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Industrial AI

Deep Learning for
Predictive Maintenance, Predictive Quality &
Visual Inspection

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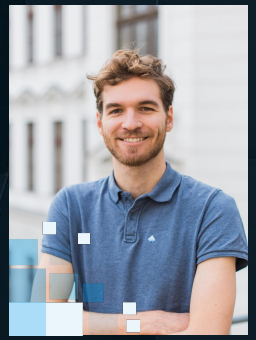
We develop prize-winning
Industrial AI



Daniel Ressi

Data Scientist @ craftworks

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Who is craftworks ?

17 Team members

Machine Learning

Biomedical Engineering

User Experience

Software Engineering

Physics

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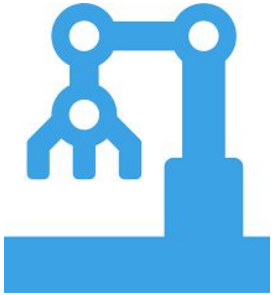
We develop prize-winning

Industrial AI

Industrial AI

Special Challenges require a Special Set of Methods



Industrial Challenges

Artificial Intelligence

"Application of machine and deep learning methods to solve industrial challenges"

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Selection of our Clients

Predictive Quality

MAHLE

Predictive Analytics

ÖBB

Predictive Analytics

ANDRITZ

Predictive Quality

Wienerberger

Predictive Quality

A1

Software Solution

Post

Computer Vision

PORSCHE INFORMATIK

Big Data Infrastructure

WIEN ENERGIE

Predictive Maintenance

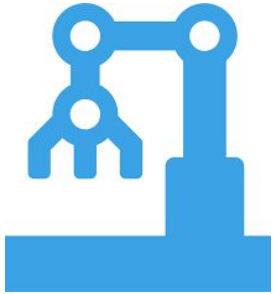
VKW Vorarlberger Kraftwerke AG

Predictive Maintenance

Industrial AI

Characteristics

- **Data**
  - High-frequency
  - Big Data
  - Lack of Standardization
  - Imbalanced Classes
- **Algorithms**
  - No off-the-shelf solutions
  - Reliability Requirements
  - Interpretability



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Deep Learning for Predictive Maintenance, Predictive Quality & Visual Inspection

1. Predictive Maintenance
2. Visual Inspection
3. Predictive Quality

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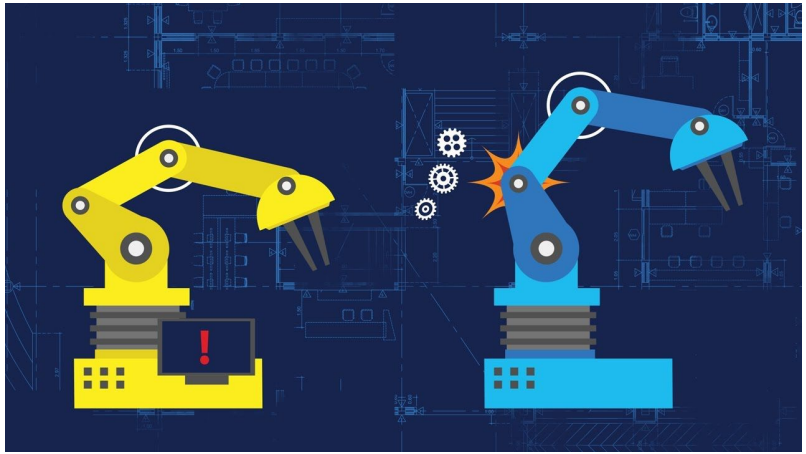
Predictive Maintenance

Predictive Maintenance

What is it?

*"Predict and forecast the **condition of machines** to plan maintenance ahead of time"*



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Predictive Maintenance

Predictive Maintenance

Why?

- **Machine Faults/Breakdowns**
  - Can stop whole production
  - High repair costs
  - Safety risk

- **Predictive Maintenance**
  1. Machine health forecast
  2. Planned maintenance schedules
  3. Cost and time efficient work

Proactive

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Predictive Maintenance

Data

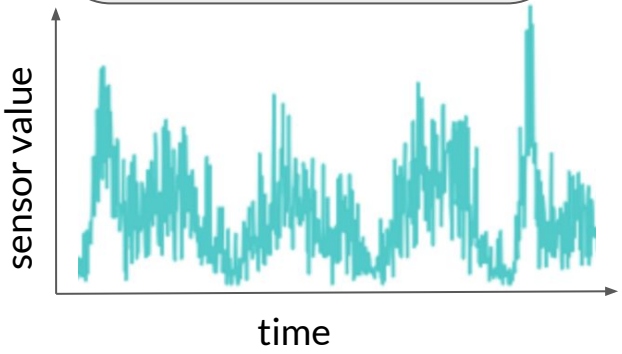
Sensors

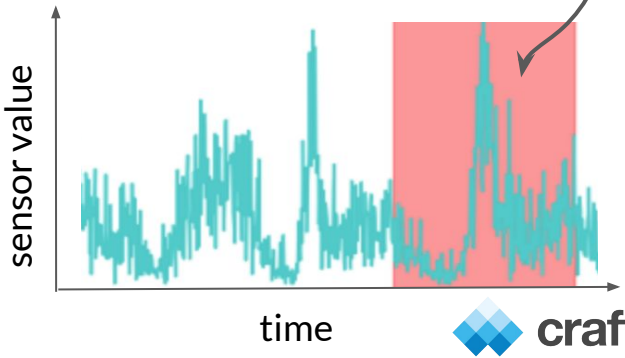
- Time series
- Machine centric
  - Temperature
  - Pressure
  - Vibration
  - Acoustic, ...

Maintenance Records

Ground Truth Issue

- Start of faults
- Unnoticed faults
- Few instances of breakdowns





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Predicting Faults in the District Heating System of Vienna

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1

Predictive Maintenance

Predictive Maintenance

District Heating Vienna

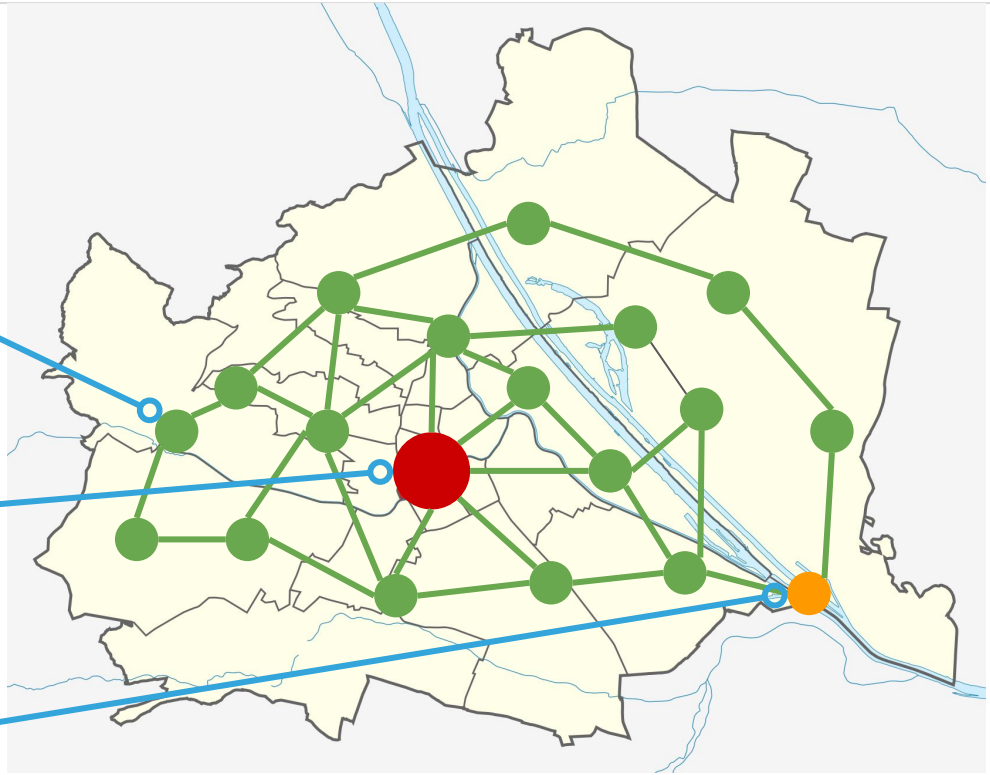
Vienna has one of the largest district heating systems in EU

