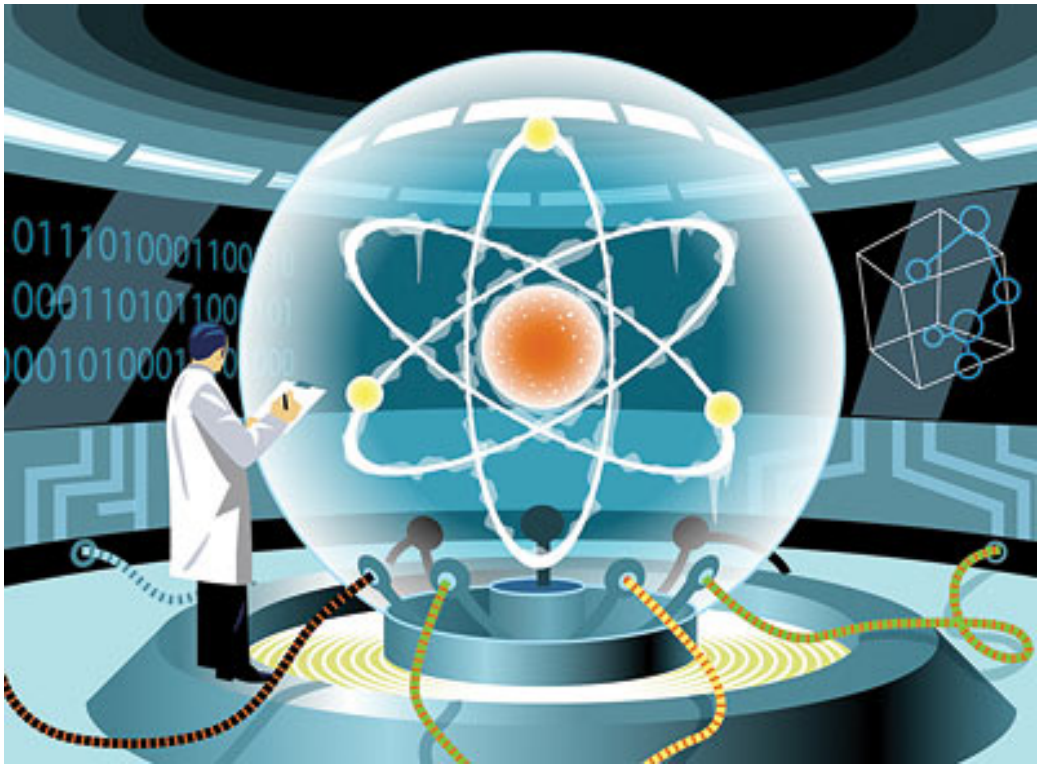
Classification of the D-Wave One Quantum Machine



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Topology of the Chimera Chip

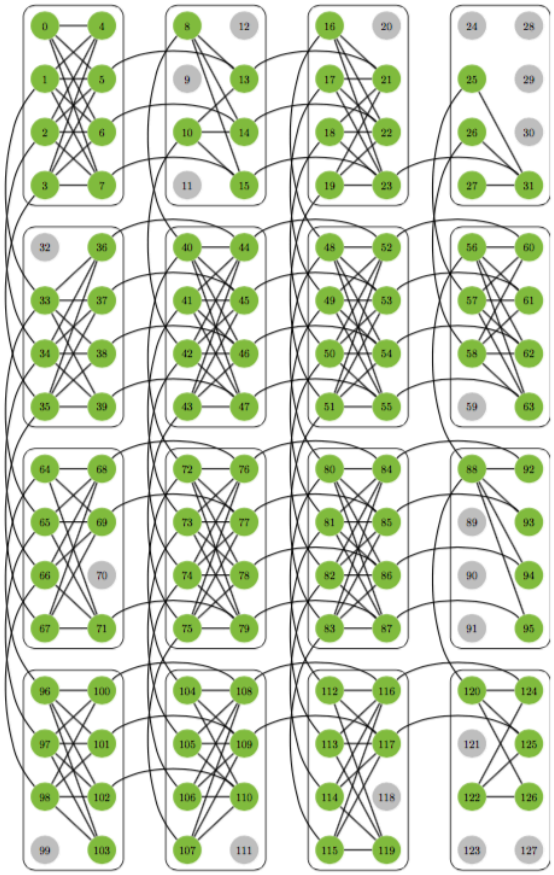


FIG. 1: **Qubits and couplers in the D-Wave device.** The D-Wave One Rainer chip consists of 4×4 unit cells of eight qubits, connected by programmable inductive couplers as shown by lines.

