APASSI

Autonomous Processes facilitated by Artificial Sensing Intelligence

AI & Photonics webinar

Janne Paaso, APASSI project manager
VTT Technical Research Centre of Finland

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APASSI AUTONOMOUS PROCESSES FACILITATED BY ARTIFICIAL SENSING INTELLIGENCE

Research partners

Tampereen yliopisto Tampere University

OULUN YLIOPISTO

VTT

Valmet

HEAD RECYCLE SYSTEMS

Paper & Plastics

Outotec

Minerals processing

oplatek

SPECTRAL ENGINES

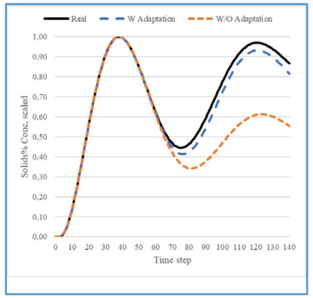
GASERA

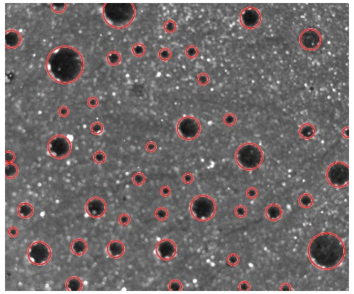
SENFIT

Sensor companies +supplier network

- About 10 M€ Business Finland Co-innovation project, 2019 - 2021
- Big goal: Make **autonomous large-scale industrial processes** possible so that the process performance with respect to asset, raw material and energy efficiency, and quality and added value is radically improved.
- Research topics: novel measurement technologies, model-based estimation methods, autonomous calibration, and dynamic optimization of measuring actions.

APASSI research & development areas





Sensors

- NIR spectroscopy
- MIR spectroscopy
- Raman spectroscopy
- Camera-based techniques
- Micro and millimeter waves
- THz spectroscopy
- Soft sensors

Intelligence to sensing

- Model-based estimation methods (digital twins and others)
- Autonomous calibration to remove the need for manual calibration work
- Dynamic optimization of measuring actions (active sensing)

Applications

- Mineralogy
- Particle and bubble characterization
- Dry content and moisture
- Replacing visual inspection
- Plastic film characterization
- Plastics identification
- Biomaterials replacing plastics
- Specialty coatings

Pilots

- Pilot lines
- Mines
- Enrichment plants

Minerals processing industry

- Pilot lines
- Paper mills
- Paper converting
- Plastics manufacturing
- Plastics recycling

Paper and plastics industry

Showstoppers

Starting point for the APASSI project: Measurement data has several showstoppers when fully autonomous processes are considered:

A. The **validity of the data** is not considered systematically, but left for the process operators to judge
B. **Measurement calibration is largely manual work** that requires both the operators’ presence and availability of laboratory facilities
C. **Process parameters measured too infrequently**
D. Process operators apply also their own **human senses** (vision, audio, feel, smell, taste) on aspects currently not directly measurable
E. Process operators decide on sampling/measurement campaigns to support process diagnostics and/or optimization under **abnormal process conditions.**

