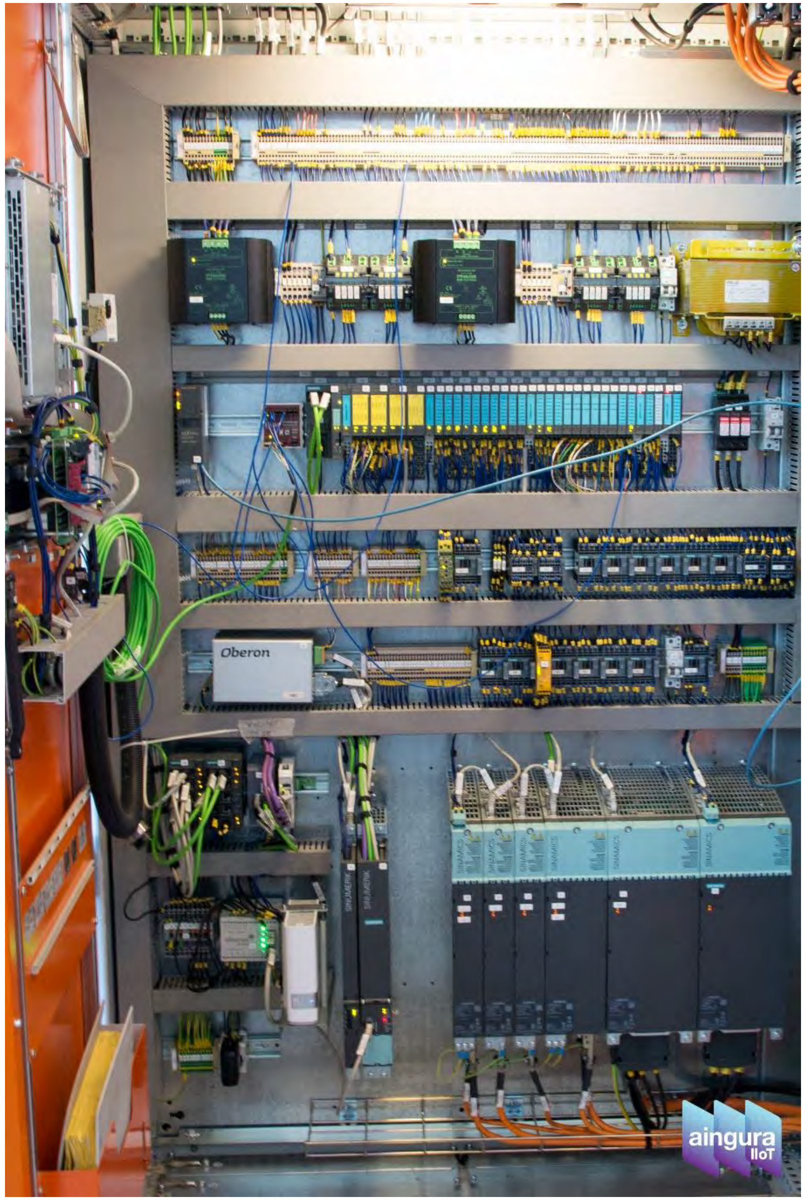
Actionable Insights Towards Competitiveness

