Intelligent Information Management System for Decision Support: Application in a lift manufacturer's shop floor

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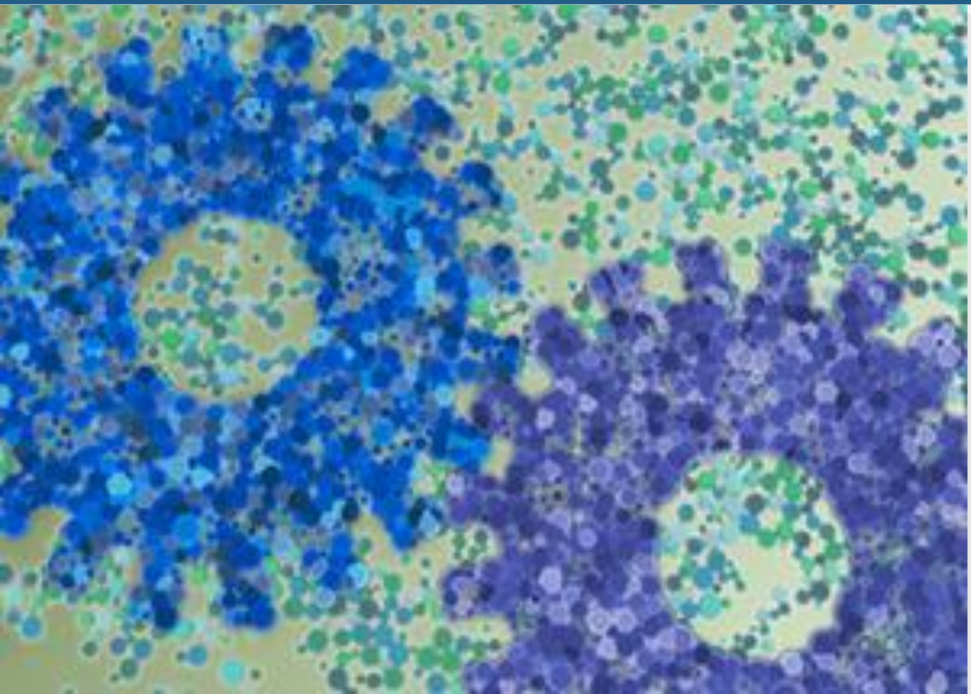

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COMPOSITION

Agenda

- Introduction
- Relevant work
- Data sources & IoT sensors
- Analysis of data
- Exploitation of data
- Maintenance decision support & fill level monitoring
- Conclusions