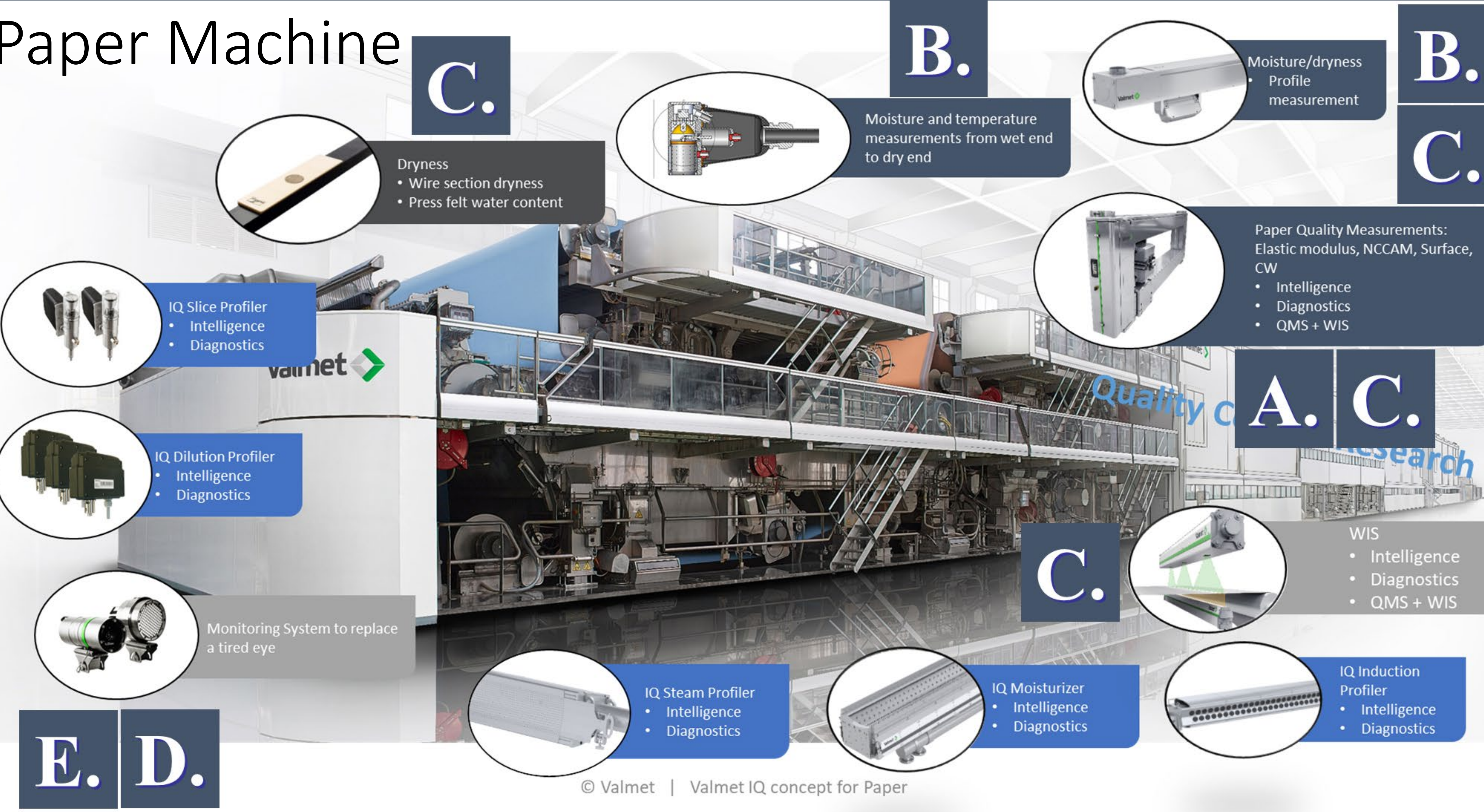
APASSI: Research questions

- RQ1: Which operators' sensing actions and laboratory measurements can be replaced by the novel a) spectroscopic, b) imaging measurements, and c) model-based measurements

- RQ2: How to operate sensing systems for optimal control and guaranteed validity of data

- RQ3: Is it possible to learn/adapt to/simulate the validity of data and identify the need and methods for autonomous calibration

Paper Machine



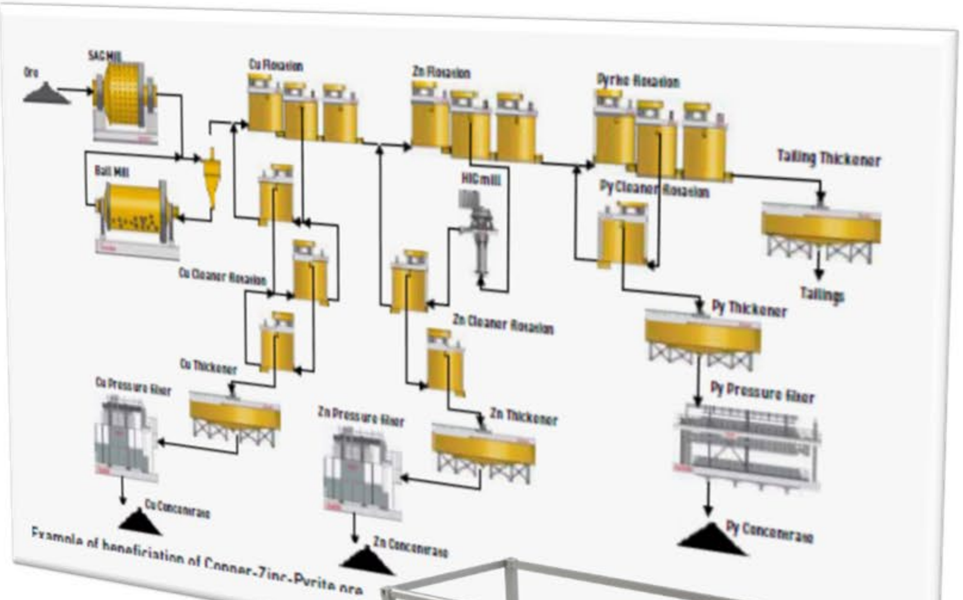
Mineral processing

A.

C.

D.

Digital twin of the process



B.

Automatic analyzer calibration

On-line imaging and characterization of mineral slurries

D.

A.

Sensor fusion for on-line mineral analysis

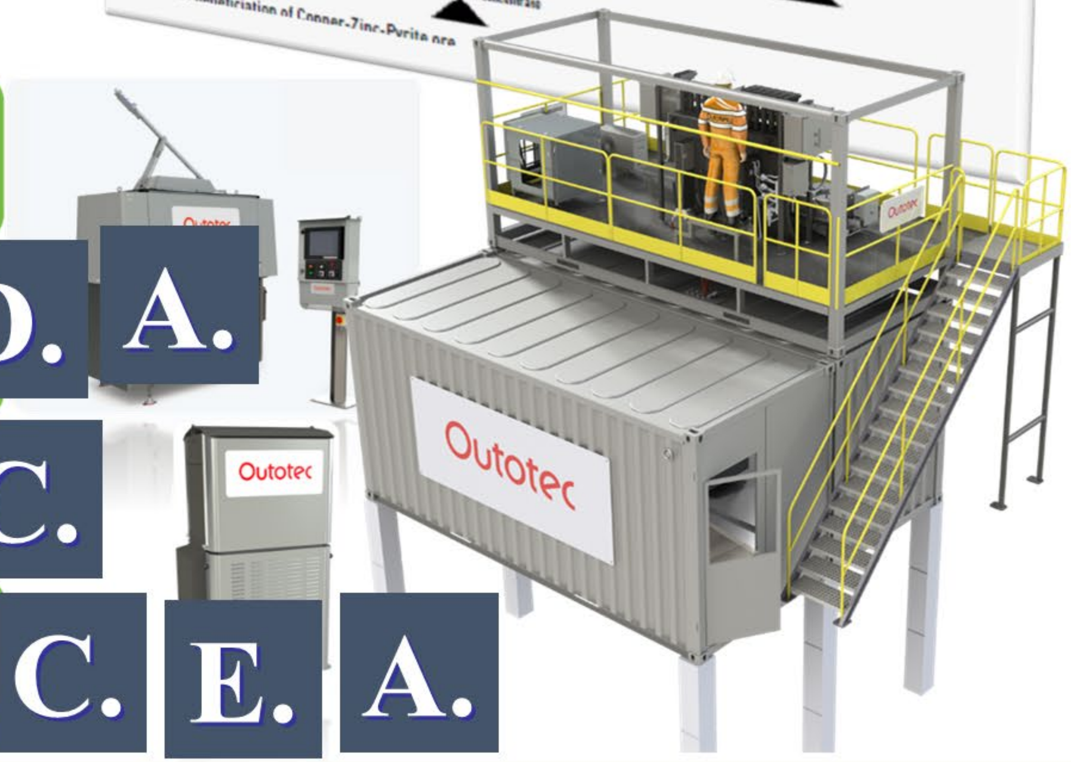
C.

