TU Delft
Faculty of Electrical Engineering, Mathematics, and Computer Science
Circuits and Systems Group

ET4350 Applied Convex Optimization

ASSIGNMENT

MIMO Detection

1 Context

Multiple Input Multiple Output (MIMO) detection is a common problem encountered in digital communications. In a MIMO system, several transmit antennas simultaneously send different data streams. The receiver often observes a linear superposition of separately transmitted information symbols. From the receiver's perspective, the problem is then to separate the transmitted symbols. This is basically an inverse problem with a finite-alphabet constraint.

This exercise consists of two parts: (a) formulate the MIMO detection problem as a suitable convex optimization problem; and (b) implement the MIMO receiver. In a group of 2 students, make a short report (4-5 pages; pdf file) containing the required Matlab scripts, plots, and answers. Also, prepare a short presentation to explain your results and defend your choices.

Dataset explanation

Consider a generic N-input M-output model

$$\mathbf{y}_\mathrm{c} = \mathbf{H}_\mathrm{c}\mathbf{s}_\mathrm{c} + \mathbf{v}_\mathrm{c}.$$

Here, $\mathbf{y}_\mathrm{c} \in \mathbb{C}^M$ is the received vector, $\mathbf{H}_\mathrm{c} \in \mathbb{C}^{M\times N}$ is the MIMO channel, $\mathbf{s}_\mathrm{c} \in \mathbb{C}^N$ is the transmitted symbol vector, and $\mathbf{v}_\mathrm{c} \in \mathbb{C}^M$ is an additive white Gaussian noise vector. In this application example we assume that the transmitted symbols follow a quaternary phase-shift-keying (QPSK) constellation; i.e., the entries of $\mathbf{s}_\mathrm{c}$ belong to the finite-alphabet set $\{\pm 1 \pm j\}$. The dataset `MIMODetection.mat` in the course webpage contains the received data symbols, channel matrix, and the true data symbols. The aim is to detect $\mathbf{s}_c$ from $\mathbf{y}_c$ in the maximum likelihood sense with the assumption that the MIMO channel is known.

2 Assignment

You will have to answer the following questions:

1. (2 pts) Formulate the MIMO detection problem as an optimization problem. Suggest a suitable convex approximation (i.e., derive a convex relaxed problem) if the true problem is not convex. Motivate the proposed formulation as well as the relaxation.

2. (2 pts) Implement the proposed convex optimization problem in your favorite off-the-shelf solver (e.g., `CVX`, `SeDuMi`, or `YALMIP`). How does this ready-made software solve your problem? Comment on the number of iterations, CPU time, and algorithm the ready-made solver uses.

   Optional: Does your solution based on randomized rounding follow Goemans and Williamson's theorem; see the reference.

3. (5 pts) Implement a low-complexity algorithm (e.g., projected (sub)gradient descent for the above problem, or provide a first-order algorithm to solve the primal and dual problems). Compare the obtained results with the solutions from the off-the-shelf solver. Comment on the number of iterations, CPU time, and convergence of your low-complexity algorithm.

4. (1 pt) Make a short presentation explaining your results clearly in 5 minutes.

3 Reference

Z.-Q. Luo, W.-K. Ma, A. Man-Cho So, Y. Ye, and S. Zhang, "Semidefinite Relaxation of Quadratic Optimization Problems," IEEE Signal Processing Magazine, vol. 27, no. 3, May 2010.

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