Comparative Analysis for Peak Detection Techniques for Signal Processing

Marta Alberola, Roger Puig, Rahul Sandhu

Master in Health Data Science — MHEDAS

January 14, 2025

Table of Contents

1. Challenge 3

2. Methods 4
   - Scipy 4
   - Hybrid 7
   - Custom 10

3. Conclusions 13

4. References 14

- **Material:**
  - 25 noisy synthetic signals + Ground truth signals
  - Sampling frequency: 10 Hz
  - One example of a clean peak of intensity one

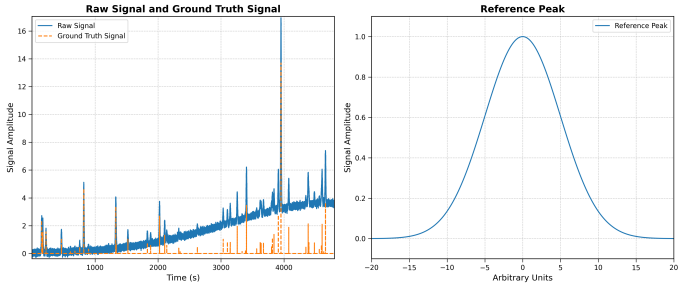
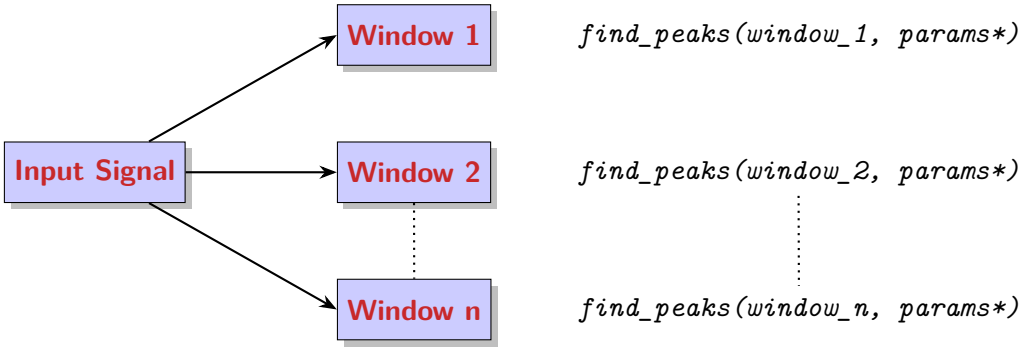


Figure: Noisy signal with ground truth peaks alongside the reference peak of intensity one.

```
scipy_method(sig, t, gt_sig, fs=10, win_dur=500, th1=0.25, th2=0.15)
```

- **Parameters:**
  - `sig`, `t`: Input signal and time vector.
  - `gt_sig`: Ground truth signal for peak detection.
  - `fs`: Sampling frequency (Hz).
  - `win_dur`: Window duration in seconds.
  - `th1`: Threshold factor for peak height.
  - `th2`: Threshold factor for peak prominence.
- **Windowed approach:**
  - **No ground truth peaks:** Skip the window.
  - **One ground truth peak:** `height` = 25% max value, `prominence` = 15% max value.
  - **Multiple ground truth peaks:** `height` = 25% max value, `distance` = average ground truth spacing × `fs`, `prominence` = 15% max value.


Input Signal
Window 1
Window 2
Window n
find_peaks(window_1, params*)
find_peaks(window_2, params*)
find_peaks(window_n, params*)