Active sensing for optimal analyzer performance

C.

E.

A.



C.

On-line concentrate moisture measurements integrated into pressure filters

E.

Adaptive model predictive control for optimized high level controls

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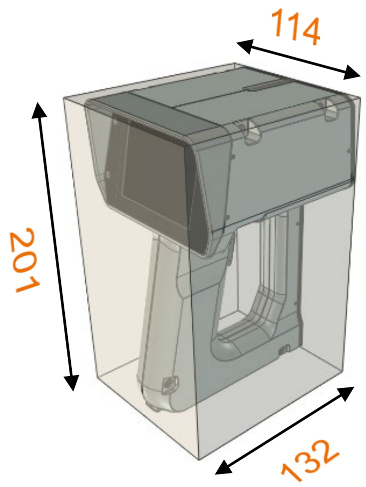
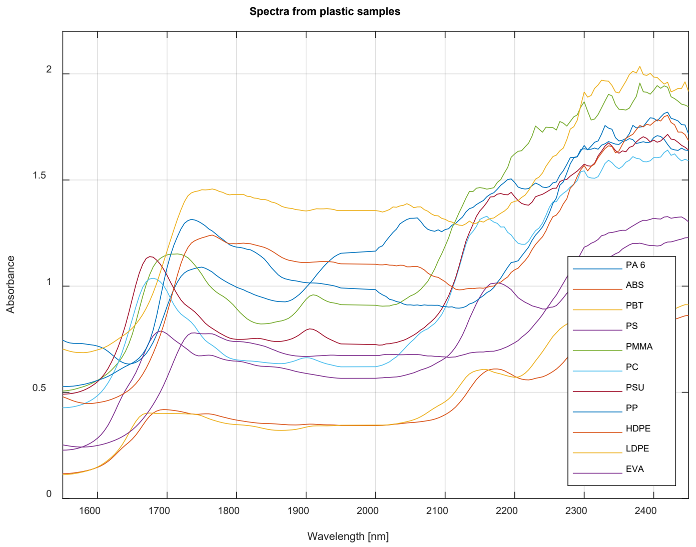
Research project results provide answers to the research questions

VTT, Tampere University, Oulu University

Replacing the senses of the operators: Hand Held NIR Spectrometer

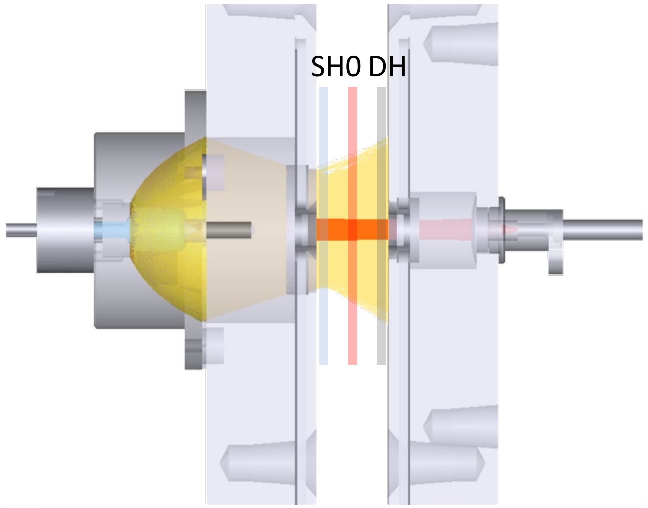
- **Problem:** The sample needs to be in contact with a typical hand held NIR spectrometer
- **Solution:** Novel hand-held NIR spectrometer capable of measuring from a 0 … 300 mm distance
- **Specifications**
    - Measurement distance 0 … 300 mm with optimal distance indicator
    - Wavelength range 1.55 … 2.45 µm
    - Simultaneous IR temperature measurement
    - Measurement time 1 … 2 s
    - White reference in front cover
    - 3.2” colour touchscreen display
    - Two measurement modes: Full spectrum mode and concentration mode
    - Bluetooth/USB data transfer to a computer