Several thousand converter stations

Checks and maintenance on a daily basis

Every warning has to be investigated

Interrupts schedules



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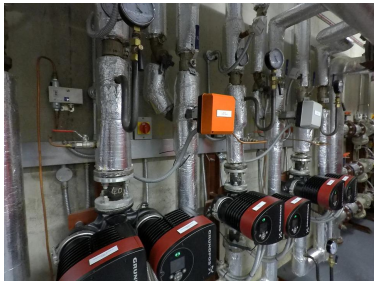
Predictive Maintenance

Predictive Maintenance

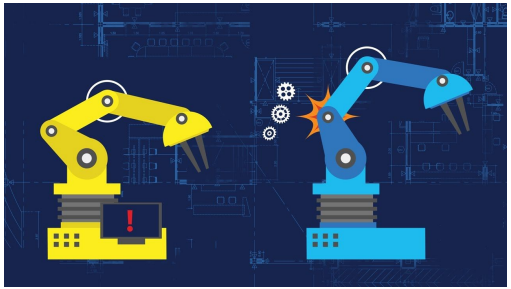
Goal



- **Predict faults in advance**
  Bonus: determine exact type of fault

Why?

- Enable more **targeted** maintenance schedules
- Reduce **interruption of work** caused by low-impact faults & issues



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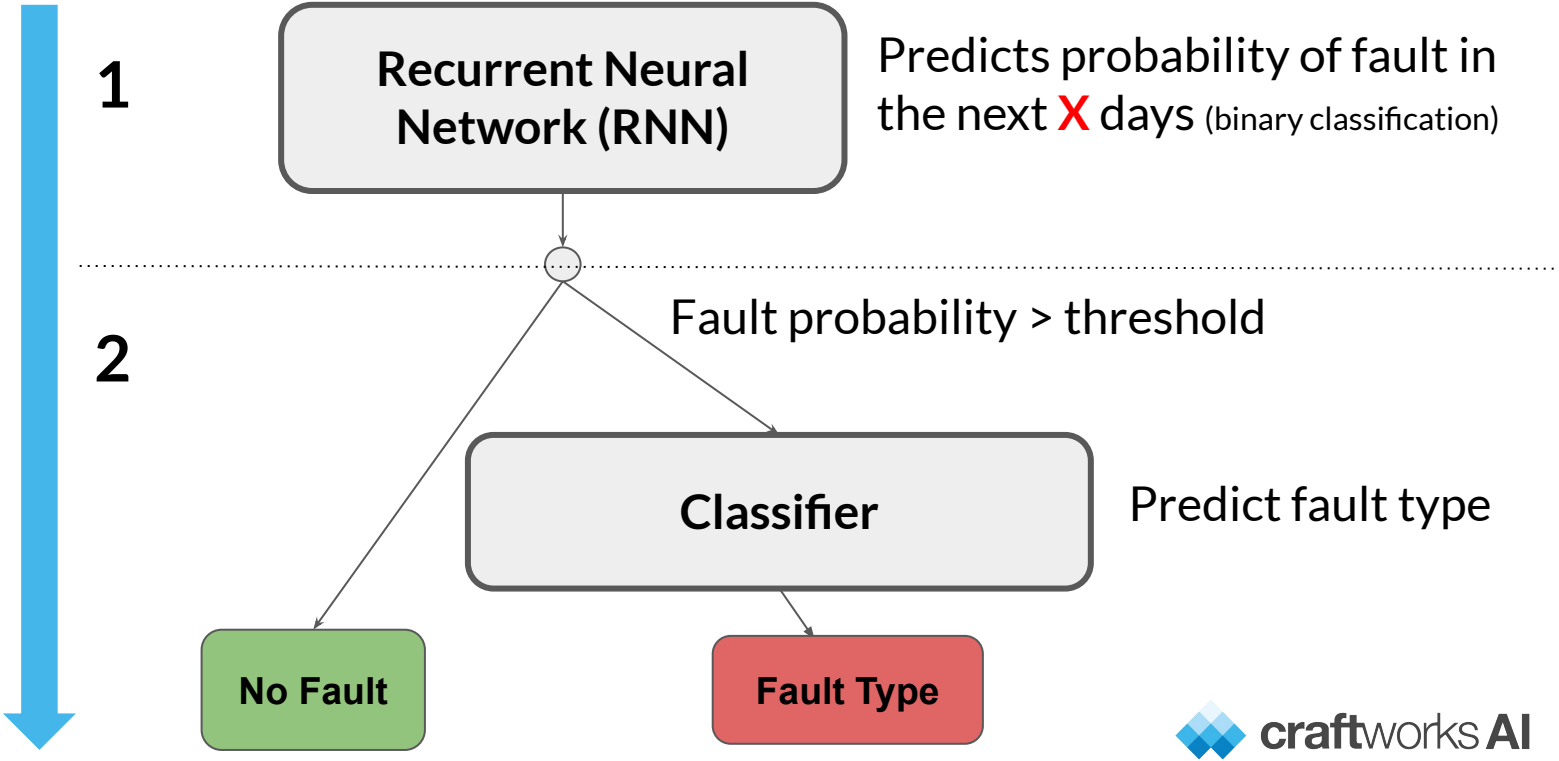
Predictive Maintenance

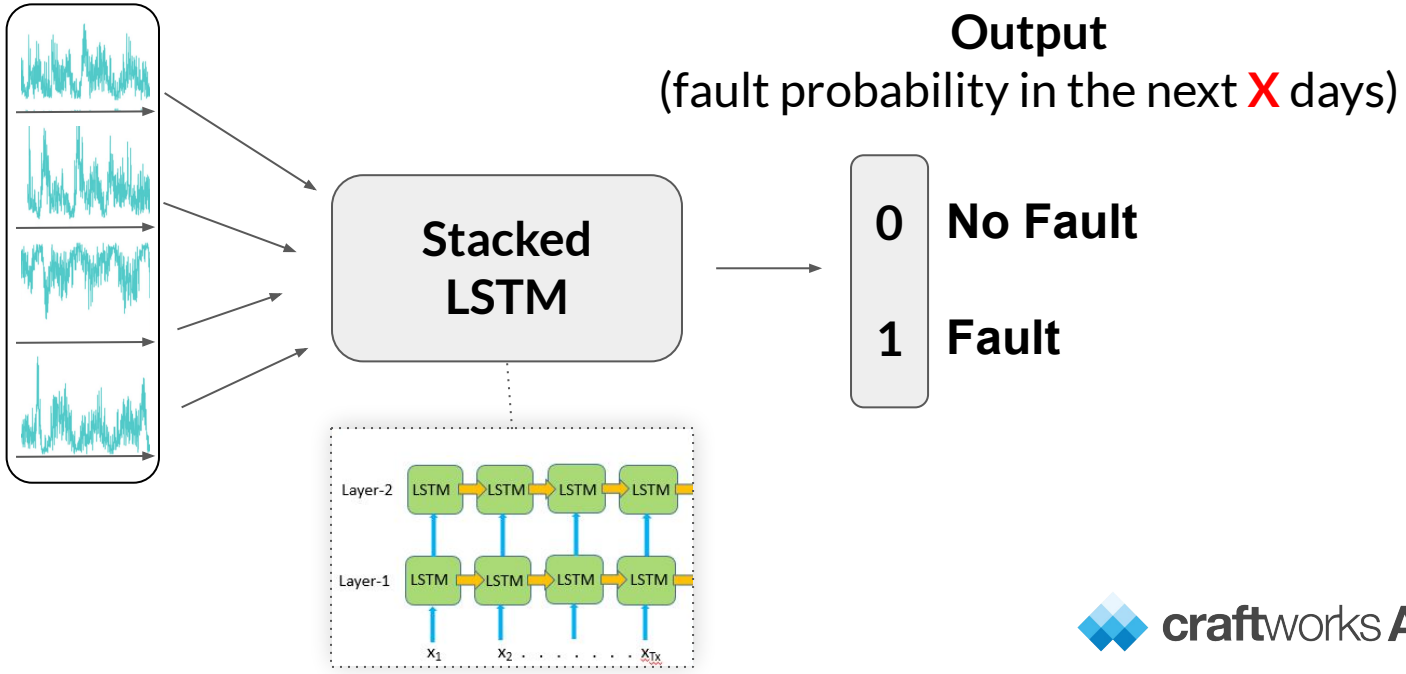
2-Stage-Solution



Predictive Maintenance

Recurrent Neural Network (RNN)

