Symbol-Level Online Channel Tracking for Deep Receivers

ICASSP, May 2022

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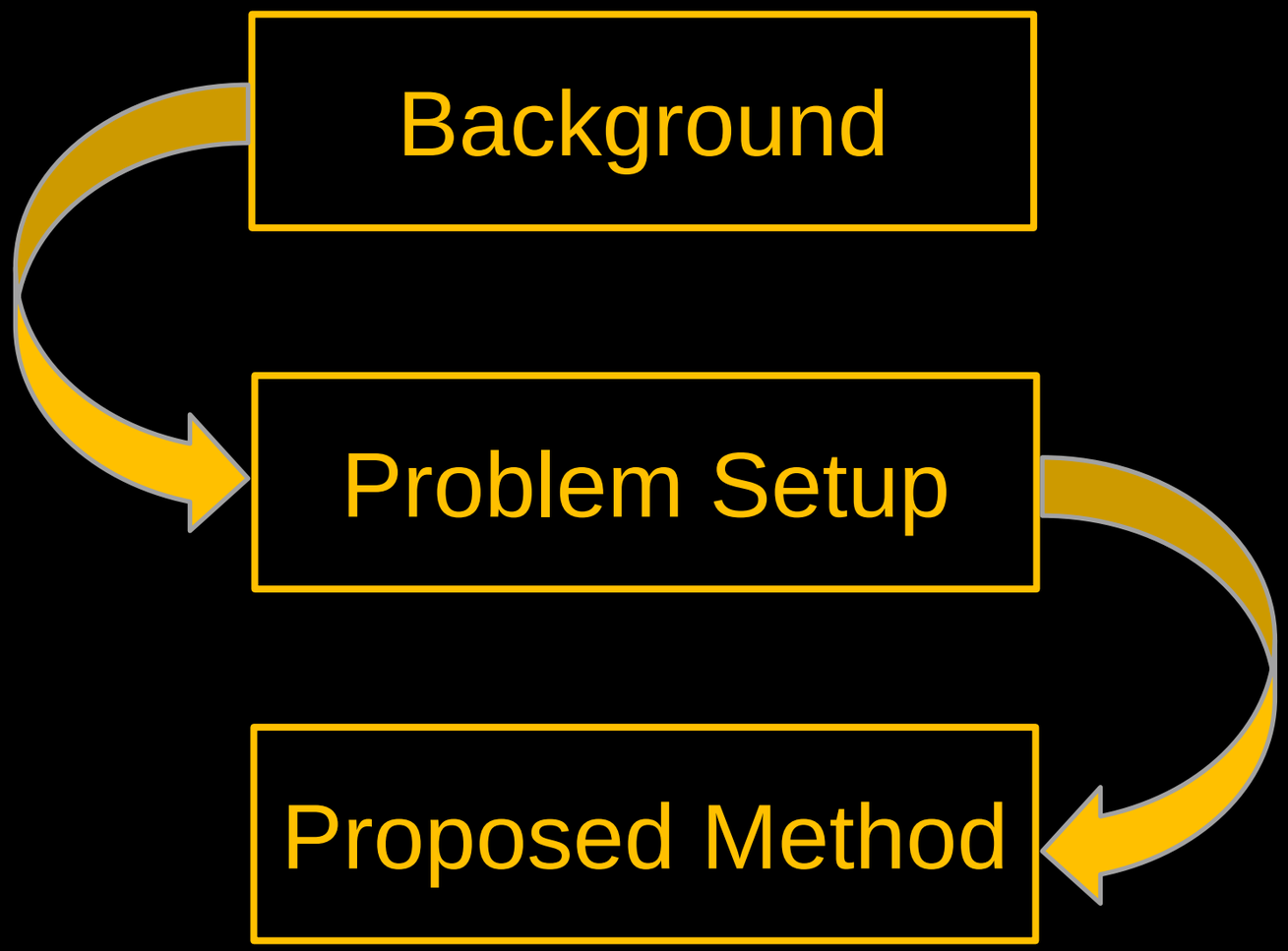
May 2022