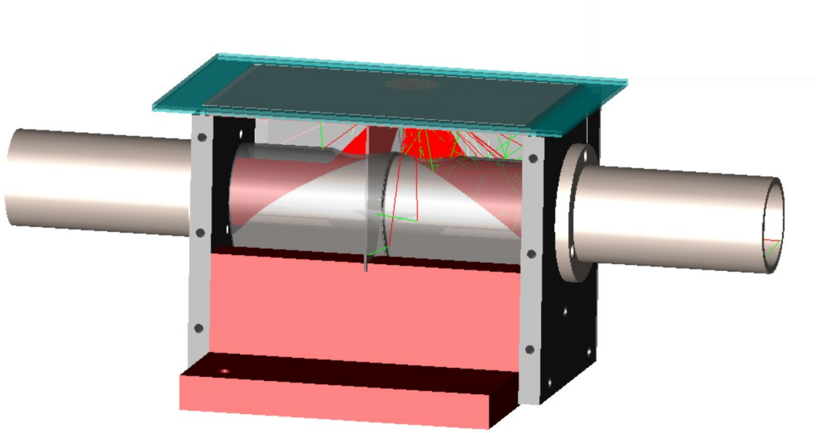
NIR and MIR measurement modules

NIR on-line transmission module



NIR on-line reflectance module

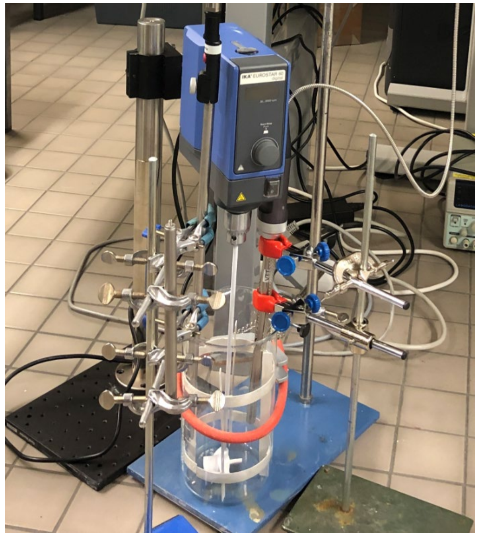
MIR on-line DRIFT module



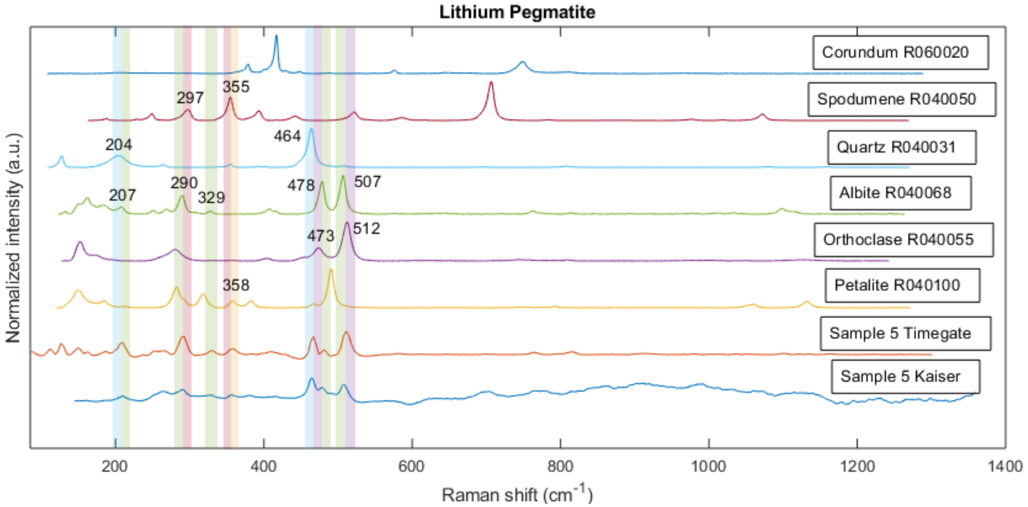
- **Problem:** Commercial high-performance measurement heads not available on the market
- **Solution:**
  - NIR on-line transmission module: Pass-line variation insensitive, high SNR
  - NIR on-line reflectance module: Pass-line variation insensitive, high SNR, low cost
  - MIR on-line diffuse reflection module: Effective specular reflection rejection

