Neural Network Metrics for Viterbi Decoding in Molecular Communication Channels

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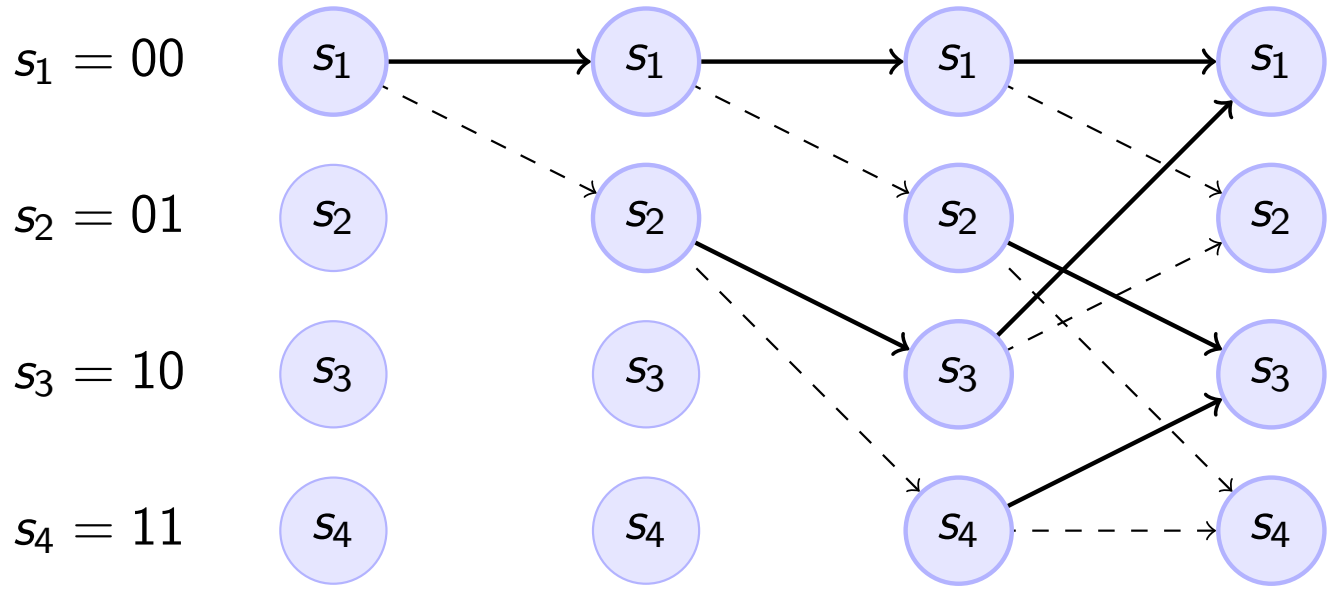
Outline