Agenda

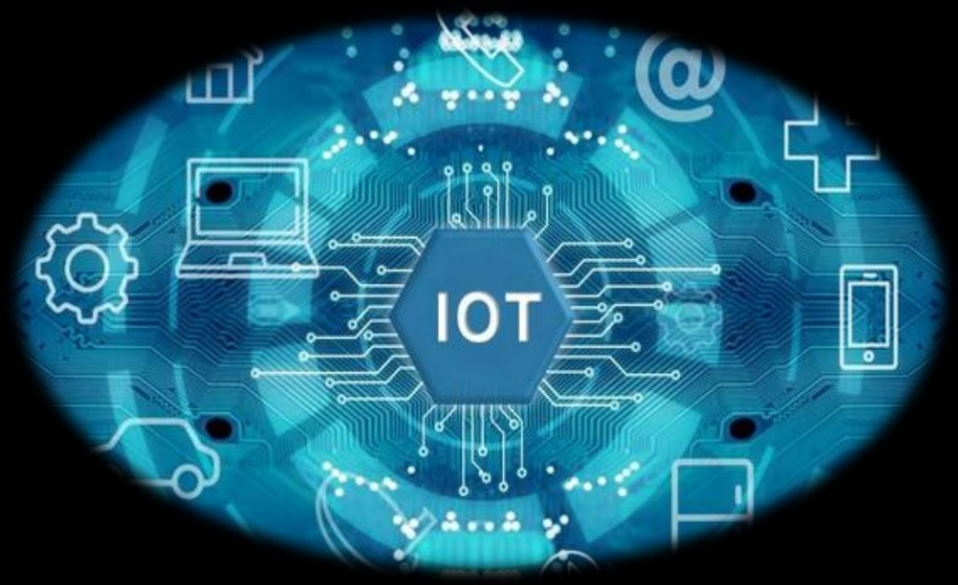


6G Demands

Grow exponentially

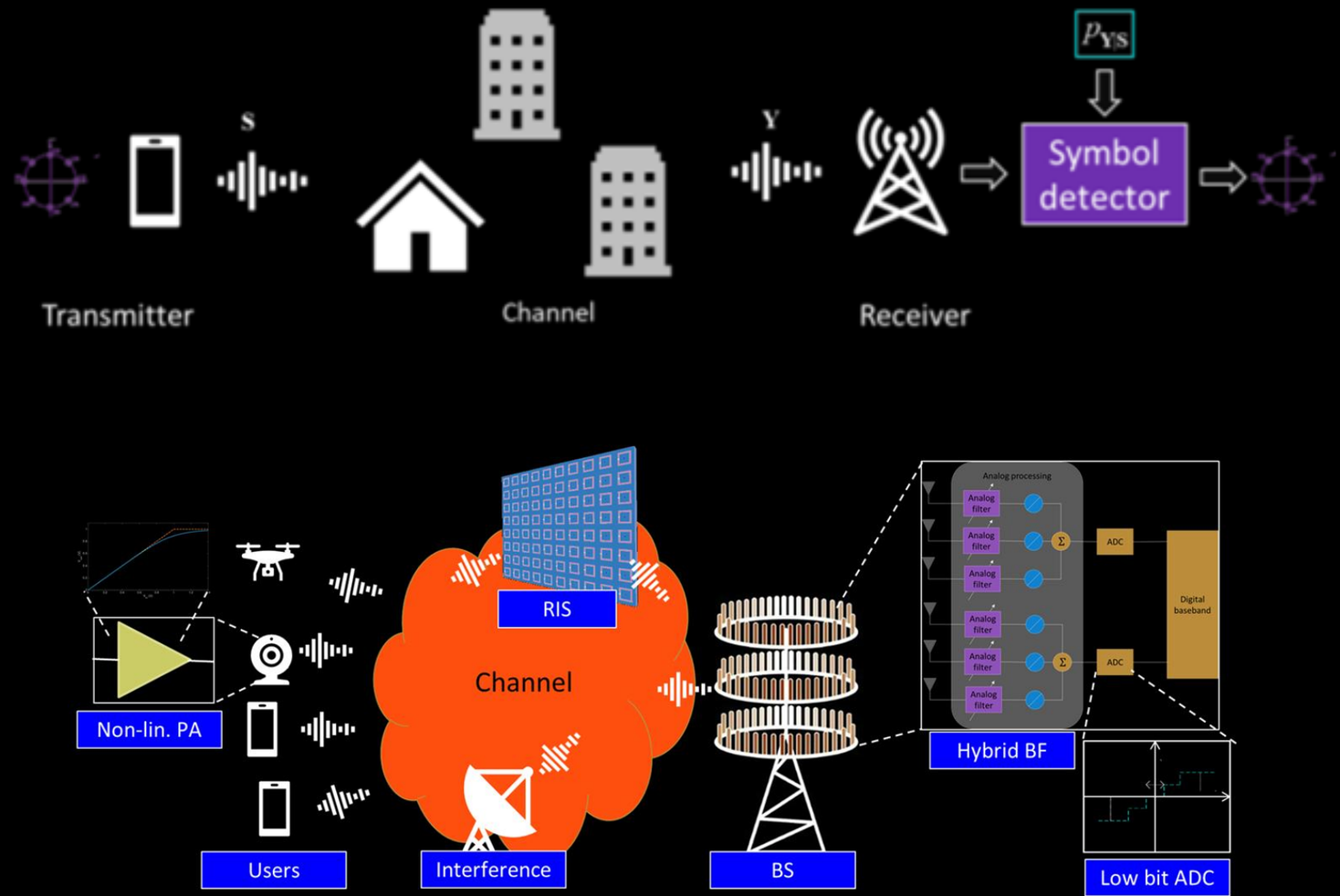
Fast adaptation

Many varying channels

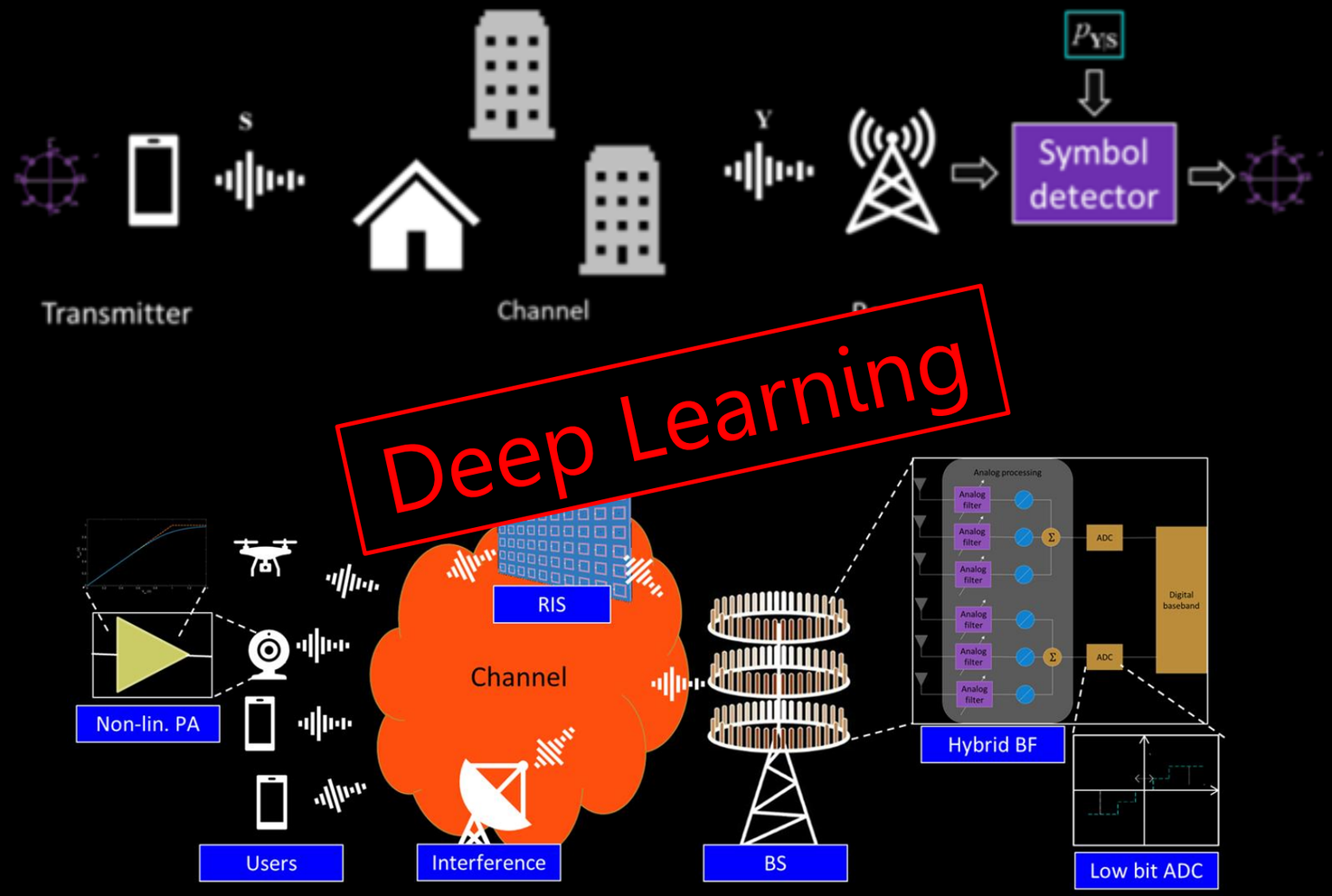


[1] V. Cisco, “Cisco visual networking index: Forecast and trends, 2017– 2022,” White Paper, vol. 1, 2018.

Detection Scenario

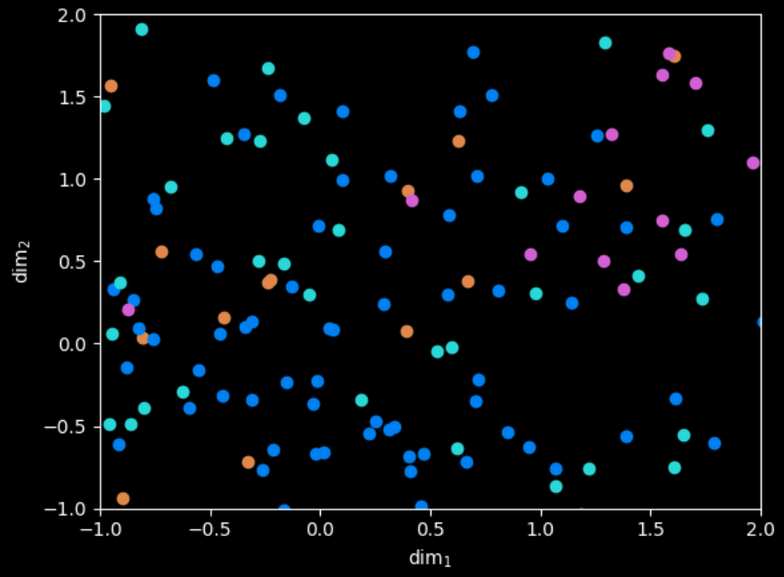


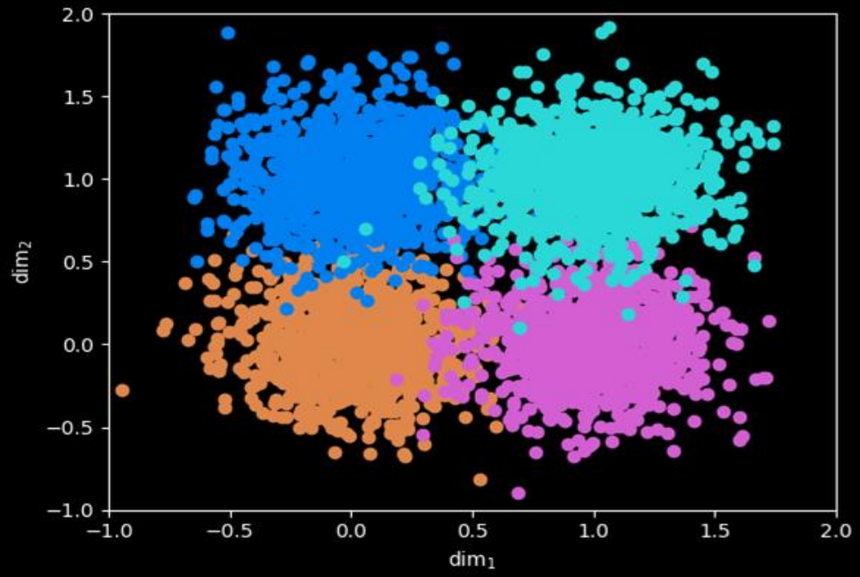
Detection Scenario



Machine-learning in Communications

Conventional versus physical layer application

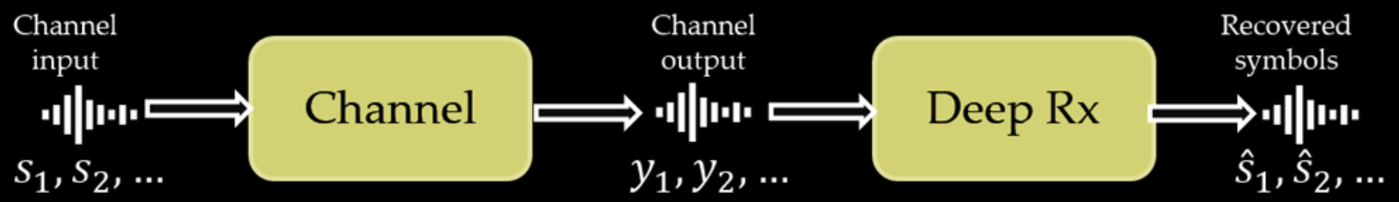




Machine-learning in Communications

Constantly changing!