Raman spectroscopy for on-line mineral analysis

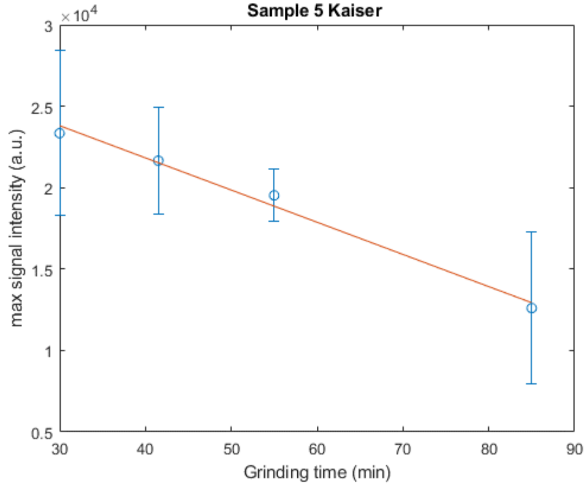
Laboratory measurement set-up



Raman spectra

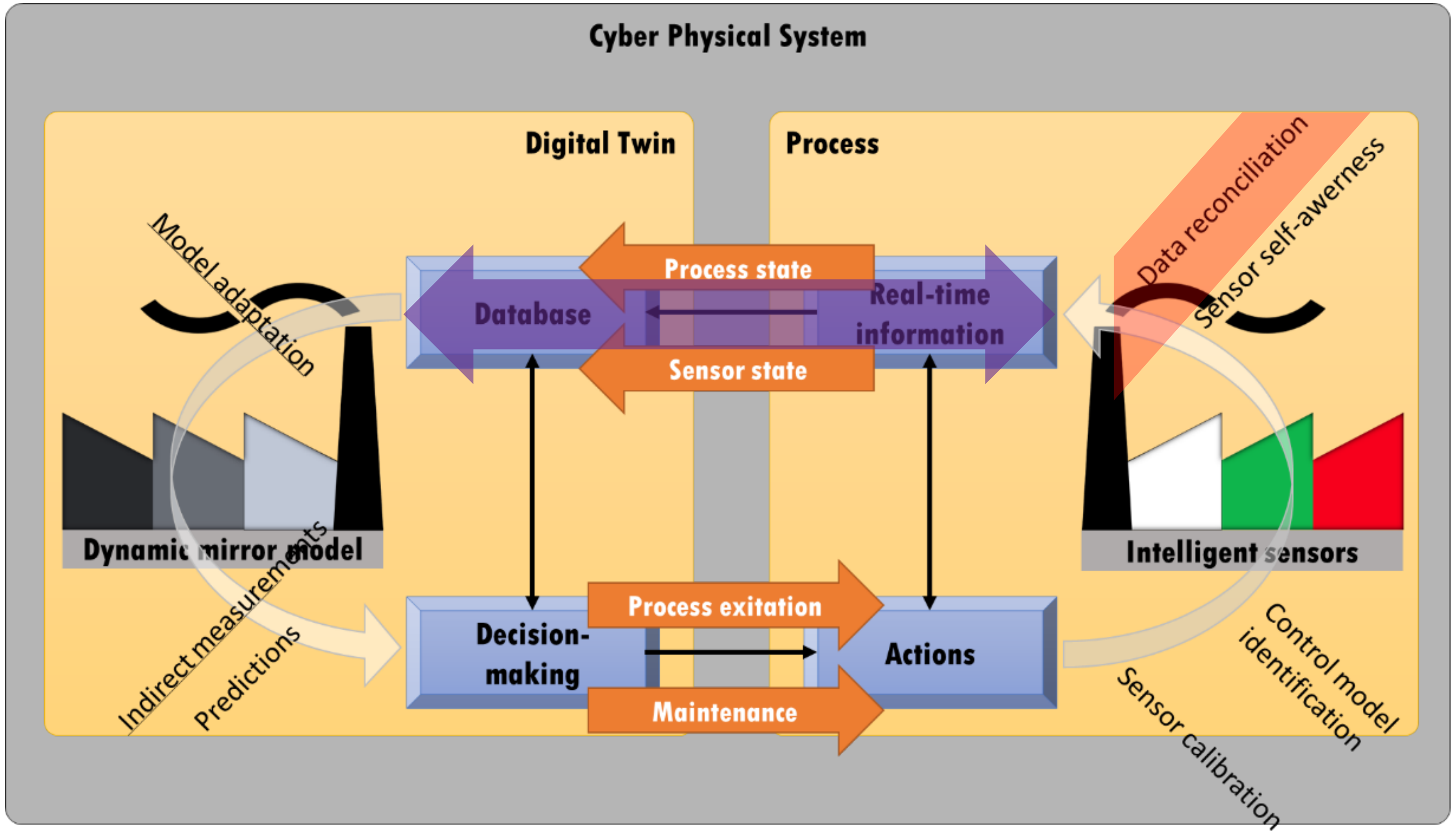


Effect of varying particle size



- **Problem:** Several challenges in Raman spectroscopy for on-line mineral analysis
- **Solution:**
  - Applicability of conventional Raman (Kaiser) and time-gated Raman (Timegate Instruments) for different ore types
  - Effect of varying particle size and solid content
  - Development of calibration models
  - ➔ Building blocks for on-line Raman spectroscopy

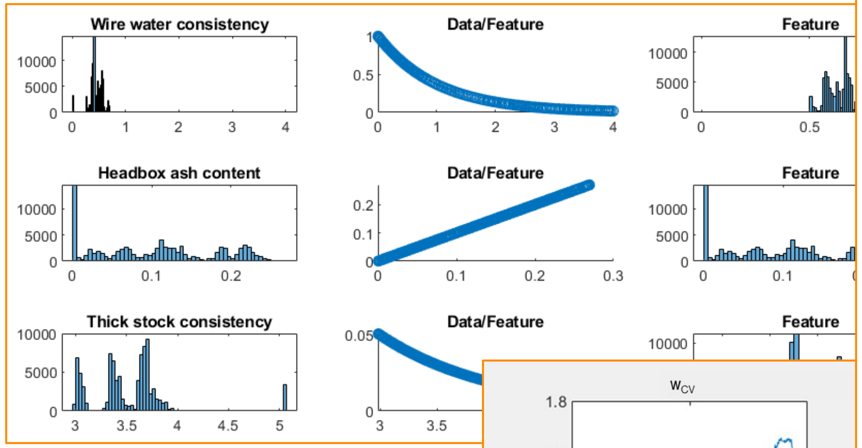
Intelligent, model-based measurements

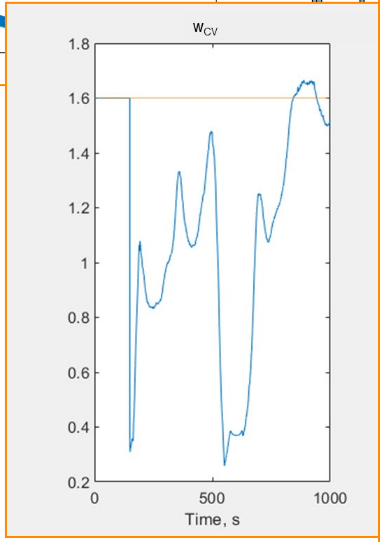


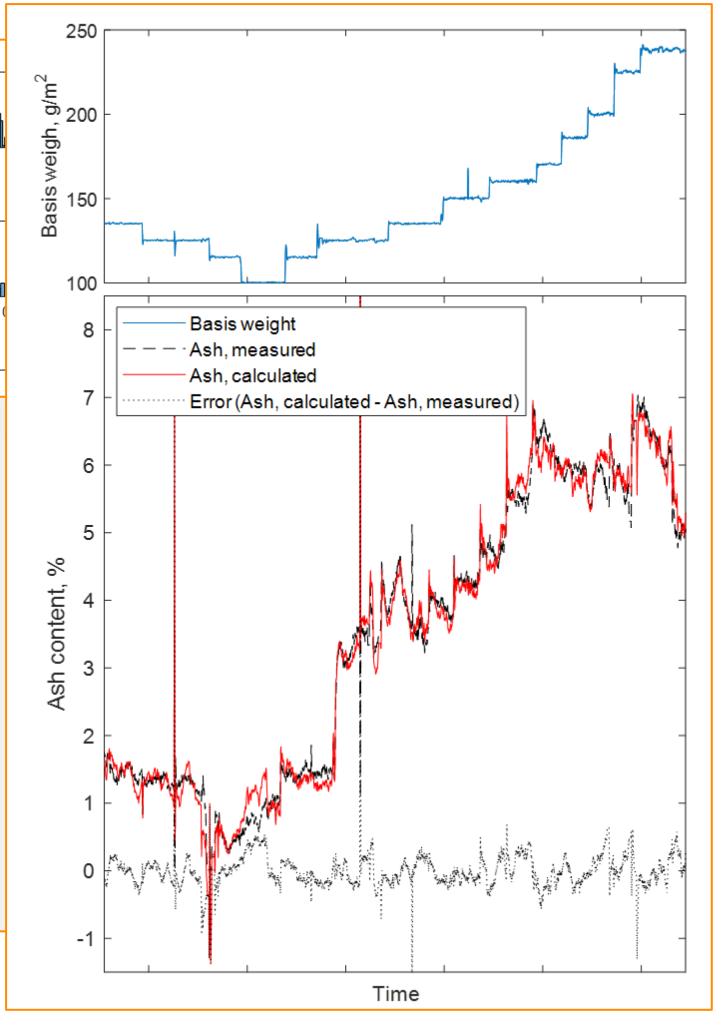
- ❑ **Data reconciliation to establish validation of the online measurements**
- ❑ **Model-based measurements derived from process data**
- ❑ **Estimation of the sensor and process state**
- ❑ **Adaptive tuning of model predictive controller**

