Improving Spike Detection
Detecting Neural Activity in MER data.

Kirk Smith
Masters Student, IEEE Member
Electrical and Computer Engineering
Portland State University

Outline

• Overview
• Goals
• Significance of Work
• Methodology
• Results
• Conclusion
• Future Work

Overview

• Goals of Biomedical Signal Processing:
  – Extract information from an underlying biological process.
  – Use extracted information to understand and/or modify state of that biological process.
  – Examples:
    ✓ Rate of heart by processing EKG or IEGM.
    ✓ Current blood pressure by processing pressure sensors in a blood pressure cuff.
    ✓ Determine the current region of the brain a probe is in by processing the electrical signals sensed by the tip of the probe.

Signal Processing “Pipeline”

– Pre amplification and filtering
  (Improve SNR, Anti-alias filtering)
– Analog to Digital Sampling
– Preprocessing
  ✓ Band pass filter
  ✓ Baseline shift
– Signal processing
– Event Detection (identify possible events)
– Event Qualification (qualify if detected event is true event)
– Event Classification (identify what type of event it was)

Action Potentials

• The characteristic waveform generated by a cell is called its “action potential”
• Action potentials are commonly “spike” like in shape. Thus algorithms that detect these kinds of events are referred to as “spike detectors.”

Overall Goal

• Process MER signals to locate and identify neural excitation events.
Stage Specific Goals

- **Spike Detection Goal:**
  - Locate possible events without regard to amplitude of spike.

- **Spike Qualification Goal:**
  - Use shape, location and amplitude of spike to qualify if this spike is a desired event.

- **Spike Classification Goal:**
  - Use shape, location, amplitude, history, and relative placement to classify the event.

Example Signal

Significance of Work

- Spike detection is the first real processing stage in the overall signal processing pipeline.
- Errors in signal detection can keep valid events from being classified.
- Errors in signal detection can also perturb state of classification algorithm introducing more error.
- In short – Event classification is dependant on having a reliable spike detector.

Methodology

- Create a “Bench Mark” data set
- Measure Performance of:
  - Optimal Threshold
  - Template Matching (SSE)
  - Template Matching (convolution)
  - Sensitivity to changes in template kernel

Template Selection

- Initial threshold is used to gather first “spikes” that will make the initial kernel
- Some algorithms will use the first template to find more candidates to create a second template from.

Example Collection of Kernels
**Resulting Template Kernel**

![Resulting Template Kernel](image)

**Error Space of “Optimal” Threshold Detector**

![Error Space of “Optimal” Threshold Detector](image)

**Template Matching (SSE)**

![Template Matching (SSE)](image)

**Template Matching (convolution)**

![Template Matching (convolution)](image)

**Sensitivity to Kernel Size**

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>True Detects</th>
<th>False Detects</th>
<th>Missed Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Template Matching SSE</td>
<td>9198</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Kernel Width = 30</td>
<td>Template Matching SSE</td>
<td>9172</td>
<td>34</td>
</tr>
<tr>
<td>Kernel Width = 100</td>
<td>Template Matching Convolution</td>
<td>8255</td>
<td>14</td>
</tr>
<tr>
<td>Kernel Width = 30</td>
<td>Template Matching Convolution</td>
<td>8217</td>
<td>93</td>
</tr>
<tr>
<td>Kernel Width = 100</td>
<td>Optimal Threshold Detector</td>
<td>8251</td>
<td>5</td>
</tr>
</tbody>
</table>

*This table shows how the detectors are sensitive to the width of the kernel.*
Variance and Noise of Kernel

Normality of Noise

Conclusion

• Selection of Template is important
  – Width of Template
  – “Normalizing” Shape of Template
• Total kernel space of template (sum of all spikes used to create template kernel) is consistent with a normal gaussian model.

Future Work

• Better Benchmark
• Maximum Likelihood using PDF of each point in template.
• Automatic reduction is size of kernel (x limits) to find “optimal” kernel size.
• Combining SSE and Convolution methods (take a convolution of the SSE error surface).

Improving Spike Detection
Detecting Neural Activity in MER data.

Kirk Smith
Masters Student, IEEE Member
Electrical and Computer Engineering
Portland State University