Problem Formulation

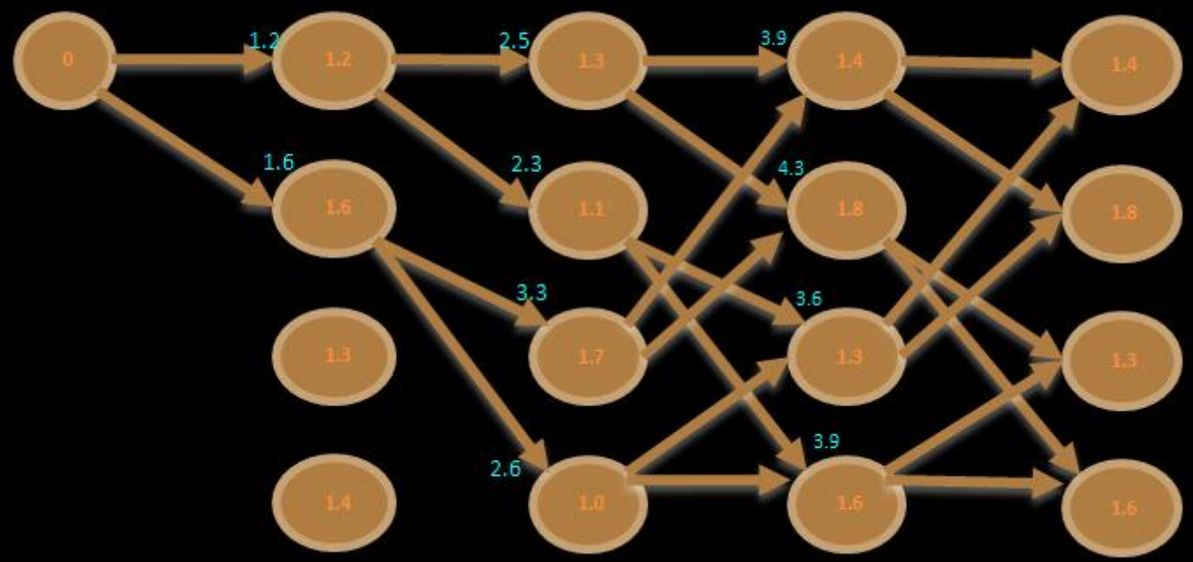


$$p_{\boldsymbol{Y}_j^B|\boldsymbol{S}_j^B}\left(\boldsymbol{y}_j^B|\boldsymbol{s}_j^B\right) = \prod_{i=1}^{B} p_{\boldsymbol{Y}_{i,j}|\bar{\boldsymbol{s}}_{i,j}}\left(\boldsymbol{y}_{i,j}|\bar{\boldsymbol{s}}_{i,j}\right)$$

$$\hat{\boldsymbol{s}}_j^B \;:\; \mathcal{Y}^B \;\mapsto\; \mathcal{S}^B \qquad\qquad \frac{1}{B}\sum_{i=1}^{B} \Pr\left(\hat{s}_{i,j}(\boldsymbol{Y}_j^B) \neq S_{i,j}\right)$$

Viterbi

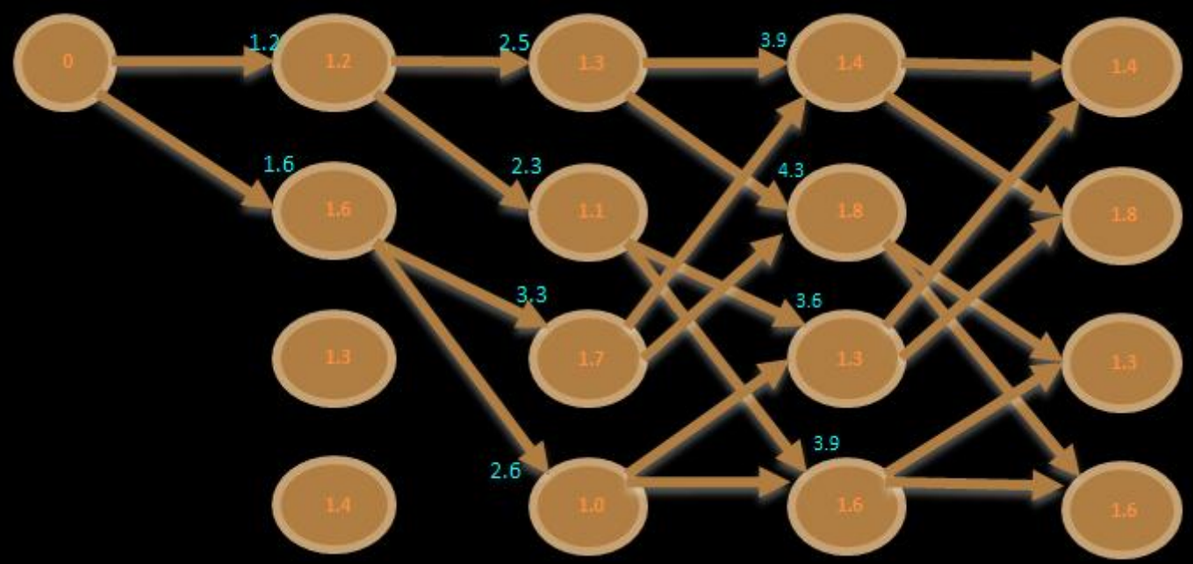
Maximum likelihood sequence detection with linear complexity



[2] A. Viterbi, “Error bounds for convolutional codes and an asymptotically optimum decoding algorithm,” IEEE Trans. Inf. Theory, vol. 13, no. 2, pp. 260–269, 1967.

Viterbi

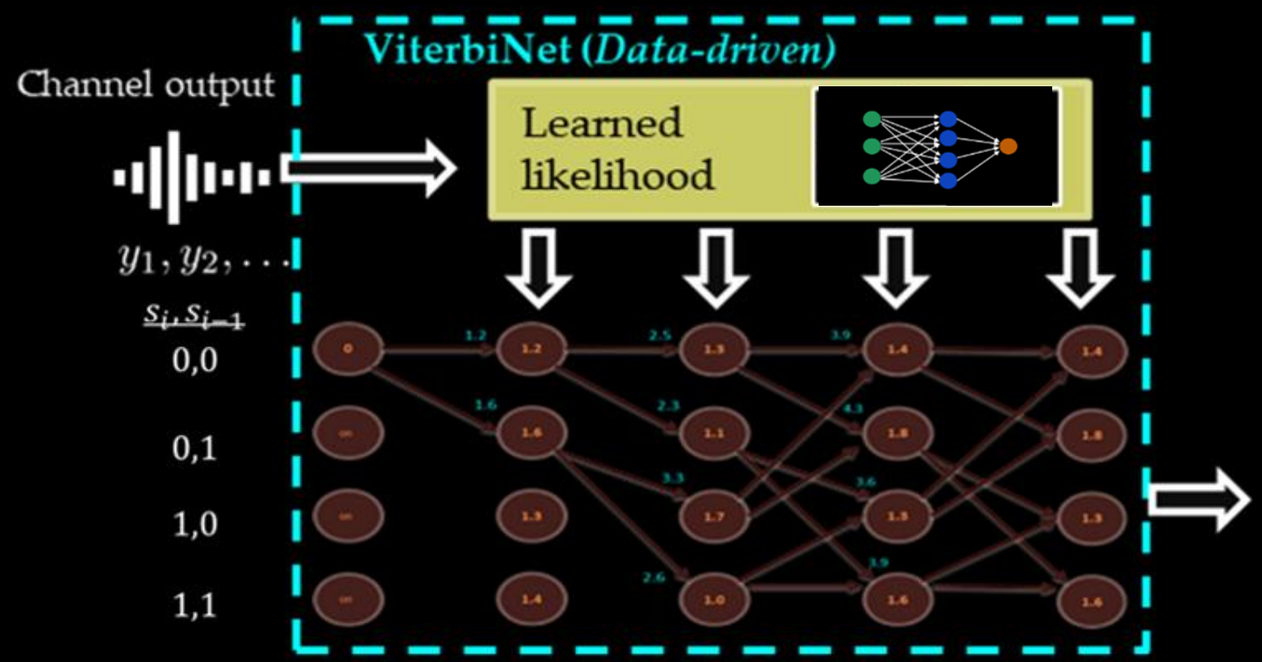
Maximum likelihood sequence detection with linear complexity



But sensitive to inaccurate model knowledge!

