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The Bethe Permanent of a Non-Negative Matrix

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(Submitted on 21 Jul 2011 (v1), last revised 20 Oct 2012 (this version, v3))

It has recently been observed that the permanent of a non-negative square matrix, i.e., of a square matrix containing only non-negative real entries, can very well be approximated by solving a certain Bethe free energy function minimization problem with the help of the sum-product algorithm. We call the resulting approximation of the permanent the Bethe permanent. In this paper we give reasons why this approach to approximating the permanent works well. Namely, we show that the Bethe free energy function is convex and that the sum-product algorithm finds its minimum efficiently. We then discuss the fact that the permanent is lower bounded by the Bethe permanent, and we comment on potential upper bounds on the permanent based on the Bethe permanent. We also present a combinatorial characterization of the Bethe permanent in terms of permanents of so-called lifted versions of the matrix under consideration. Moreover, we comment on possibilities to modify the Bethe permanent so that it approximates the permanent even better, and we conclude the paper with some observations and conjectures about permanent-based pseudo-codewords and permanent-based kernels.

Comments:	Accepted for IEEE Transactions on Information Theory. Manuscript received July 21, 2011; date of current version October 20, 2012. Changes compared to v1: see v2. Changes compared to v2: changed t to \tau in Section IV in order to distinguish it from iteration number t in Section V. Fixed some typos
Subjects:	**Information Theory (cs.IT)**; Computational Complexity (cs.CC); Mathematical Physics (math-ph); Combinatorics (math.CO)
Cite as:	**arXiv:1107.4196 [cs.IT]**
	(or **arXiv:1107.4196v3 [cs.IT]** for this version)

Submission history

From: Pascal Vontobel [view email]
[v1] Thu, 21 Jul 2011 08:19:30 GMT (564kb)
[v2] Wed, 10 Oct 2012 00:11:47 GMT (550kb)
[v3] Sat, 20 Oct 2012 07:45:09 GMT (551kb)

Which authors of this paper are endorsers?