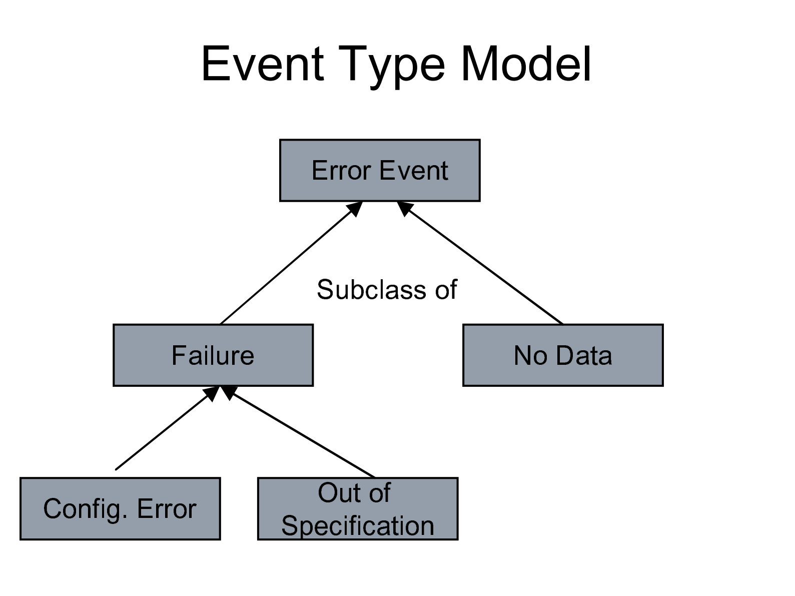
Situation = (temporal, causal) correlation between events

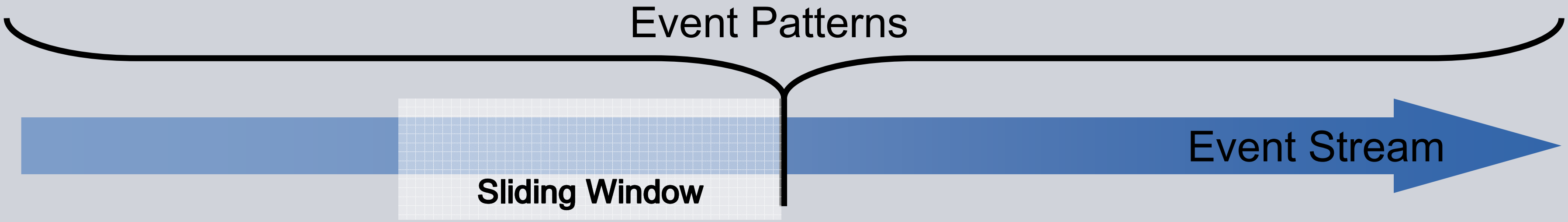
Situations



Example from: Ancic, Fodor, Stühmer, Rudolph, Stojanovic: ETALIS: A Rule-based System for Complex Event Processing, 2010



Events



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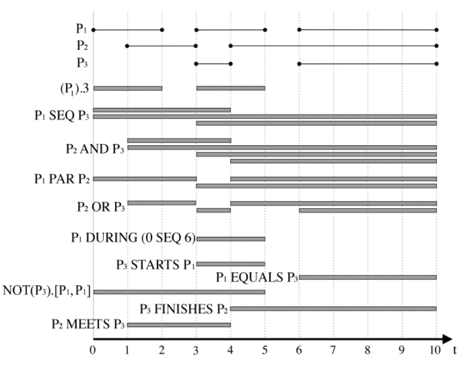
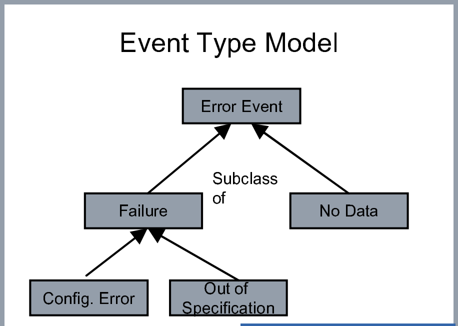
Rule-based Event Processing