Intelligent, model-based measurements

Successful validation of online ash content measurement in a range of paperboard grades using basis weight, moisture and fiber amount measurements







Learning-based methods in soft sensor development and MPC tuning

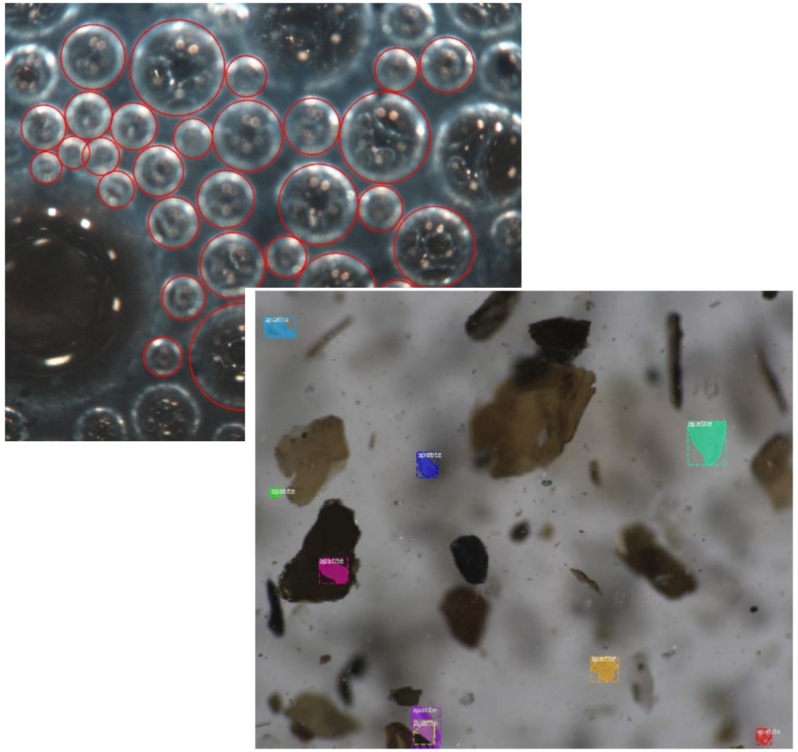
- Data reconciliation to establish validation of the online measurements
- Model-based measurements derived from process data
- Estimation of the sensor and process state
- Adaptive tuning of model predictive controller

Artificial Intelligence for future autonomous processes

AI assisted industrial measurements are key towards remotely operable or fully autonomous industrial processes of the future

Challenges

- AI techniques require a lot of annotated data. In industrial applications, the **amount of annotated data is limited**, and laborious to obtain.
- Industrial sensors and instruments need to be very **robust and reliable**. Therefore, an AI-enhanced instrument has to be **“self-aware”,** meaning that it must be able to assess the reliability of its data.



Example: Segmentation of transparent objects – eyes to the process

AI research in APASSI

- AI based techniques for sensor data analysis
- Application of **unsupervised and semi-supervised learning** methods in industrial setting to reduce the need for manual annotation
- AI techniques are applied to **selected use cases**, where automated calibration, uncertainty estimation and other sensor self-awareness functions are required

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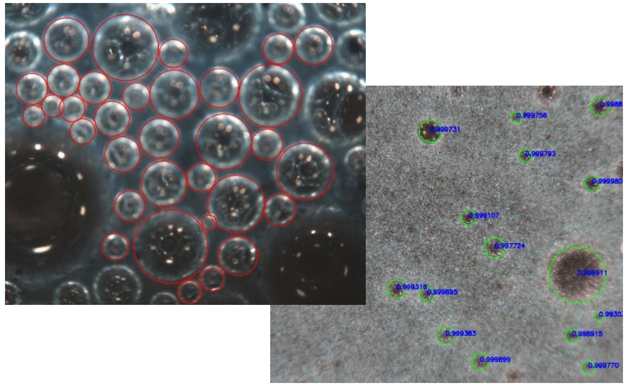
AI based techniques for sensor data analysis

AI-based techniques allow to optimize data analysis based on training data to calibrate a measurement device to be used during operation.