Smart Manufacturing: Data-based actionable insights

Javier Diaz
IIoT Team Leader

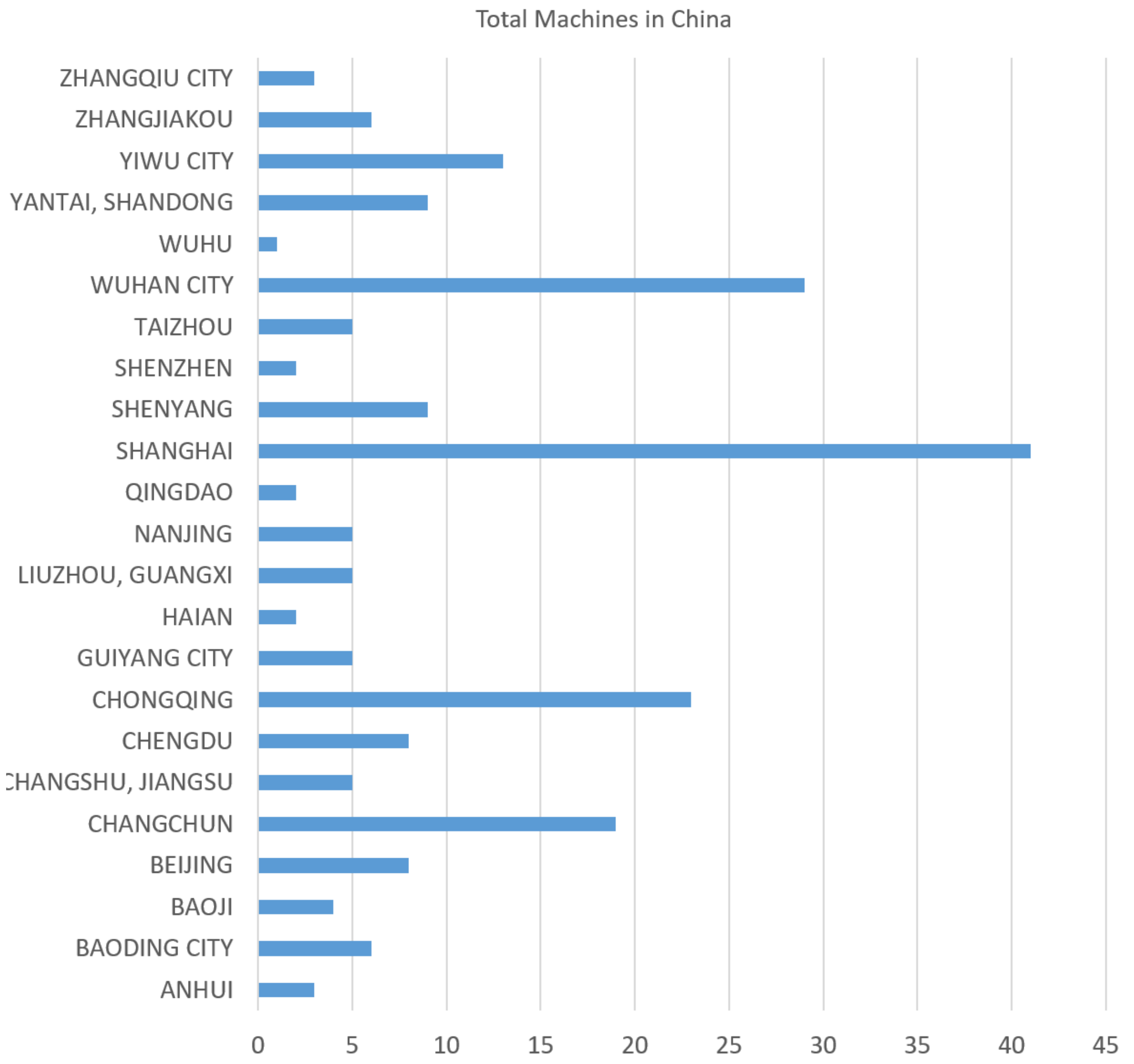
About Aingura IIoT



Our objective is to use data and domain knowledge to provide added value bringing competitiveness to the industry, at product and process level, through machine learning-based failure diagnosis, prognosis and energy efficiency actionable insights.

IIoT Use Case Example

Using IIoT to increase machine availability

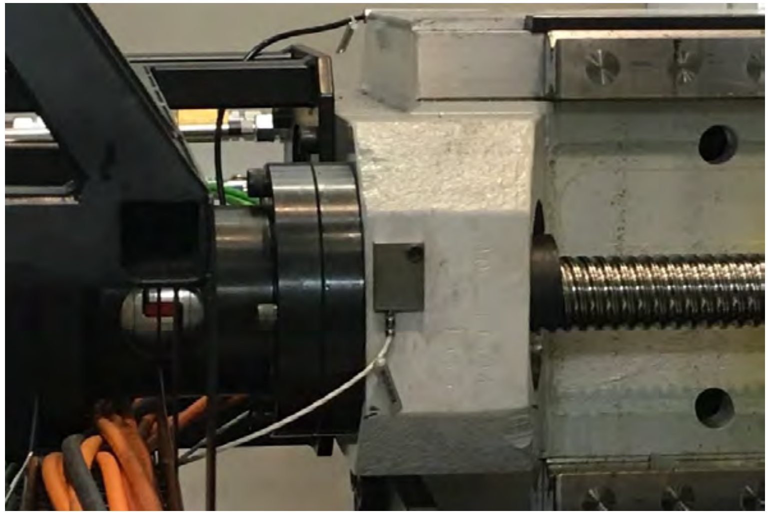


- **Chinese automotive OEMs**
  - More than 300 machines working
- **None of the above are performing the same operation**
- **However, all of them are looking to:**
  - minimize downtime
  - increase availability