Current Approach: Complex Event Processing using Rule Engines

Event Correlation Language





OWL 2 RL

Situation

EventPattern → *Situation*

Rule Engine

Prolog, Clips, Drools

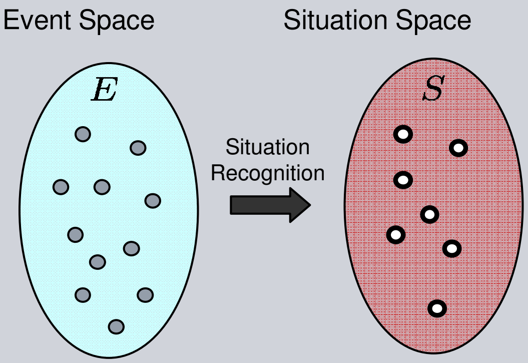
Various approaches in literature for

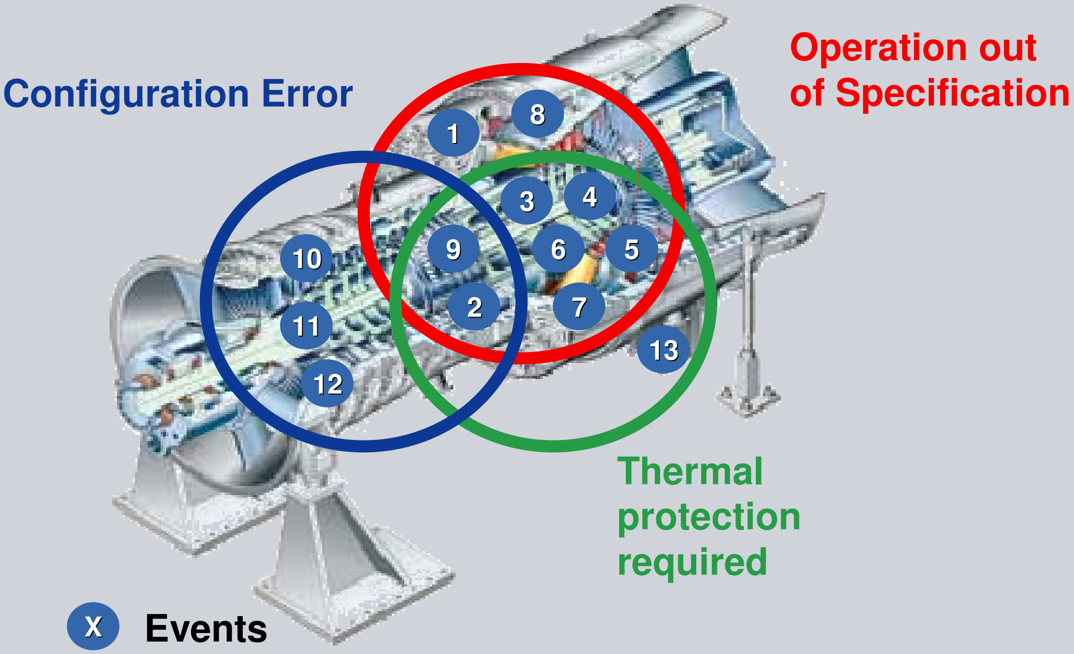
- semantics of temporal language constructs, e.g. RETE extensions
- Consumption policies to implement sliding window over events

Reasoning for Situation Understanding

Deductive Reasoning for Situation Understanding

- Requires full information about relation between events and situations
  - *EventPattern* → *Situation*