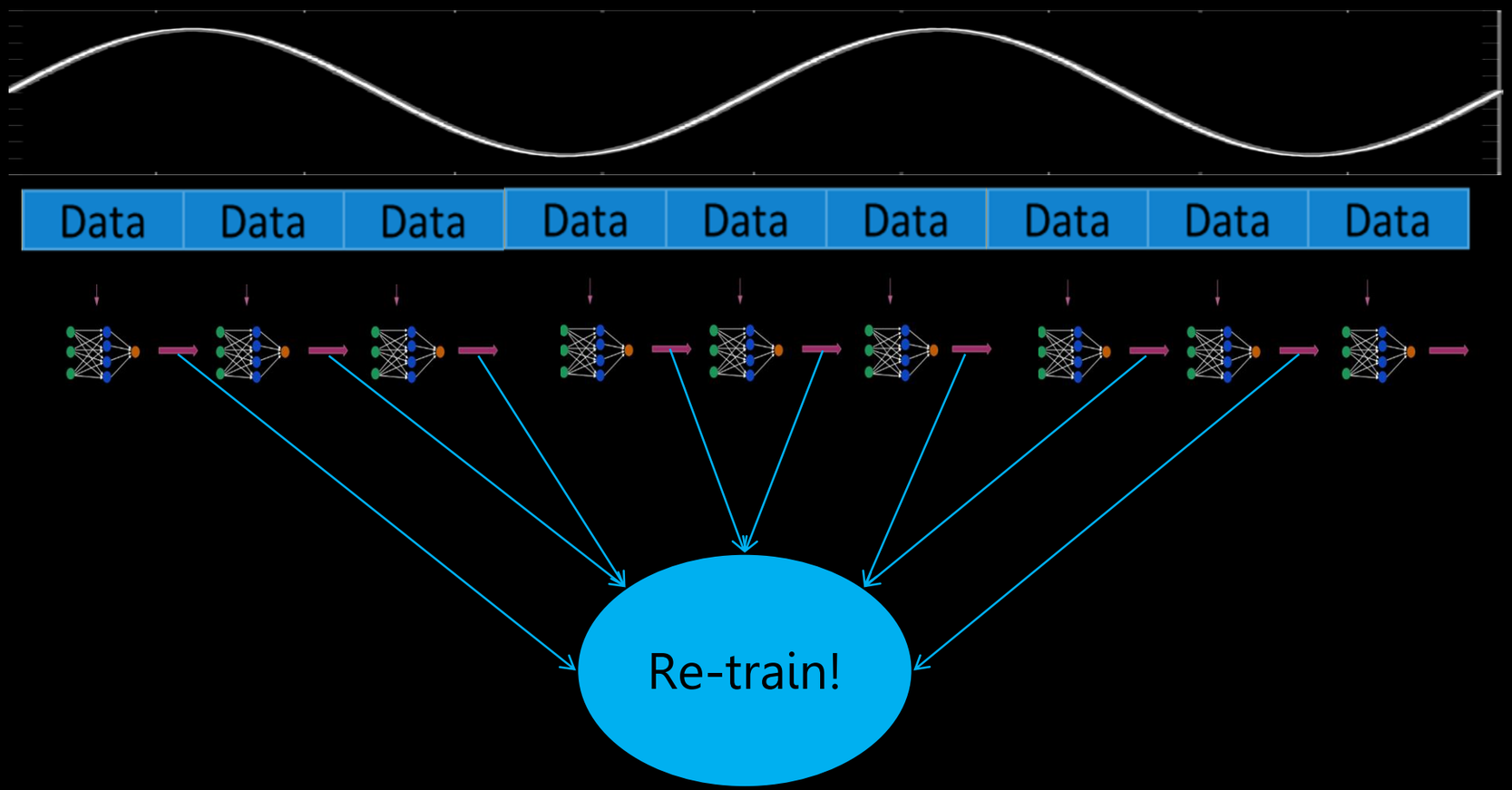
[2] A. Viterbi, “Error bounds for convolutional codes and an asymptotically optimum decoding algorithm,” IEEE Trans. Inf. Theory, vol. 13, no. 2, pp. 260–269, 1967.

ViterbiNet



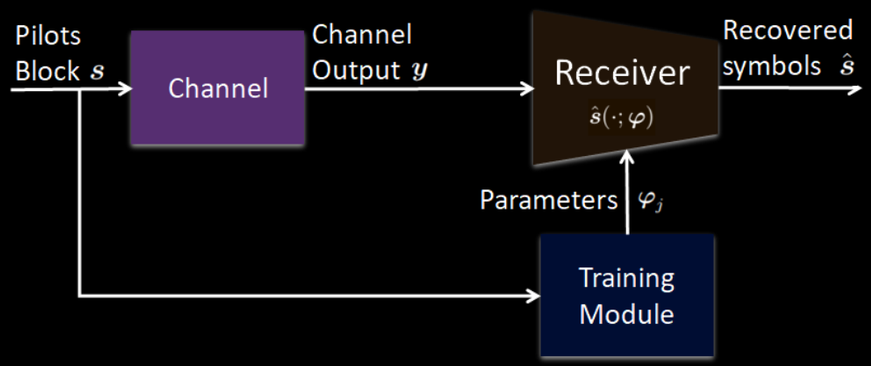
[3] N. Shlezinger et al. "ViterbiNet: A deep learning based Viterbi algorithm for symbol detection." *IEEE Transactions on Wireless Communications* (2020).

