iFE Material Handling

Lehrstuhl für Aufbereitung und Veredlung

i-STEP

A Case Study: Machine Learning Powered Condition Monitoring of a Linear Motion Industrial Vibrating Screen

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- Industrial Vibrating Screens – Black Box Model during Operation
- New Vibration Sensors
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Material Handling

We are worldwide the only manufacturer that offers tailor-made, complete solutions in the fields of **conveyor, screening and magnetic** technology.

Product Groups

Conveyor Technology

Screening Technology

Magnetic Technology

IFE TODAY

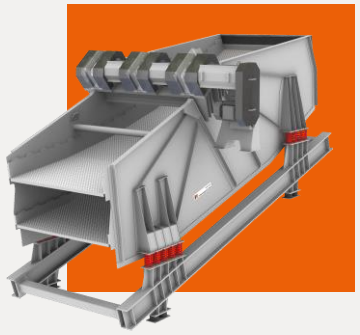
- privately owned
  owner & CEO Walter Scherzenlehner
- **115** employees (as of December 1, 2024)

Industrial Vibrating Screens

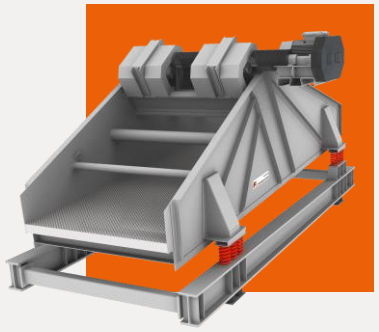
INDUSTRIAL VIBRATING SCREENS

- Extremely versatile and widespread use-cases in practically every mineral or waste processing plant
- Advantages:
  - Robust machines
  - High screening efficiencies
  - High throughput rates
  - High active time ratios
  - Long lifespans
- Numerous different designs available

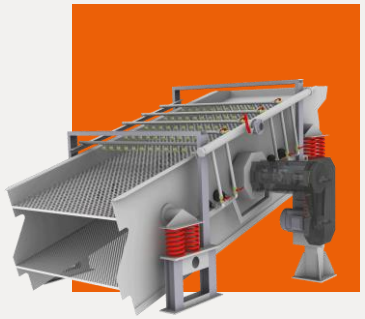
Source [1]



Banana Screen



Linear Motion Vibrating Screen



Circular Motion Vibrating Screen

Waste Screen

Flip Flop Screen

Common uncertainties during industrial vibrating screen operation

- True state of the screen unclear:
  - Is the machine operating in optimal condition?
  - Is the current throughput efficient, too high or too low?
  - Are there damaged or loosened parts?
- True vibration pattern unknown – not measured
- Maintenance for vibrating screens is usually based on experience and not on the real wear of machine parts

Why?

→ **Vibrating Screens are most often not equipped with precise condition monitoring!**

Source [2-4]

- For other Machinery, e.g. Crushers, Mills, Pumps currently available Condition Monitoring Systems usually involve:
  - Monitoring of **bearing vibration** → expensive system → no information about screen vibration → engine itself is a vibrating part
  - Monitoring of **oil-quality** → only secondary insight into machine condition → slow reaction time
  - Monitoring of **energy consumption** → only secondary insight into machine condition → some issues don´t affect energy intake

→ Potentials for Optimization by **new Condition Monitoring System** that **directly monitors the vibration** driving the screening process

Source [5-7]

i-STEP WORKBENCH

SMART VIBRATION SENSORS

New specifically developed **smart sensor** to measure the oscillation of any vibrating screen

