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Finding a Hadamard matrix by simulated quantum annealing

We propose a simulated quantum annealing (QA)-based method to find a 4k order Hadamard matrix, where k is any positive integer. Using the analogy with the spins of the Ising model, the binary spins are replaced by a binary vector called SH (Seminormalized Hadamard)-spin vectors; which are 4k length vectors with balanced number of +1 and -1. Connections among the SH spins-vectors are represented by a graph that reflects orthogonality relationship among the vectors. Optimization is conducted based on the PIMC (Path-Integral Monte-Carlo) QA of the SH-spin vector system, with an applied transverse magnetic field whose strength is decreased over time. In the numerical experiments, the proposed method is employed to find some low order H-matrices, including the ones that cannot be constructed trivially by the Sylvester method. We also compare the performance with the SA (Simulated Annealing) method by measuring residual energy after a sufficiently large number of iterations in finding a high-order H-matrix. With both of the QA and SA use linear annealing schedule, we found that the QA outperforms the SA.