Viterbi Setup

Maximum Likelihood sequence decoding can be formalized as

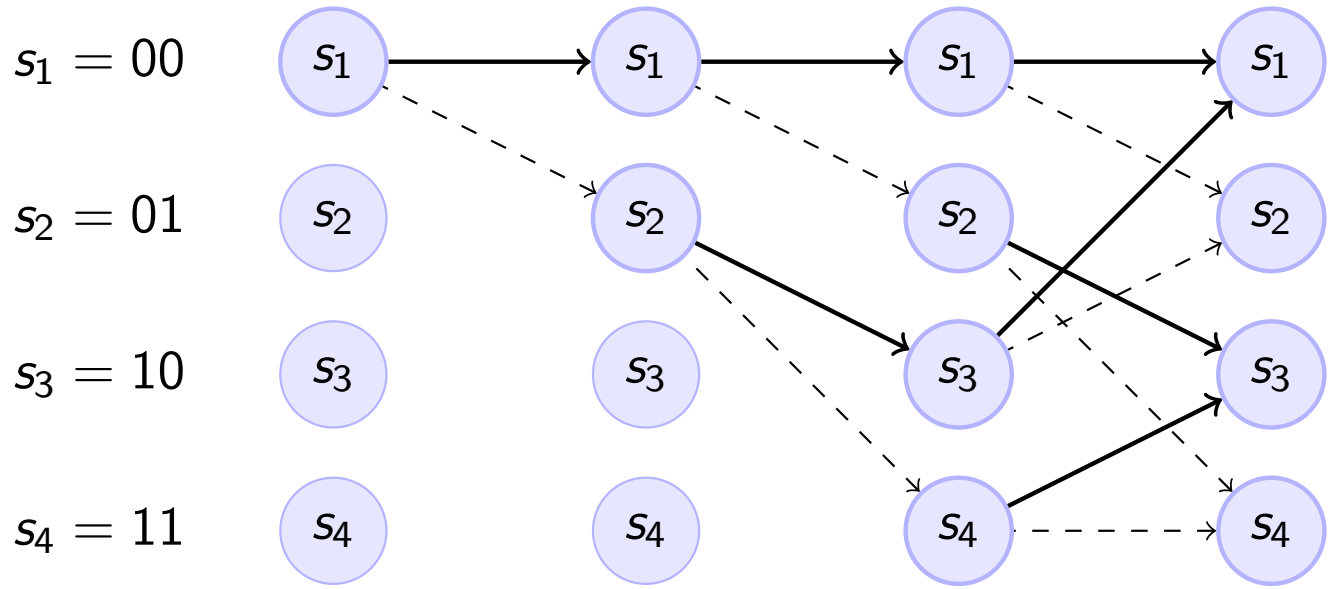
$$\begin{aligned} \underset{\mathbf{x}}{\text{maximize}} \quad & Pr(\mathbf{y}|\mathbf{x}) \\ \underset{\mathbf{x}}{\text{maximize}} \quad & \prod_{\mathrm{i}=1}^{\mathrm{N}} Pr(y_{\mathrm{i}}|\mathbf{x}) \\ \underset{\mathbf{x}}{\text{minimize}} \quad & \sum_{\mathrm{i}=1}^{\mathrm{N}} -log(Pr(y_{\mathrm{i}}|\mathbf{x}))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



Viterbi Setup Continued

Each state change is decided by the metric $Pr(y_i|\mathbf{x})$. 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 $Pr(y_i|\mathbf{x}_{i-l}^{i})$ (or its parameters).

- **Solution**

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

Problem 2

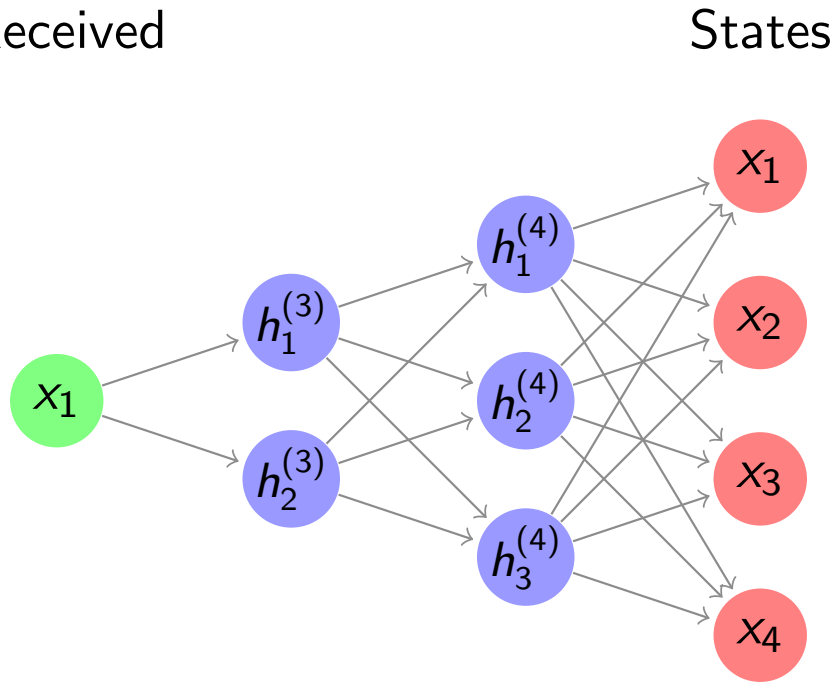
Generating training data $Pr(y_i|\mathbf{x}_{i-l}^{i})$ requires knowledge of the channel and its (current) parameters.