Reasoning for Situation Understanding

Problem: Incomplete Information

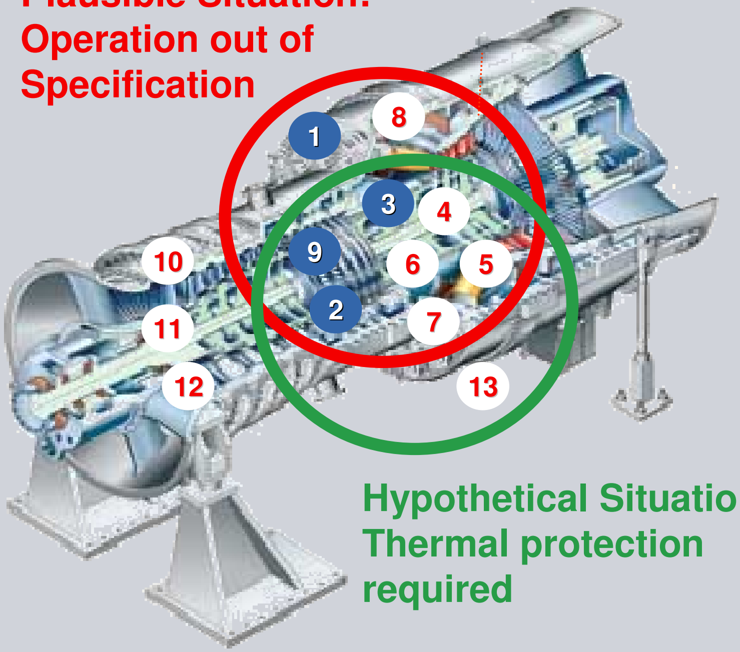
- Not applicable to predictive maintenance
- Reasons for the particular situations are often unknown

Current Approach

- Introduce classification of situations: certain, plausible and hypothetical situations
- Rank plausible and hypothetical situations according to heuristics as well as explicit preferences
- Support for simple event patterns only

Some challenges

- Abduction reasoning for situation understanding with incomplete information
- Probabilistic reasoning for handling uncertain information
- Inductive reasoning enables iterative improvements of (deductive) situation understanding



Plausible Situation: Operation out of Specification

Hypothetical Situation: Thermal protection required

X Observed event

X Unknown

Situation-aware Applications: Challenges for Semantic Technologies

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Towards “on-board diagnostics”

Example: Proactive Maintenance for Complex Industrial Processes

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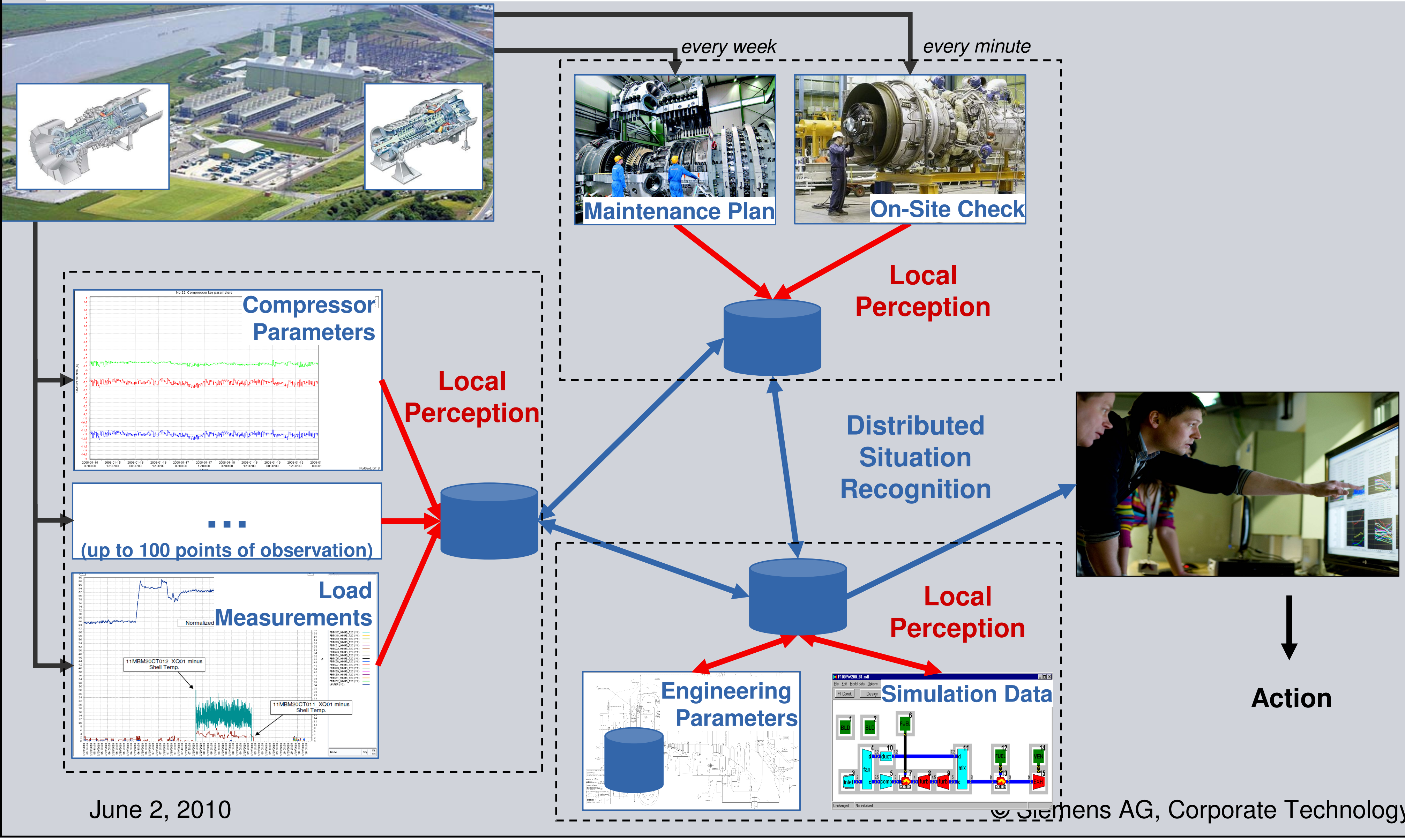