Input
(sensor data of last Y hours)



Output
(fault probability in the next X days)

0 **No Fault**

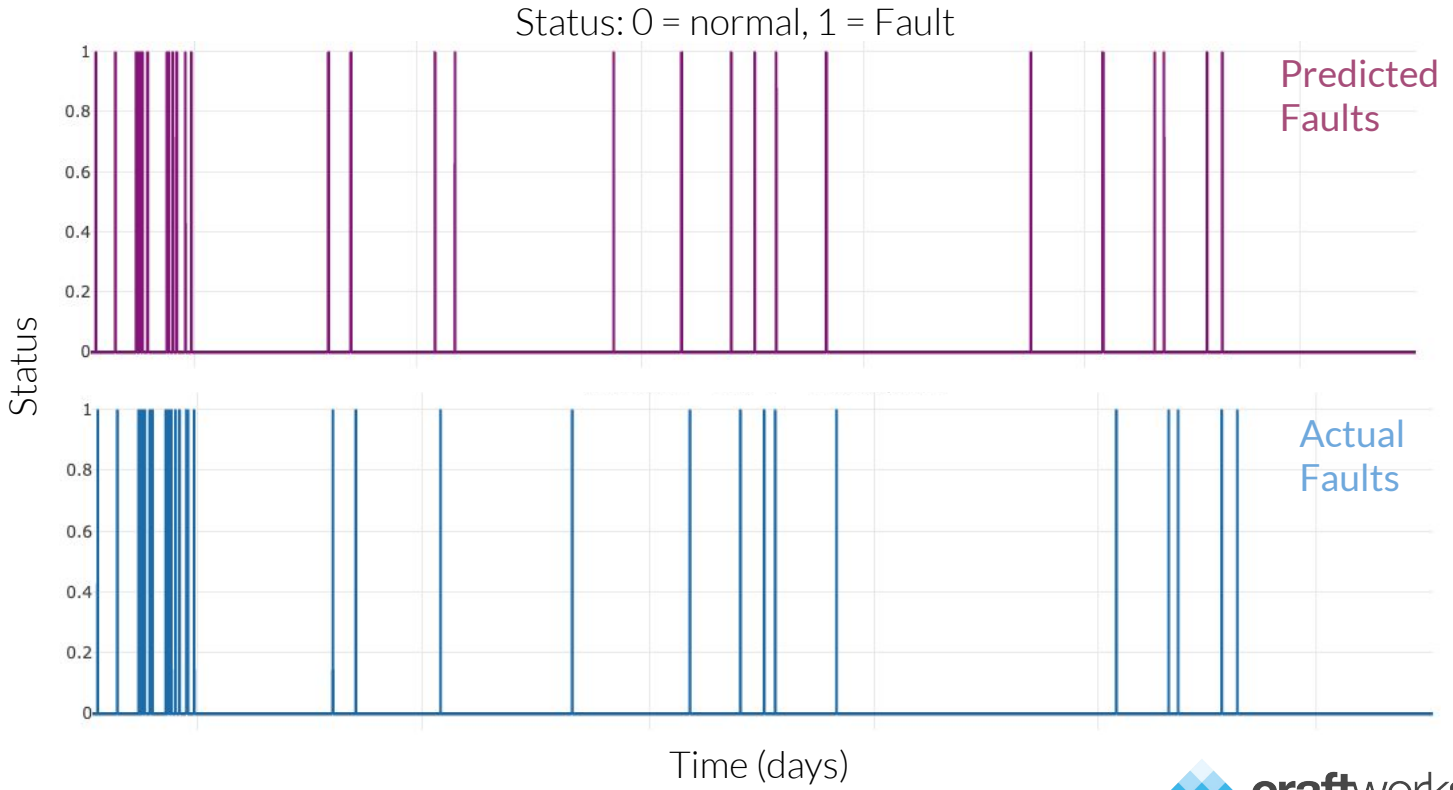
1 **Fault**

1

Predictive Maintenance

Predictive Maintenance

91% of Faults can be detected 7 days in advance



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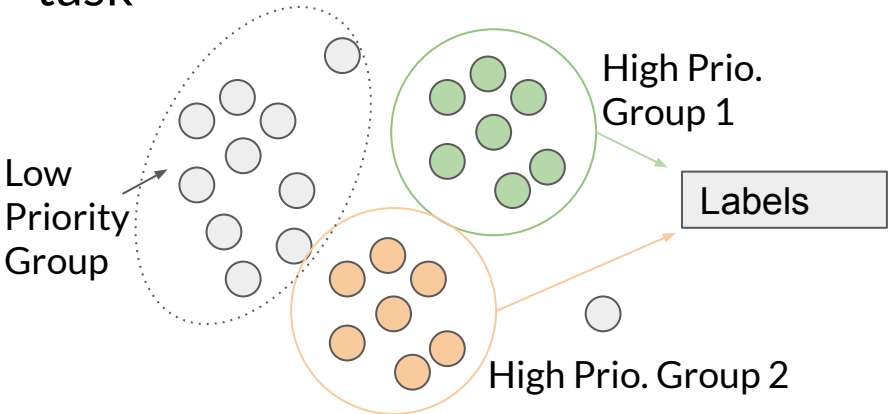
Predictive Maintenance

Predictive Maintenance

Can the exact fault types be determined?

- Several thousands **unique** fault types
  - Each fault type consists of 3 keywords
  - High priority types form clusters
- Fault types were clustered into coherent groups
- Selected 2 most **high priority** groups for classification task



98% Accuracy
Fault Type Group

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Industrial AI

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1. Predictive Maintenance
2. Visual Inspection
3. Predictive Quality

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2

Visual Inspection

Visual Inspection

What is it?

*"Method of quality control using **vision**"*

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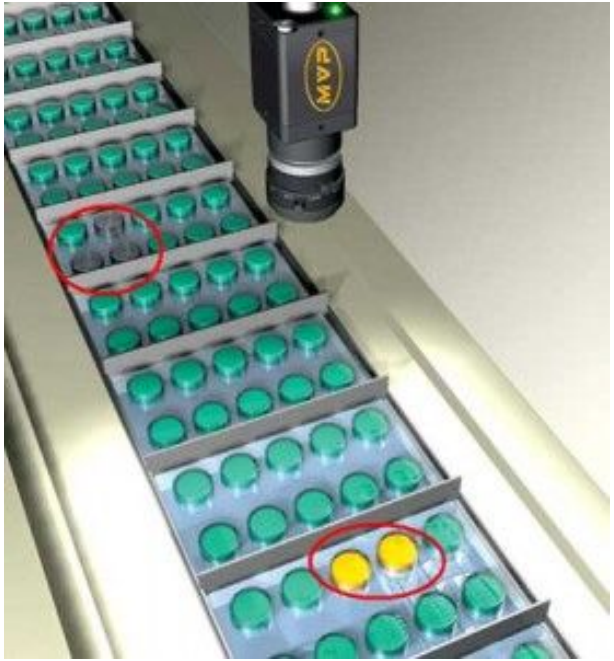
2

Visual Inspection

Visual Inspection

Automation is Wide-Spread



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Visual Inspection: Detecting and Explaining Defects in Industrial Parts