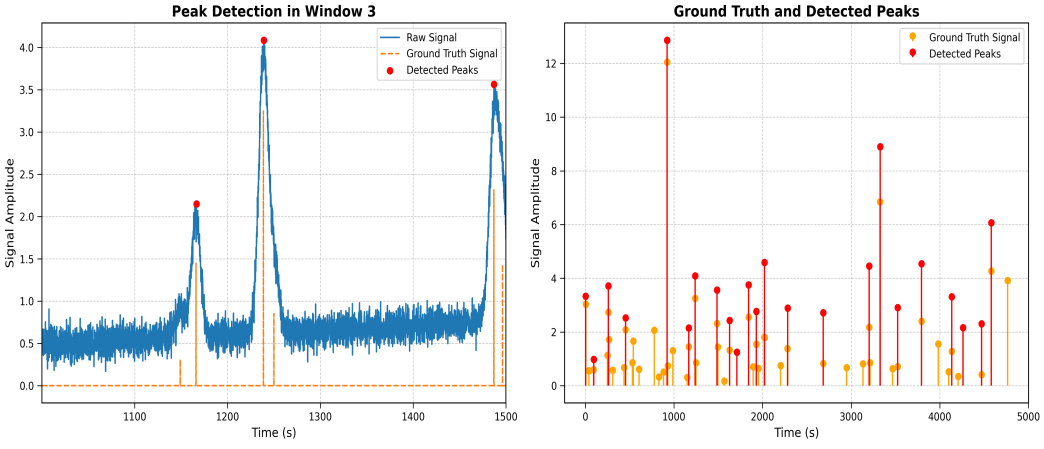


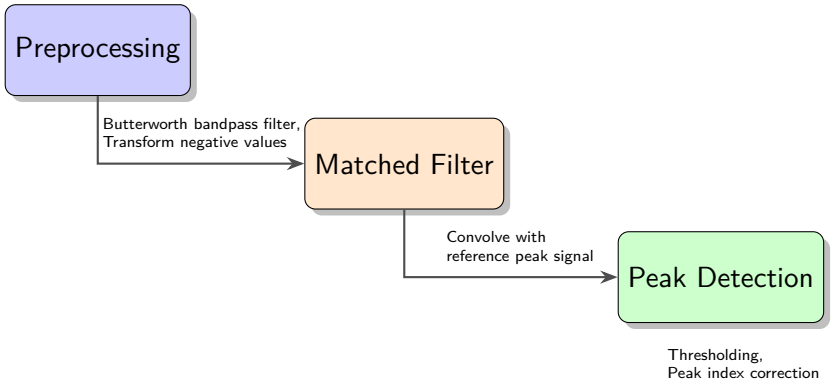
Figure: Peak detection process for a single window, along with the comparison of all detected peaks to ground truth peaks using the SciPy method.

Hybrid

```
hybrid_method(sig, t, ref, fs=10, order=1, lc=0.01, hc=0.1, th=0.01)
```

- **Parameters:**
  - `sig`, `t`: Input signal and time vector.
  - `ref`: Reference peak window for matched filtering.
  - `fs`: Sampling frequency (Hz).
  - `order`, `lc`, `hc`: Filter order, low cutoff frequency, and high cutoff frequency for the band-pass filter.
  - `th`: Threshold factor to determine the peak detection threshold.

Hybrid


Preprocessing
Butterworth bandpass filter,
Transform negative values
Matched Filter
Convolve with
reference peak signal
Peak Detection
Thresholding,
Peak index correction

Hybrid

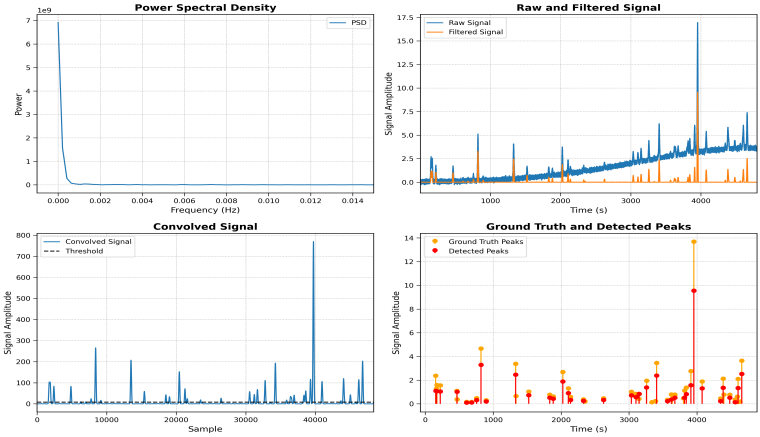


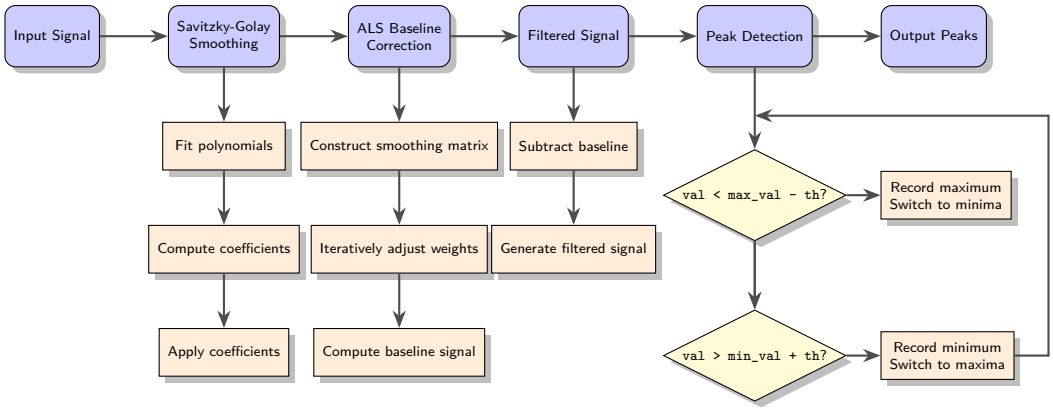
Figure: Representation of the power spectral density (PSD), raw signal, filtered signal, convolved signal, and the alignment of ground truth peaks with detected peaks using the hybrid method.

