Machine Learning for condensed matter physics

by

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Brief into …

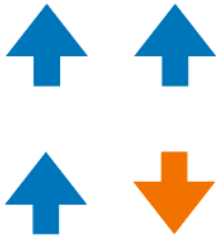
- ❑ Classical Ising model
- ❑ Su-Schrieffer-Heeger (SSH)

Classical Ising model

$$H = -J \sum_{<i,j>} \sigma_i \sigma_j$$

$$p(\sigma) = \frac{e^{-\beta H(\sigma)}}{Z}$$

= probability of configuration σ at the temperature T = 1/β



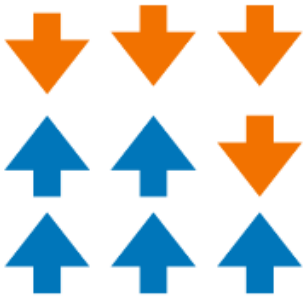
$\sigma_i \sigma_j = 1$ energy = - J

$\sigma_i \sigma_j = -1$ energy = + J

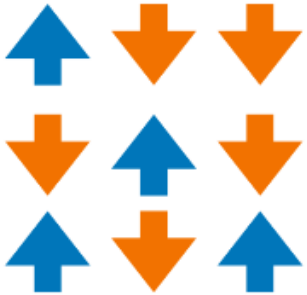
adding temperature makes the difference smaller

Classical Ising model

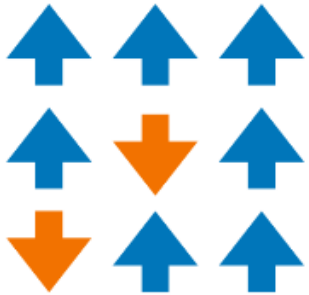
Ising QUIZ
Which of these has the lowest energy?



A



B

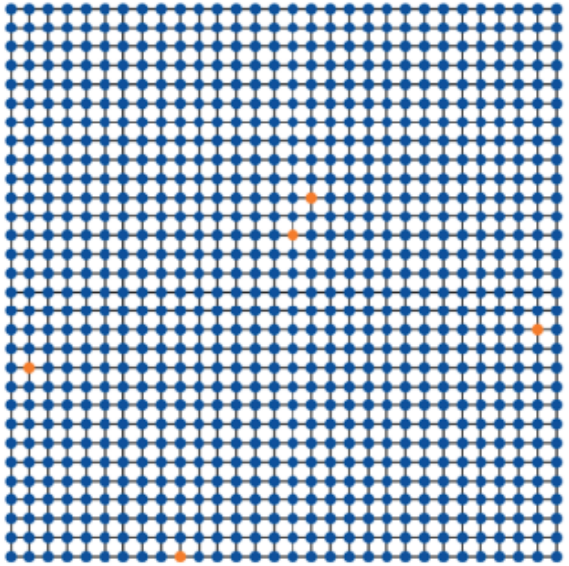


C

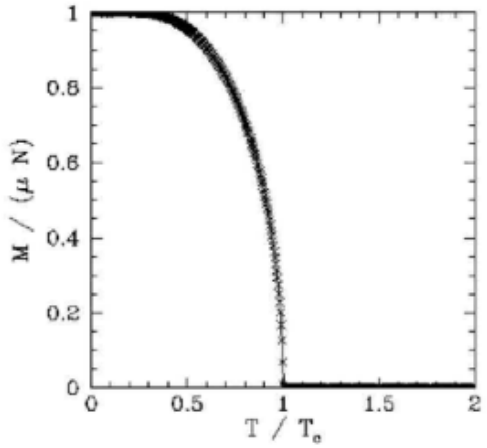
$$H = -J \sum_{<i,j>} \sigma_i \sigma_j$$