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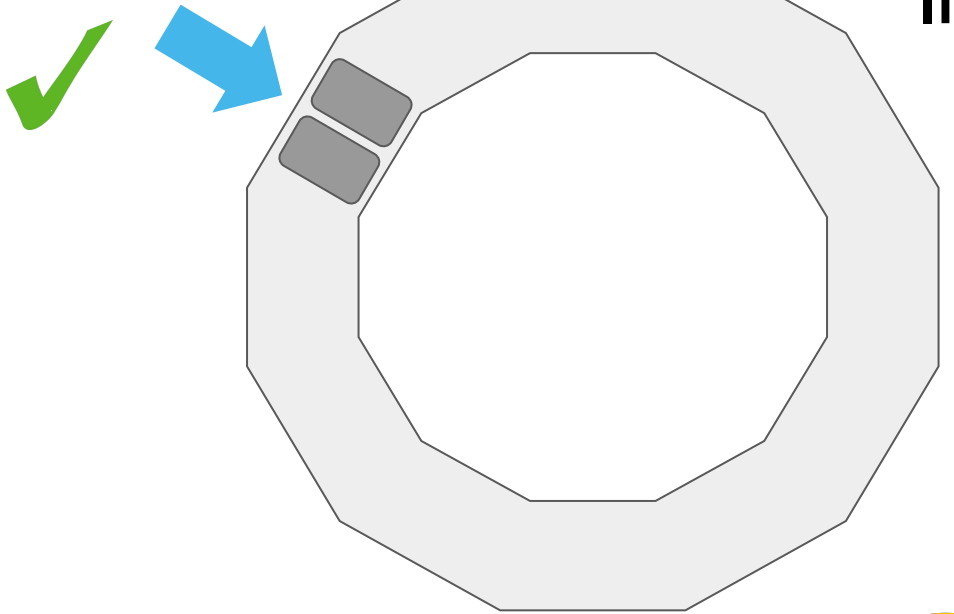
2

Visual Inspection

Visual Inspection

Detecting and Explaining Defects in Industrial Parts

Glued Patches



Industrial Part

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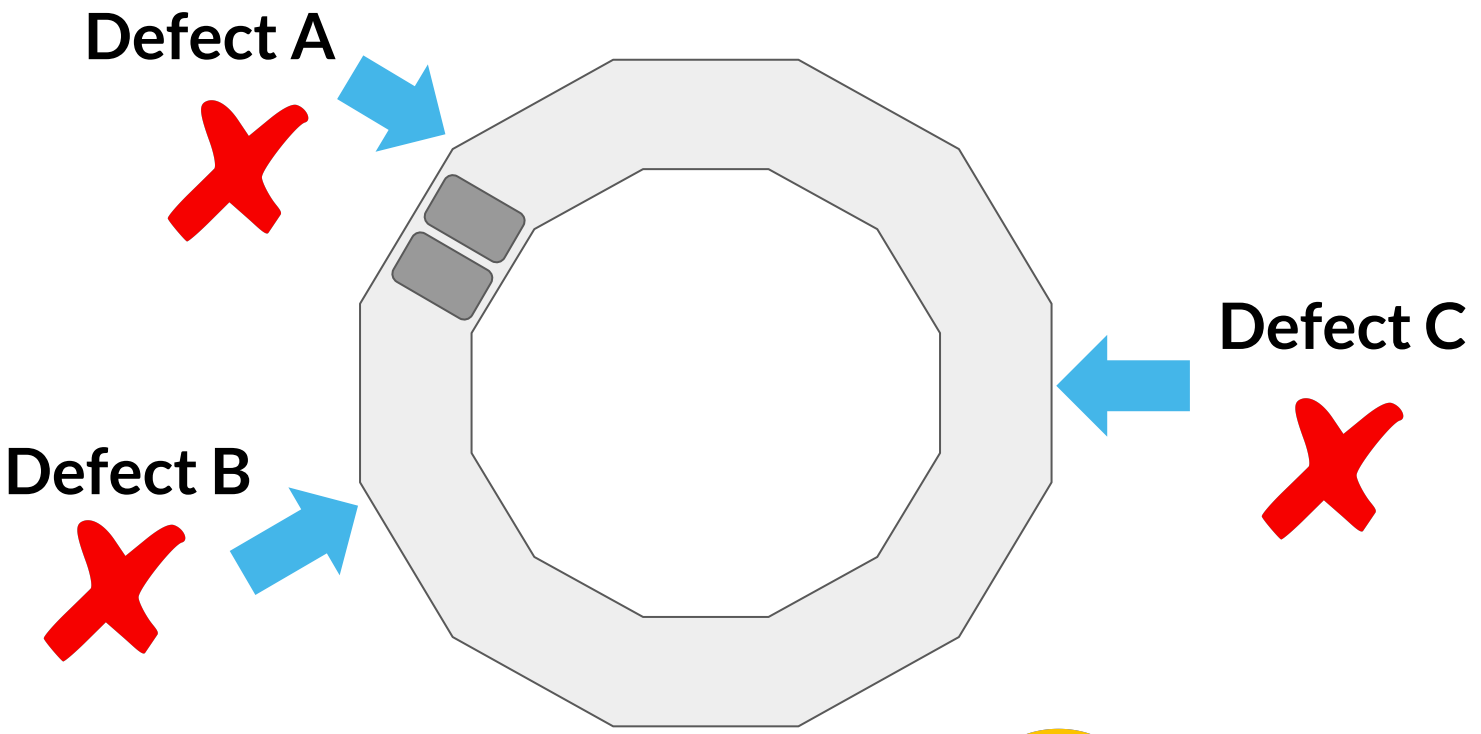
2

Visual Inspection

Visual Inspection

Detecting and Explaining Defects in Industrial Parts



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Visual Inspection

Visual Inspection

Detecting and Explaining Defects in Industrial Parts

Goals

- **Self-Learning** System
- Perfect Classification in **OK / Defect**
- Best Possible Classification of **Type of Defect**

- **Inspection** Capabilities
- **Explanation** of Model Output
- **Feedback** to ensure Continuous Learning

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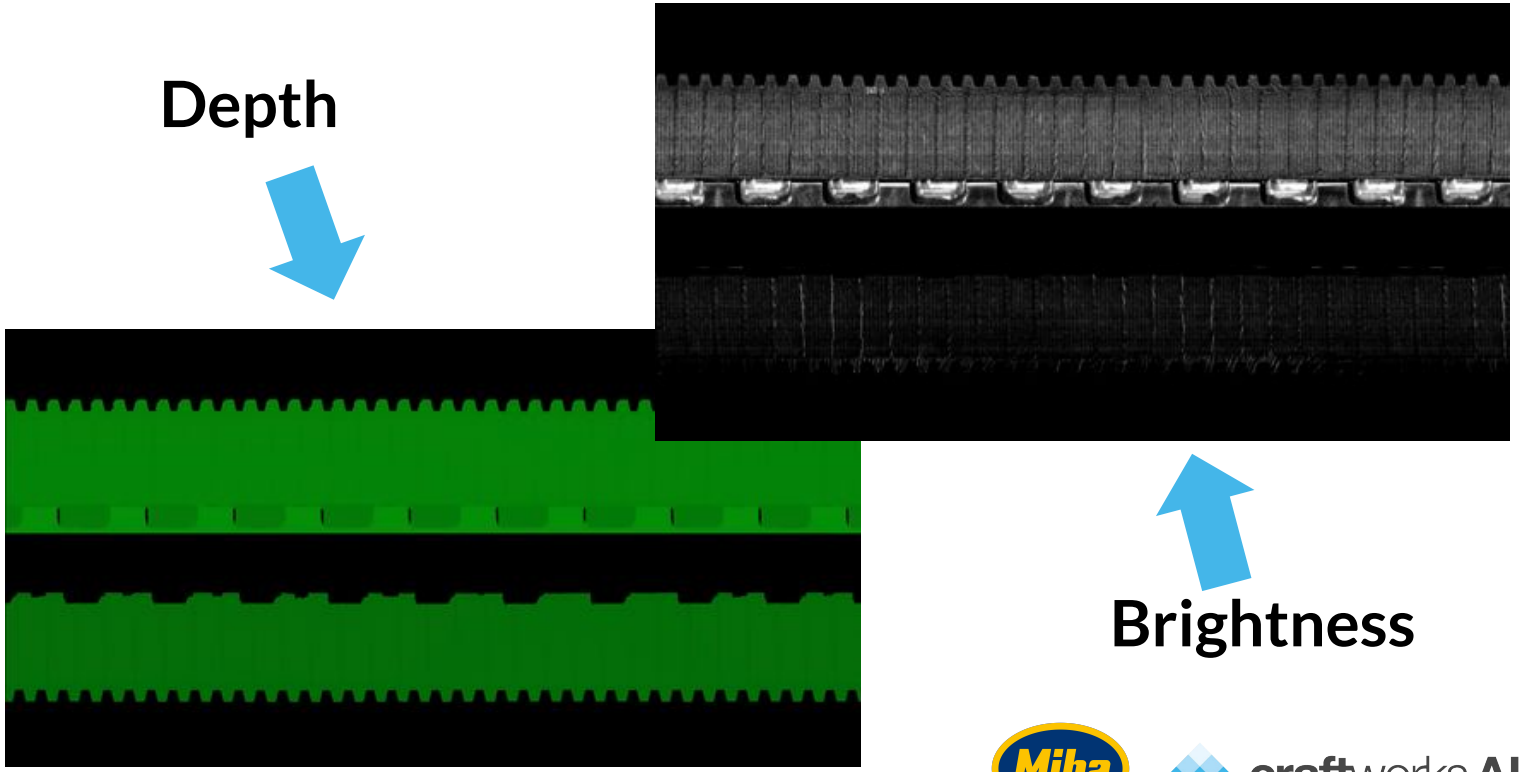
Visual Inspection

