P502

UNIVERSITY OF TRENTO - Italy

apc|m europe

ENVELOPE-BASED ANOMALY DETECTION FOR HIGH-SPEED MANUFACTURING PROCESSES

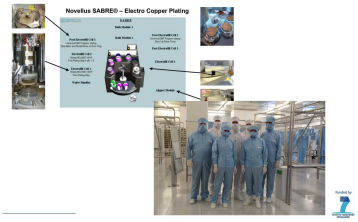
Katsiaryna Mirylenka[1], Alice Marascu[2], Themis Palpanas[1], Matthias Fehr[3], Stefan Jank[3], Gunter Welde[3], Daniel Gröber[3]

[1] University of Trento, Italy, [2] IBM Research-Ireland, [3] Infineon Technologies, Germany

General Work Description
Introduction

- In manufacturing data rates may exceed 1,000 events/sec.
  - The data need to be processed and analyzed in real time to enable condition-based maintenance and proactive monitoring.
- We propose an algorithm for online identification of abnormalities in manufacturing processes.
  - The abnormalities correspond to operational parameters and behaviours that are not within the bounds of normal operation.
- The algorithm operates in two steps.
  1. **Training** on data series that constitutes normal behaviour by constructing envelopes of normal behaviour.
  2. **Testing**, the algorithm is monitoring in real-time the operation of the manufacturing process, and reports as outliers those parts of the data series that are outside the normal operation envelopes

Motivation
ECD Tool – Electro Copper Depostion



Motivation
During Wafer processing – so much can happen

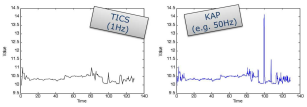
Problem description
Cu fill defects in egg signature, variation wafer to wafer, seen at defect density inspection

Root Cause
Strong corrosion on a clip from an 3-channel-valve leads to sporadic drops of H2SO4 on wafer → redistribution of Cu leading to Cu voids and shorts

Impact
Wafers scraped
Recurrent disturbance (different tools affected)
Potential reliability risk → additional scrap based on defect density

Motivation
Improvement of sampling frequency

- Sampling Frequency up to 10 kHz
- Additional parameters Current, Voltage, Valve switching, …



Infineon Requirements

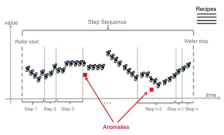
REQUIRMENTS

- Binary and analogue signals needed
- High sampling rates up to 10 kHz
- Data filtering & aggregation
- Self learning system

Envelope Approach
Infineon Use Case

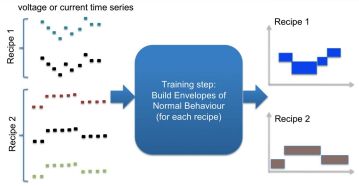
Given a set of normal steps (reference data)

Find their envelope
&
Detect the anomalies of new streaming steps with respect to this envelope in **real time**

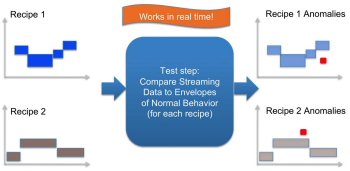


Envelope-based approach can be used for various signals

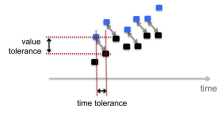
Proposed Technique
Supervised Anomaly Detection. Training step



Proposed Technique
Supervised Anomaly Detection. Training step



Mathematical Underpinnings
Envelope Construction – Step Combination



Mathematical Underpinnings
Envelope Construction – Step Combination

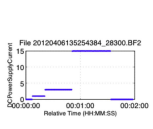
LCSS (Longest common subsequence): minimizes distance among points and maximizes number of matches

$$l(i,j) = \begin{cases} 1+l(t-1,i-1) & \text{if } \left(dist(S,P)<\gamma \wedge \left(|t-s(i,i)+1|-i\right)\leq\delta\right) \\ \max[l(t-1,i),l(t,i-1)] & \text{otherwise} \end{cases}$$

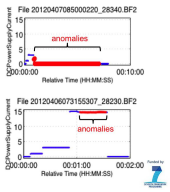
- Provides optimal match between points
- Allows different time (and value) scaling factors
- Automatically detects the time (and value) variations
- Allows gaps
- Dynamic programming solution
- Extended for effective envelope construction

Results
Infineon Data

normal wafer sequence



wafers with detected anomalies



Conclusions

- **Enveloped-based anomaly detection (Current achievements with Infenion data)**
  - Correctly identify all anomalies (100% recall in all tests)
  - No false positives (100% precision in all tests)
  - Real time anomaly detection
    - less than 0.1 ms/point, more than 11,000 points per second (11kHz)
    - identify outliers the moment they appear