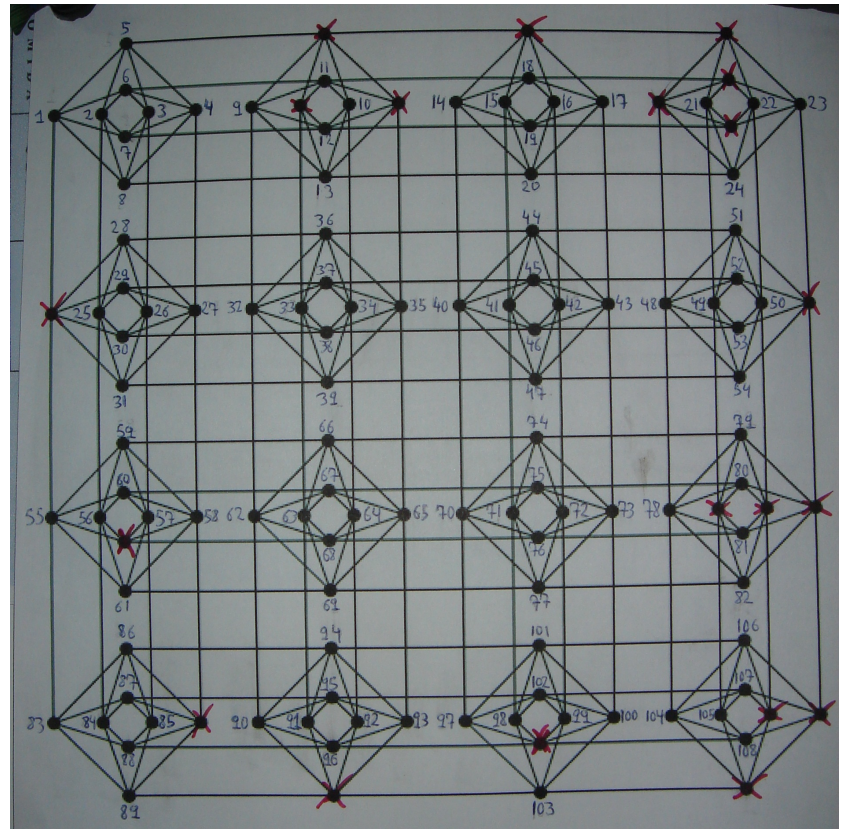


FIG. 2: A topology that emphasizes the bipartite node structure of each unit cell and the connections between cells. The Chimera structure is adapted to solving quadratic unconstrained binary optimization problems.

Methods

- Modern-day quantum computing research aims invent quantum devices with capabilities that surpass those of classical computers.

- On May 11, 2011, D-Wave Systems announced what they claimed to be the world's first commercial quantum computer, the D-Wave One, which they described as a quantum annealer with 128 qubits [1]. Quantum annealing is a process can solve hard optimization problems by finding the lowest energy state of a quantum system.

- D-Wave critics, however, argue that the machine fails to provide this quantum speed-up, given that certain classical models may lead to the same results [2]. We shed light on this debate by applying machine learning tools to determine the correlation between the performance of D-Wave and that of simulated classical annealer. By comparing the features, we hope to delineate the similarity between D-Wave's success rate to that of the quantum annealer, thereby providing evidence that the D-Wave machine achieves a "quantum" speed-up over classical algorithms.

[1] Boixo, Sergio, et al. Quantum annealing with more than one hundred qubits arXiv/1304.4595v2.pdf

[2] John A. Smolin. Graeme Smith. Classical signature of quantum annealing. http://arxiv.org/abs/1305.4904

Data Set

- For the edification of the scientific community, D-Wave released data that describes the performance of the machine on a number of optimization problems. Given initializations of the edge energies of the Chimera chip for 1,000 test problems, the D-Wave is run for 1,000 trials with the goal of determining the reach the optimal energy.
- The success rate is the probability that the machine will reach the optimal solution for a test problem, averaged over all trials. For classification purposes, we define a “hard” problems as those where D-Wave One has a low success rate, and an “easy” problem with a high success rate.

```
# name: /Users/.../Benchmarking--...-13-55-11.mat with energy -173
1 5 -1
1 6 -1
1 7 -1
1 8 -1
2 5 1
2 6 -1
...
...
```