every week

every minute

Maintenance Plan

On-Site Check

Local Perception

Compressor Parameters

...

(up to 100 points of observation)

Load Measurements

Local Perception

Distributed Situation Recognition

Local Perception

Engineering Parameters

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Action

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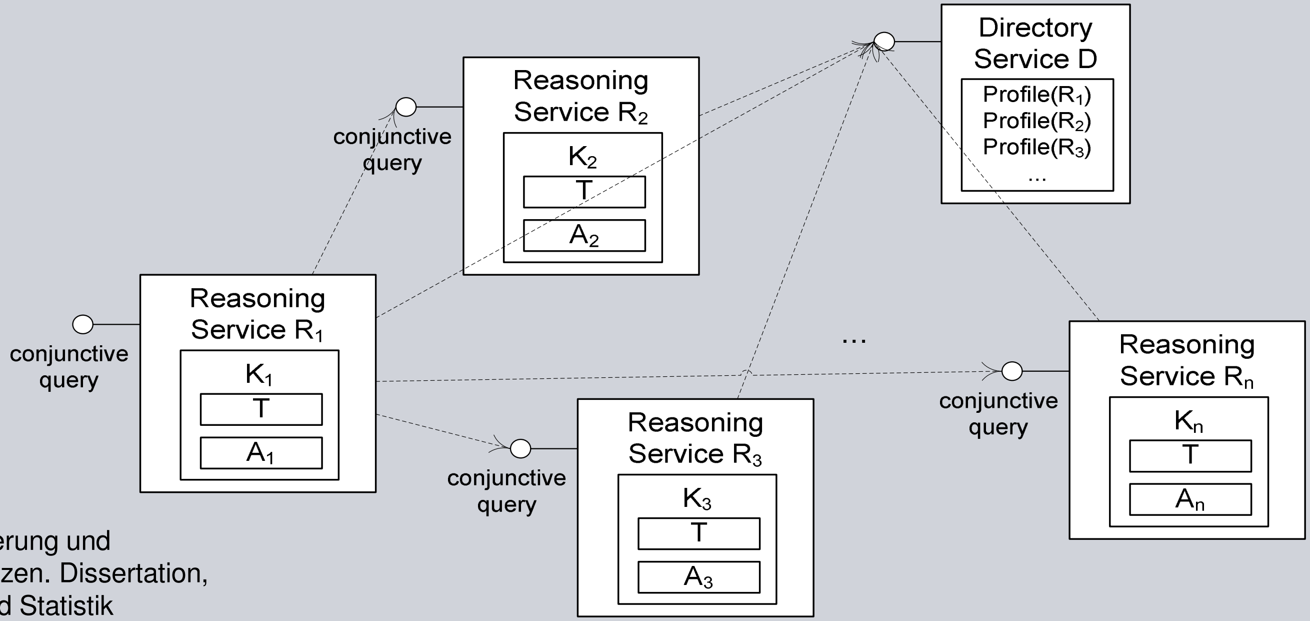
Distributed Situation Recognition

