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Sorted Orthotope Sphere Decoding for MIMO Detection

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Abstract

An efficient variation of the sphere decoding (SD) is the orthotope sphere decoding (OSD). In simulations for many channels, the OSD has lower complexity than the SD. For this lower complexity achieving algorithm, there have been no enumeration schemes. In this paper, we present the orthotopic Schnorr-Echner (OSE) enumeration to further reduce the complexity of the OSD. By using O-metric for the enumeration, the partial Euclidean distance (PED) computations, which are the most complex operations in SD, are reduced considerably. OSE enumeration has lower overhead than the Schnorr-Echner (SE) enumeration. Thanks to OSE enumeration, the complexity of the OSD becomes reduced significantly, which are shown in simulation.

Keywords: MIMO detection, sphere decoding, low complexity

1. Introduction

By applying Schnorr Echner (SE) enumeration to sphere decoding (SD) [1], a famous basic complexity reduction algorithm for MIMO detection, a considerable complexity reduction is achieved [2]. In [3], Orthotope sphere decoding (OSD) has been proposed as an alternative to the SD. OSD has been shown in simulation to be less complex than SD is. However, there has been no enumeration method to OSD so far.

In this paper, we propose an enumeration method to OSD for another big complexity reduction as the SE eneuration has done to SD. The proposed enumeration which is called orthotopic SE (OSE) enumeration reduce the complexity of OSD considerably.

In Section 2, we review the SE-SD and OSD. Section 3 explains the proposed OSE enumeration. Section 4 shows the simuation results.

2. Preliminaries

SD is a depth first tree search algorithm. During the search, it calculates partial Euclidean distances (PEDs) of the visited nodes. If the PED of any node is bigger than a certain threshold, the sphere radius, the sub-trees branching from the node are pruned. This is sphere constraint (SC). The sphere radius for SC test is updated whenever SD visits a leaf by the PED value of the leaf node; the PED of the leaf is always smaller than the sphere radius.

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SE-SD tries to visit the leaf nodes whose PED value is the smallest among the other leaves. For this, at each level of the tree, SE-SD visit the node with the smallest PED first. This reduce the sphere radius quicker so that more sub-trees are pruned by SC tests than those of the SD.

OSD introduces another constraint, orthotope constraint (OC), in addition to SC. The PED computations for SC tests are the most complex operations in SD, also in SE-SD. The metric for OC test, let us call this O-metric, is even simpler to compute than the PED. By using OC test, OSD tries to prune many sub-trees without PED computations. Only those who have not been pruned by the OC test are passed for the SC tests which require PED computataions. This reduces the complexity of the SD more.

3. Orthotopic SE (OSE) enumeration

In OSD whose aim is to minimize the number of PED computations, the direct application of the SE enumeration is not desirable. It is because SE enumeration requires PED computation of all the children node of the currently visited node to select the child node having the smallest PED value. It increases the PED computations. Also the overhead for SE enumeration is too big.

In the proposed method, we aim to reduce the enumeration overhead by selecting the list of nodes to which PED computation are performed. To select the list, we propose to use O-metric. First, the children of a node are grouped so that the group members have the same O-metric. Second, the group with the smallest O-metric searched through first. Third, inside the group, the node with the smallest PED is searched first.

For the steps given in the previous paragraph, the O-metrics of all the children should be computed. These are not complex operations as the O-metric computation is simple. After grouping the children by their O-metrics, the PEDs of the first group members should be computed. So far the PED computations for the first group members are enough. By searching the sub-trees of these members, there might be many updates on the SC and also the OC. With this updates, the groups which are placed after the first group become to have higher probability to be pruned by the updated OC. Besides, these groups have larger O-metric than the previous group. The stricter OC and the larger O-metric results in many pruning by the OC test. This saves PED computations, and maximizes the efficiency of the OSD.

4. Simulation results

To compare the computational complexity of four schemes *viz*, SD, SE-SD, OSD, and OSE-OSD, we measured the number of FLOPs by simulation. In each channel, the FLOPs are averaged over 10^4 runs.

We note that the proposed schem is always better for low SNRs for 16-QAM and larger modulations. **Fig. 1** shows the complexity of the four schemes for 2-by-2 16-QAM system. At -3dB SNR, the OSE-OSD outperforms the SD by 62%, the SE-SD by 48% and the OSD by 47%.

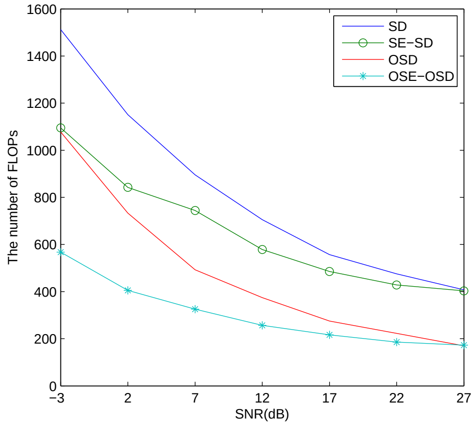

Fig. 1. Mean number of FLOPs for the SD, the SE-SD, the OSD, and the OSE-OSD, for 2-by-2 16 QAM system.

5. Conclusions

In this paper, we have proposed an enumeration for OSD. In the proposed OSE enumeration, the O-metric is used to select the list of which the PED computations are performed. By restricting the number of PED computations, the overhead of the proposed enumeration becomes small. And the OC pruning efficiency becomes maximized. As a result, the OSD with the proposed enumeration could achieve the lower complexity than the SD, the SE-SD, and the OSD.

References

[1] E. Agrell, T. Eriksson, A. Vardy, and K. Zeger, "Closest point search in lattices," *IEEE Trans. on Inf. Theory*, vol. 48, no. 8, pp. 2201–2214, Aug. 2002.

[2] C. P. Schnorr and M. Euchner, "Lattice basis reduction: Improved practical algorithms and solving subset sum problems," *Math. Programming*, vol. 66, no. 2, pp. 181–199, 1994.

[3] C. Z. W. H. Sweatman and J. S. Thompson, "Orthotope sphere decoding and parallelotope decoding - reduced complexity optimum detection algorithms for MIMO channels," *Signal Processing*, vol. 86, no. 7, pp. 1518–1537, July 2006.