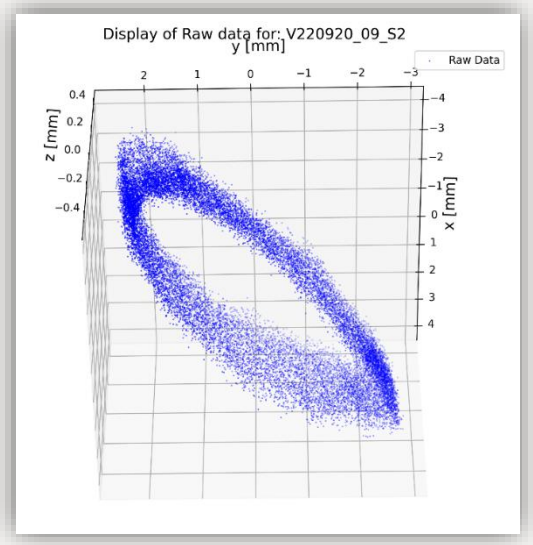
- **SMS – battery powered version**
  - Main use for maintenance workers via **i-STEP Vibrosense Smartphone App**
  - For quick analysis of vibrating machines
  - For operation in industrial areas (IP67)
  - 1 sensor with possible multiple measurement points
  - Simply to mount on any vibration machine with included magnets

i-STEP VIBROSENSE

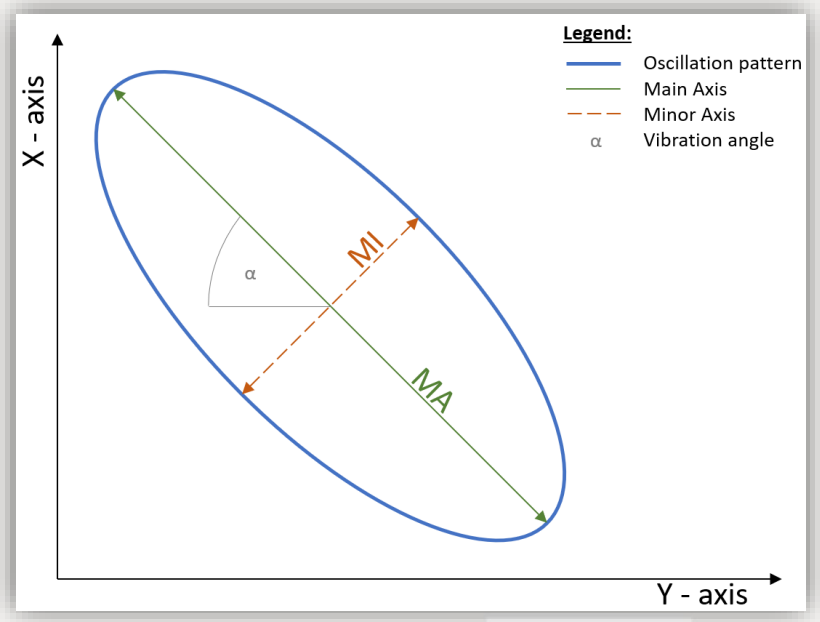
- **SES – wired version**
  - Main use for permanent monitoring combined with **i-STEP Workbench**
  - Condition monitoring and asset management
  - 2-6 sensors on each machine recommended
  - Retrofitting to any vibration machine possible

i-STEP WORKBENCH

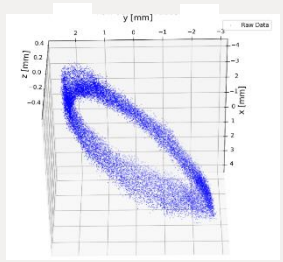
- Sensor measures accelerations in 3D
  - → Converts into displacements
  - → Fits ellipse in point cloud (FFT)
- Computes main, minor axis and angle of the vibration ellipse as well as the vibration frequency
- Substantial reduction of data → sending to cloud → long-term analysis

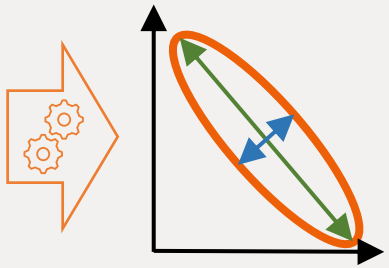


Fitting



Source [8-10]