Using IIoT to increase machine availability

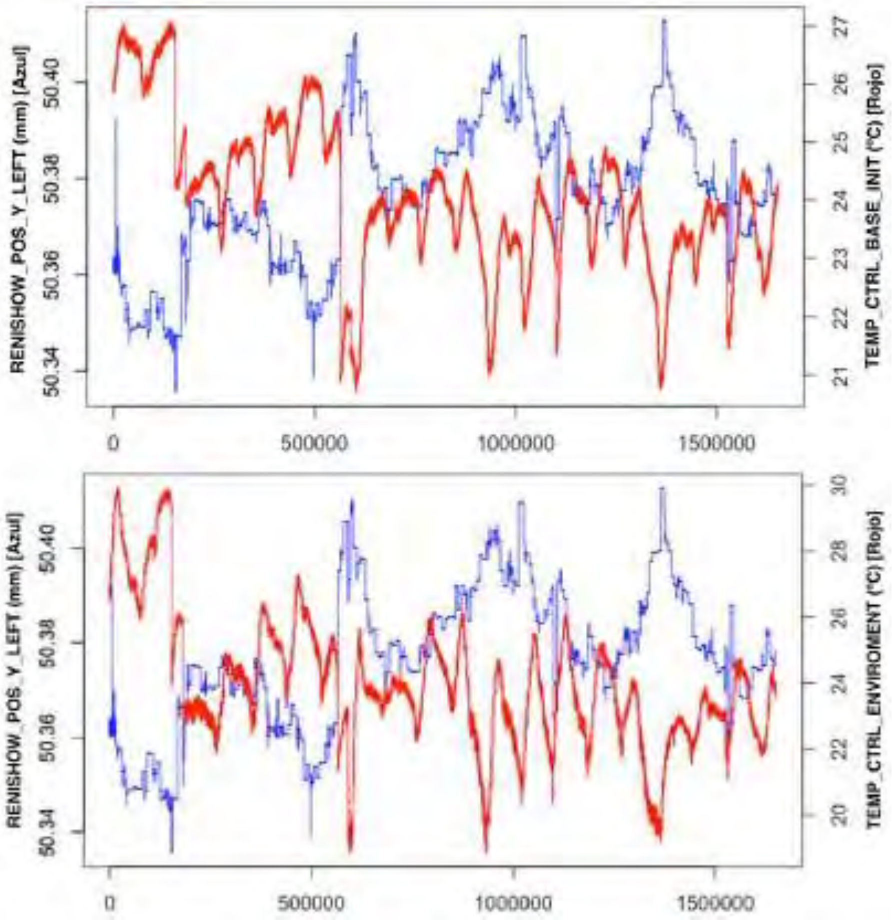
- **Product**
  - Powertrain crankshaft
- **Cycle time**
  - 60 seconds
- **Average production**
  - 1.000 parts/day
- **Required availability**
  - 95%
- **Problem**
  - Large temperature gradients within production facility
  - Reduced availability when machine stopped by low temperature
  - Loss of precision
  - Quality issues risk
  - Machine stop could be up to 2 hours per day
  - That is, more than 80 crankshafts not produced.
  - A stop machine can costs around $50k per hour

Using IIoT to increase machine availability



- **Sampling rate**
  - Probe measurement: 240s
  - Temperature: 80s
- **Number of variables**
  - 15
- **Main variables**
  - X and Y tooltip position,
  - 9 machine structure and fluids temperatures
  - Environment temperature.
- **Sampling time**
  - 12 months
- **Total dataset size**
  - 2.4 GB

Using IIoT to increase machine availability



- **Machine Learning application**
  - Feature subset selection
    - Select the most relevant variables (sensors) that has influence on the tooltip position
  - Multi-output regression
    - Find how variables influence on the tooltip position
    - Predict the tooltip position
    - Provide feedback to the compensation control at the CNC
- **Results:**
  - One part of the machine basement is the responsible for tooltip deviation
    - New machine materials are studied for further design improvement.
  - Compensation of the CNC system is improved by this model
- **Outcome:**
  - To provide better knowledge from the machine to the designers
    - Direct impact the machine design in terms of materials used and their specification
  - Dynamical compensation of machine-tool behavior during production
  - An increase crankshaft quality in terms of tolerance variation during thermal changes and machine availability.
  - An important increase in availability
    - Avoiding machine-tool stop until stable environmental temperature is reached.
  - Saved downtime costs up to $100k per day.

IIC Testbed:
Smart Factory Machine Learning for Predictive Maintenance

SFML Testbed

industrial internet CONSORTIUM

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SMART FACTORY MACHINE LEARNING FOR PREDICTIVE MAINTENANCE

SMART FACTORY MACHINE LEARNING FOR PM • TESTBEDS

Testbed in Action

CASE STUDY: VALUE OF PREDICTIVE MAINTENANCE

This case study exemplifies where Predictive Maintenance with Machine Learning would have avoided significant financial and production line delay in a high volume manufacturing system. Shortly after experiencing initial problems, an unknown degradation in system

FAST FACTS

MEMBER PARTICIPANTS:

Aingura IIoT, Xilinx

SUPPORTING COMPANIES INCLUDE:

aicas, Bosch Software Innovations, GlobalSign, Infineon Tec
Thingswise, Titanium Industrial Security, and XMP

MARKET SEGMENT:

Industrial Manufacturing

GOALS:

- Evaluate & validate Machi ... on high volume production machinery to deliver optimiz
- Achieve increased uptime & i ... utilizing Machine Learning techniques for advanced detection of system anomalies ... prior to failure.

CHALLENGE:

Today's methodology of Preventative Maintenance, taking machines offline on a regularly scheduled timeline is not cost efficient and does not necessarily ensure addressing the actual problems leading to system failure. Gaining accurate, actionable insight from the tremendous amount of data acquired in real-time, to understand key component anomalies during operation before system failure, for Predictive Maintenance is a daunting challenge. Furthermore, the root cause of over 80% of failures is not understood.

