Adaptive Wavelet Downsampling of Battery Storage Data

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Introduction

- 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, which 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.

Decimated Downsample
- Downsamples 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(N²) complexity.
- Provides even better approximation “at a glance.”
- Still can miss peaks.

Ramer-Douglas-Peuker [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 factors ensures similar results for all datasets.

The Wavelet Transform

- 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 log(N)).

Implementation and Algorithm

- A sinusoid with frequency of 2 Hz and N=64 points has a spike added at t=0.5 s with magnitude of 0.5.
- By cumulating the wavelet coefficients, we ensure that the magnitudes are always ascending, which allows for proper thresholding.
- The resulting cumulative wavelet tree clearly indicates a spike at top levels, with decreasing impact at bottom levels.


Fig. 1. Problem overview.

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

Decimated Downsample

Largest Triangle 1-Bucket [1]

Largest Triangle 3-Bucket [1]

Ramer-Douglas-Peuker [2]

Cumulative 2nd Order [3]

Our Method

Table 1. Compression results of an example dataset with 631,031 points.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Reduction Factor</th>
<th>PSNR (dB)</th>
<th>Computation Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>12.38</td>
<td>47.80</td>
<td>12.40</td>
</tr>
<tr>
<td>Current</td>
<td>10.63</td>
<td>50.42</td>
<td>12.64</td>
</tr>
<tr>
<td>Temperature</td>
<td>18.60k</td>
<td>20.53</td>
<td>10.14</td>
</tr>
<tr>
<td>Charge Energy</td>
<td>15.27</td>
<td>48.90</td>
<td>11.90</td>
</tr>
<tr>
<td>Discharge Energy</td>
<td>19.63</td>
<td>49.79</td>
<td>12.48</td>
</tr>
<tr>
<td>Charge Capacity</td>
<td>14.61</td>
<td>59.87</td>
<td>12.21</td>
</tr>
<tr>
<td>Discharge Capacity</td>
<td>19.78</td>
<td>61.84</td>
<td>12.59</td>
</tr>
</tbody>
</table>

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