Evaluating Spintronic Ising Machines for solving Max-Cut

Luciano Mazza[1], Andrea Grimaldi[2], Eleonora Raimondo[2], Pietro Tullo[1], Davi Rodrigues[1], Kerem Camsari[3], Vincenza Crupi[2], Mario Carpentieri[1], Vito Puliafito[1], Giovanni Finocchio[2]

[1] *Department of Electrical and Information Engineering, Politecnico di Bari, 70126, Bari, Italy*

[2] *Department of Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, 98166, Messina, Italy*

[3] *Department of Electrical and Computer Engineering, University of California Santa Barbara, 93106, Santa Barbara, CA, USA*

Combinatorial optimization problems (COPs) play a key role in the optimization of industrial processes, and the bottleneck at the moment is represented by the exponential increase of the complexity observed for a linear increase in the size of those problems; for this reason, heuristic paradigms like Ising machines are recently gaining interest in the academic and industrial world.

Ising machines map a COP with the Hamiltonian energy function of physical system in such way that the natural evolution to a ground low-energy state of the system leads to a configuration corresponding to a solution of the starting problem. For its peculiar nonlinear features, low power, area occupancy and CMOS compatibility, spintronics is often seen as an excellent candidate for the implementation of future devices. We have analyzed how magnetic tunnel junctions (MTJs) can be used for realizing a coherent Ising machine for the solution of the Max-Cut problem.

The Max-Cut problem consists in finding the optimal bipartition of an undirected weighted graph, in such way that the sum of cut edges is maximized.

The coherent Ising machine (CIM) is realized exploiting the coupling mechanisms of oscillators governed by the Hamiltonian energy and the binarization, necessary for the solution, is realized with a second harmonic signal, as shown in [1]; a 8-nodes spintronic implementation has been recently proposed [2].

We implemented the CIM with the state-of-the-art Kuramoto model, and with a mathematical model developed by Slavin in [3] that well represents the behavior of spintronic oscillators, observing comparable performances for randomly generated cubic problems, as shown in Figure 1; the latter model is characterized by a higher computational complexity which limited the size of explored problems. The benefits of this implementation rely on the continuous definition and exploration of the energetic landscape.

A grid search of the intrinsic parameters of the realistic model shows that the nonlinearities of spintronic devices are improving the performances of the system.

Both systems provide excellent results for the solution of Max-Cut problems, and our results underline the effectiveness of a future implementation for hybrid CMOS-MTJ chips.

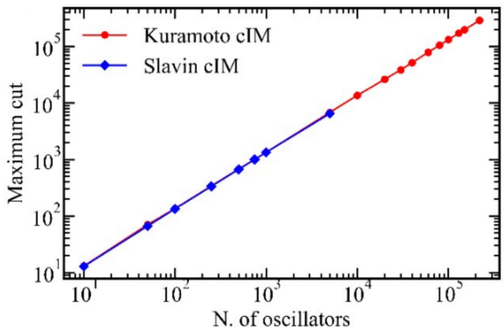

Figure 1: Comparison of Kuramoto and Slavin cIMs for random cubic graphs for problem sizes.

References

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