Visual Inspection

Imaging Device captures two Types of Images

Depth



Brightness

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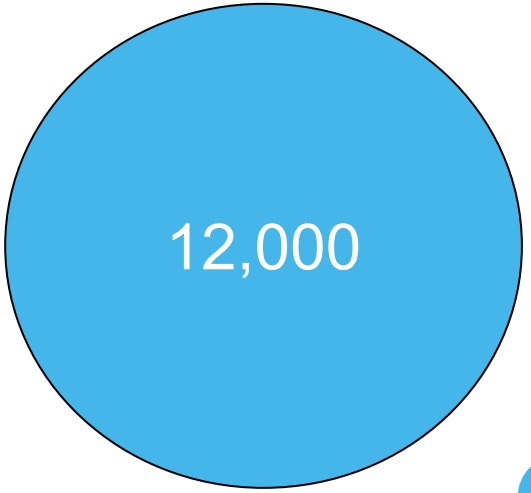
Visual Inspection

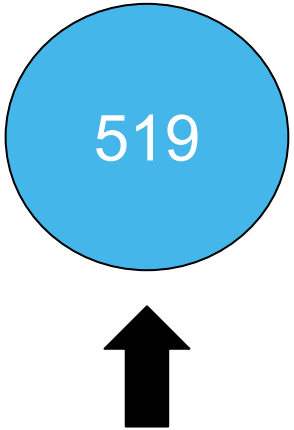
Visual Inspection

Data contains very few Labelled Images

Unlabelled



Labelled



Challenge
Very Few Labelled Images

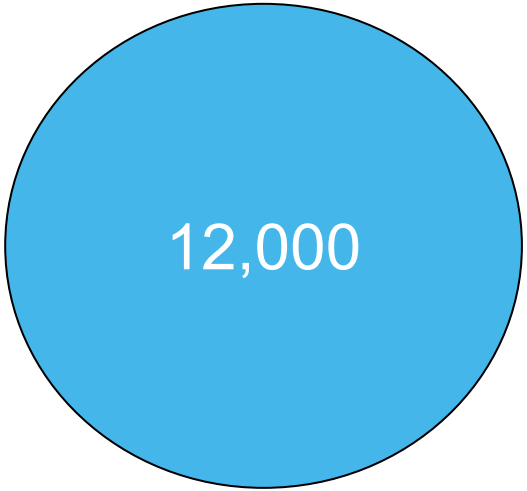
2

Visual Inspection

Visual Inspection

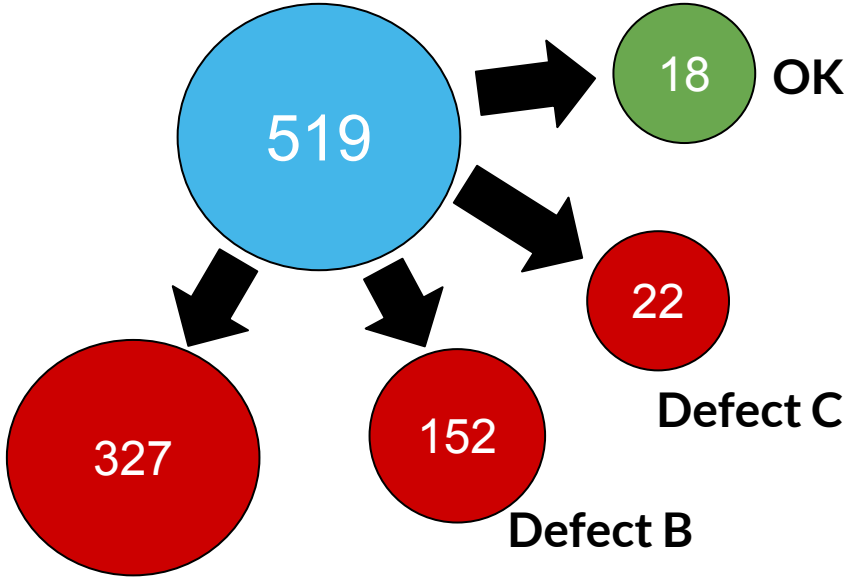
Highly Imbalanced Class Frequencies

Unlabelled



Vast majority of unlabelled data is **OK**

Labelled



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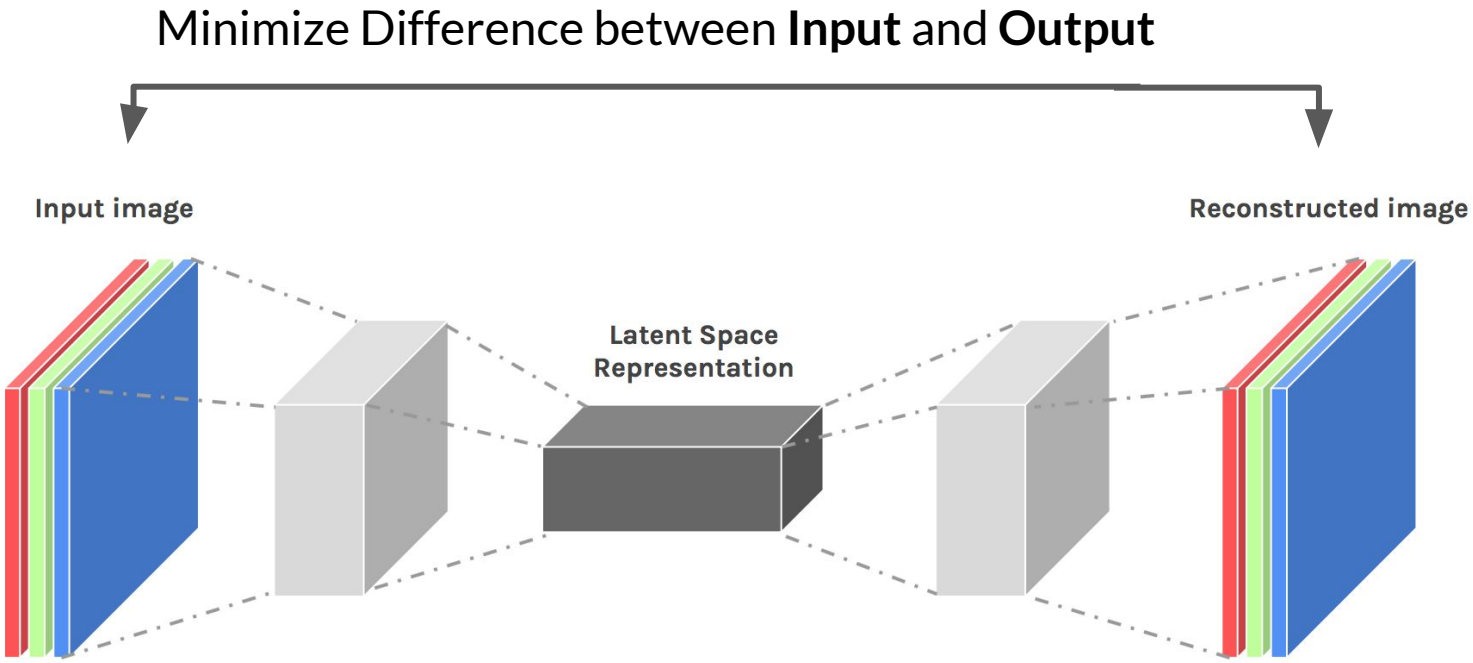
Visual Inspection