Introduction

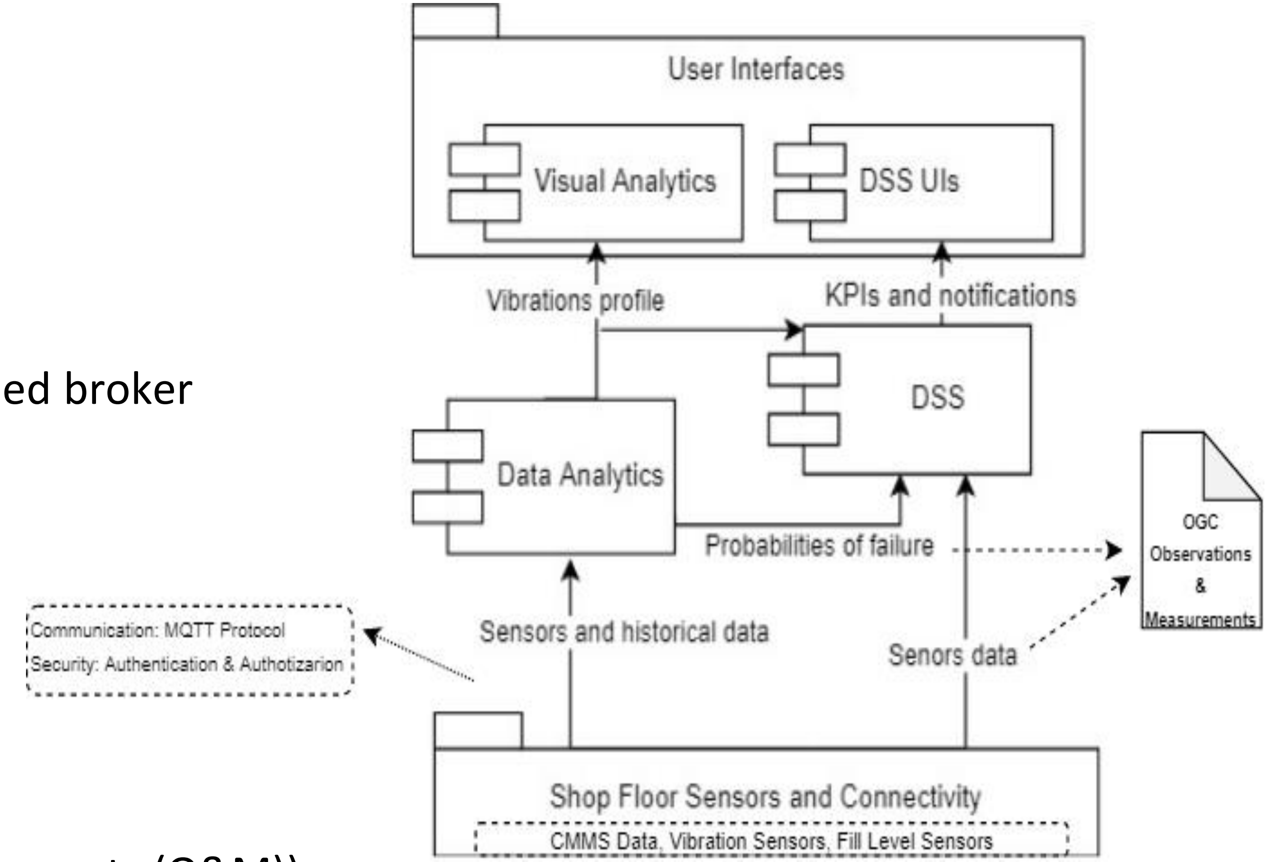
- **Lift manufacturer** application
- **Full shop floor cycle**
  - Production -> Scrap Metal Transportation
- **Data analysis**
  - Failure predictions
  - Scrap metal collection optimization
  - Bin fill level real – time notifications
  - Optimal routes suggestions
- **End to end process** in **one tool**

Relevant work

- **5Vs analysis –** Volume, Variety, Velocity, Validity, Value
- **Model optimization** in the **rule engine**
- **AI & ML algorithms for decision – making process**
  - automation
  - High complexity split by smaller autonomous agents.
- **Manufacturing DSS parameters represent:**
  - inputs
  - outputs

System Architecture

- **CMMS data**
- **Live data by deployed sensors for**
  - Polishing machine
  - Scrap metal
- **Data transmission protocols:**
  - MQTT protocol & a corresponded broker
  - HTTP

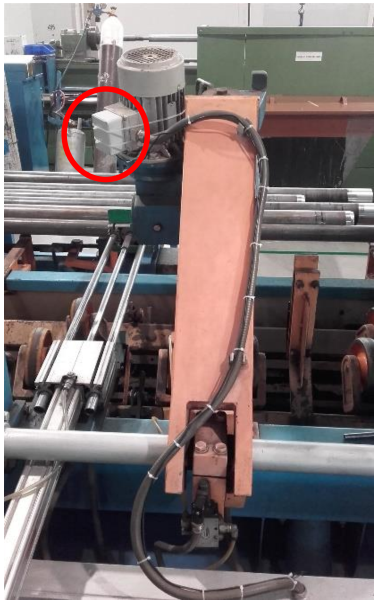


- **Data format**
  - OGC Observations and Measurements (O&M))
- **Security**
  - **authentication** & **authorization** services of the message broker

Data sources & IoT sensors

Predictive Maintenance

- **Vibration** sensors
- **Analytics and DSS connection *for monitoring and rule creation***
- Machine's **power supply / micro – USB wires**
- **Wi-Fi** communication



Smart transportation of scrap metals

- **Fill level sensors** deployed in scrap metal bins
- **Light sensors prototypes** used to enable the **fill level measurement,** enclosed in a **plastic case** & the complete sensor modules enclosed in **3d printed cases**
- DSS connection for **notifications** to empty bins
- **Batteries**
- **LoRa wireless network**.

