



Solving Constraint Satisfaction Problems Efficiently on Loihi

Neuromorphic Computing Lab | Intel Labs

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Solving CSPs with SNNs

Given a generic CSP:

$$CSP = \{X_i, D_i, \{Y_j, R_j\}\}$$

Variable subsets (pointing to $\{Y_j, R_j\}$)
 Value restrictions (pointing to R_j)
 Variables (pointing to X_i)
 Value domains (pointing to D_i)
 Constraints (pointing to R_j)

Represent CSP as energy minimization in binary domain:

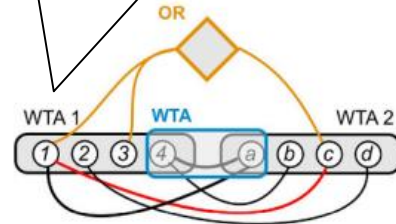
$$E = S^T \cdot W \cdot S$$

$$S \in \{0,1\}^N, \quad W \in \{-1,0,1\}^{N \times N}$$

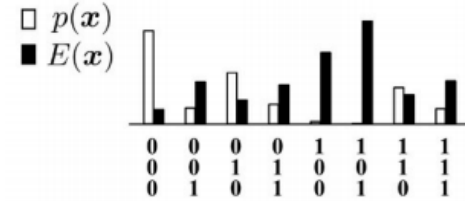
SNN with noise stochastically searches to find the minimum energy solution:

Variables represented by Winner-Take-All (WTA) circuits

Minimization \Leftrightarrow Sampling from probability distribution $p(x)$

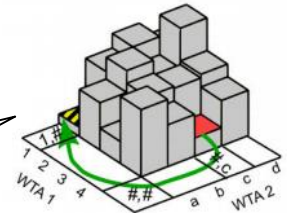


$$p(x) \propto e^{-E(x)}$$



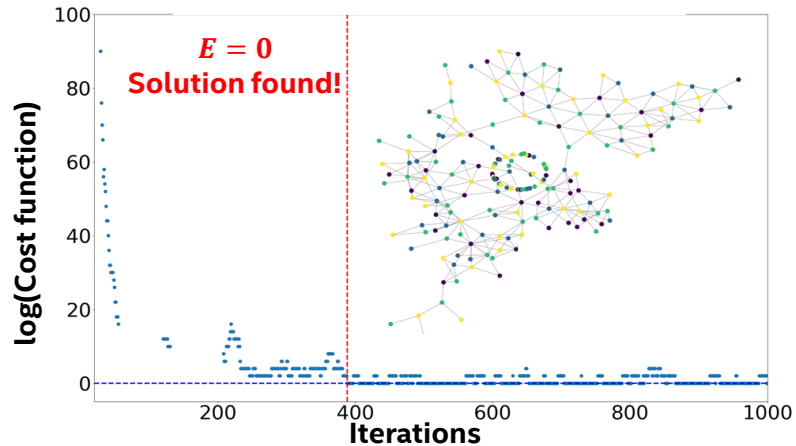
Encode constraints into interconnectivity between WTAs

Stochastic search via SNN enables faster convergence than pure gradient dynamics



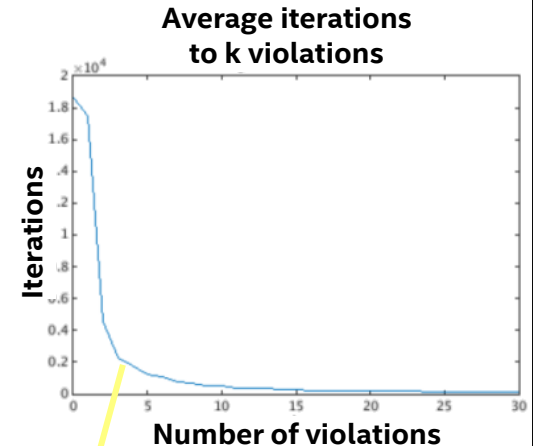
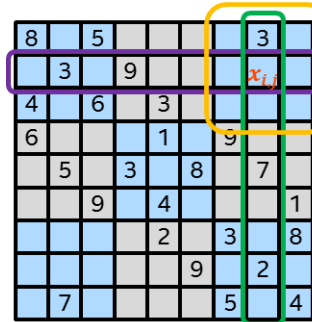
Results for Map-Coloring and Sudoku

Example: 4-coloring of world map



$\approx 10\mu\text{s}/\text{step}$ results in $\approx 4\text{ms}$ time to solution.

Example: Sudoku



Finds solutions with few violations quickly & improves solution over time.

Tutorial: Solving CSPs with Loihi



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