Visual Inspection

Deep Convolutional Autoencoder

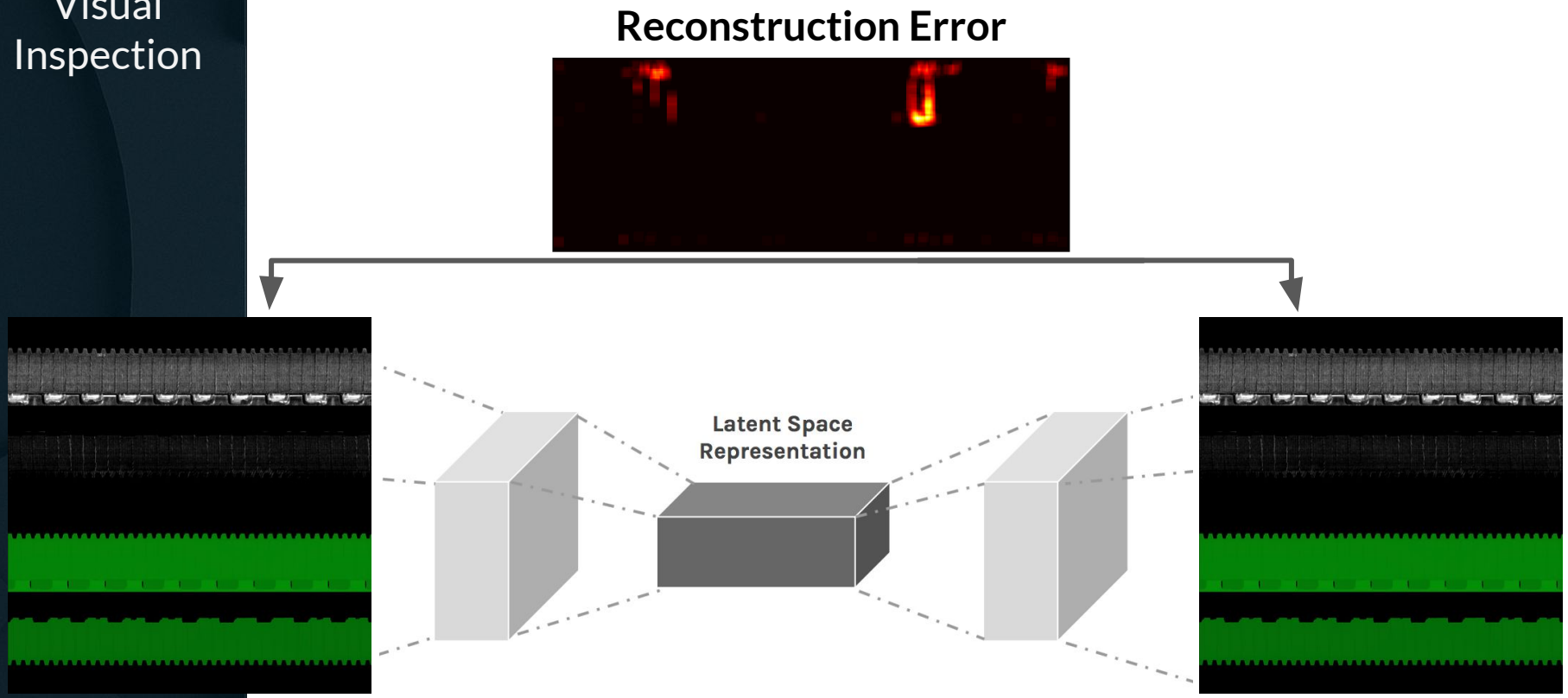


2

Visual Inspection

Visual Inspection

Visualizing Anomalies using Reconstruction Error



2

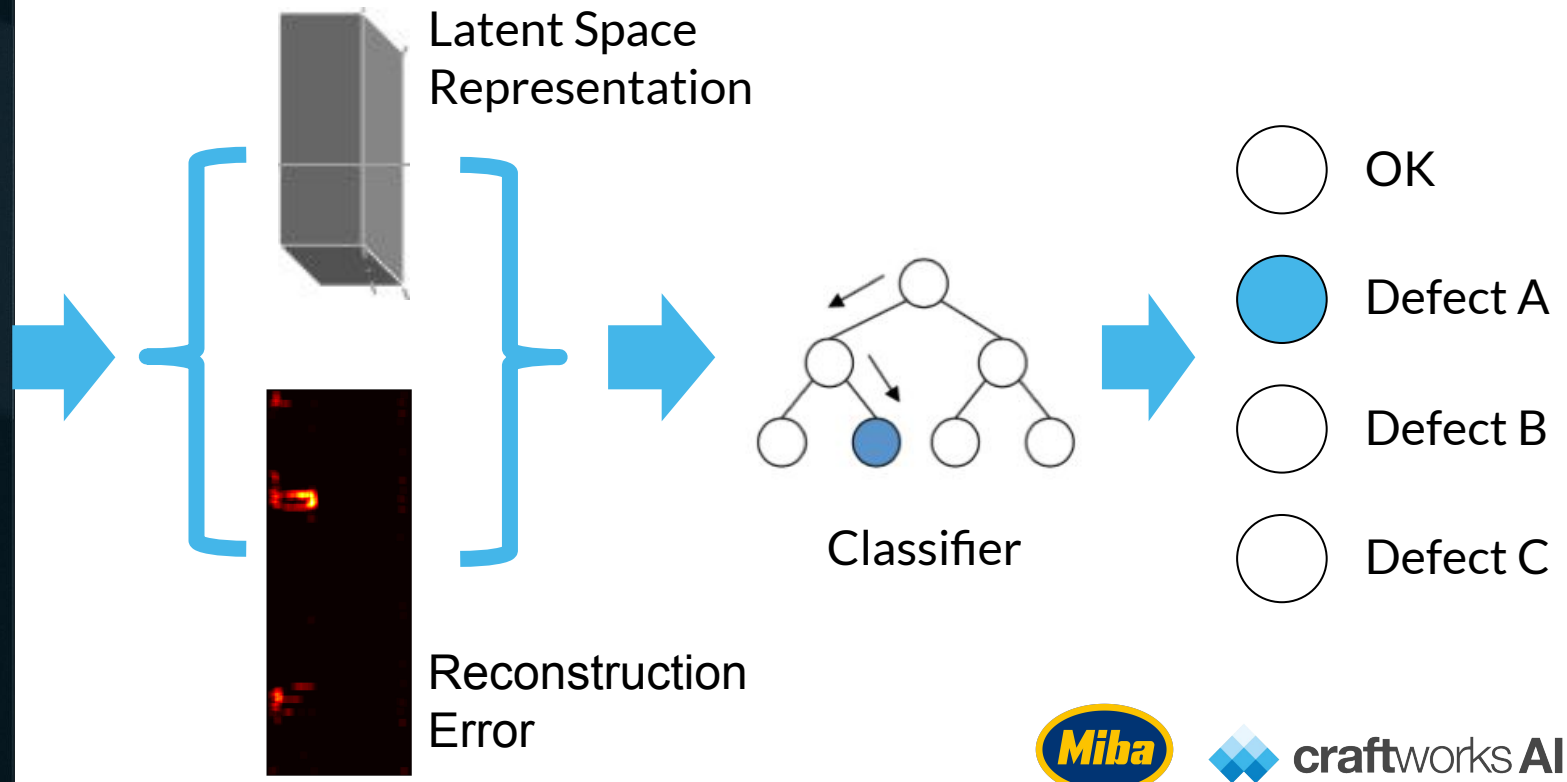
Visual Inspection

Labelled

519

Visual Inspection

Classification of OK and Defect Types



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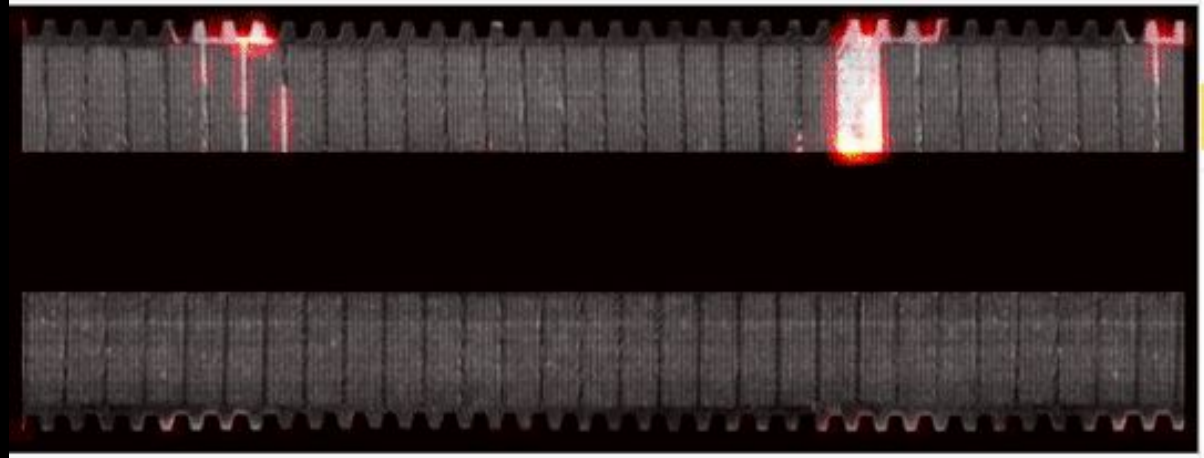
Innovation in Motion Miba

Predictive Quality

ALT + KLICK um Bereiche einzuzeichnen
SHIFT + MAUSRAD um zu zoomen



0

Show Z-Information

Detected Error

Defect B

Show root causes

Next Image >

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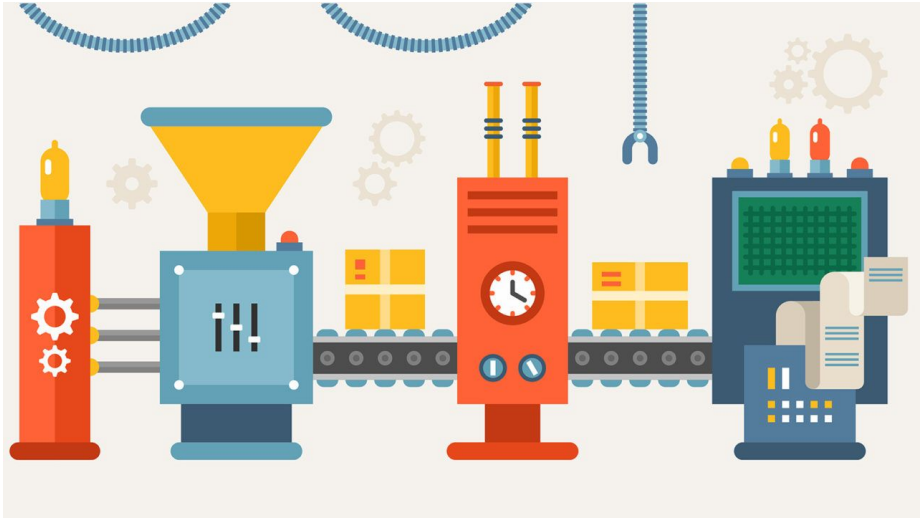
3

Predictive Quality

Predictive Quality

What is it?

*"**Estimating the output quality** of a manufacturing process from start to finish"*