- **Solution**

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

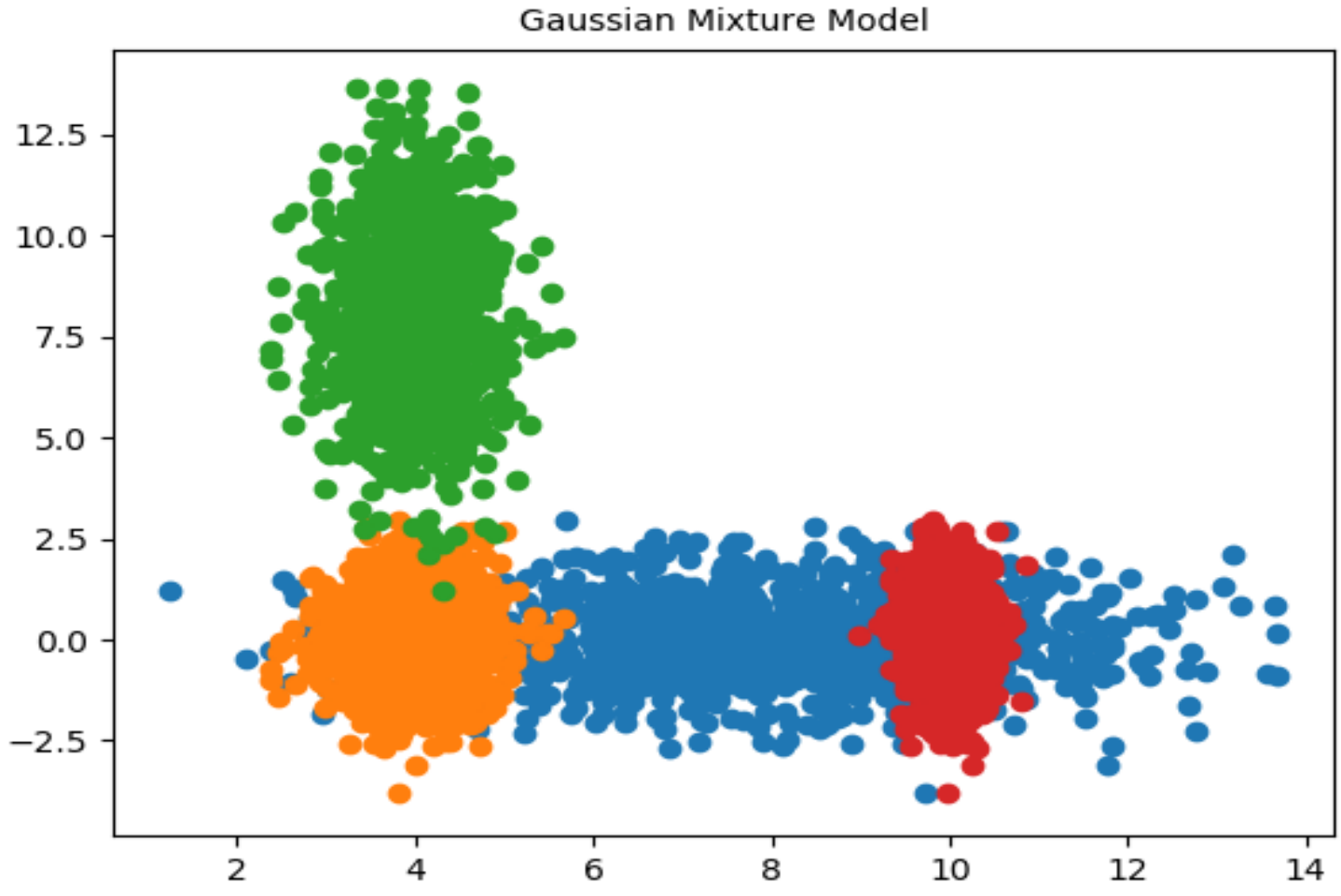
$$Pr(y_i|\mathbf{x}_{i-l}^{i}) = \frac{Pr(\mathbf{x}_{i-l}^{i}|y_i)Pr(y_i)}{Pr(\mathbf{x}_{i-l}^{i})} \tag{6}$$