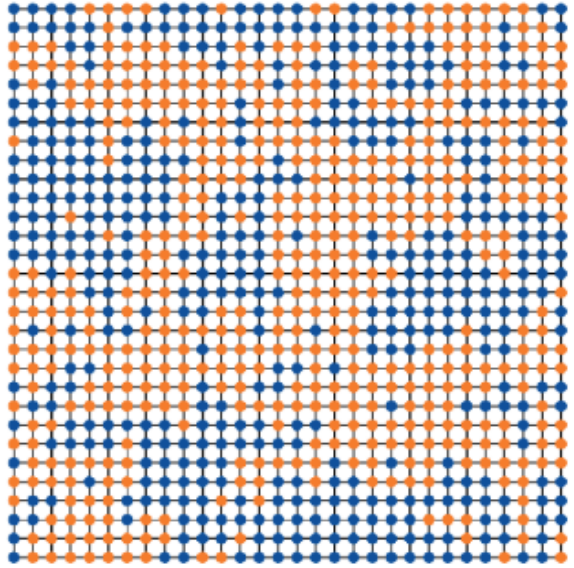
Classical Ising model

Phase Transition



$$T_c = \frac{2J}{k \ln(1+\sqrt{2})}$$





Classification: a mini example

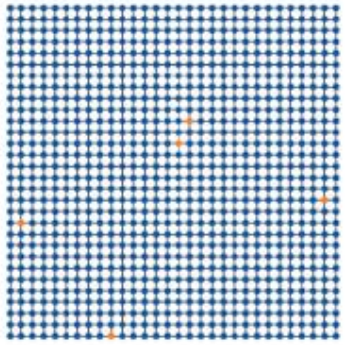
Label: $p(x)$ $\begin{bmatrix}1\\0\end{bmatrix}$ $\begin{bmatrix}0\\1\end{bmatrix}$

Network output: $q(x)$ $\begin{bmatrix}q(class\ A)\\q(class\ B)\end{bmatrix}$

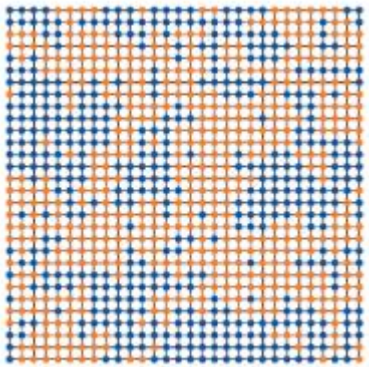
Loss: -1 log(q(class A)) - 0 log(q(class B)) -0 log(q(class A)) - 1 log(q(class B))

!the loss is minimal if q(x) matches the labels!

Back to ~~home~~ physics

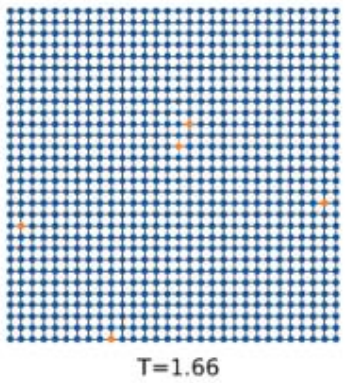


Ordered



Disordered

Notebook 1: Supervised learning



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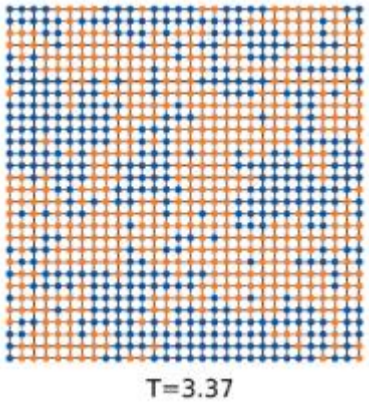

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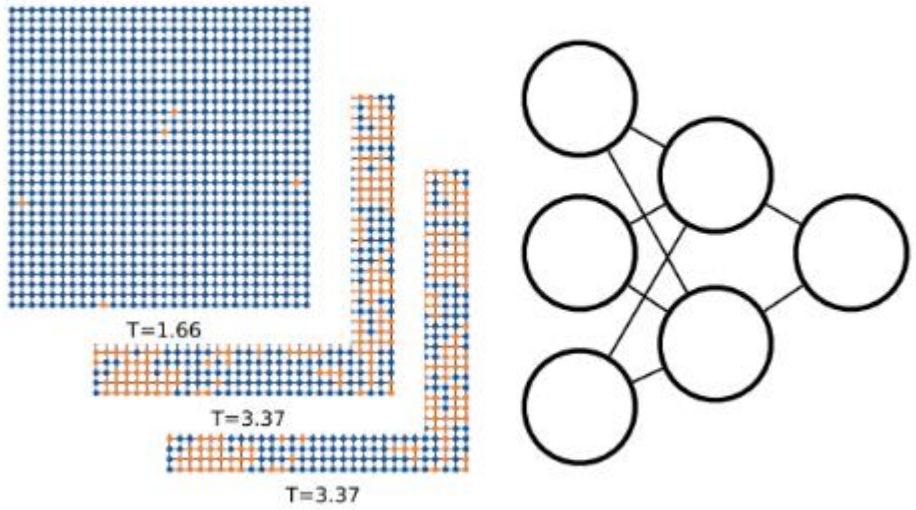