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Predictive Quality

Predictive Quality

What? Why?

- **Automatic, Continuous, Proactive**
  - Predict (future) quality at every process stage
  - Identify potential influences on quality

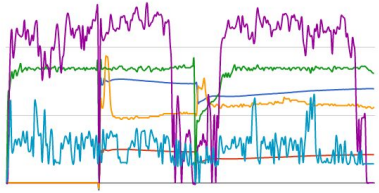
- **Saves time, costs and resources**
  - **Prevent** quality issues
    - Reduce scrap → minimize resource consumption
    - Know when a bad quality output is produced **BEFORE** it is produced

Predictive Quality

Data Sources

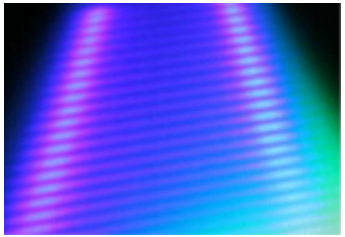
Sensors

- Vibration
- Temperature
- Pressure
- ...



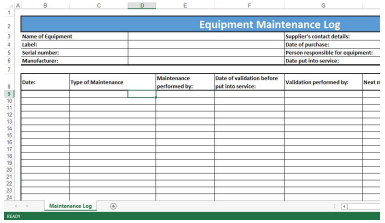
Images

- RGB
- Laser scans
- Infrared images



Meta-data

- Quality checks (**ground truth**)
- Shift schedules
- Maintenance records
- Fault logs

