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ScienceDirect

Procedia Manufacturing 11 (2017) 2018 – 2024

Procedia MANUFACTURING

27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017, 27-30 June 2017, Modena, Italy

Anomaly Detection Approaches for Semiconductor Manufacturing

Gian Antonio Susto*, Matteo Terzi, Alessandro Beghi

Department of Information Engineering, University of Padova, via Giovanni Gradenigo 6/B, 35131 Padova, Italy
Human Inspired Technology Centre, University of Padova, via Luzzatti 4, 35121 Padova, Italy

Abstract

Smart production monitoring is a crucial activity in advanced manufacturing for quality, control and maintenance purposes. Advanced Monitoring Systems aim to detect anomalies and trends; anomalies are data patterns that have different data characteristics from normal instances, while trends are tendencies of production to move in a particular direction over time. In this work, we compare state-of-the-art ML approaches (ABOD, LOF, onlinePCA and osPCA) to detect outliers and events in high-dimensional monitoring problems. The compared anomaly detection strategies have been tested on a real industrial dataset related to a Semiconductor Manufacturing Etching process.

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Peer-review under responsibility of the scientific committee of the 27th International Conference on Flexible Automation and Intelligent Manufacturing

Keywords: Anomaly Detection, Advanced Monitoring Systems, Data Mining, Etching, Fault-diagnosis, Machine Learning, Optical Emission Spectroscopy, Semiconductor Manufacturing

1. Introduction

Smart production monitoring is a crucial activity in advanced manufacturing for quality [1], control [2, 3] and maintenance purposes [4]. Advanced Monitoring Systems (AMSs) aim at detecting anomalies and trends; anomalies

* Corresponding author. Tel.: +39 049-827-7760.
E-mail address: gianantonio.susto@dei.unipd.it

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Peer-review under responsibility of the scientific committee of the 27th International Conference on Flexible Automation and Intelligent Manufacturing
doi:10.1016/j.promfg.2017.07.353

are data patterns that have different data characteristics from normal instances [5], while trends are tendencies of production to move in a particular direction over time.

Instruments to implement efficient AMSs are provided by Machine Learning (ML). ML approaches have proliferated in recent years Advanced Process Control (APC) solutions for Semiconductor Manufacturing [6], thanks to the algorithmic advancements in the field and the increased computational and storage capabilities in the IT architecture of the Fabs; ML-based approaches have been used for Virtual Metrology, Predictive Maintenance and Fault Detection applications. In this work, we compare state-of-the-art ML approaches to detect outliers and events in high-dimensional monitoring problems.

The compared anomaly detection strategies have been tested on a real industrial dataset related to a Semiconductor Manufacturing Etching process.

The contributions of the paper are: (i) compare state-of-the-art anomaly detection techniques, (ii) apply such techniques in a real industrial Semiconductor Manufacturing applications and (iii), to the best of our knowledge, applying such techniques for the first time in Semiconductor Manufacturing.

The rest of the paper is organized as follows: Section 2 is dedicated to present and compare the anomaly detection methodologies employed in this work; in Section 3 the Semiconductor Manufacturing case study is illustrated and the Experimental results are provided. Finally, in Section 4 the concluding remarks are provided.

A list of the notation employed in this work is reported here:

Nomenclature

N	Observations available in the dataset
p	Number of features monitored
$q \in [1, \dots, p]$	A generic feature
$X = \{x_1, \dots, x_n\}$, $x_i \in \mathbb{R}^p$	Input matrix
x_{new}	New observation, to be monitored/classified
s	Anomaly Score (AS)
τ	Threshold on AS
m	[osPCA-onlinePCA] Iterations of the Power Method
k	[ABOD] Number of considered neighbours
$d_k(x)$	[LOF] Distance of $x \in \mathbb{R}^p$ from its k-nearest neighbor
$r_k(y,x) = max\{d_k(x),\ d(y,x)\}$	[LOF] Reachability distance
lrd_k	[LOF] Local Reachability distance
K	Monte Carlo Simulations

2. Anomaly Detection Methodologies

In this Section, a list of the compared Anomaly Detection methodologies is presented. Each of the listed techniques define an *Anomaly score (AS)* s: a quantitative index that defines the 'outlierness' degree of an observations. Automatic Monitoring policies are generally based on triggering a reaction/intervention if the AS for a new observation is above a predefined threshold τ.

2.1. osPCA and onlinePCA

OsPCA [7] is an anomaly detection method based on the analysis Principal Component Analysis (PCA) [8]. Given a matrix $X \in \mathbb{R}^{\{N \times p\}}$, PCA employs an orthogonal transformation in order to find a new orthogonal basis (columns are linearly independent) whose elements are called principal components (PCs). Informally, PCs are the most informative directions (with highest explained variance) decreasingly ordered (first PC is the most informative).

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