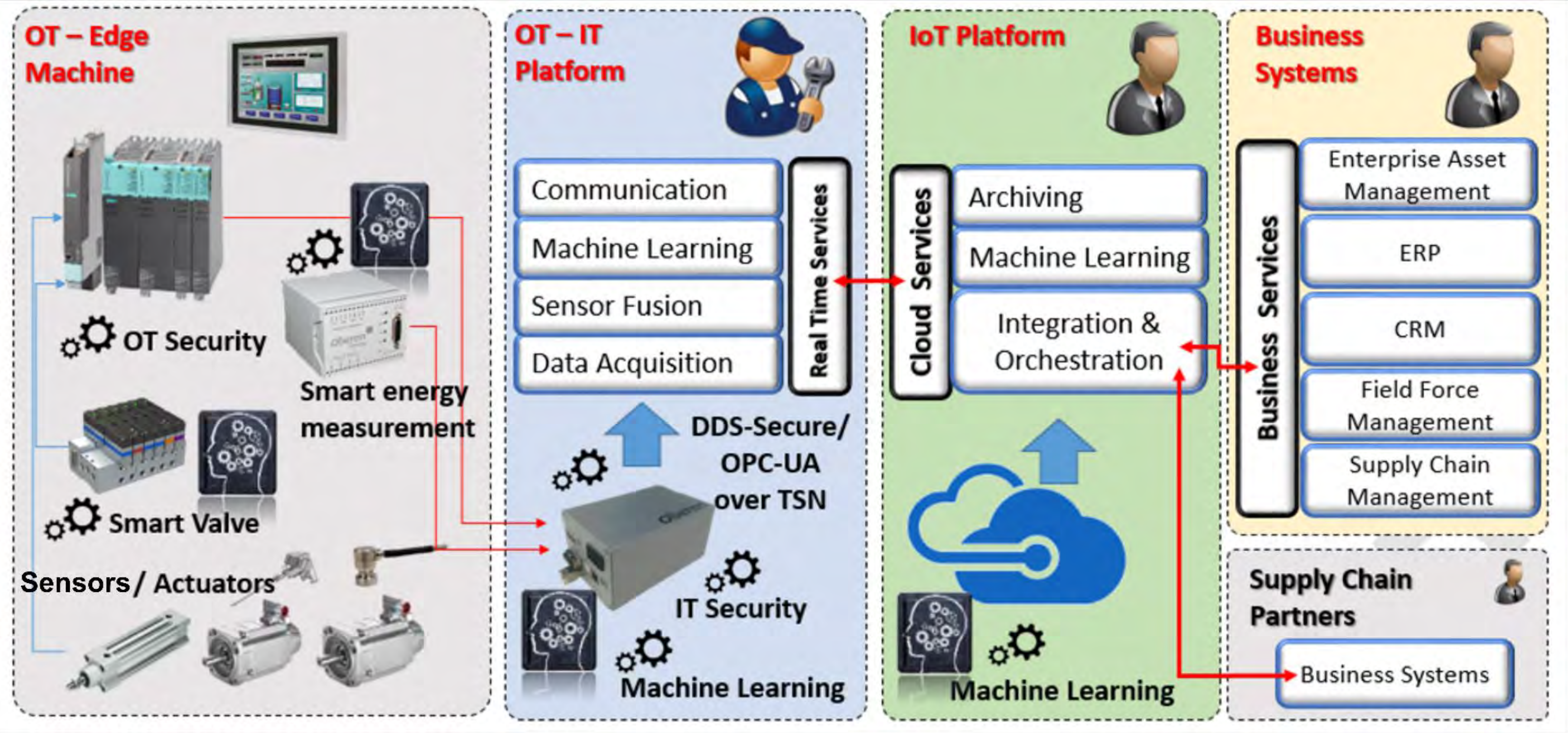
Industrial Internet Consortium Launches Smart Factory Machine Learning Testbed

NEEDHAM, Mass.--(Business Wire)--The Industrial Internet Consortium® (IIC™), the world's leading organization transforming business and society by accelerating the adoption of the Industrial Internet of Things (IIoT), today announced the Smart Factory Machine Learning Testbed

Sep 18, 2017 17:08 UTC

http://www.iiconsortium.org/smart-factory-machine-learning.htm

SFML Testbed

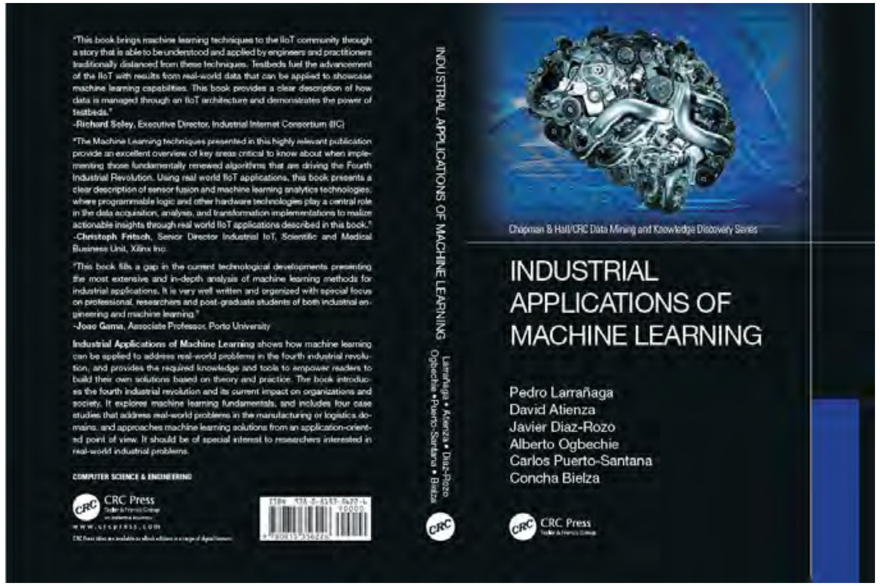


- **Phase 1: Lab Development and Test**
  Utilizes simulated data and degradation/fault conditions for ML exploration
- **Phase 2: Pilot Factory**
  Initial Deployment in limited production facility – Etxe-Tar
- **Phase 3: Production Facility**
  Deployment of ML and real-time analytics in Automotive OEM facility