Custom

```
custom_method(sig, t, win_len=151, poly_order=3, lam=1e8, pen=0.001,
                                max_iter=50, th=0.1)
```

- **Parameters:**
  - `sig`, `t`: Input signal and time vector.
  - `win_len`: Window length for Savitzky-Golay smoothing.
  - `poly_order`: Polynomial order for smoothing.
  - `lam`: Smoothing parameter for ALS baseline removal.
  - `pen`: Penalty parameter for ALS baseline removal.
  - `max_iter`: Maximum iterations for ALS baseline removal.
  - `th`: Threshold for peak detection.

Custom


Input Signal
Savitzky-Golay Smoothing
ALS Baseline Correction
Filtered Signal
Peak Detection
Output Peaks
Fit polynomials
Construct smoothing matrix
Subtract baseline
Compute coefficients
Iteratively adjust weights
Generate filtered signal
Apply coefficients
Compute baseline signal
val < max_val - th?
Record maximum
Switch to minima
val > min_val + th?
Record minimum
Switch to maxima

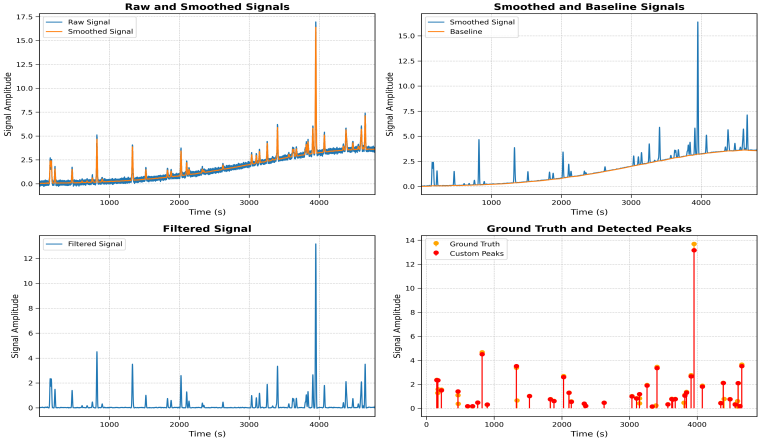


Figure: Raw, smoothed, baseline, and filtered signals processed using the custom method, along with detected peaks and ground truth peaks for comparison.

Conclusions

- **SciPy**: High variability, especially in specificity.
- **Hybrid**: Balanced performance, moderate variability.
- **Custom**: Consistent across all metrics.

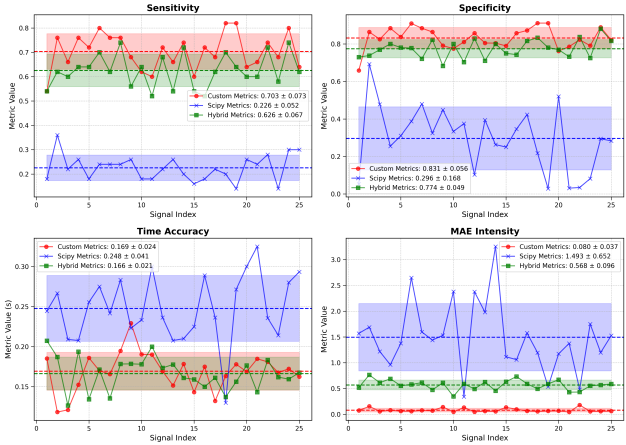


Figure: Performance comparison of all methods (tolerance = 500 ms).

References I

The SciPy Community.
SciPy Documentation, 2025.
Accessed: 2024-12-12.

GeeksforGeeks.
Window sliding technique, 2025.

Geek Culture.
Implement a sliding window using python, 2025.
Accessed: 2024-11-29.

Stack Overflow.
Explanation of scipy find peaks function, 2025.
Accessed: 2025-01-02.

References II

MATLAB Central.
Butterworth and baseline removal filtering, 2025.
Accessed: 2024-12-21.

DSP Stack Exchange.
Understanding the matched filter, 2025.
Accessed: 2024-11-30.

Stack Overflow.
Python: Simple convolution in numpy, 2025.
Accessed: 2024-12-27.

github/krvajal.
Peak detection matlab implementation, 2025.
Accessed: 2024-12-15.

References III

NIRPy Research.
Two methods for baseline correction in spectral data, 2025.
Accessed: 2024-12-18.

Eli Billauer.
Peak detection in matlab/octave, 2009.
Accessed: 2025-01-03.

Comparative Analysis for Peak Detection Techniques for Signal Processing

Marta Alberola, Roger Puig, Rahul Sandhu

Master in Health Data Science — MHEDAS

January 14, 2025