Reasoning over Distributed Knowledge Bases

- Avoid collection of all sensor data in one central knowledge base
- Instead of collecting data distribute queries to remote reasoners and integrate results



Source: Fuchs, Florian (2008): Semantische Modellierung und Reasoning für Kontextinformationen in Infrastrukturnetzen. Dissertation, LMU München: Fakultät für Mathematik, Informatik und Statistik

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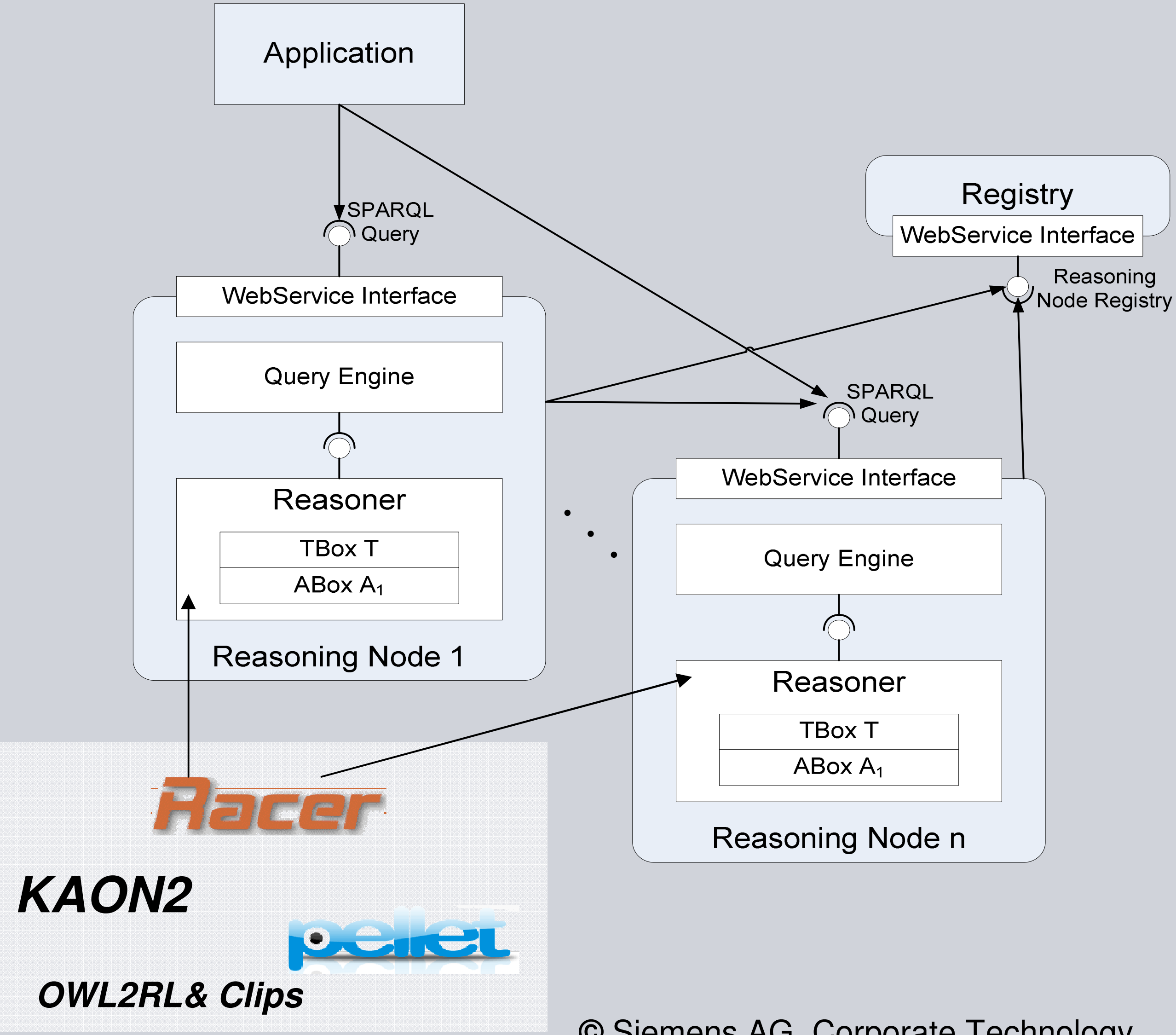
Distributed Situation Recognition: Implementation