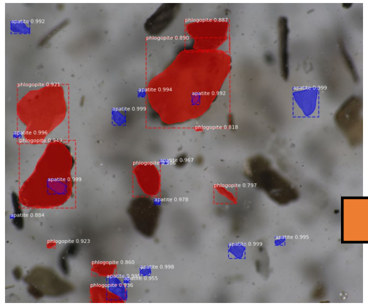
Flotation process monitoring

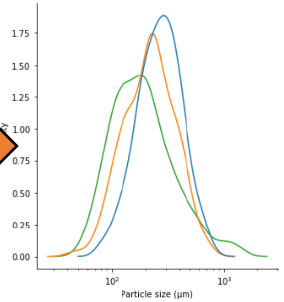
- One of the key parameters of flotation process is the bubble size distribution.
- AI based techniques were utilized for bubble detection and measurement based on bubble analyzer prototype (WP3)



Particle size estimation

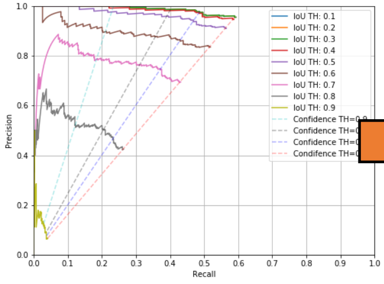
- Particle size distribution is a key parameter for flotation process and grinding circuit optimization.
- Challenging case with semitransparent particles was considered.
- Using instance segmentations enables the simultaneous monitoring of size distribution for different particle types



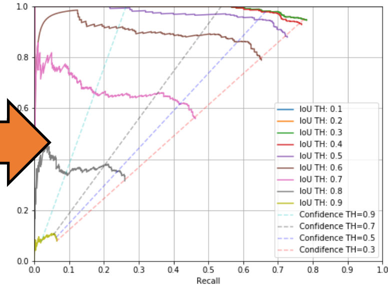


Semi-supervised learning

- In industrial applications, the amount of annotated data is often limited, and laborious to obtain.
- To reduce the manual annotation requirement, **unlabeled data was utilized to improve** the training with both bubble and particle data



Very small labelled training dataset



Unlabelled data included in training

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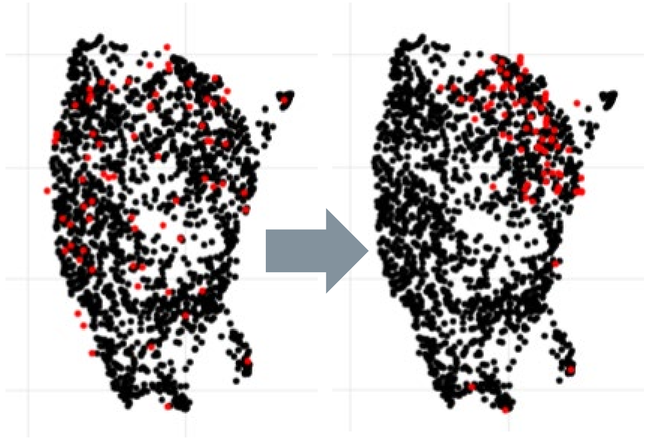
Self diagnostics and self calibration

During operations, the monitoring of the sensor performance and the maintenance of the measurements are of utmost importance.

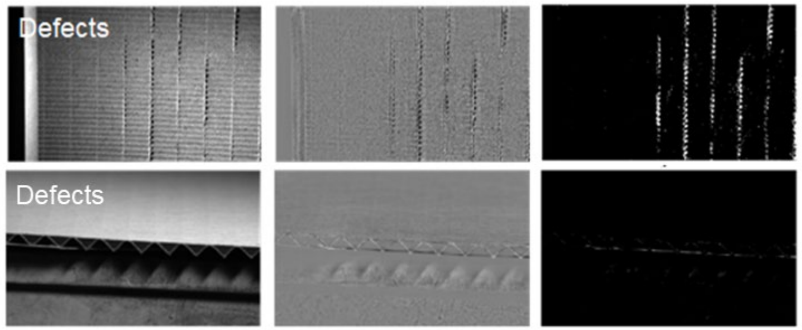
Unsupervised learning

- Changes in the measurement conditions can affect the reliability of measurements
- Dimension reduction allows to map the structure of measurement space to monitor the changes in measurement state



Anomaly detection

- Unsupervised learning was applied to detect anomalies from corrugate images
- A neural network based approach was developed to localize defects without providing defect labels in training.



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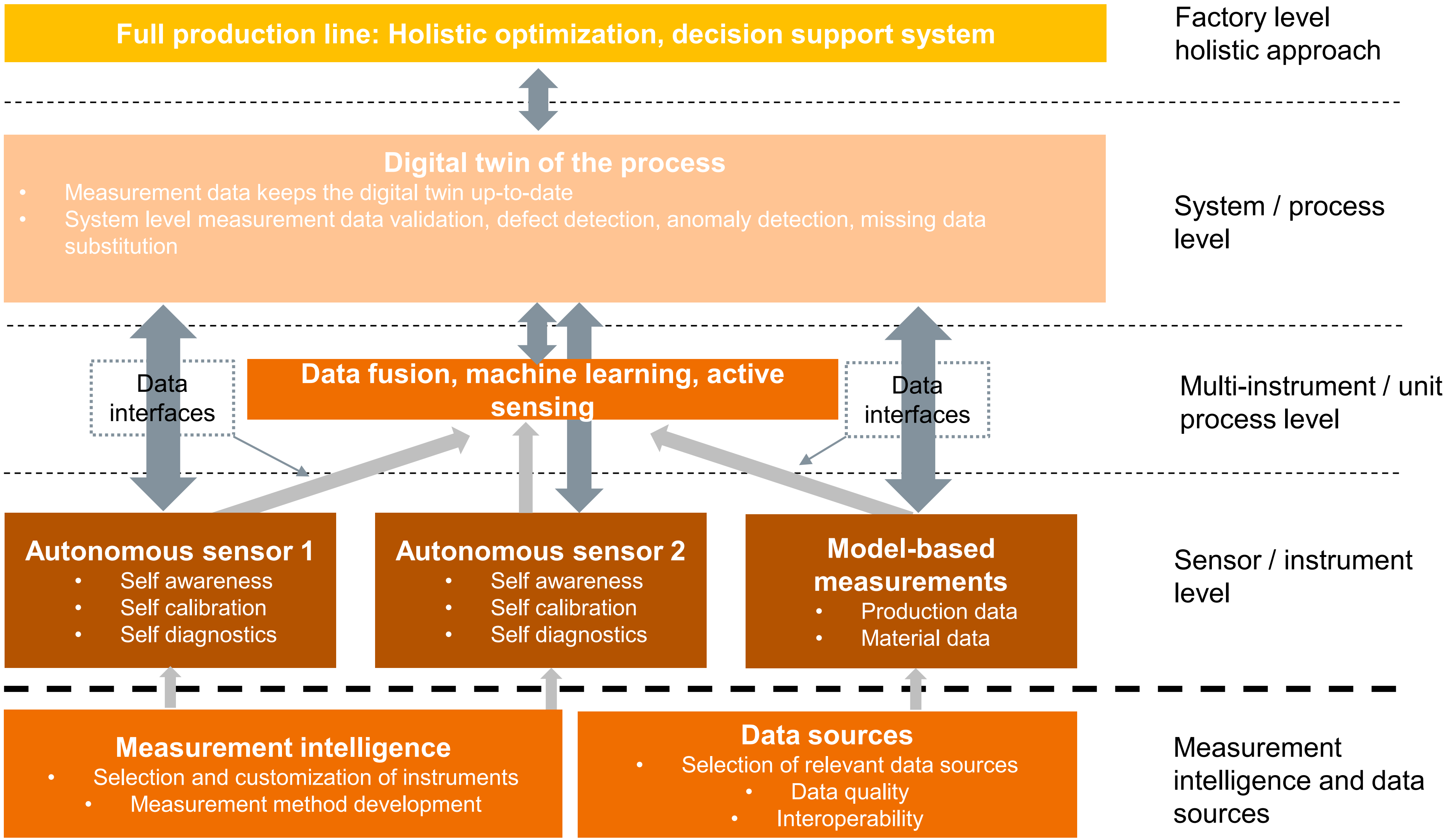
From measurement intelligence to digital twins and holistic optimization