Rationale



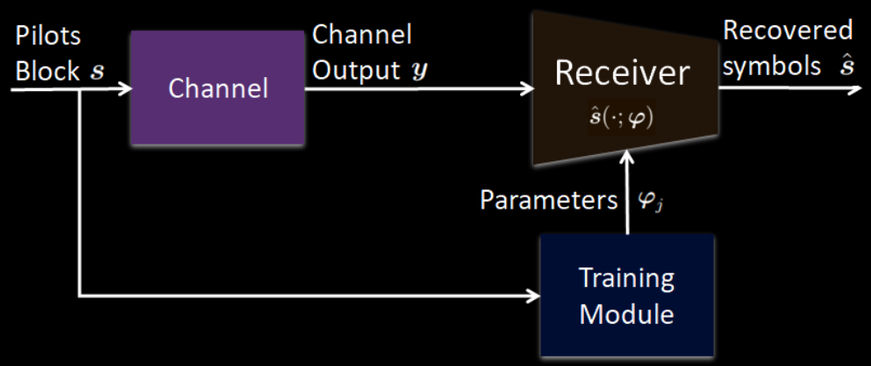
Naïve Approach

Pilots Transmission

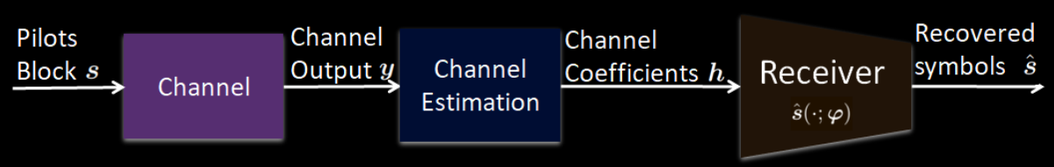


Naïve Approach

Pilots Transmission

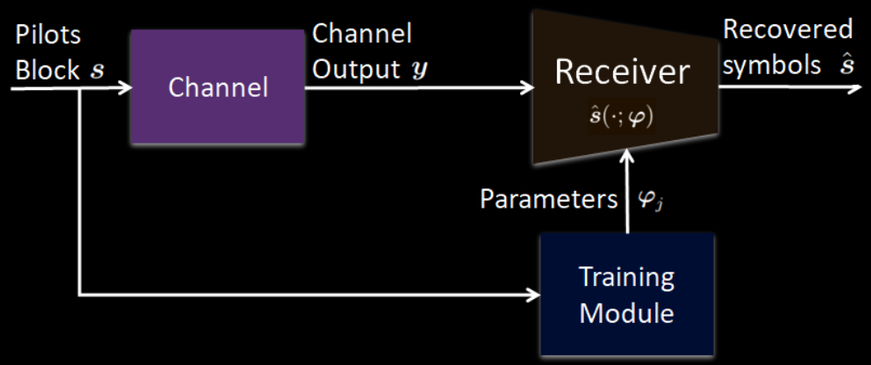


Channel Estimation

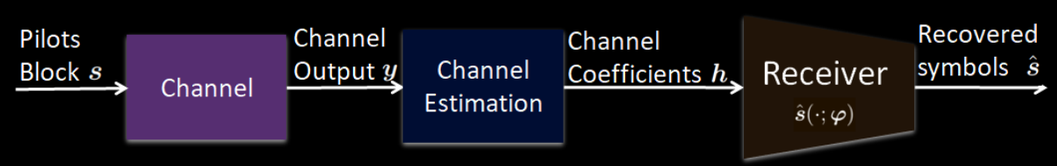


Naïve Approach

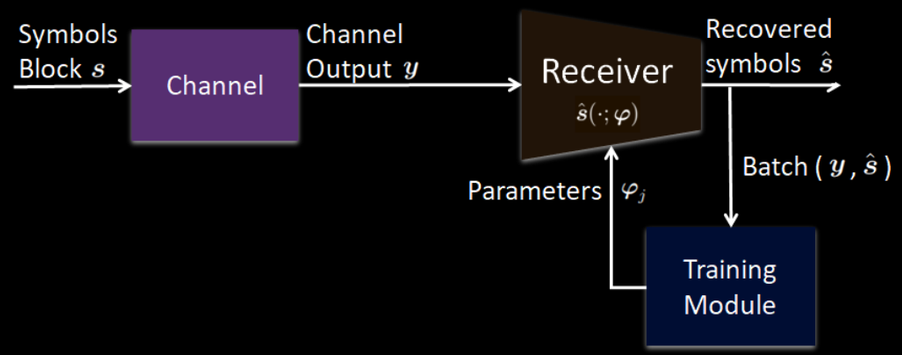
Pilots Transmission



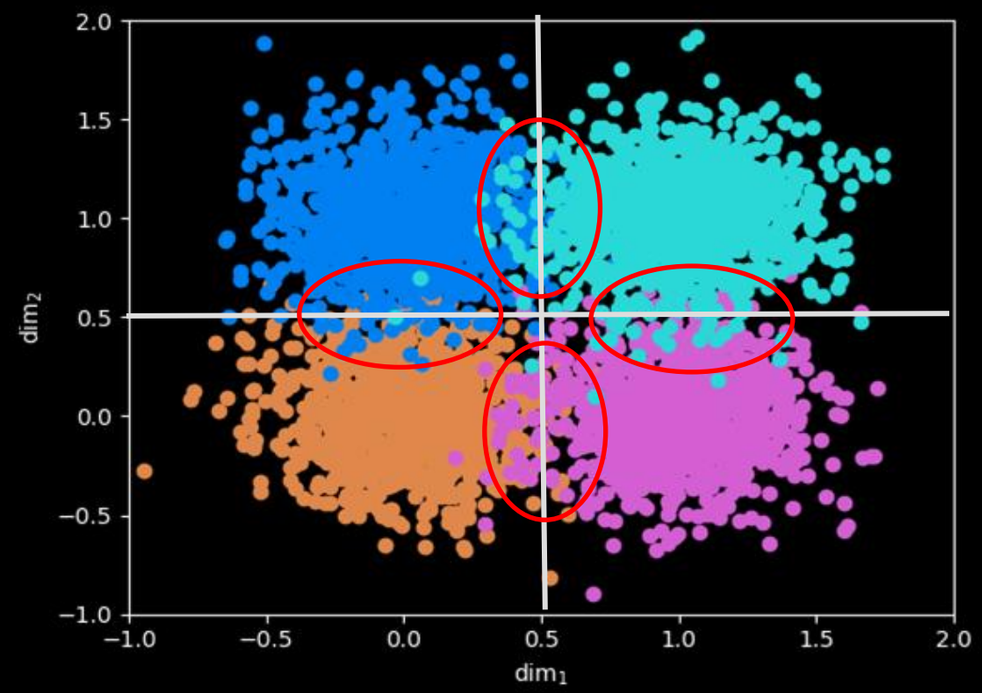
Channel Estimation



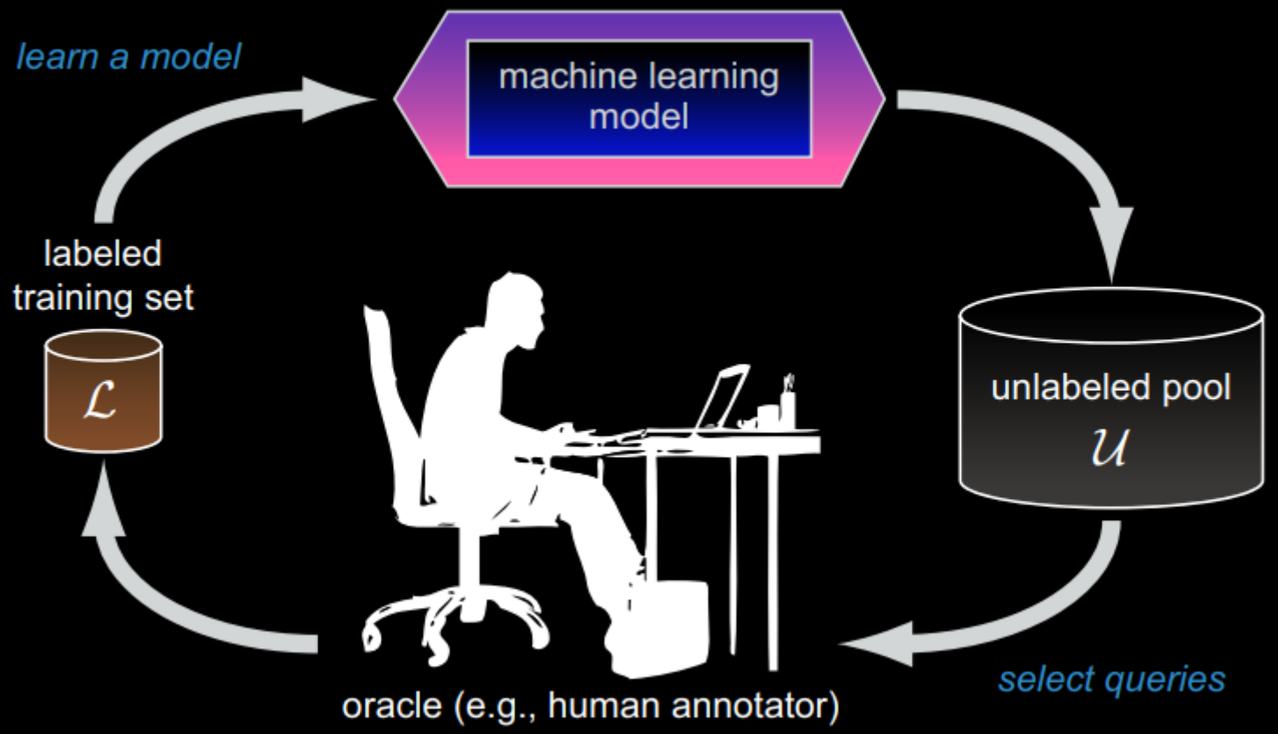
Self Supervised Re-training



Dealing with Rapid Variations

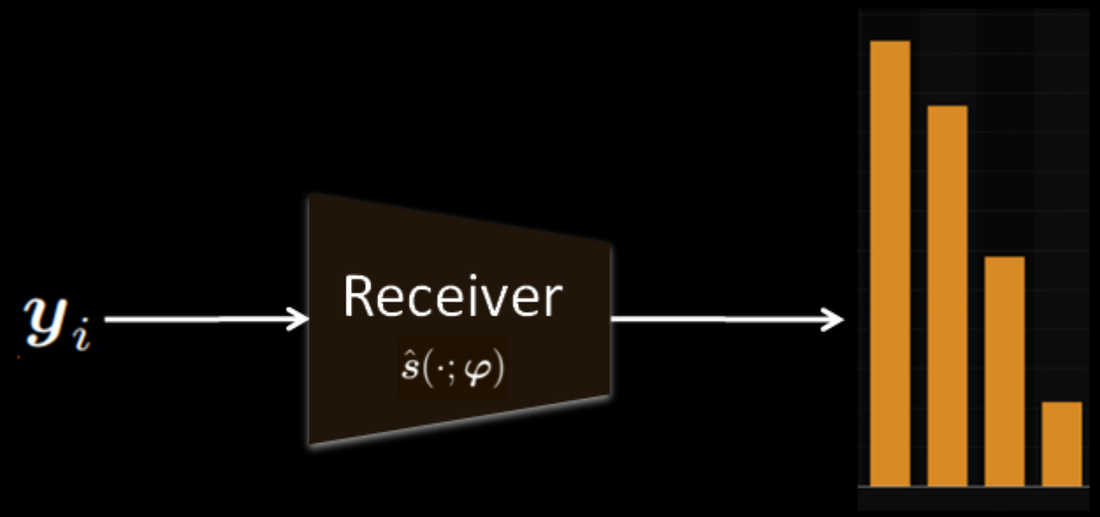


Active Learning



[4] Settles, Burr. "Active learning literature survey." (2009).

