Learnable Binary MIMO Detection based on Inexact ADMM

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***Abstract*—In this paper, we propose a signal detection network in MIMO systems with one-bit ADCs based on alternating direction methods of multipliers (ADMM). The proposed learnable detection method performs better than the existing methods.**

***Index Terms*—Binary MIMO detection, negative penalty, neural networks.**

I. Introduction

We consider binary MIMO systems, where the received signals are quantized with one bit. We propose a learnable binary MIMO detection with a negative penalty based on alternating direction methods of multipliers (ADMM). The proposed MIMO method performs better than the existing detection methods.

II. System Model for Binary MIMO Systems

We consider uplink massive MIMO systems with one-bit A/D converters (ADCs) at the base station

$$\mathbf{y} = \operatorname{sgn}(\mathbf{Hx} + \mathbf{n}), \tag{1}$$

where $\mathbf{x} \in \mathcal{S}^M = \{-1, +1\}^M$ is the transmitted symbol vector, $\mathbf{H} = [\mathbf{h}_1 \ \cdots \ \mathbf{h}_N]^T \in \mathbb{R}^{N \times M}$ is a channel matrix, and $\mathbf{n} \sim \mathcal{N}(0, \sigma^2)$ is a Gaussian noise vector. We consider a binary MIMO detection with a negative penalty while relaxing $\mathbf{x} \in \mathcal{S}^M$ to the box constraint $\mathbf{x} \in \bar{\mathcal{S}}^M = \{x | -1 \leq x \leq 1\}^M$

$$\min_{\mathbf{x} \in \bar{\mathcal{S}}^M} -\sum_{i=1}^{N} \log \Phi\left(\frac{y_i \mathbf{h}_i^T \mathbf{x}}{\sigma}\right) - \frac{\lambda}{2}\|\mathbf{x}\|^2, \tag{2}$$

where $\Phi(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi}} e^{-t^2/2} dt$ is the CDF of the standard Gaussian distribution and $\mathbf{h}_i^T$ is the i-th row of $\mathbf{H}$.

III. Learnable ADMM for Binary MIMO Detection

We reformulate Problem (P2) with introducing $\mathbf{z}$

$$\begin{aligned} \min_{\mathbf{x} \in \bar{\mathcal{S}}^M, \mathbf{z} \in \mathbb{R}^N} \quad & -\sum_{i=1}^{M} \log \Phi\left(\frac{z_i}{\sigma}\right) - \frac{\lambda}{2}\|\mathbf{x}\|^2. \\ \text{s.t.} \quad & \mathbf{z} = \operatorname{diag}(\mathbf{y})\mathbf{Hx}. \end{aligned} \tag{3}$$

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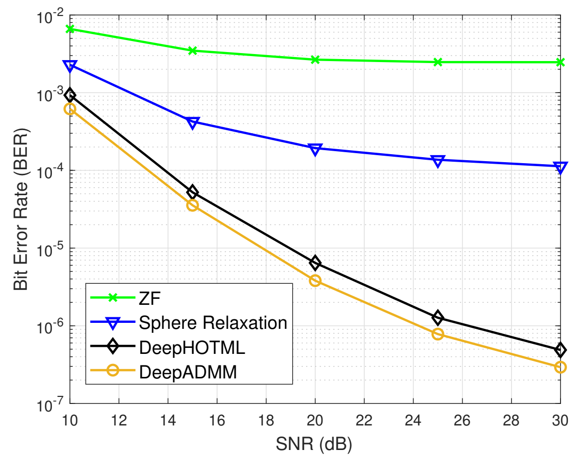

Fig. 1. BER versus SNR (dB) ($N = 120$, $M = 20$).

We propose the MIMO detection with the negative penalty using an inexact ADMM

$$\begin{aligned} \mathbf{x}_{k+1} &= \Pi_{\bar{\mathcal{S}}^M}((1+\zeta_k)\mathbf{x}_k - \delta_k \mathbf{H}^T \operatorname{diag}(\mathbf{y})(\mathbf{e}_k - 2\hat{\mathbf{z}}_k + \hat{\mathbf{v}}_k)) \\ \mathbf{e}_{k+1} &= \operatorname{diag}(\mathbf{y})\mathbf{H}\mathbf{x}_{k+1} \\ \mathbf{v}_{k+1} &= \alpha_k \mathbf{e}_{k+1} - \alpha_k \hat{\mathbf{z}}_k + \hat{\mathbf{v}}_k \\ [\mathbf{z}_{k+1}]_i &= [\mathbf{v}_{k+1}]_i - \mu_k \nabla g([\mathbf{v}_{k+1}]_i), \ \forall i, \\ \hat{\mathbf{v}}_{k+1} &= \mathbf{v}_{k+1} + \gamma_k(\mathbf{v}_{k+1} - \mathbf{v}_k) \\ \hat{\mathbf{z}}_{k+1} &= \mathbf{z}_{k+1} + \gamma_k(\mathbf{z}_{k+1} - \mathbf{z}_k). \end{aligned} \tag{4}$$

We compare our proposed DeepADMM with zero-forcing (ZF), Sphere Relaxation [1], DeepHOTML [2]. Fig. 1 shows that the proposed DeepADMM achieves about 2 dB SNR gain over DeepHOTML at BER 10^{-6}.

IV. Conclusion

In this paper, we proposed a new learnable binary MIMO detection network based on inexact ADMM using one-bit ADCs at the base station. The proposed algorithm has better detection performance than the existing algorithms.

References

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