- **Sponsors:**
  - Aingura IIoT
  - Xilinx
- **Supporting:**
  - Aicas,
  - Bosch Software Innovations,
  - GlobalSign,
  - Infineon Technologies,
  - iVeia,
  - Microsoft,
  - PFP Cybersecurity,
  - RTI,
  - Thingswise,
  - Titanium Industrial Security, and
  - XMPro

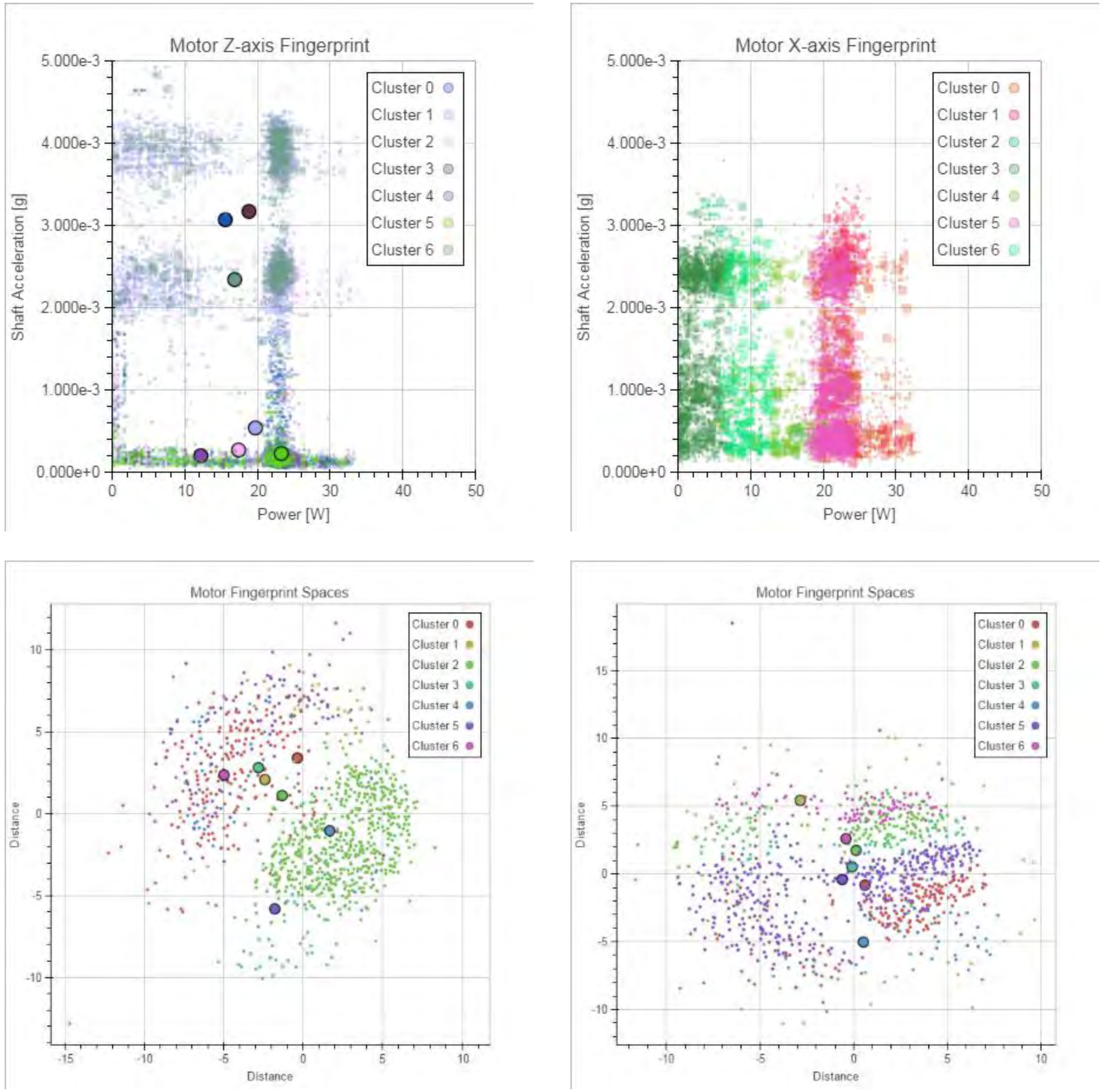
Preliminary Public Results

Industrial Applications of Machine Learning



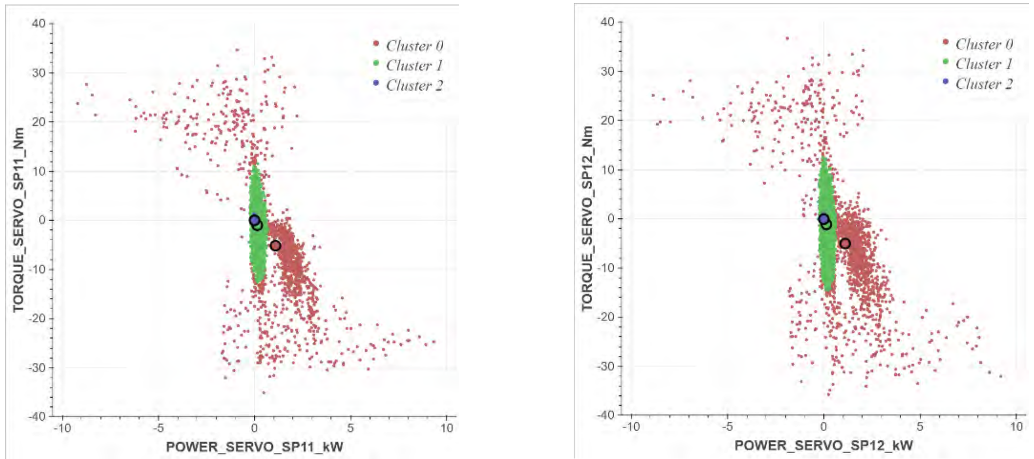
- **Book details:**
  - Title: "Industrial Applications of Machine Learning"
  - Series: Chapman & Hall/CRC Data Mining and Knowledge Discovery Series
  - ISBN 9780815356226 - CAT# K346412
  - CRC URL: https://goo.gl/psf3Xi
  - Table of Contents
    1. The Fourth Industrial Revolution
    2. Machine Learning
    3. Applications of Machine Learning in Industrial Sectors
    4. **Component-Level Case Study: Remaining Useful Life of Bearings**