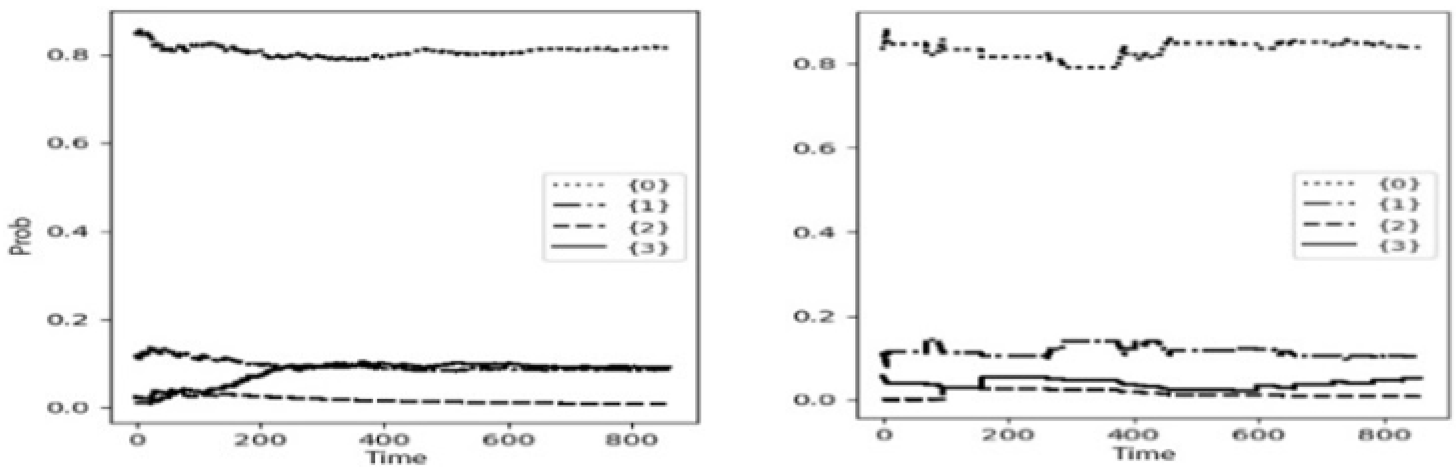
Analysis of data (1/3)

Probabilities model for machine predictive maintenance

- PDM based on the calculation of probabilities of an upcoming event based on no-fault scenarios prior to that event. 3 types of machine faults (labeled as: **{1} → electrical, {2} →hydraulic, {3} → mechanical, {0} -> no fault**
- **10 years range**
- 4 scenarios that point to **time ranges prior to that fault** where **no fault** was happened

- Scenario 1 (no-fault = 0.81, electrical = 0.09, hydraulic = 0.01 and mechanical = 0.09)
- Scenario 4 (no-fault = 0.84, electrical = 0.1, hydraulic = 0.01 and mechanical = 0.05)

Scenario 1 *Scenario 4*



Analysis of data (2/3)

Machine Vibrations Profile and Visual Analytics

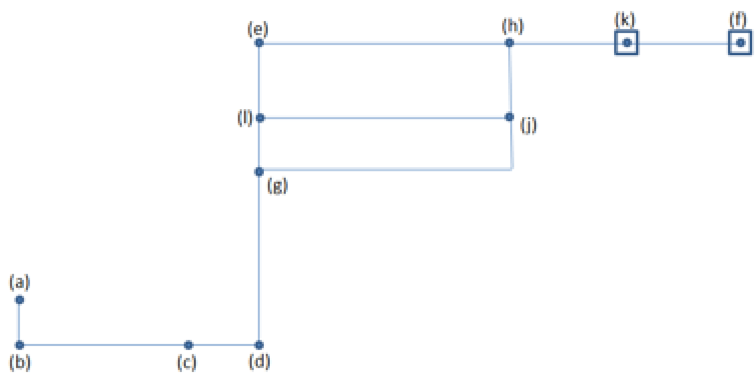
- Dynamic solution based on **real-time data**
- **Real-time detection** of **abnormal vibrations** (Machine Vibration Diagnosis Profile, MVDP)
- Detect the **time point(s)** when abnormal vibrations occur from the **profile of the eigenvalues sums**, where is the time of the recording, and the **calculated variance** in a sliding window of fixed size and step one, calculated from the vibration sensor recordings from the **three axis (x, y, z)**
- The basic assumption of MVDP is that **significant eigenvalue sums** with **simultaneous significant variations** could point out to **abnormal vibrations**
- Maintenance manager visually informed via the **Visual Analytics** when the machine's activity surpasses the abnormal vibration threshold.