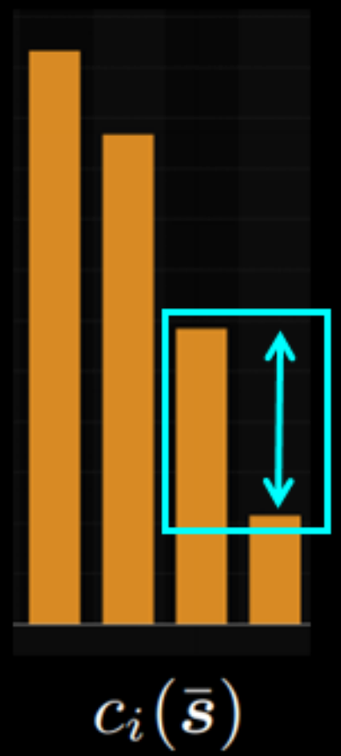
Confidence Gap



$c_i(\bar{\boldsymbol{s}})$

$$c_{i,j}(\bar{\boldsymbol{s}}) := -\log p_{\boldsymbol{Y}_{i,j}|\bar{\boldsymbol{S}}_{i,j}}\left(\boldsymbol{y}_{i,j}|\bar{\boldsymbol{s}}_i\right)$$

Confidence Gap



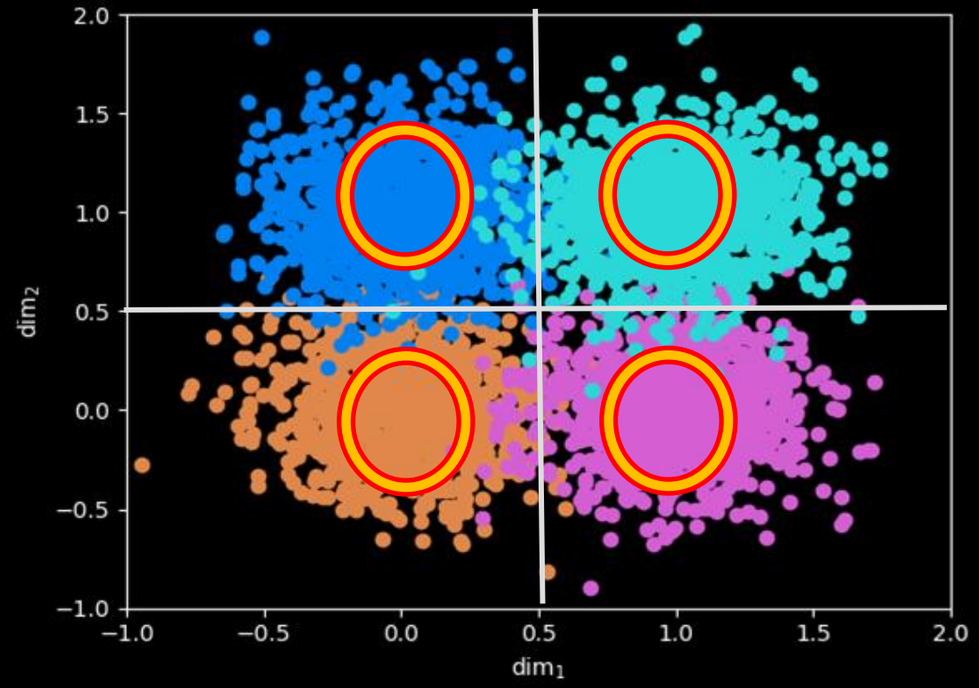
$c_i(\bar{\boldsymbol{s}})$

|Lowest-2nd Lowest|

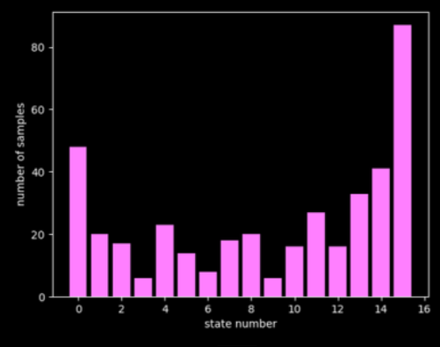
$$g_i \triangleq |c_i(\bar{\boldsymbol{s}}_i^*) - c_i(\bar{\boldsymbol{s}}_i^{**})|$$