Architecture:

- Java Axis2 WebServices
- ReasoningNode as black box
- Intelligence in Query Engine: generates sub queries
- Deployment in servlet engine (e.g. Tomcat)
- Different setups possible (e.g. hierarchical, mesh-networks, etc.)



Restrictions w.r.t. OWL DL:

- Shared roles must not be universally quantified (forall r.C' not allowed)
- Shared roles must not be restricted in cardinality (≤n r not allowed)

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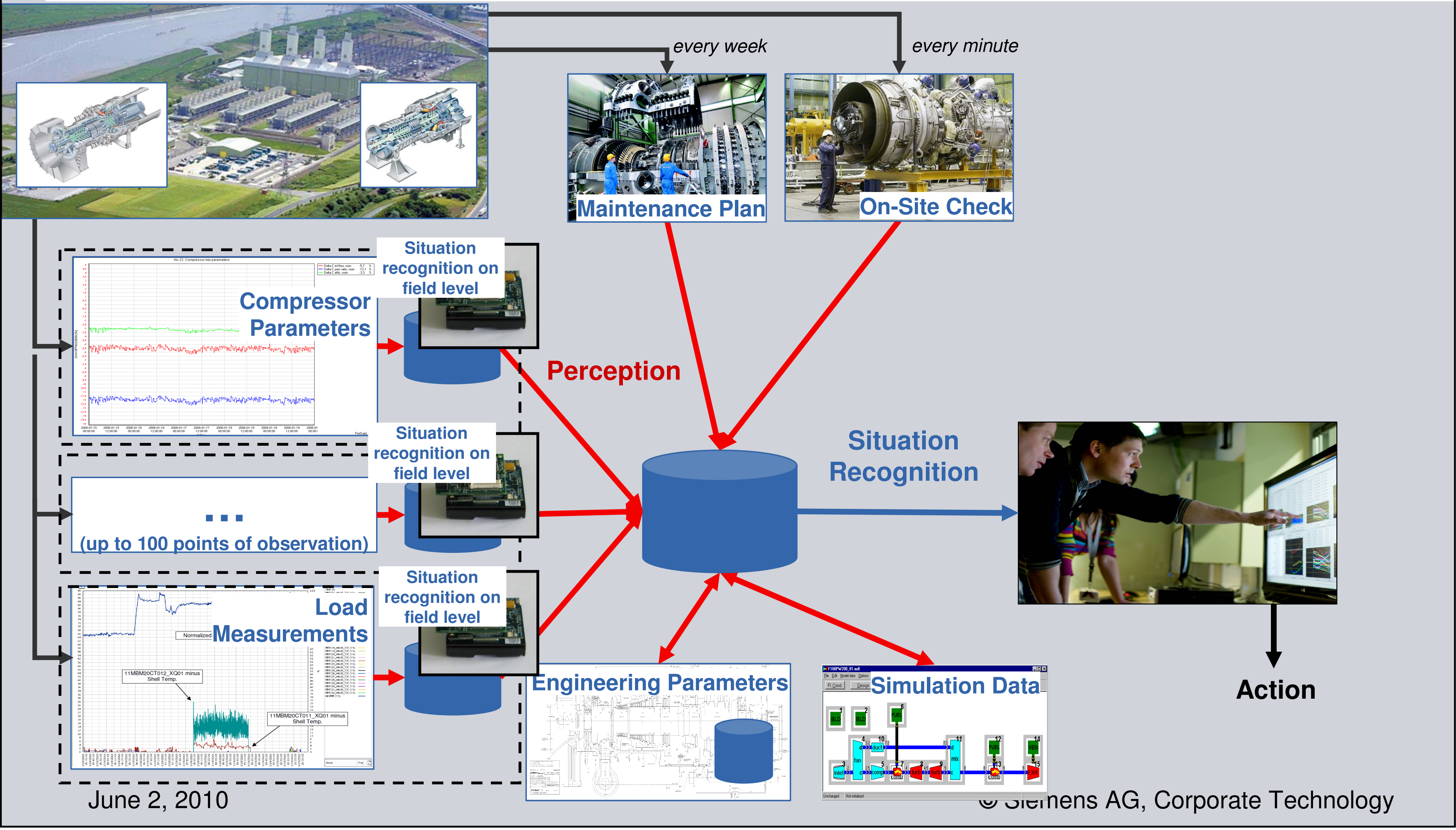

