Comparative study of Potts machine dynamics and performance

Bjarke Frederiksen[a], Robbe De Prins[b], Peter Bienstman[b]

[a] Technical University of Denmark, Lyngby, Denmark
[b] Ghent University - imec, Ghent, Belgium

Potts machines (PMs) are extensions of Ising machines (IMs) that use multi-state spins. Many combinatorial optimization problems such as Max-*k*-Cut (a type of graph coloring) are naturally defined using multivariate integer variables. PMs allow for compact embedding of these problems, (i) requiring fewer resources and (ii) yielding more convex energy landscapes than IMs. While the literature has seen extensive comparisons of different IM types, such as different nonlinearities and techniques to counter amplitude inhomogeneity [1], no such studies have yet been conducted for PMs.

This work constitutes the first comparative study of PMs, both qualitatively and quantitatively. Through numerical simulations, we examine the dynamics of four distinct PM implementations from the literature [2, 3, 4, 5], identify key features, and propose two new PMs to address feature gaps. Subsequently, we perform a quantitative study over a benchmark set of Max-3-Cut problems to compare the performance of the PMs in absolute terms. A sigmoid-based IM [1] is included in this study to compare PMs and IMs.

Figure 1**a** illustrates how Max-3-Cut problems are mapped to the Potts model. Figure 1**b** shows our ranking of the Potts and Ising machine models by the number of benchmark problems on which they achieve the highest success rate (SR). A Bose-Einstein condensate-inspired model [2] excels, supporting amplitude homogeneity and chaotic destabilization of local minima. Yet, none of the considered PMs manage to simultaneously suppress phase and amplitude inhomogeneity while annealing adiabatically.

Future work should aim to address phase and amplitude inhomogeneity while being compatible with adiabatic annealing. We believe that destabilizing fixed points will yield further performance improvements, as it is also found with chaotic amplitude control for IMs.

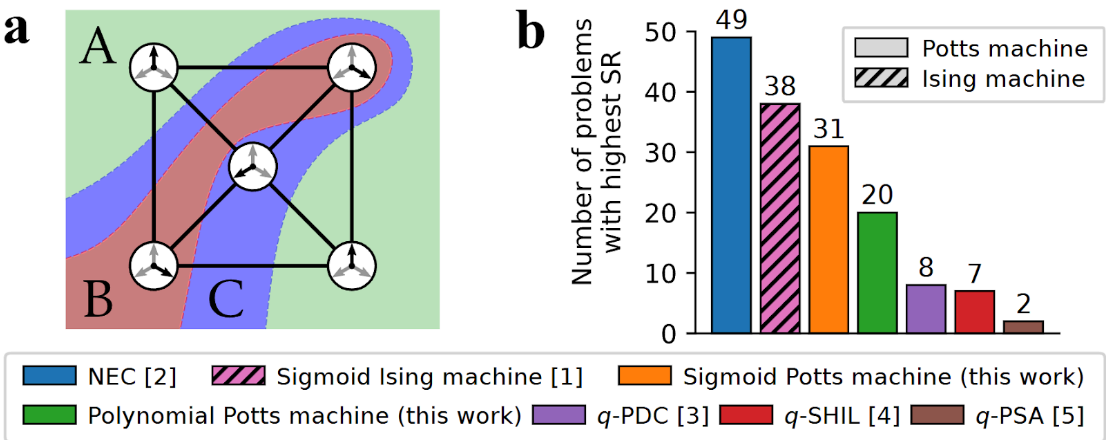

Figure 1: **a** Example Max-3-Cut problem with five nodes mapped to the 3-Potts model. **b** Ranking of Potts/Ising machine models by number of problems with the highest success rate (SR) on benchmark Max-3-Cut problems.

[1] F. Böhm, Comm. Phys. **4** (2021), 149.
[2] K. Kalinin, Phys. Rev. Lett. **121** (2018), 235302.
[3] M. Honari-Latifpour, Comm. Phys. **5** (2022), 104.
[4] J. Roychowdhury, EECS Tech. Rep. (2022), UCB/EECS-2022-198.
[5] K. Inoue, Opt. Comm. **528** (2023), 129022.