Significantly reducing the amount of data for storage

Smart Edge Sensors

Cloud

ML-Algorithms

Identification of Condition states

Characterize and predict the onset of errors

Provide process relevant information

Vibrating Screen

Monitoring, Maintenance, Plant Statistics, Customer Support …

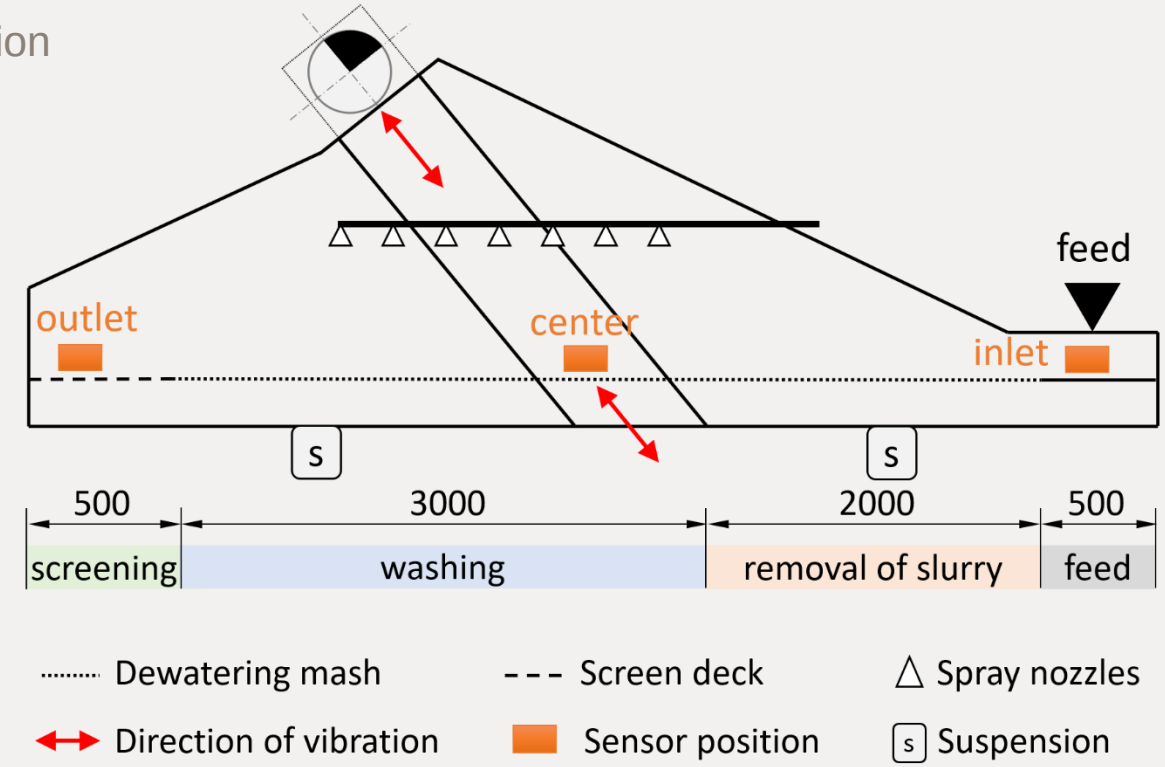
adapted from [9]

Case Study

Based on the recent Peer Review Article in IEEE Sensors Journal [10]

Identification of Condition States

- Screen located after heavy media density separation
- Used for dewatering and screening
  → 4 condition states can be identified:
  (0. Off)
  1. Idle state → operational without any load
  2. Slurry state → operational with only slurry as input
  3. Regular state → operational with slurry and particles as feed
- Manually distinguishable states, based on:
  - Data of belt-weigher (plant feed)
  - Slurry pump (density separation step)



Collected Dataset

- Condition State →1 Target variable
- 6 Sensors x 3 Axis values →18 Input features
- Around 9000 data points

Source [9]