Analysis of data (3/3)

Optimal route for scrap metal bins' transportation

- **Dijkstra's algorithm - >** optimal/shortest path
- **Triggered** -> bins' fill level > 80%
- **Graph theory** -> shortest path problem -> **finding a path between two nodes** in a graph where the **sum of the weights of its constituent edges is minimized**
- **Dijkstra's algorithm –> finds a shortest path tree from a single source node**, by building a set of nodes that have the **minimum distance from the source**
- **Scrap metal bins** placed on **(a), (c), (g), (j), open top containers** placed in nodes **(k), (f)**
- The **distance matrix** is the main input. After the application of proposed algorithm on distance matrix, the **optimal paths from scrap metal bins** to **scrap metal open top containers** are given.

Source node of pilot plant site



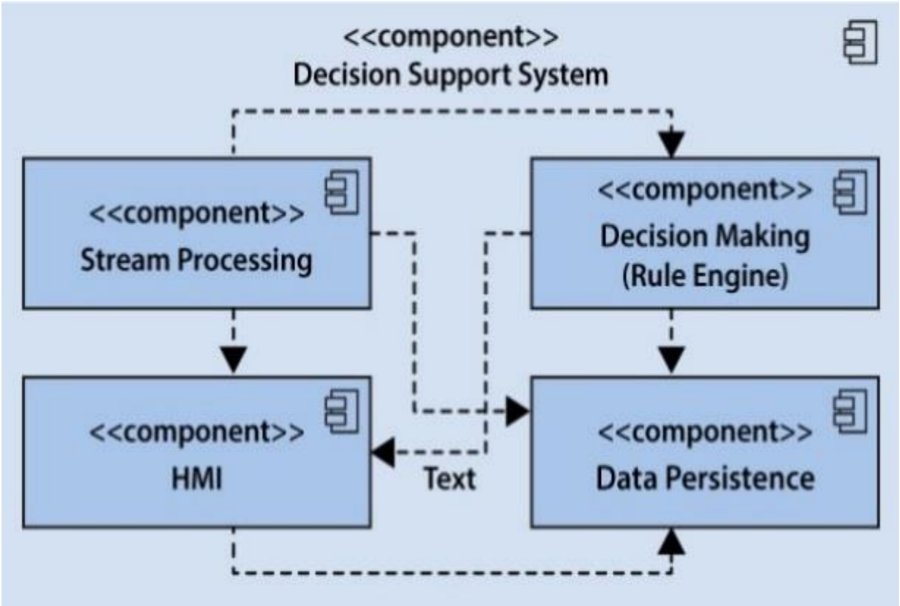
Optimal path (A to B)

Point A	Point B	Route
(a)	(f)	(a) → (b) → (d) → (e) → (f)
(c)	(f)	(c) → (d) → (e) → (f)
(g)	(k)	(g) → (e) → (k)
(j)	(k)	(j) → (h) → (k)

Exploitation of data (1/3)

Decision Support System

- **Model-driven** and **data-driven DSS -> consists of 4 main** sub-components
  - **Rule engine**
  - **Stream processing**
  - **Data persistence**
  - **HMI**

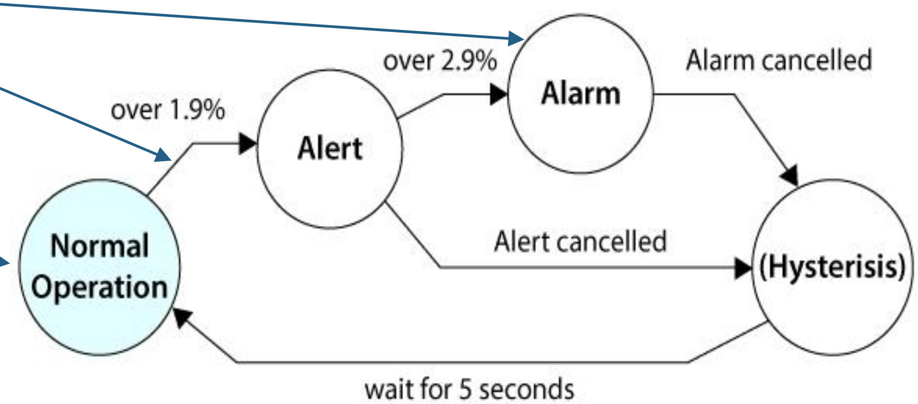


The Analytics tools provide the input data to the DSS in OGC O&M format via either HTTP or MQTT communication protocols.