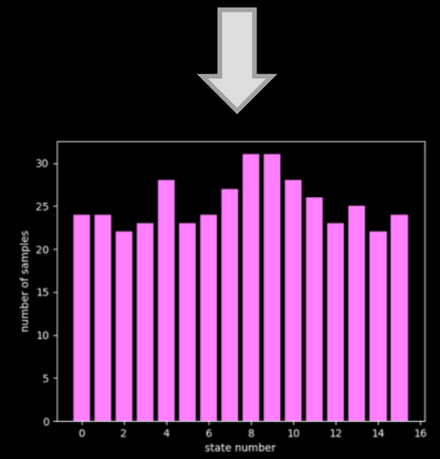
Diversity

Reliability Diversity



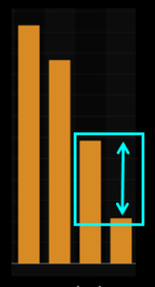
Symbol Diversity

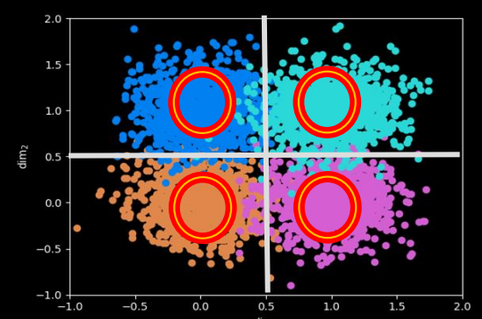


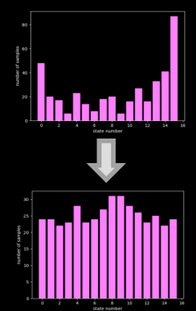


Proposed Approach

Confidence Gap Reliability Diversity Symbol Diversity





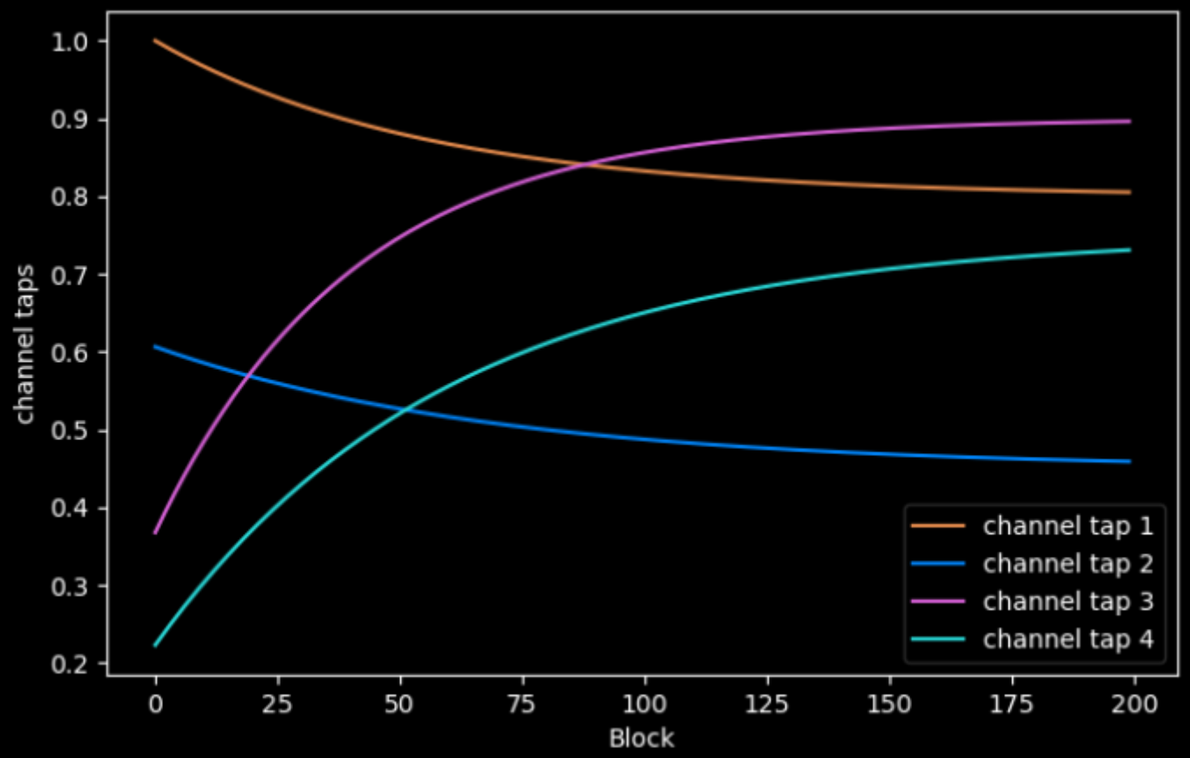


Algorithm 1: Self-Supervised Active Learning

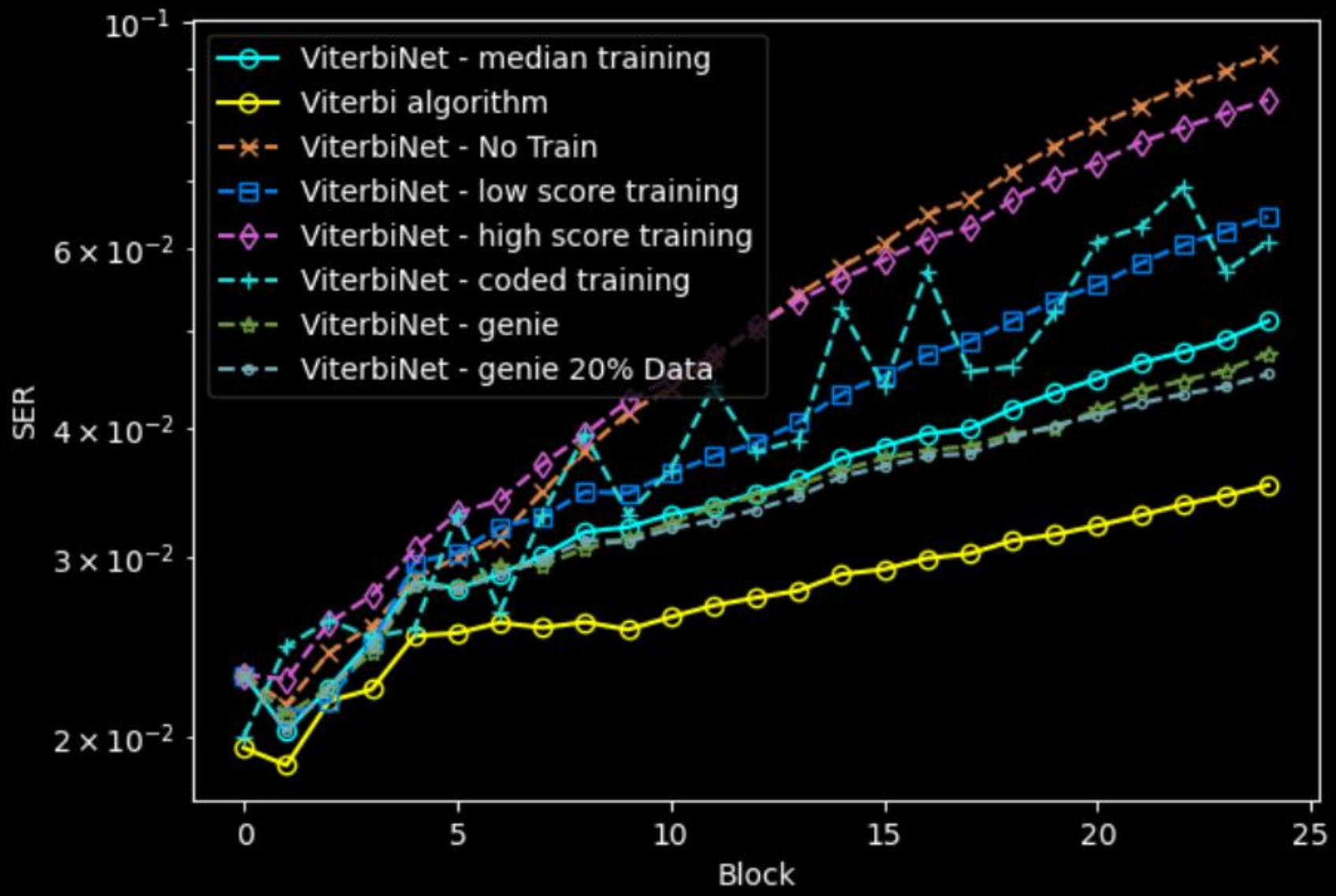
Initialization: empty buffer $\mathcal{Q}$
Input : current detector $\boldsymbol{\varphi}_j$
received channel-block $\boldsymbol{y}_j^B$
ℓ, u lower and upper percentiles
Output : improved model $\boldsymbol{\varphi}_{j+1}$

Self-Supervised Active Learning $(\boldsymbol{\varphi}_j, \boldsymbol{y}_j^B, \ell, u)$
  $c_{i,j}(\bar{\boldsymbol{s}}) \leftarrow$ calculate by (3), $(\bar{\boldsymbol{s}}, i) \in \mathcal{S} \times \mathcal{B}$;
  $\hat{\boldsymbol{s}}_j^B \leftarrow$ calculate by (2);
  $\boldsymbol{g}^B \leftarrow$ calculate by (4);
  $P_\ell, P_u \leftarrow$ thresholds of confidence ℓ, u percentiles;
  for i *in* $\mathcal{B}$ **do**
    if $P_\ell \leq g_i \leq P_u$ **then**
      add $(\boldsymbol{y}_{i,j}, \hat{s}_{i,j})$ to Q;
  end
  $\boldsymbol{\varphi}_{j+1} \leftarrow$ train model $\boldsymbol{\varphi}_j$ using data $\mathcal{Q}$;
  return $\boldsymbol{\varphi}_{j+1}$