    5. **Machine-Level Case Study: Fingerprint of Industrial Motors**
    6. Production-Level Case Study: Automated Visual Inspection of a Laser Process
    7. Distribution-Level Case Study: Forecasting of Air Freight Delays

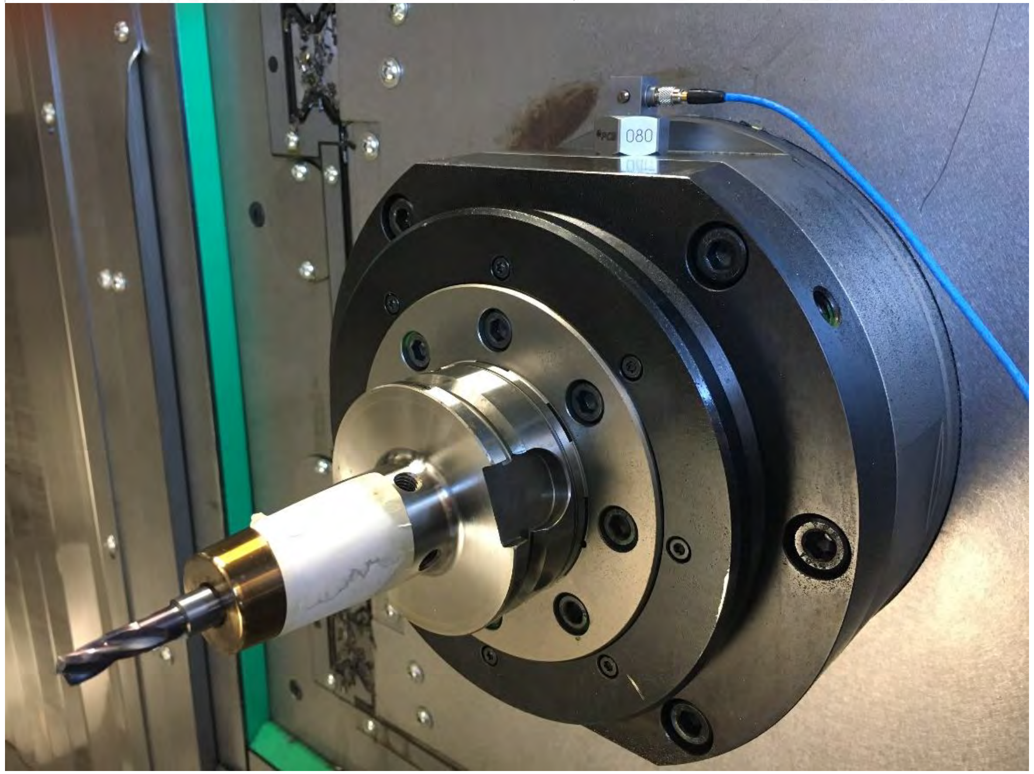
Industrial Applications of Machine Learning



- **Exploratory analysis**
  - Explore in the data without clear idea
  - For small amounts of data, conventional visualization methods
  - For large amounts of data, dimensional reduction
- **Example**
  - Real Application on machine tool
  - Performance analysis of 3 servomotors
  - 13 variables per servo
  - 5 different algorithms:
    - Agglomerative hierarchical clustering
    - K-means clustering
    - Spectral clustering
    - Affinity propagation clustering
    - Gaussian mixture model clustering