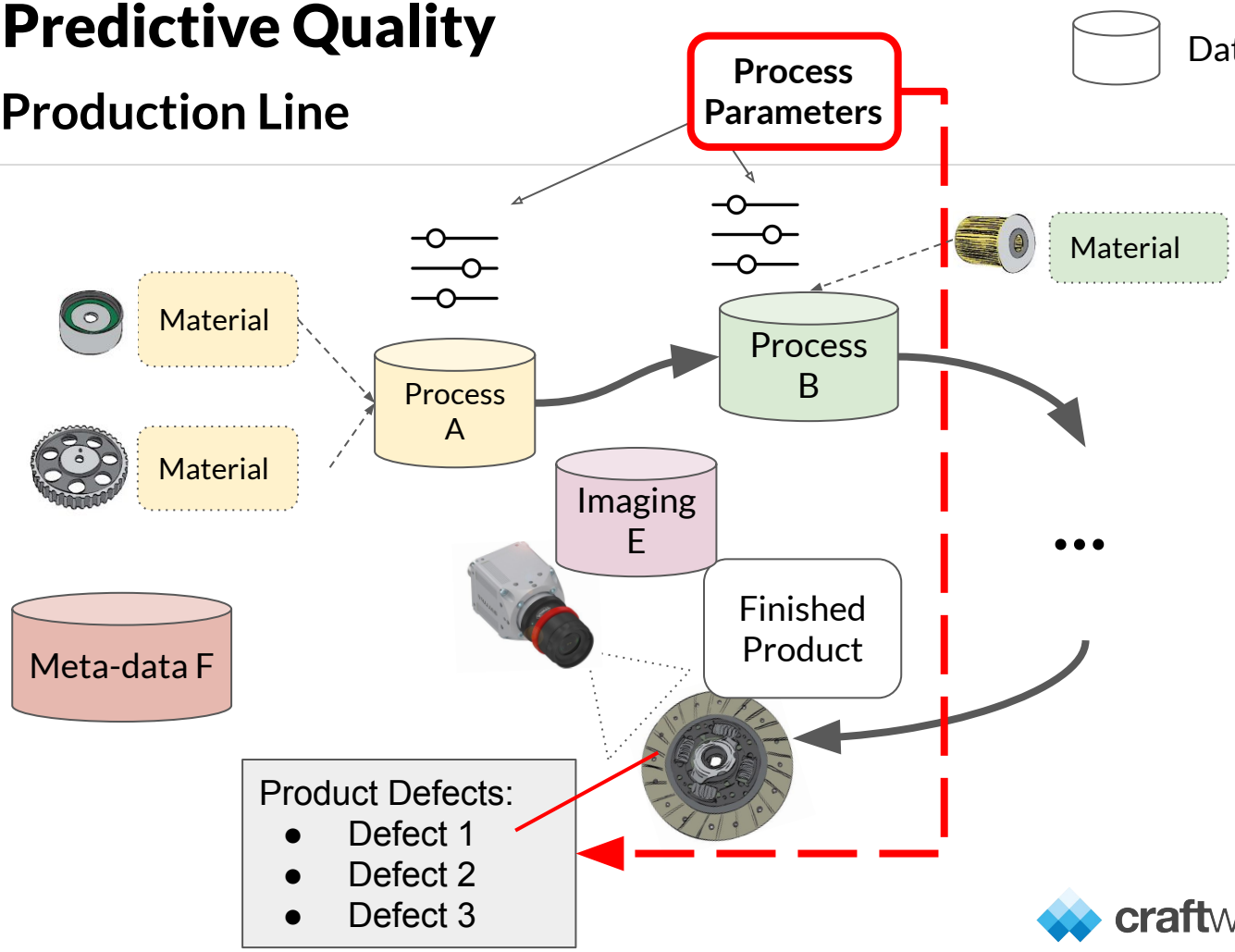


3

Predictive Quality

Predictive Quality

Production Line



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Predictive Quality

Predictive Quality

Typical Problem

- Production line:
  - Sequence of processes / stages
  - Each process is sequence of steps itself
  - High volume of process data
  - Additional meta data
- Random Quality checks
  - Small number of labelled data
- Goal:
  - Predict quality accurately

Miss-match

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Predicting Quality in Industrial Production Lines

Predictive Quality

Predictive Quality

Solution

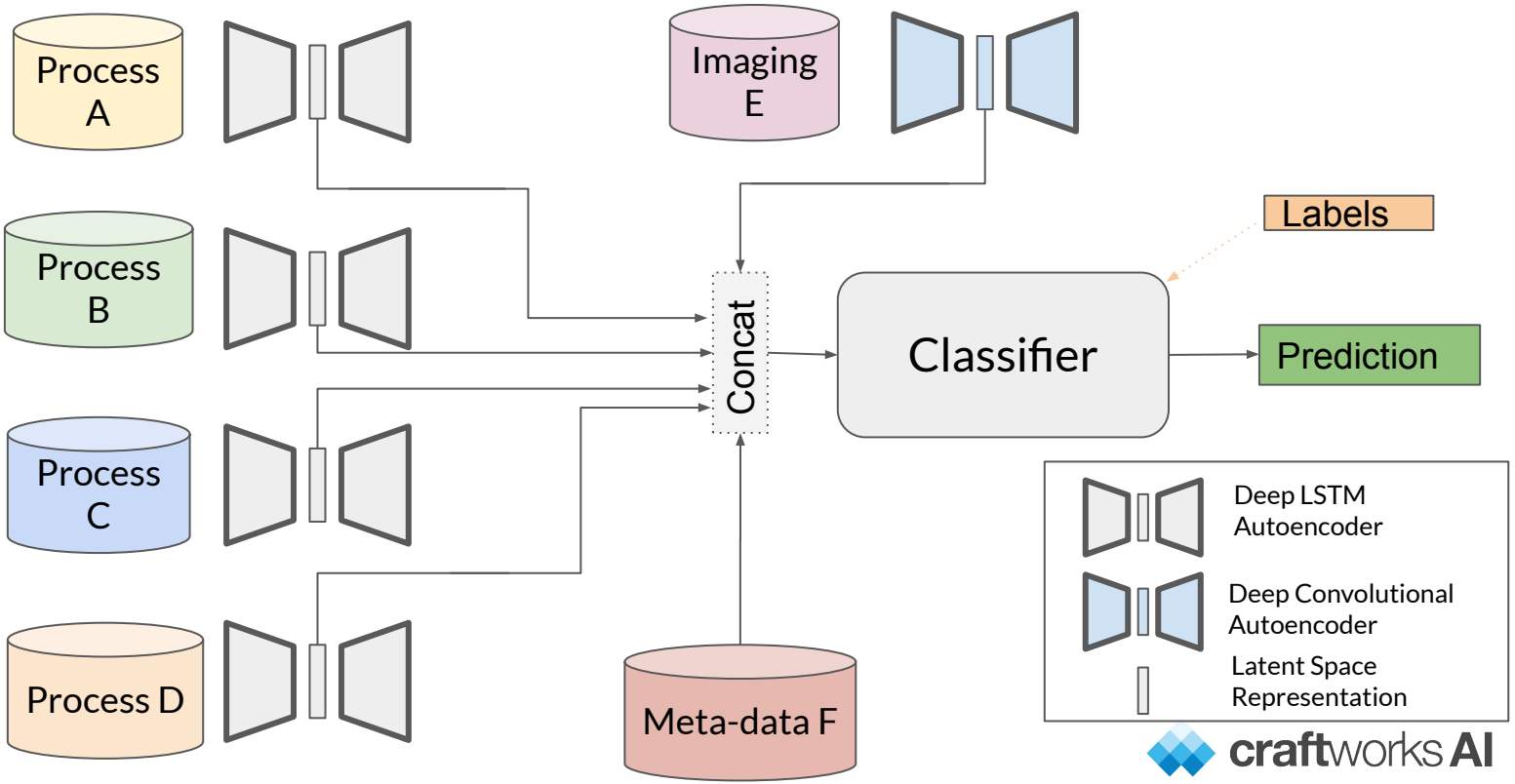
1. Train **LSTM Autoencoder** for each process
   - Feature extractor (Latent Space Representations)
   - Aggregate processes on (super-)process-level
2. Train **Convolutional Autoencoder** for image data
3. Concatenate features
4. Train **Supervised Model** on labelled data
   - Extreme Gradient Boosting
5. Use **SHAP/LIME** to explain influence of different stages on product quality

3

Predictive Quality

Predictive Quality

Solution



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Predictive Quality

Predictive Quality

Result

1. Good performance (depending on data quality)

2. Overcomes problem of **small labelled data** size

3. Overcomes **black-box** problem
   - **Explainable** on process level
   - Analysis of autoencoder **reconstruction errors** for fine grained insights within process

Industrial AI

Deep Learning for Predictive Maintenance, Predictive Quality & Visual Inspection

1. Predictive Maintenance
2. Visual Inspection
3. Predictive Quality

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Learnings

- ✓ Start simple & don’t over-engineer details
- ✓ Implement complete workflow asap (REST API, ...)
- ✓ Ensembling & combination of methods wins
- ✓ Keep business metrics in mind
- ✓ Industrial AI requires ML all-arounders

Join us!

Computer Vision Engineer / Data Scientist

(Senior) Web Developer

Marketeer/Growth Hacker

Agile Project Manager

No fit for you? Send us your application anyway - we are always looking for **talent**.

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Research with us!

Are you a student?

We offer exciting research **internships** and **thesis** topics!

Currently, topics are available in the **areas** ...

Reinforcement Learning

Unsupervised Deep Learning

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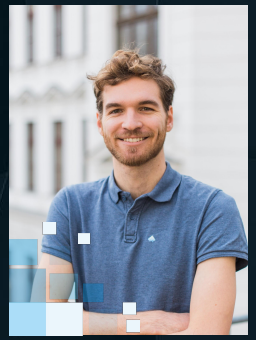
We develop prize-winning
Industrial AI



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