Why Machine Learning

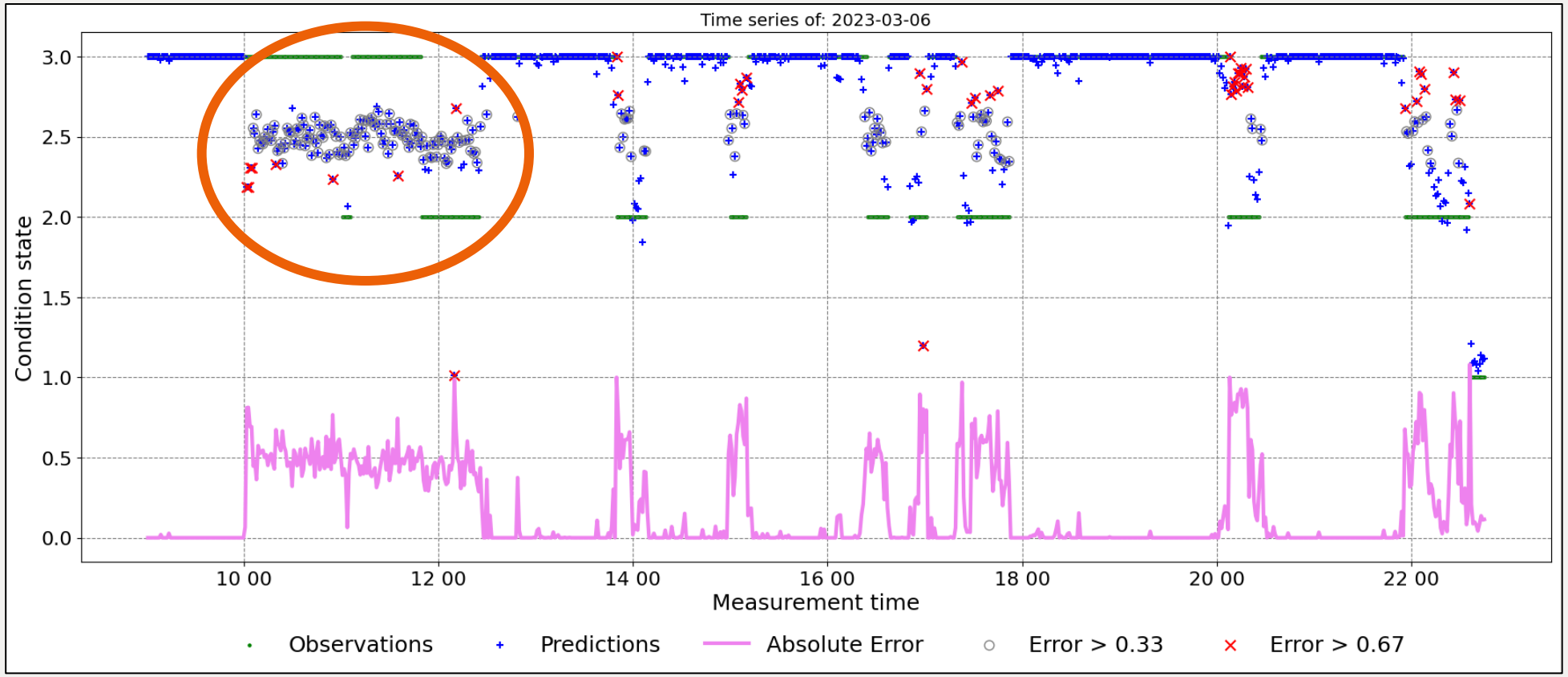
- 18 input features → difficult to interpret for humans
- Different feed material → different effects on the vibration pattern
- Fluctuating values results → fixed threshold values provide low quality prediction

→ Machine Learning Model

- has to distinguish between the Condition States
- has to outperform a rule-based Expert System

CASE STUDY – LINEAR MOTION VIBRATING SCREEN

- During modelling with Multi-Layer-Perceptron (MLP) regressor, results exhibiting a prediction **error of between 0.33 and 0.67** seemed to occur frequently at certain times