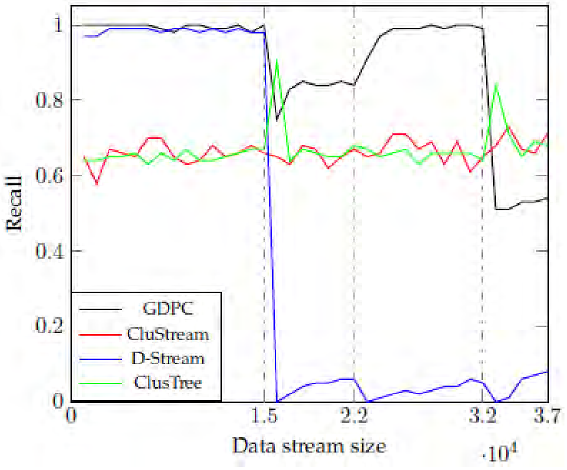
Knowledge discovery with real data

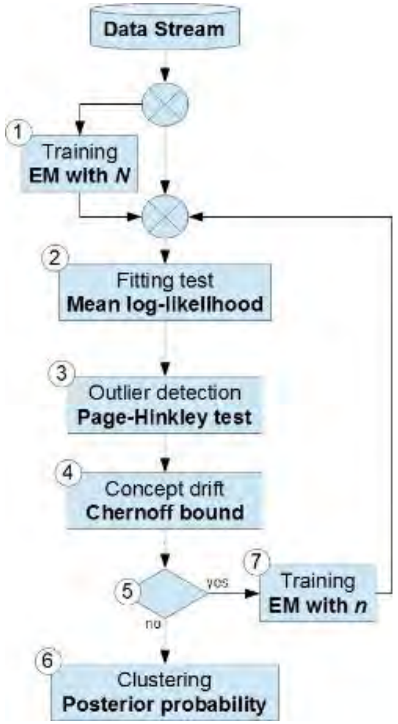




- **Testing 3 different clustering algorithms to find new knowledge**
  - K-Means, agglomerative hierarchical, Gaussian mixture model.
  - J. Diaz-Rozo, C. Bielza, and P. Larrañaga, “Machine learning-based CPS for clustering high throughput machining cycle conditions,” *Procedia Manufacturing*, vol. 10, pp. 997–1008, 2017.
- **Machine-tool for powertrain manufacturing**
  - Cycle time 60 seconds
  - Utilization over 95%
- **Spindle head – Key critical component**
  - Power 10 kW
  - Primary function: Material removal
- **Failure cost :**
  - Costs USD 30,000 up to 250,000
  - Repair time: 5 working shifts
  - Impact: 200 direct jobs
- **Understand Cluster Evolution:**
  - Cluster shapes (how the identified machining characteristics change over time)
  - Number of clusters (identify new machining characteristics).
- **Gaussian mixtures**
  - Provides new information about different states of the spindle

