



Adaptive Wavelet Downsampling of Battery Storage Data

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Introduction

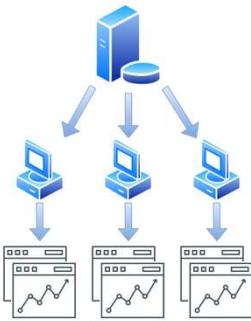


Fig. 1. Problem overview.

- Battery Archive (www.batteryarchive.org) allows users to download battery storage data and view it on a plot.
 - Measurements include voltage, current, energy, temperature, etc.
- Some datasets can contain more than 1 million points, this can take a very long time to download and plot.
- Certain characteristics of the data can be simplified to reduce the amount of data to transmit, but key features must be preserved.

Data Reduction Techniques

65536 voltage measurements were downsampled to 2048 points using various methods. A small set of charge cycles were chosen to demonstrate the results.

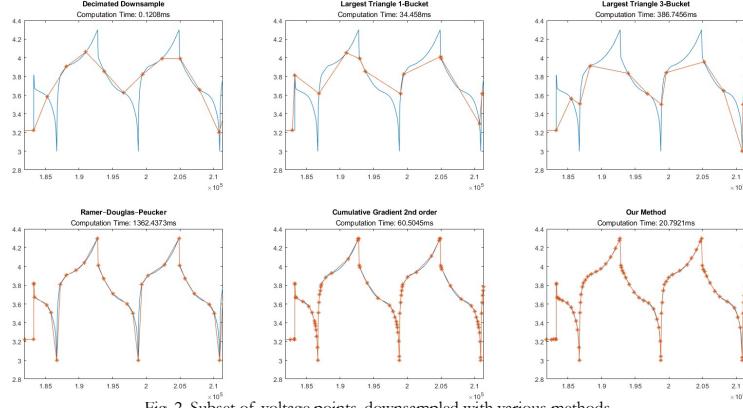


Fig. 2. Subset of voltage points, downsampled with various methods.

Decimated Downsample

- Downsample by factor of N/n (in this case 32).
- Does not preserve any specified behavior such as peaks.
- Very simple and fast to calculate.

Largest Triangle 1-Bucket [1]

- Divides data into "n" buckets, picks point of largest triangular area.
- Does not necessarily preserve peaks.
- Fast to calculate.
- Good approximation "at a glance."

Largest Triangle 3-Bucket [1]

- Calculates triangle area using points in previous and following buckets.
- $O(N^2)$ complexity.
- Provides even better approximation "at a glance."
- Still can miss peaks.

Ramer-Douglas-Peucker [2]

- Approximates curves based on a tolerance input value.
- Preserves peaks well but overshoots curves.
- Very long computation times, increases as more points are added.

Cumulative 2nd Order [3]

- Cumulative sum of 2nd derivative of data.
- Nearest neighbor interpolation to find steep changes.
- Good reconstruction and decent computation time.
- Input variable is number of points, but it returns much fewer unique points.

Our Method

- Identifies locations of importance spectrally.
- Best reconstruction of the set.
- Assigns proper number of points for both curves and peaks.
- Lowest computation time with $O(N)$ complexity.
- Input quality factor ensures similar results for all datasets.

The Wavelet Transform

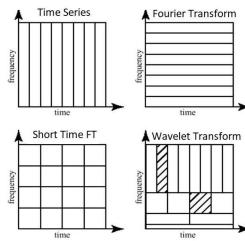


Fig. 3. Data representation for varying transforms [4].

- The Discrete Wavelet Transform (DWT) is like a Fast Fourier Transform (FFT), but the frequency bins vary in size depending on the frequency being observed.
- Gives local and global information about frequency content of points.
- Lifting schemes [5] have $O(N)$ complexity, FFT has $O(N^2 \log(N))$.

Implementation and Algorithm

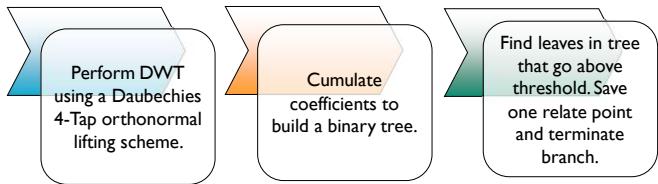


Fig. 4. Adaptive Wavelet Downsampling Algorithm steps.

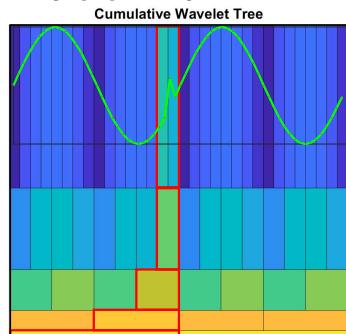


Fig. 5. Cumulative Wavelet Tree of a spiked sinusoid.

Compression of Test Dataset with Quality Factor of 100

Measurement	Reduction Factor	PSNR (dB)	Computation Time (ms)
Voltage	12.38	47.80	12.40
Current	10.63	50.42	12.64
Temperature	18.60k	-20.53	10.14
Charge Energy	15.27	48.40	11.90
Discharge Energy	19.63	49.79	12.48
Charge Capacitance	14.61	59.87	12.21
Discharge Capacitance	19.78	61.84	12.59

Table. 1. Compression results of an example dataset with 651,031 points.

Conclusions

- Adaptive Wavelet Downsampling can greatly reduce the number of points needed to represent a dataset, while ensuring locations of interest are preserved.
- The battery storage database can greatly reduce the data sent to users for plotting.

References

- [1] S. Steinrass, "Downsampling Time Series for Visual Representation," thesis, 2013.
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- [4] A. Taspinar, "A guide for using the wavelet transform in machine learning," ML Fundamentals, 21-Dec-2018. [Online]. Available: <https://ataspinar.com/2018/12/21/a-guide-for-using-the-wavelet-transform-in-machine-learning/>. [Accessed: 19-Sep-2022].
- [5] I. Daubechies and W. Sweldens, "Factoring wavelet transforms into lifting steps," The Journal of Fourier Analysis and Applications, vol. 4, no. 3, pp. 247-269, 1998.