every week

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Situation recognition on field level

Compressor Parameters

Situation recognition on field level

...

(up to 100 points of observation)

Situation recognition on field level

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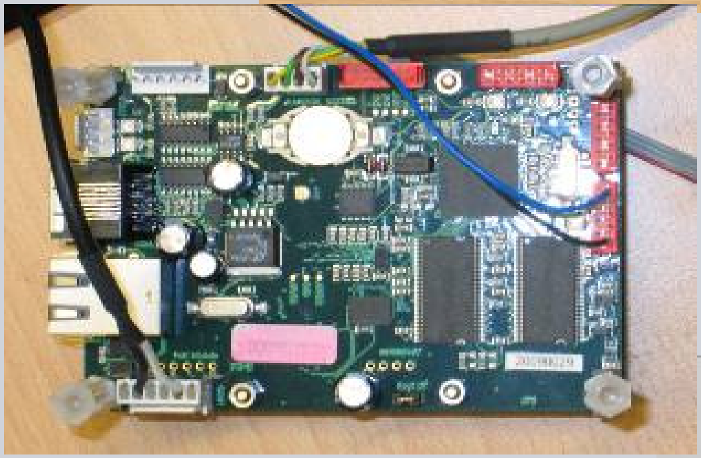
Simulation Data

Normalized
11MBM20CT012_XQ01 minus Shell Temp.
11MBM20CT011_XQ01 minus Shell Temp.
inlet
fan
duct
comp
comb
mix
FUEL
EXH

Possible Hardware

Gumstix Verdex Pro XM4 COM

- Processor: Marvell™ PXA270,
- Speed:ARM XScale 400MHz
- Memory: 64MB RAM, 16MB Flash
- Linux 2.6



AUG Development Board

- ATMEL AT91SAM9261 (ARM9)
- Speed: 200MHz
- Memory: 64 MByte SDRAM, 256 MByte NAND Flash

xBow Imote2

- PXA271 processor at 13–416MHz
- 256kB SRAM, 32MB FLASH, 32MB SDRAM
- Integrated 802.15.4 Radio

Reasoners under investigation….

FaCT++ ⚡

- Programming language C++
- Stand-alone → I/O error caused by ARM
- OWL API → Alpha version for FaCT++ dosn‘t work

Pellet ⚡

- Programming language Java
  →no working Java environment
- GNU classpath – not fully compatible
- SUN Embedded for Java – no required lib

CEL ⚡

- Programming language Lisp
- Only Allegro CL → closed source, no ARM-version (cross-compiling necessary)

Racer ⚡

- Programming language Lisp
- closed source, no ARM-version (cross-compiling necessary)

Clips rule engine as OWL2RL reasoner

- Small, light, and rather fast
- Uses Rete algorithm, forward chaining
- Implemented in C, C++ wrapper available
- Available for various platforms (e.g. Windows, Linux, Unix)
- License: Open Source