Gaussian-based Dynamic Probabilistic Clustering



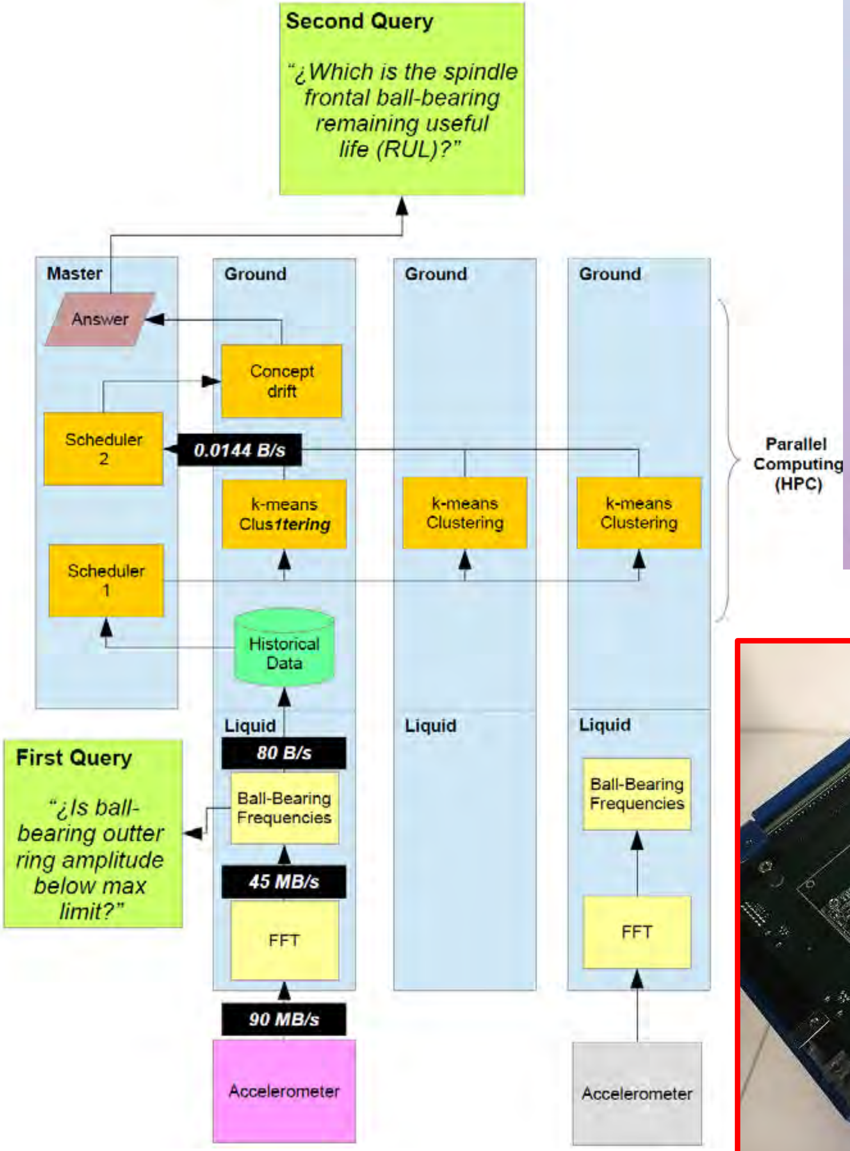


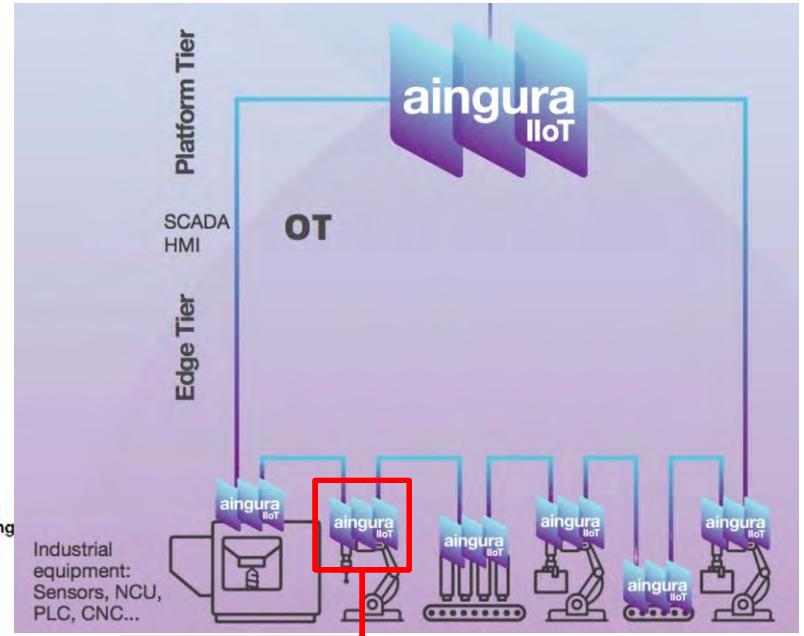
- **GDPC is an algorithm developed by Aingura IIoT to measure component degradation**
  - J. Diaz-Rozo, C. Bielza, and P. Larrañaga, "Clustering of Data Streams with Dynamic Gaussian Mixture Models. An IoT Application in Industrial Processes," IEEE Internet of Things Journal, 2018.
  - https://doi.org/10.1109/JIOT.2018.2840129
- **Data stream analytics**
  - Able to perform analytics in Real-Time
  - No need of data storage
  - Machine Learning at the edge
- **Update the learnt model once the component degrades**
  - Concept drift

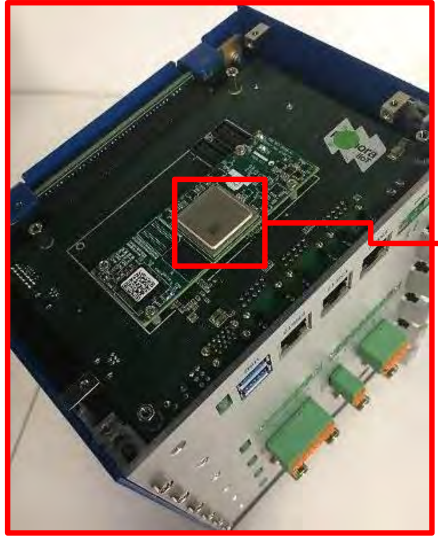
Edge Computing Node

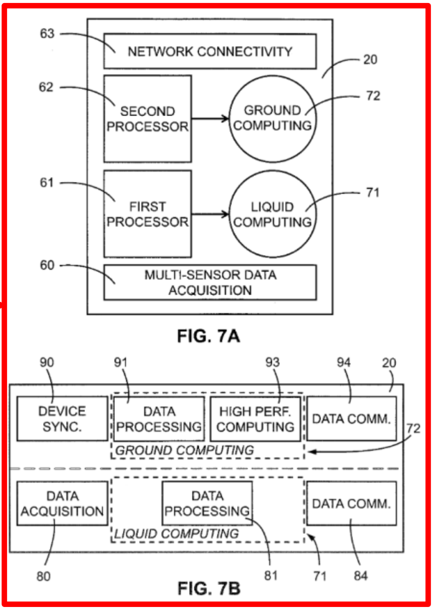
- **Integrated modules for:**
  - Analog sensors
  - High speed energy measurement
  - Vibration
  - Ethernet/switching
  - Storage
- **Powered by Xilinx MPSoC Ultrascale+**

Edge computing deployment









- **There could be a need for computing power at the edge**
  - Traditional computing devices not suitable for industrial environments
  - Large amounts of data to be pre-processed depending on application
  - Complex algorithms to solve specific questions
  - Extremely fast computing needs to provide actionable insights in Real-Time
- **Steps for industrial computing at the edge**

  US Patent 10031500B1

  "Device and system including multiple devices for supervision and control of machines in industrial installation"

Javier Diaz
IIoT Team Leader
jdiaz@ainguraiiot.com

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