Peak Detection in Time Series Data - (Tensor Decomposition)

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Contents

Introduction

Peak detection - Identifying points in a time-series dataset where the signal reaches a **local maximum (peak)** or **minimum (trough)**.

Types of Peaks:

- **Local Maximum**: A point higher than its immediate neighbors.
- **Local Minimum**: A point lower than its immediate neighbors.

Applications:

- **Stock price** surges or crashes
- **Temperature** spikes / Power or Voltage Surges
- **ECG** peak detection

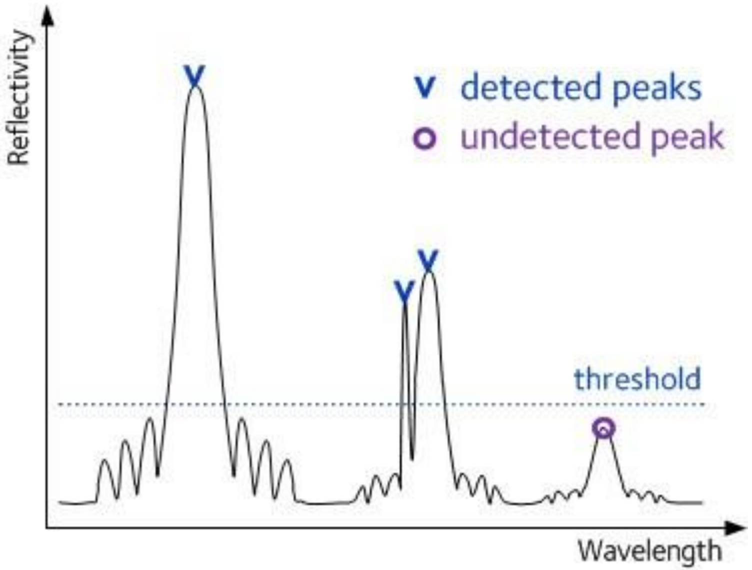

Figure 1: Images by a GAN created by NgeneratedVIDIA.

https://www.hbm.com/tw/4741/smart-peak-detection-for-fiber-bragg-sensors/

State-of-the-Art Approaches

Approach	Algorithms
Statistical Methods	AR (Autoregression) MA (Moving Average) ARMA (Autoregressive Moving Average) ARIMA Autoregressive Integrated Moving Average ES (Exponential Smoothing PCI (Prediction Confidence Interval (PCI) Z-Score
Machine Learning Methods	STSC (Shapelet Transform + K-Means Clustering) PCA-based Isolation Forest One-Class SVM
Deep Learning Methods	Autoencoder, MLP (NNAR), LSTM Forecasting Model CNN Forecasting Model

https://arxiv.org/abs/2004.00433

Statistical Methods

- **Advantages of Statistical Methods**:
  - High interpretability
  - Fast execution
  - Good performance on point and collective anomalies
  - Work well even on small datasets

- **Disadvantages** :
  - Require manual parameter tuning (e.g., window size, ARIMA order)
  - Assume data comes from a known stochastic model (e.g., stationary, Gaussian)
  - Less effective on contextual anomalies
  - Sensitive to noisy data

Machine Learning Methods

- **Advantages of Machine Learning Methods:**
  - Do not require strong assumptions about the data distribution
  - Better at capturing nonlinear relationships
  - Versatile and generic Can be applied to various time-series shapes and patterns (especially with sliding windows)

- **Disadvantages :**
  - Require hyperparameter tuning
  - Need transformation of time-series into feature space
  - Struggle with real-time detection

Deep Learning Methods

- **Advantages of Deep Learning Methods:**
  - Highly expressive models (Capable of capturing complex, nonlinear, and contextual patterns in time series)
  - No need for manual feature engineering (Automatically learn representations from raw time-series data (especially CNNs, LSTMs)

- **Disadvantages** :
  - High computational cost - Training deep models (Autoencoders, LSTMs, CNNs) takes time and resources
  - Can overfit on noisy or imbalanced data - Especially if anomalies are rare and not well-distributed

Tensor Decomposition

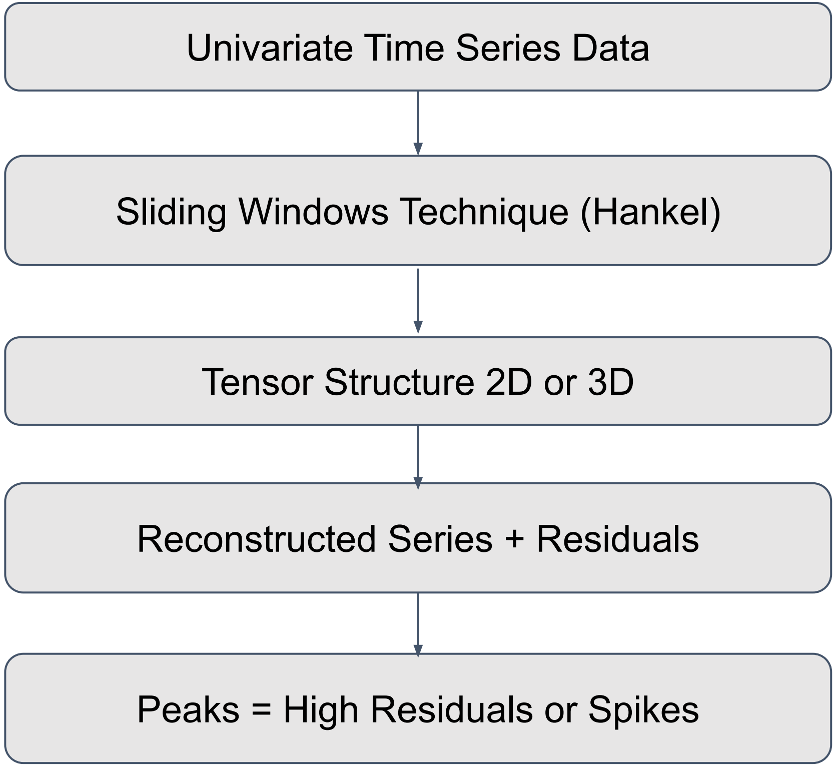

Figure 1: Tensor Decomposition Methodology

Tensor Decomposition - Advantages

- **Extracts Hidden Patterns**

  Separates trend, seasonality, and anomalies, making peaks stand out clearly.

- **Reduces Noise**

  Filters out random fluctuations, improving peak detection robustness.

- **Works Without Labeled Data**

  Completely unsupervised — no need for manual peak labeling or prior knowledge.

- **Highlights Anomalies via Residuals**

  Peaks naturally emerge as large residual errors after decomposition.

- **Compresses Data for Faster Analysis**

  Reduces dimensionality while preserving essential structures, speeding up detection.

https://arxiv.org/abs/2004.09655

Future Work

- Algorithms used in Tensor Decomposition (CP or Tucker)
- Research about Architecture and Methodology

References

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2. Girish Palshikar, Tata Consultancy Services (2009). Simple Algorithms for Peak Detection in Time-Series https://www.researchgate.net/publication/228853276_Simple_Algorithms_for_Peak_Detection_in_Time-Series
3. Sebastian Wagner, Mohammad Braei, (2020). Anomaly Detection in Univariate Time-series: A Survey on the State-of-the-Art arXiv:2004.00433
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Generative Adversarial Networks for Time Series

Thank You For Your Attention!

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