Exploitation of data (2/3)

Finite state machine in the DSS

- Focused on **real – time** shop floor data training based on **computational models**
- Based on a tuple $\boldsymbol{D(Q, \Sigma, \delta, q0, F)}$ and the derived language
- **Vertices** are the states
- **Labelled arcs** are the **transitions** of the system
  - The arcs are made from **words** derived by the finite state machine alphabet
- The **initial state** is always the normal operation

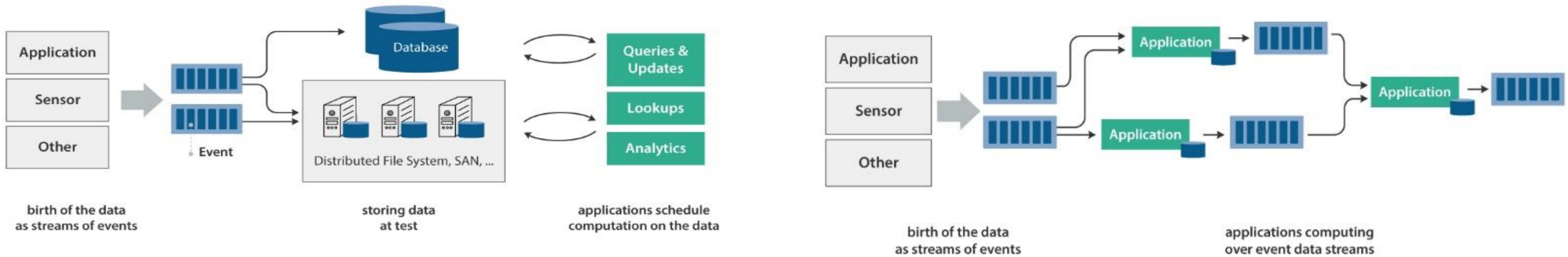


- **The alphabet** is the **conditions** for each state

Exploitation of data (3/3)

Data Streaming Process for the DSS

- **Stream processing** includes **continuous streams of data.** Suitable for mathematical analysis and simulations
- **Batch processing** provides data in batch format in **certain time intervals**
- Both processing techniques **timestamp** data at the **source**
- Timestamp is carried through data **acquisition, transformation and exploitation**



- The DSS uses:
  - **Stream processing** (used in **storage, analysis and training**)
  - **Batch processing** (used in the **data acquisition** from other components, based on MQTT and HTTP protocols)

Maintenance decision support & fill level monitoring

Predictive maintenance

- Piston production line -> **polishing machine** -> most **critical** -> requires **effective maintenance** to improve **availability**
  - **Probabilities** for the prediction electrical, hydraulic, mechanical failures and the **outcomes** of the **MVDP & VA** are **fed into the DSS**
  - Maintenance Manager sets **specific rules** in the **Rule Engine** & **prescribes** actions to be taken
  - Personnel at the shop floor receive **notifications & guidelines** for actions **via the DSS**

Scrap metal collection

- **Handling scrap metal** produced on shop floor. Collected in bins and its **removal is critical**
- **Early & automated detection** of scrap metal **fill levels** to **empty the bins before they get full**
- Forklift drivers pick up tens of scrap metal bins, transport the collected material to the open top containers to dispose the scrap metal. **Congestion** within the factory or **delays in other tasks**
- A **shortest path proposition** & a **timely notification** is needed. The scenario ends in the suggestion of **optimal routes** within the shop-floor.

Conclusions

Major contribution

- **IIMS** is applied, validated and demonstrated a **real-world setting**

Benefits

- **Real time condition monitoring & failure predictions estimation**
- **Real time notification to empty the bins along with fill level monitoring & optimal path calculation**
- Combination of **heterogeneous data** sources & **multiple data analysis** methods
- Development of the DSS **data streaming process** subcomponent
- Robust solution to support real-life situations

Advantages

- **General nature** & **transferability to other shop-floors** and **industrial use-cases**

Future Work

- Investigation of the **transfer & application** of the developed solutions to **other production processes & plants**

Thanks for your attention

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