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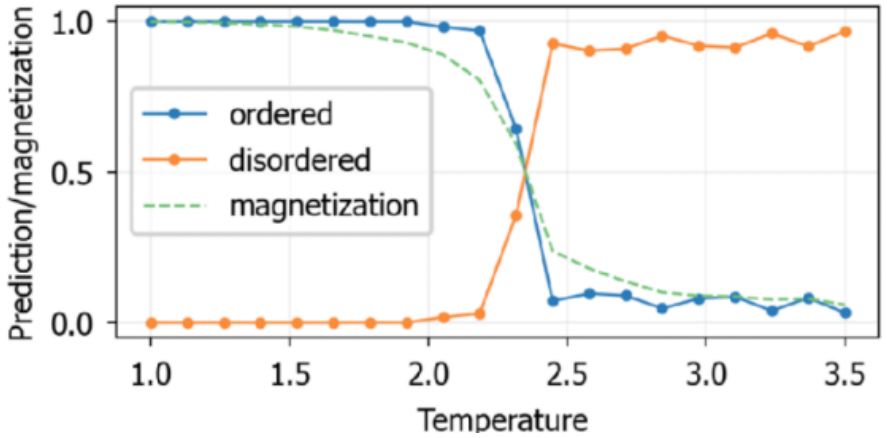
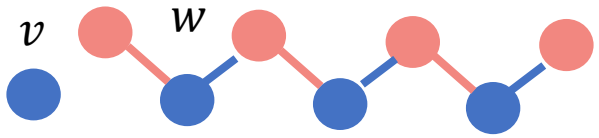
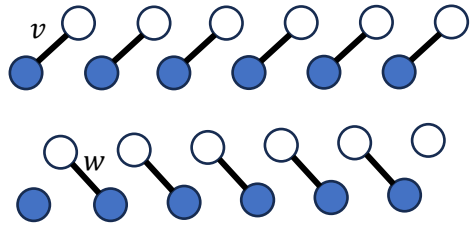


Su-Schrieffer-Heeger (SSH)

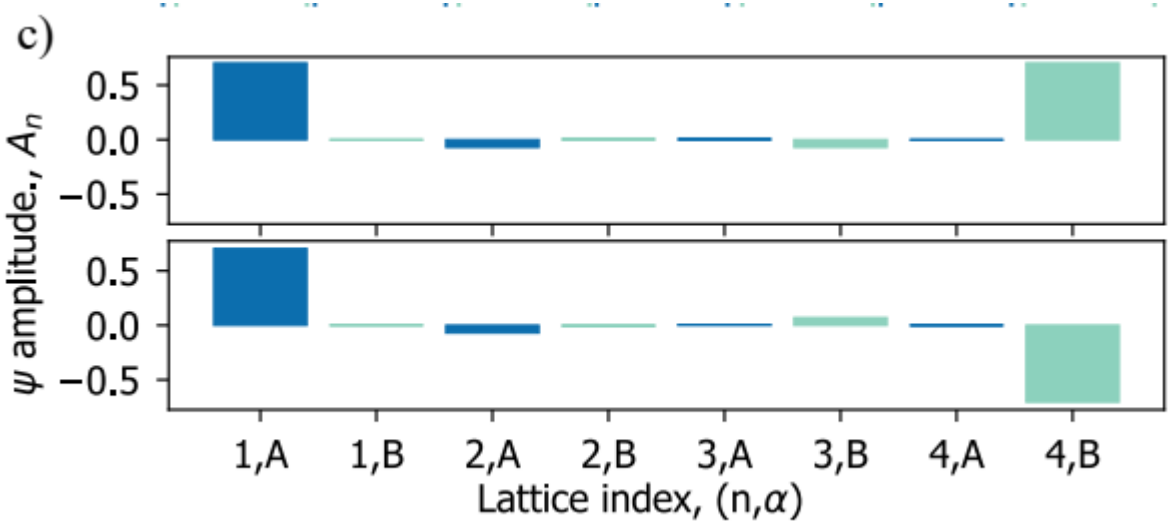
$$H = \sum_{n=1}^{N} (v_n c_{n,A}^{\dagger} c_{n,B} + w_n c_{n,B}^{\dagger} c_{n+1,A} + h.c.),$$





