ENHANCING ISING MACHINES FOR COMPLEX OPTIMIZATION WITH THE ADAM OPTIMIZER

Stijn Van Vooren,[1,*] Guy Van der Sande,[1] and Guy Verschaffelt[1]

[1] *Applied Physics Research Group (APHY), Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium*

Optimization problems—choosing the best option among many—are central to understanding adaptive and emergent behavior in complex systems. Ising machines offer a physics-inspired approach by mapping such problems to interacting binary variables, where the system naturally evolves toward low-energy states that represent optimal or near-optimal solutions. Physical implementations of Ising machines, such as photonic platforms, are particularly attractive due to their high bandwidth and energy efficiency. Most Ising machines use gradient descent, however this can be both slow and prone to getting stuck in local minima. Adam optimization addresses these issues simultaneously: momentum helps escape local minima, and adaptive learning rates accelerate convergence. While Adam has previously been applied in a single photonic Ising machine implementation, we incorporate it into general Ising machine dynamics. We evaluate this approach on standard benchmark problems. Compared to gradient-based methods, Adam-enhanced dynamics consistently converge faster and yield better solutions. This shows how integrating techniques from machine learning with physics-based models offers new tools for complex optimization tasks.

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[1] R. A. Brown et al., Lecture Notes in Computer Science, Springer Nature **14742**, 109 (2024).

* Stijn.Van.Vooren@vub.be