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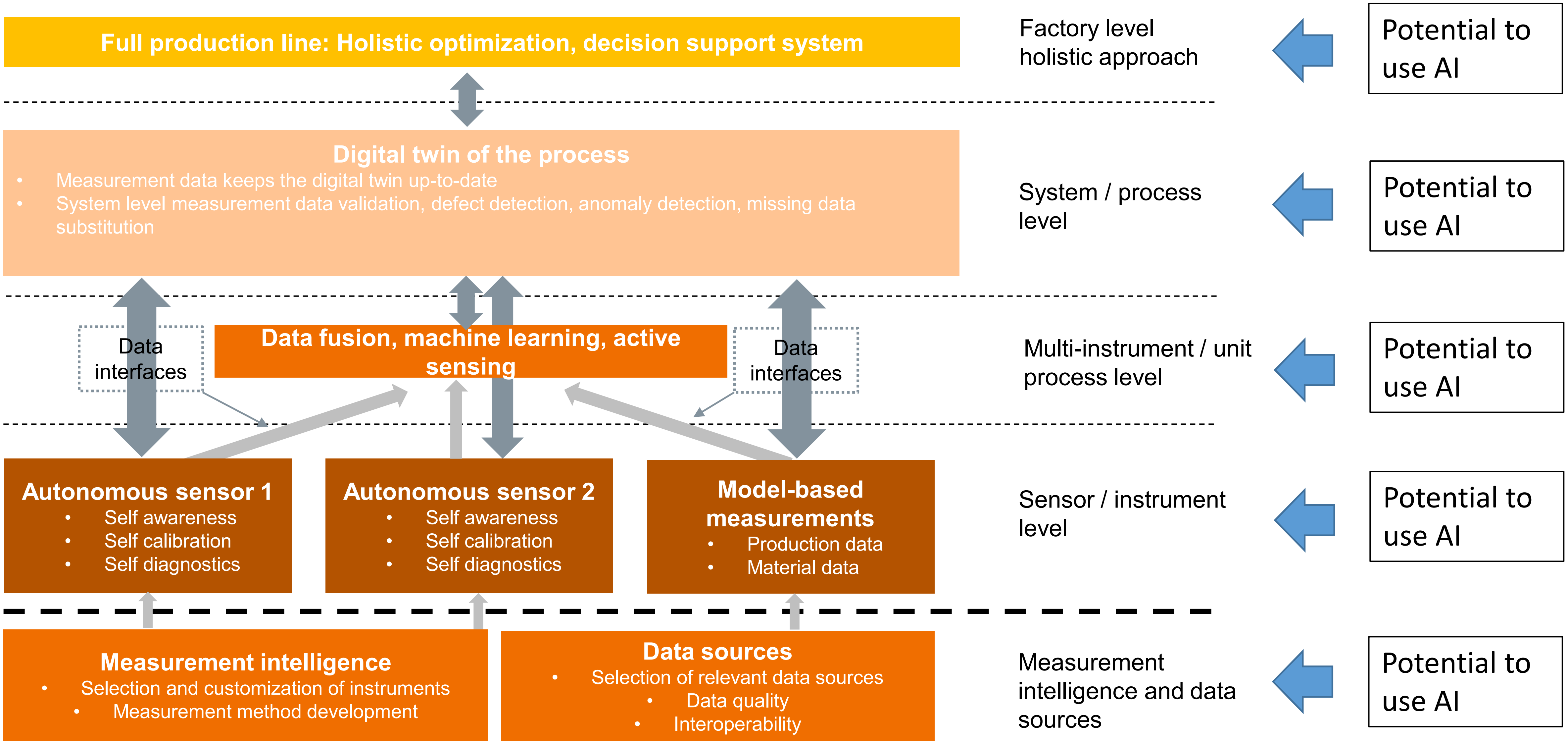

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Thank you for your attention!

www.apassi.fi

janne.paaso@vtt.fi