Trivial phase
$v = 1, w = 0$

Topological phase
$v = 0, w = 1$



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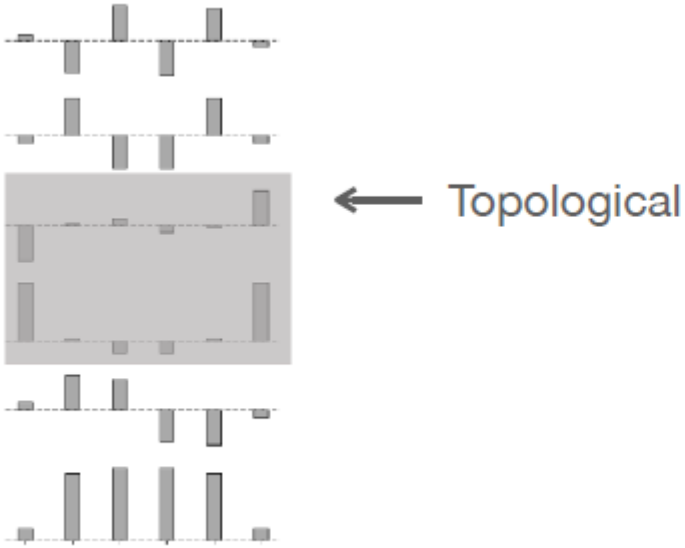
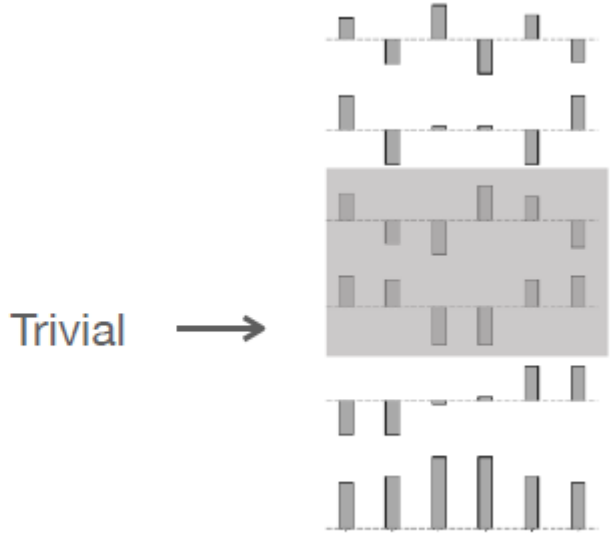
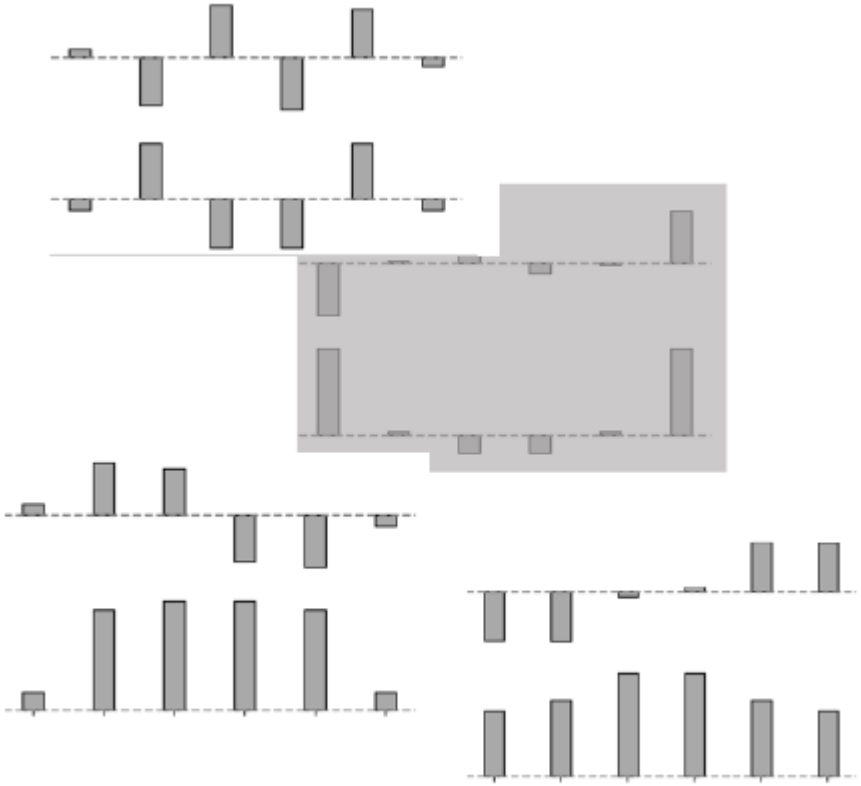
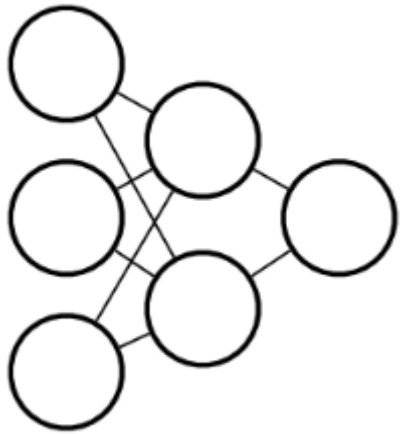