Metrics for $Pr(x_{i-1}^{i}|y_i)$



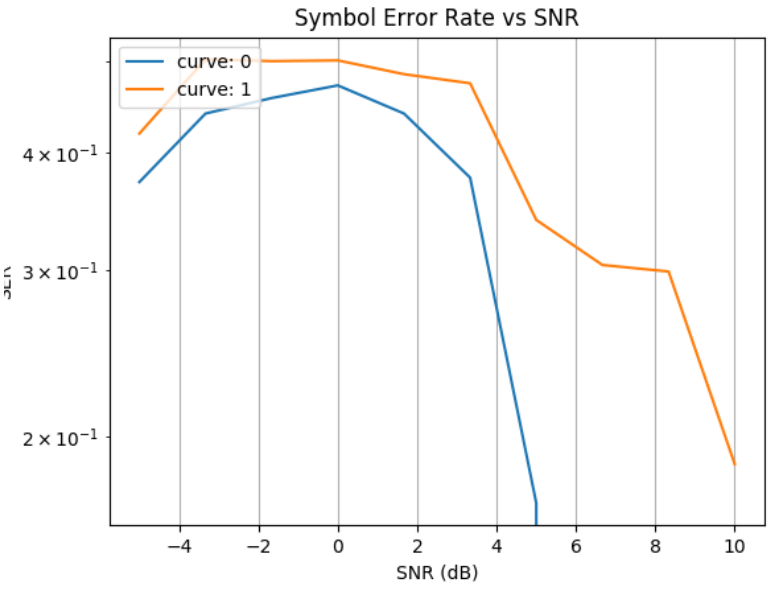
Metrics for $Pr(y_i)$

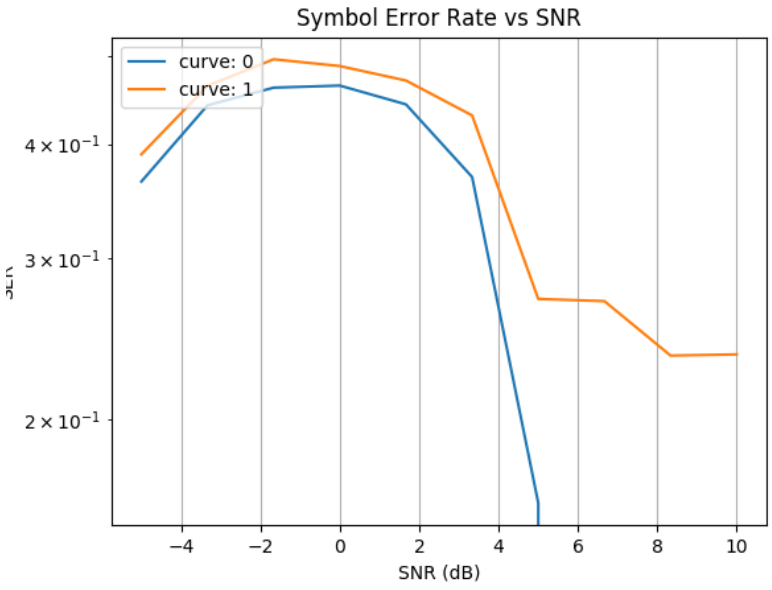
Gaussian Mixture Model using Expectation-Maximization algorithm



Outline

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.