Correction of amplitude heterogeneity for solving combinatorial optimization problems efficiently using optoelectronics

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It has been suggested that mapping the classical Ising Hamiltonian to the energy landscape of analog systems such as analog neural networks and the coherent Ising machine[1-4] can be useful for solving efficiently combinatorial optimization problems. This mapping is achieved by the relaxation of the Ising (binary) spins $\sigma_i = \pm 1$ to analog values $x_i$ with $x_i \in \mathbb{R}$. Although these analog systems are ideal for efficient implementation on dedicated hardware[1], it is believed that they do not perform as well as state-of-the-art heuristics because of the improper mapping of the energy function that results from the relaxation of the spins to analog values[2,3].

In this talk, we will introduce an error correction scheme[4] (see left figure) that corrects the amplitude heterogeneity of the analog state and prevents the system from being trapped in suboptimal solutions. We have tested the proposed scheme by solving MAXCUT problems from standard benchmark sets against state-of-the-art heuristics and orders of magnitude decrease of the time-to-solution can be obtained in the case of an implementation on the coherent Ising machine (see table). This research was funded by the ImPACT Program of the Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

<table>
<thead>
<tr>
<th>Id</th>
<th>Best cut (BLS)</th>
<th>Best cut (proposed)</th>
<th>Time-to-solution (BLS w. CPU)</th>
<th>Time-to-solution (proposed w. CPU)</th>
<th>Time-to-solution (proposed w. CIM*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>7689</td>
<td>7690</td>
<td>444 s</td>
<td>285.74 s</td>
<td>0.54 s</td>
</tr>
<tr>
<td>38</td>
<td>7687</td>
<td>7688</td>
<td>461 s</td>
<td>199.44 s</td>
<td>0.38 s</td>
</tr>
</tbody>
</table>

* Estimation of the time-to-solution in the case of the proposed implementation on the coherent Ising machine, calculated using the value of the time normalization constant (the cavity photon lifetime) that has been obtained experimentally[1], vs. state-of-the-art heuristic called breakout local search[5] (BLS) for the instances with id 37 and 38 from the GSET benchmark set[5].