Notebook 2: Supervised learning

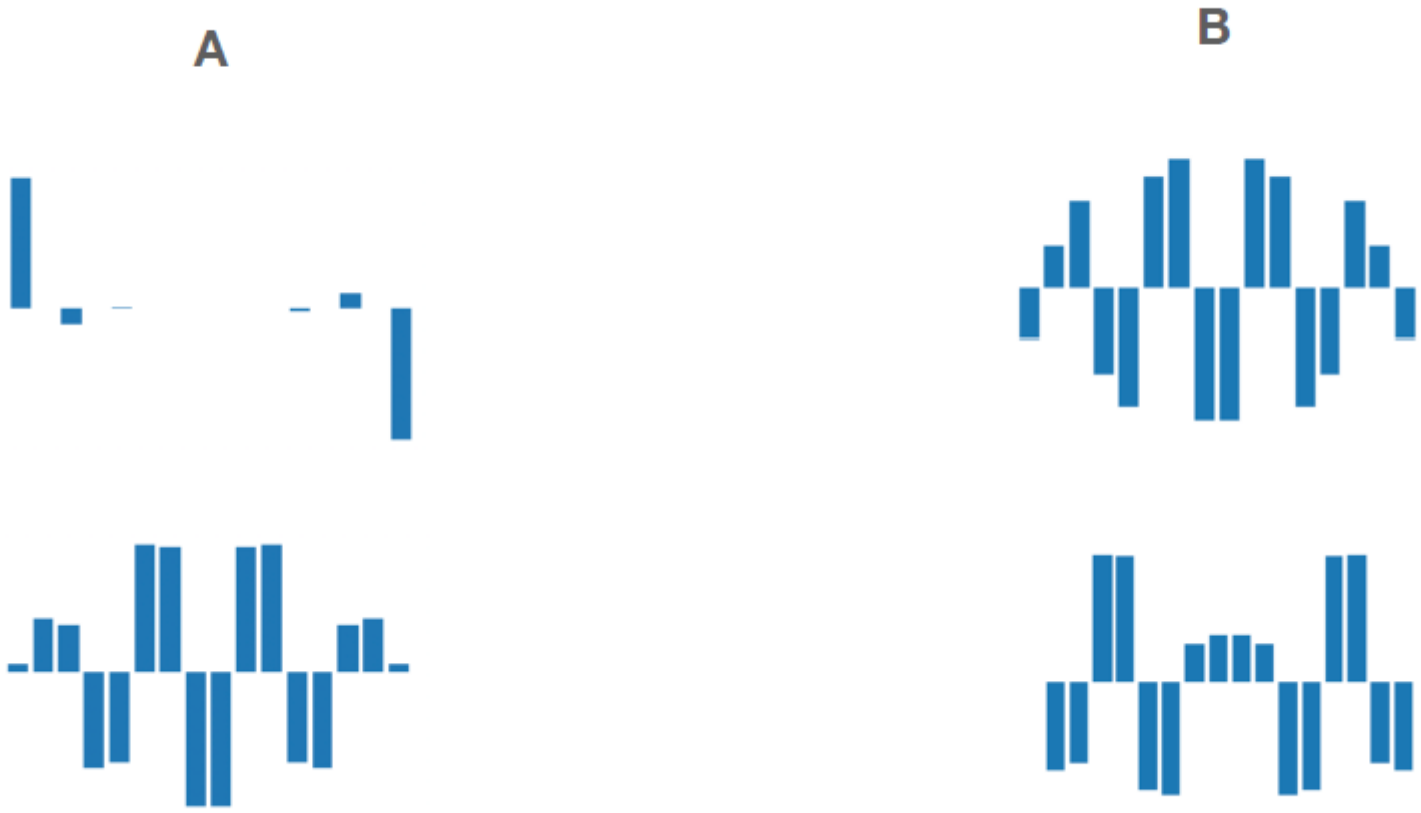




Topological

Trivial

QUIZ: SSH Human Classification



Topological

Trivial

Break a little time