# Estimation of Channel Distribution Functions using a Neural Network

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# Outline

# The Channel State

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# Sampling Channel State

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The channel is a random process that realizes a specific state for each time index $k$. Specifically give the example of the LTI channel.

# Estimating the True Channel State

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# MAP Sequence Detection

Include decomposition and example for LTI channel.

# Utilizing the General Definition of State

Include decomposition and example for LTI channel.

# Something about reduced state

Include decomposition and example for LTI channel.

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Include decomposition and example for LTI channel.

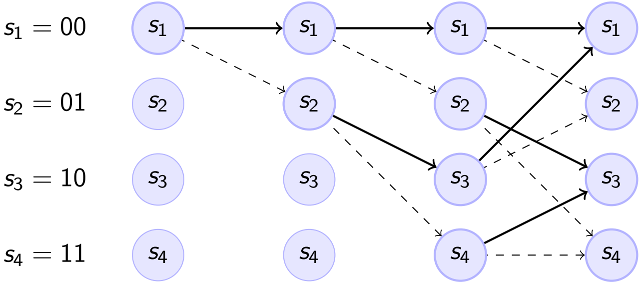
# Viterbi Setup

Maximum Likelihood sequence decoding can be formalized as

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

# 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 $Pr(y_{\mathrm{i}}|\mathbf{x}_{\mathrm{i}-1}^{\mathrm{i}})$.




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.

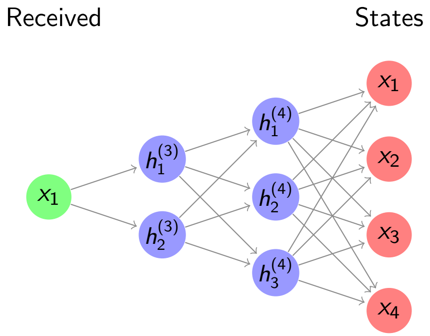
- Solution

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

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

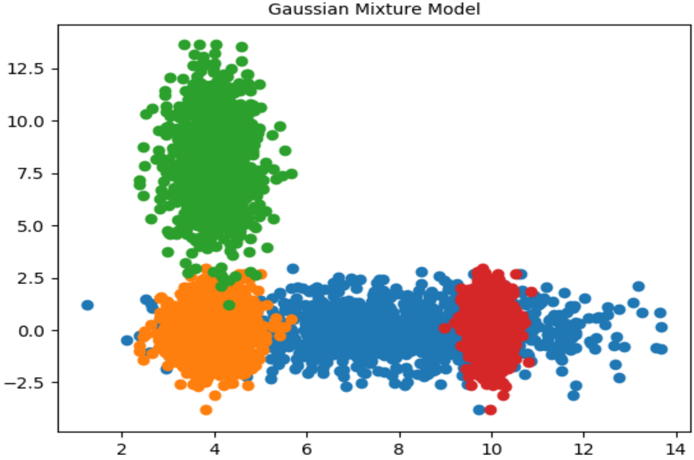
.

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



# Metrics for $Pr(y_{\mathrm{i}})$

Gaussian Mixture Model using Expectation-Maximization algorithm



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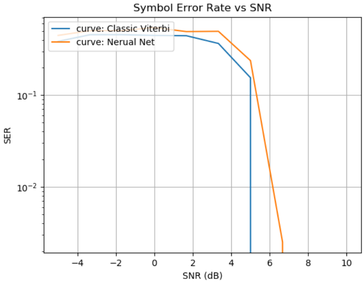
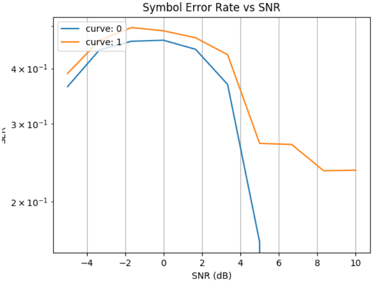
# Detection Performance

Without ISI

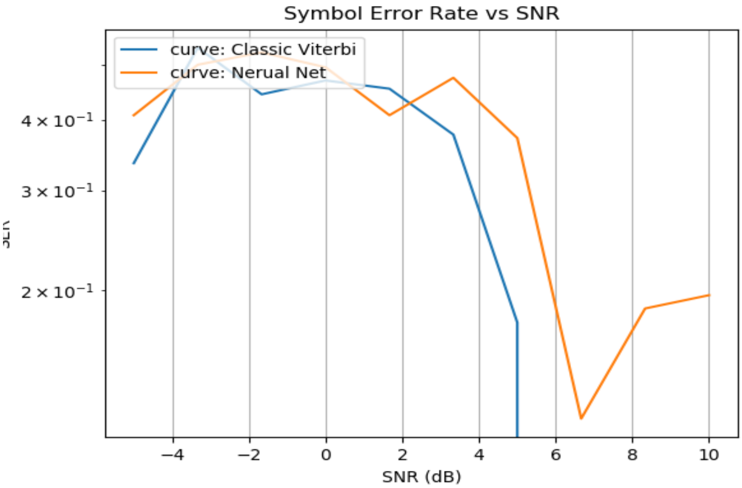



With ISI



# Detection Performance

Reduced Training data (100 vs. 1000 symbols)



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# 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?*