E(V(1), V(2)), Energy

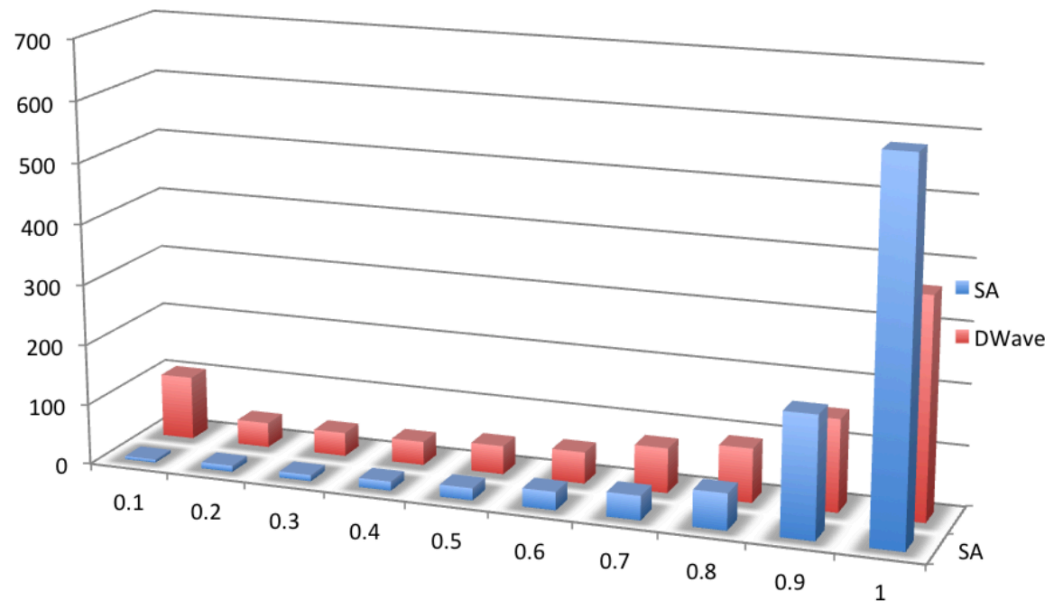


FIG. 1: Histogram of success rates for simulated classical annealer and the D-wave One machine.

Classical/Quantum Correlations

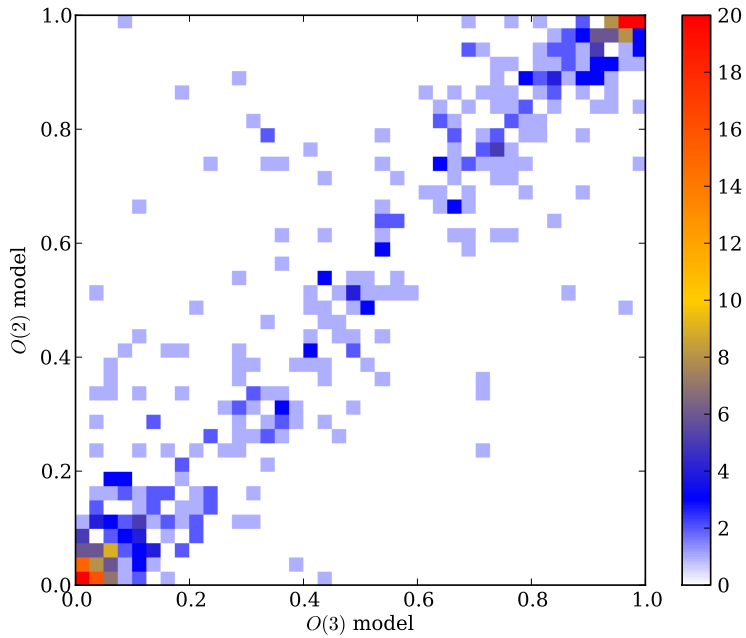


FIG. 1. Correlations of success probabilities between the simulated quantum annealer and the D-Wave device.

