# 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

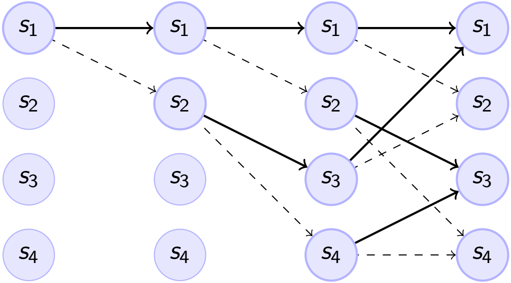
$$
\begin{aligned}
&\underset{\mathbf{x}}{\text{maximize}} \quad Pr(\mathbf{y}|\mathbf{x}) \\
&\underset{\mathbf{x}}{\text{maximize}} \quad \prod_{\mathrm{i}=1}^{\mathrm{N}} Pr(y_{\mathrm{i}}|\mathbf{x}) \\
\\
&\underset{\mathbf{x}}{\text{minimize}} \quad \sum_{\mathrm{i}=1}^{\mathrm{N}} -log(Pr(y_{\mathrm{i}}|\mathbf{x}))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

$s_1 = 00$

$s_2 = 01$

$s_3 = 10$

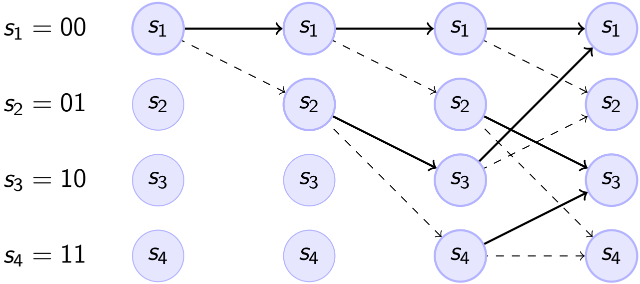
$s_4 = 11$



# Viterbi Setup Continued

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

Example with channel impulse response length 2 and constellation size 2




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

# Incorporating Neural Net into Viterbi Decoding

## Problem 1

Viterbi algorithm requires distribution $Pr(y_\mathrm{i}|\mathbf{x}_{\mathrm{i}-\mathrm{l}}^{\mathrm{i}})$ (or its parameters).

- **Solution**

  Have Neural Network learn $Pr(y_\mathrm{i}|\mathbf{x}_{\mathrm{i}-\mathrm{l}}^{\mathrm{i}})$

## Problem 2

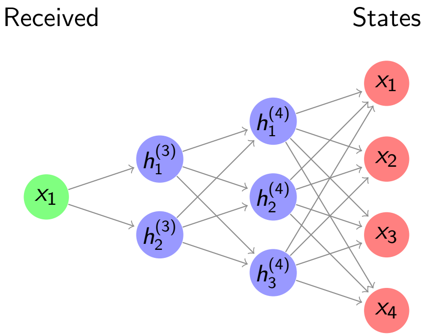
Generating training data $Pr(y_\mathrm{i}|\mathbf{x}_{\mathrm{i}-\mathrm{l}}^{\mathrm{i}})$ requires knowledge of the channel and its (current) parameters.

- **Solution**

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

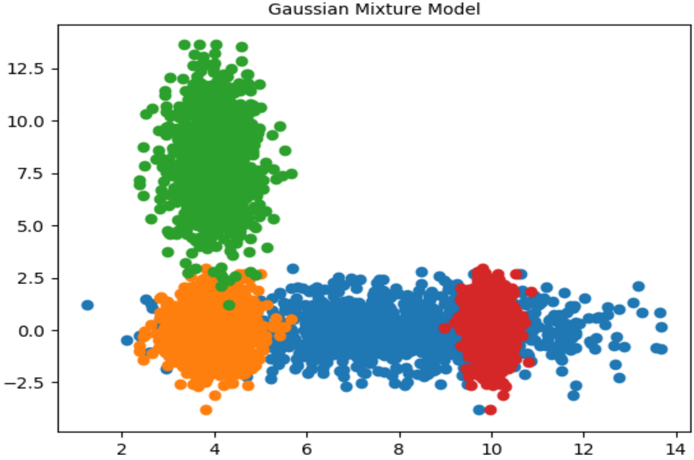
$$Pr(y_\mathrm{i}|\mathbf{x}_{\mathrm{i}-\mathrm{l}}^{\mathrm{i}}) = \frac{Pr(\mathbf{x}_{\mathrm{i}-\mathrm{l}}^{\mathrm{i}}|y_\mathrm{i})Pr(y_\mathrm{i})}{Pr(\mathbf{x}_{\mathrm{i}-\mathrm{l}}^{\mathrm{i}})} \tag{6}$$

# 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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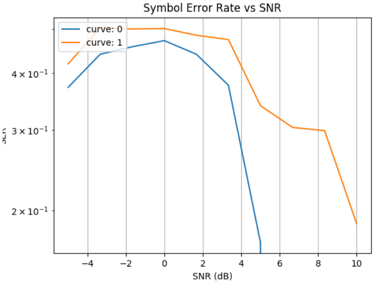
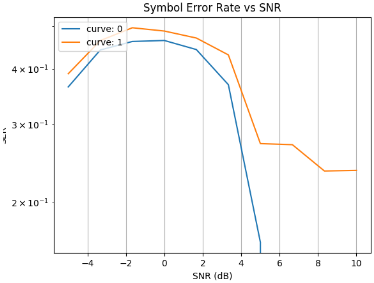
# Detection Performance



# Next Step

- Apply to a sampled molecular communications channel.
  - Estimate matched filter
- Generate training data for molecular communications channel and test "transfer learning" to real data.