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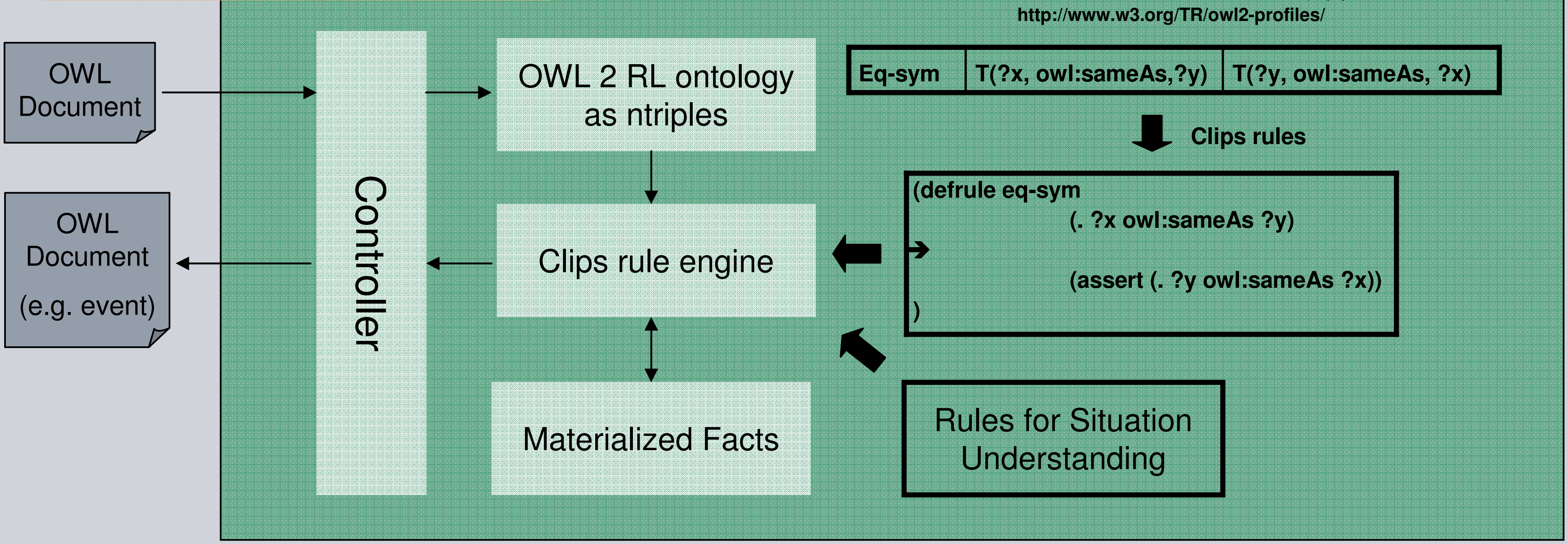
Embedded situation recognition

- Simplified architecture of embedded reasoning on Gumstix hardware

OWL 2 RL/RDF rules axiomatization (approx. 80 rules)

http://www.w3.org/TR/owl2-profiles/


OWL Document
OWL Document (e.g. event)
Controller
OWL 2 RL ontology as ntriples
Clips rule engine
Materialized Facts
Clips rules
Rules for Situation Understanding

Eq-sym	T(?x, owl:sameAs,?y)	T(?y, owl:sameAs, ?x)

```
(defrule eq-sym
                    (. ?x owl:sameAs ?y)
→
                    (assert (. ?y owl:sameAs ?x))
)
```

Current work: improve approach w.r.t. memory usage

Conclusions

- Many applications of situation-aware applications in energy, industry and healthcare sector

- Situation-aware applications require
  - Identification of_relevant events based on multi-model sensor inputs
  - Recognition of complex situations
  - Triggering of appropriate actions

- Challenges for situation recognition
  - Efficient data stream processing with complex event patterns
  - Realization of distributed situation recognition algorithms
  - On-board diagnostics with situation recognition algorithm embedded on device

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Thank you for your attention!

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