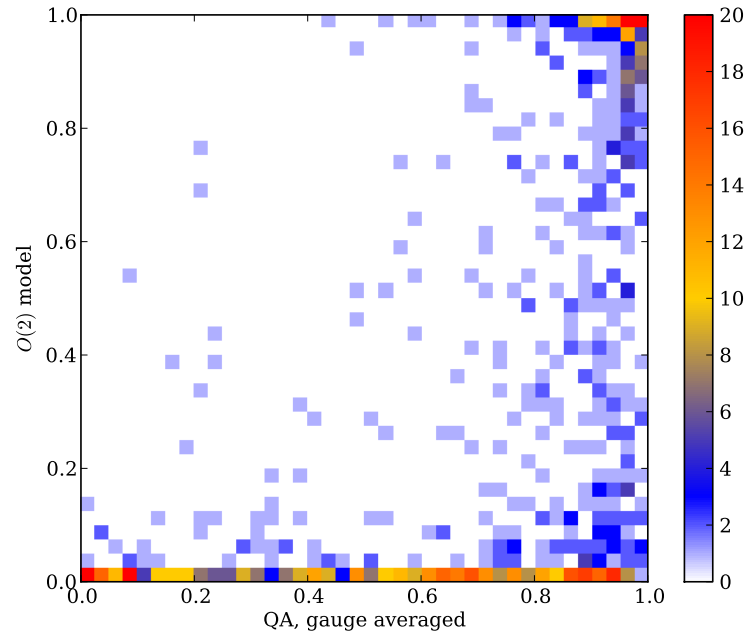
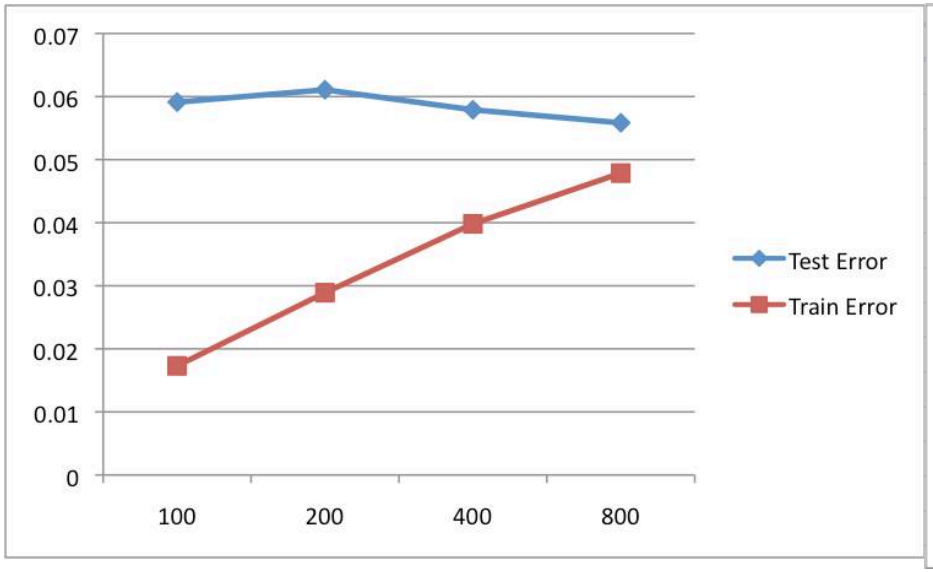


FIG. 2. Correlations of success probabilities between the classical annealer and the D-Wave device.

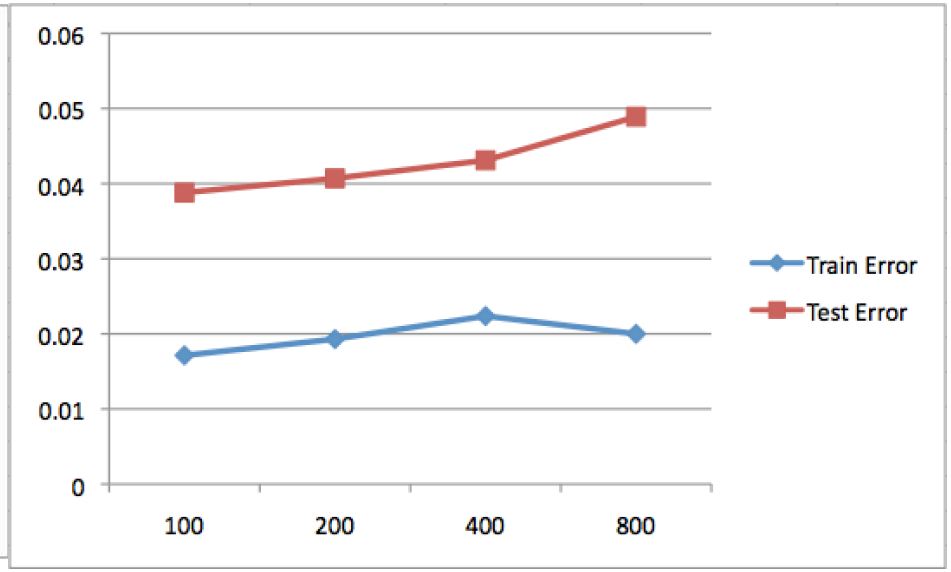
Naïve Bayes Classifier

Individual edge energies (255 features)



Number of Training Examples

Pairs of edge energies (1,029 features)



Number of Training Examples

Conclusions:

- More data is required to fit features, even using the Naïve Bayes independence assumption. Generalization error is poor due to overfitting.
- Naïve Bayes assumes that the bits of the energy states are independent