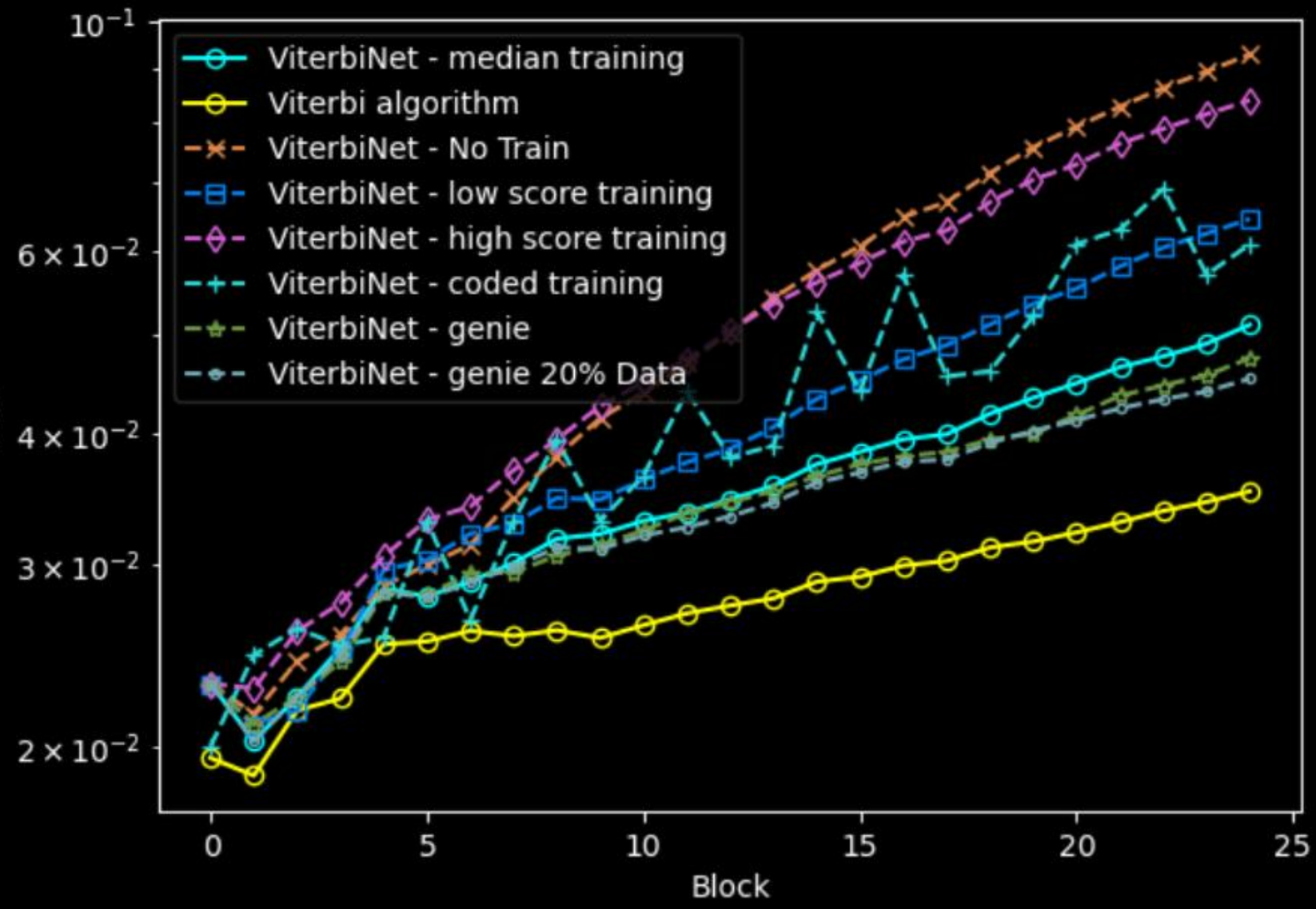
Results - Channel



Results - SER

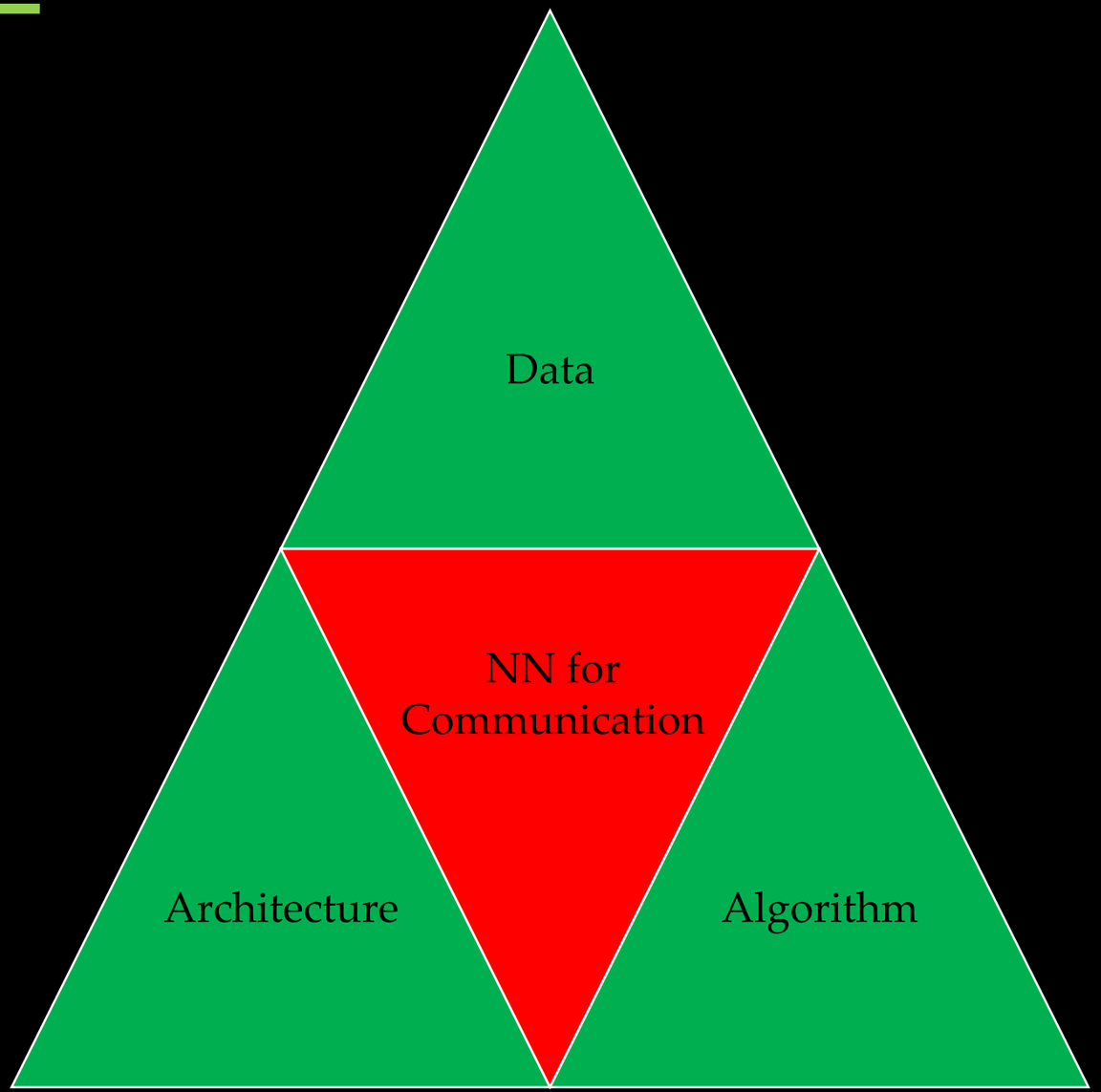

ViterbiNet - median training
Viterbi algorithm
ViterbiNet - No Train
ViterbiNet - low score training
ViterbiNet - high score training
ViterbiNet - coded training
ViterbiNet - genie
ViterbiNet - genie 20% Data
SER
10^{-1}
6×10^{-2}
4×10^{-2}
3×10^{-2}
2×10^{-2}
0
5
10
15
20
25
Block

Results - SER



Close to genie!

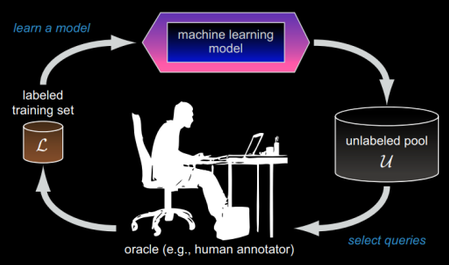
NN for Communication



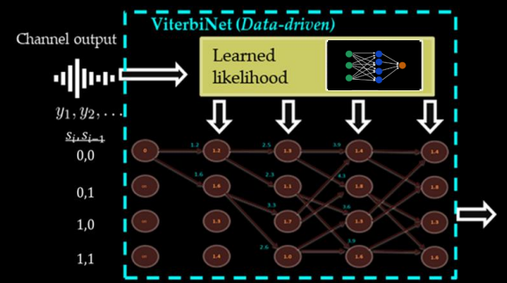
[5] Raviv, Tomer, et al. "Meta-ViterbiNet: Online meta-learned Viterbi equalization for non-stationary channels." 2021 IEEE International Conference on Communications Workshops (ICC Workshops). IEEE

Conclusions

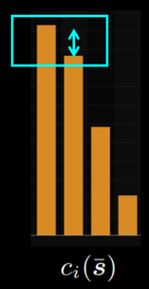
Active learning



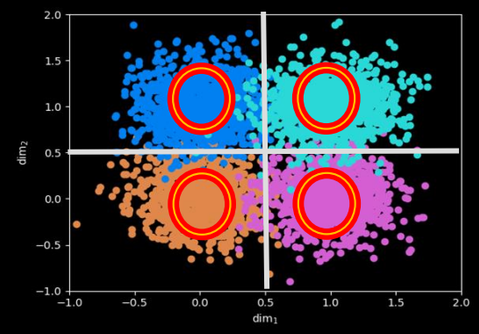
Neural-based Receiver



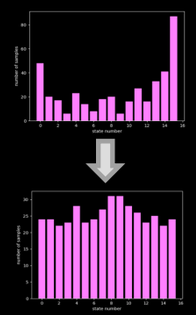
Confidence Gap



Reliability Diversity



Symbol Diversity



Final Words

Paper & github code in video description

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[2] A. Viterbi, “Error bounds for convolutional codes and an asymptotically optimum decoding algorithm,” IEEE Trans. Inf. Theory, vol. 13, no. 2, pp. 260–269, 1967.

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