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Predictive Analytics in Power Plants

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Smart data – from Descriptive to Prescriptive Analytics

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Value and Complexity

Act

Analyze

Inform

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

Examples

Descriptive	Diagnostic	Predictive	Prescriptive
• Plant operation report • Fault report	• Alarm management • Root cause identification	• Power consumption prediction • Fault prediction	• Operation point optimization • Load balancing

Current penetration across all industries (according to Gartner 2013)

Descriptive	Diagnostic	Predictive	Prescriptive
99% Adopt by vast majority but not all data	30% Adopted by minorities	13% Still few adopters	3% Very few early adopters

Predictive Analytics for Decision Support in Energy Engineering

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Ingenuity for life

Physics → Data → Data Analytics → Business Intelligence → Business Innovation → Customer Value

Data

Structured

Sensors
Schedules
Transactions
Configurations
…

Unstructured Multi-structured

Logs
Reports
Specifications
…

Image

Technologies

Data presentation
Visual analytics, dashboards, reports

Data modeling and analysis
Optimization
Reasoning / Semantics
Natural Language Processing / Search
Data Mining / Machine Learning (incl. Neural Networks)

Data management
Data warehouse, NoSQL(inc. Hadoop), Stream processors (parts of Lambda Architecture)

Data integration
Physical-, Virtual-, Semantic-, integration, ETL, Quality-, Metadata- management

Applications

Prescriptive analytics
Operation planning, Operation and control optimization, Product configuration

Predictive analytics
Fault-, Production-, Demand- prediction, Price forecasting

Diagnostic analytics
Monitoring, Alarm management, Root cause analysis, Diagnostic advice

Descriptive analytics
Performance and cost reports, Fault reports, Operation dashboards

Siemens Digital Services Powered by AI –
Example: Optimization of Gas Turbine Operations

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Results

Reduced NOx Emissions

Extension of service intervals

Improved Performance

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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

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

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A Coal-Fired Plant Use Case:
Gas Concentration Reconstruction for Coal-Fired Boilers Using Gaussian Process

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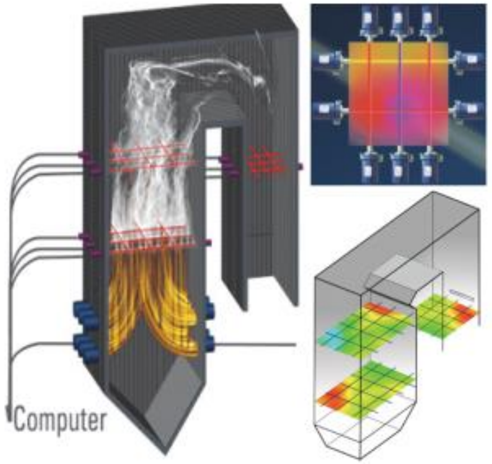
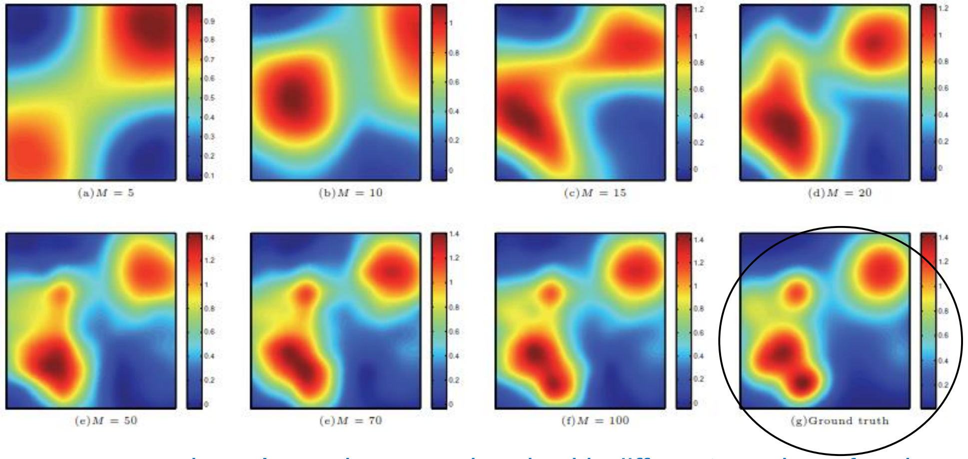
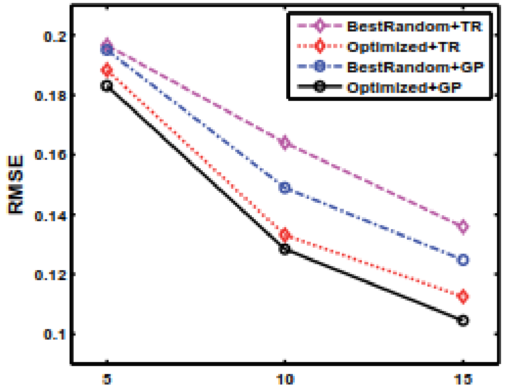


Gas concentration reconstruction. The left plot shows the geometry of an operating coal-fired boiler. 2D cross section gas concentration images (bottom right). TDLAS paths are installed on the wall of a boiler. Each path reads the average value along the path (top right)



Reconstructed results vs the ground truth with different number of paths.



Comparing optimized path arrangement with best random path arrangement

- Combustion optimization of a coal-fired boiler: improve its operating efficiency while reducing emissions
- Take measurements for key combustion ingredients, such as O2, CO, H2O for the feedback.
- Use Tunable Diode Laser Absorption Spectroscopy (TDLAS) to measure the average value of gas concentration along a laser beam path to reconstruct gas concentration images based on these path averages.
- Number of paths is usually very limited, leading to an extremely under-constrained estimation problem.
- How to arrange paths such that the reconstructed image is more accurate
- Bayesian approach based on Gaussian process (GP) to address both image reconstruction and path arrangement problems
- GP posterior mean as the reconstructed image, and average posterior pixel variance as objective function to optimize the path arrangement.
- Algorithms implemented in **Siemens SPPA-P3000** control system for real-time combustion optimization of boilers

Ref:

Yuan, C. et al, KDD '15 Proceedings of the 21th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, Pages 2247-2256