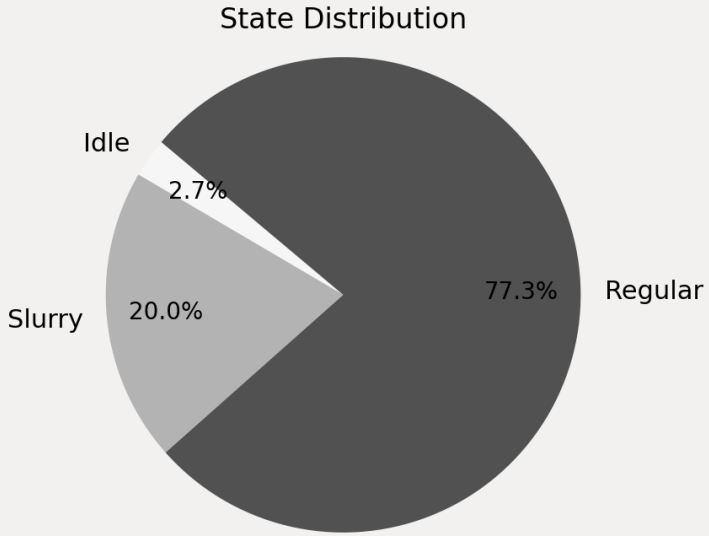
→ **termed “intermediate states”**

→ **Cluster around times of screen cleaning**

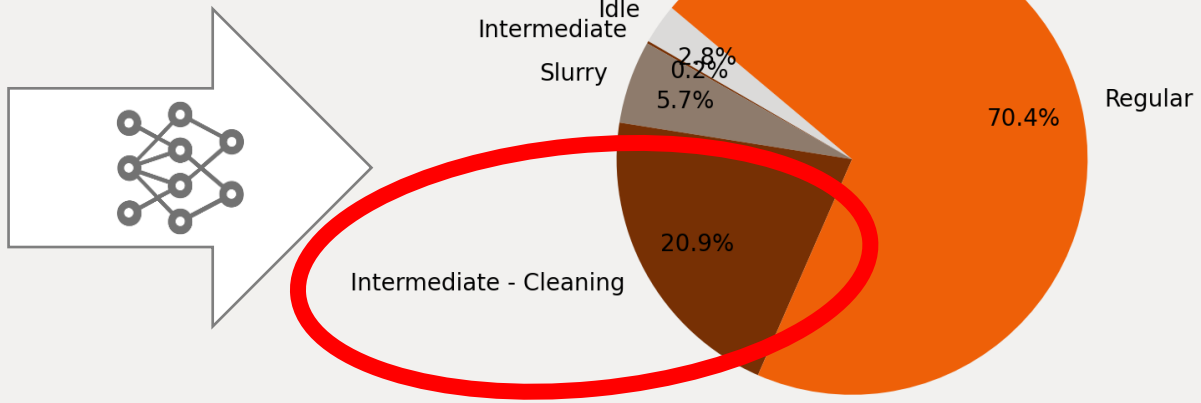
Prediction of condition states by Multi-Layer-Perceptron

- Pre-defined condition states were identified by MLP classifier with **prediction accuracy of ~ 93%**
  → Percentage of **false classifications ~ 6%**
- By introducing **intermediate states** with MLP regressor, the number of **false classifications** was reduced **to ~ 3%**
- **Analysis revealed: ~ 21% of the screen´s operation time is actually attributable to screen cleaning**

→ Major optimization potential identified



Distribution of recorded condition states based on manually attributed labels



Distribution of recorded condition states based on MLP regressor predictions

Summary

- IFE´s Software application for
  - Condition Monitoring
  - Predictive Maintenance
  - Plant Optimization
  - Extended customer support

- Possibility of including all necessary types of sensors to accurately monitor various machines
- Adaptable to all types of IFE machines and beyond
- Adaptable interface to specifically suit the needs of plant managers

- **Possibility of retrofitting to existing processing machinery**

- Sensor data usable as a basis for Machine Learning models
  → specifically trained to suit the needs of plant operators

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