Neural Network Metrics for Viterbi Decoding in Molecular Communication Channels

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Outline

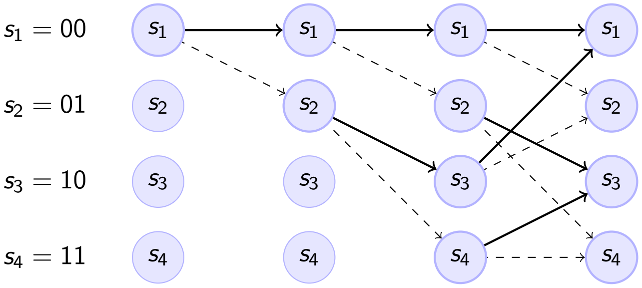
Background

Initial Results

Viterbi Setup

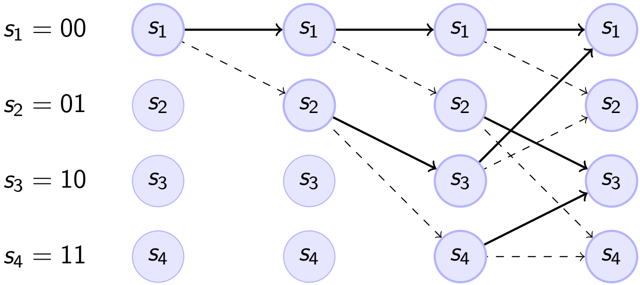
Maximum Likelihood sequence decoding can be formalized as

$$
\begin{aligned}
&\underset{\mathbf{x}}{\text{maximize}} \quad Pr(\mathbf{y}|\mathbf{x}) \\
&\underset{\mathbf{x}}{\text{maximize}} \quad \prod_{\mathrm{i}=1}^{\mathrm{N}} Pr(y_{\mathrm{i}}|\mathbf{x}) \\
\\
&\underset{\mathbf{x}}{\text{minimize}} \quad \sum_{\mathrm{i}=1}^{\mathrm{N}} -log(Pr(y_{\mathrm{i}}|\mathbf{x}))
\end{aligned}
\tag{5}
$$



Viterbi Setup Continued

Each state change is decided by the metric $Pr(y_{\mathrm{i}}|\mathbf{x})$. In a linear channel with length l impulse response , this metric becomes $Pr(y_{\mathrm{i}}|\mathbf{x}_{\mathrm{i-l}}^{\mathrm{i}})$.



Example with channel impulse response length 2 and constellation size 2.

Incorporating Neural Net into Viterbi Decoding

Problem 1

Viterbi algorithm requires the distribution $Pr(y_i|\mathbf{x}_{i-l}^{i})$.

- ## Solution

  Have a neural network learn $Pr(y_i|\mathbf{x}_{i-l}^{i})$.

Problem 2

Generating training data $Pr(y_i|\mathbf{x}_{i-l}^{i})$ requires knowledge of the channel and its (current) parameters.

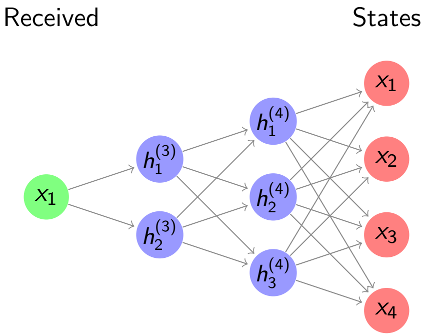
- ## Solution

  Decompose $Pr(y_i|\mathbf{x}_{i-l}^{i})$ into

$$Pr(y_i|\mathbf{x}_{i-l}^{i}) = \frac{Pr(\mathbf{x}_{i-l}^{i}|y_i)Pr(y_i)}{Pr(\mathbf{x}_{i-l}^{i})} \tag{6}$$

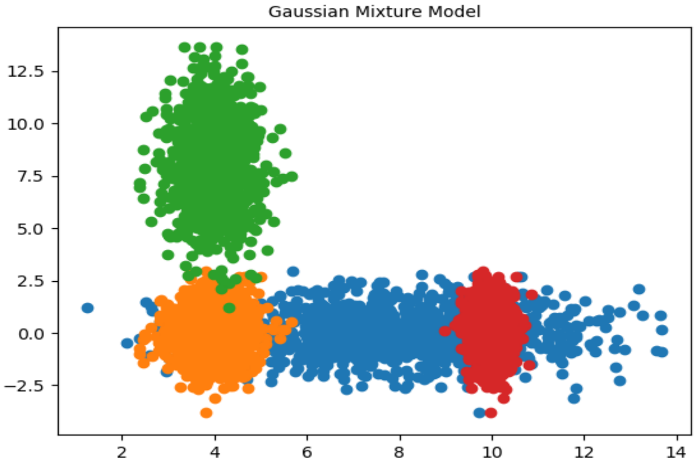
.

Metrics for $Pr(x_{i-l}^{i}|y_i)$



Metrics for $Pr(y_i)$

Gaussian Mixture Model using Expectation-Maximization algorithm



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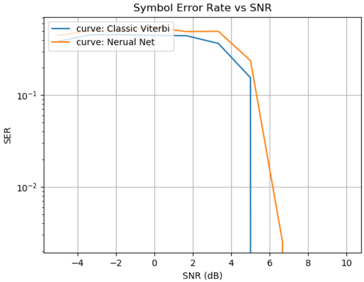
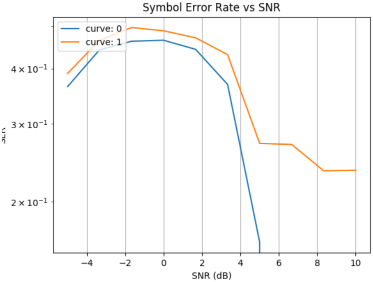
Detection Performance

Without ISI

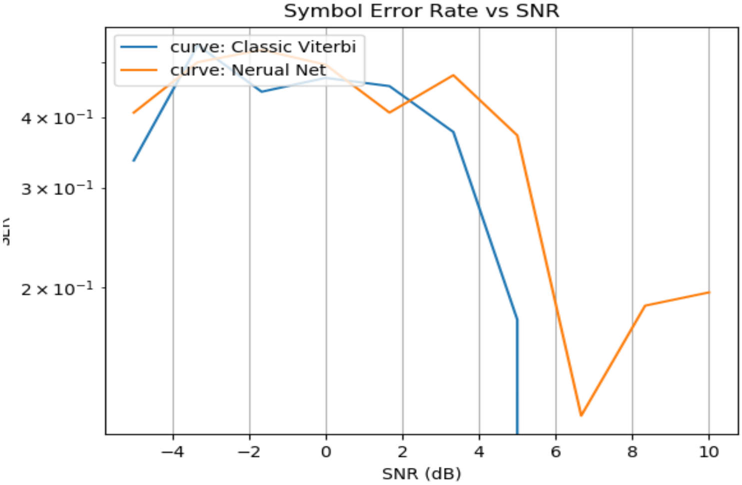


With ISI



Detection Performance

Reduced Training data (100 vs. 1000 symbols)



Next Steps

- Improve decoding performance with neural net.
- Apply to a sampled molecular communications channel.
  - Estimate matched filter
- Generate training data for molecular communications channel and test "transfer learning" to real data.

Thank You.

Questions or Comments?