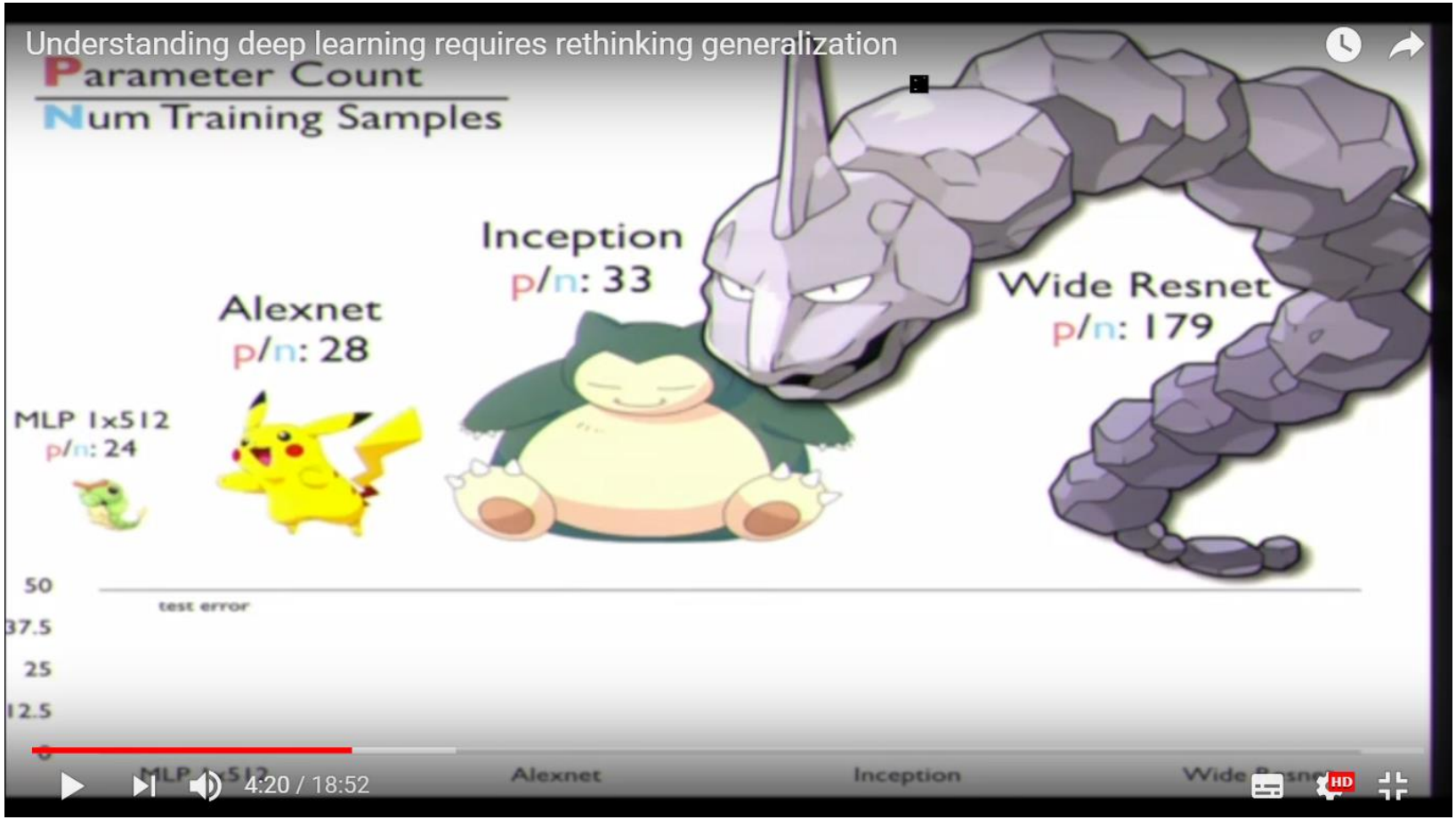
Generalization Ability

We use very large network today

參數量是遠大於training data的量的



Source of image: https://www.youtube.com/watch?v=kCj51pTQPKI

機器學習基石
https://youtu.be/XxPB9GlJEUk

Generalization Gap

R:training data 量

M: model capacity(function set)大小

No matter the data distribution

With probability $1-\delta$

$$E_{train} \leq E_{test} \leq E_{train} + \Omega(R, M, \delta)$$

Smaller δ, larger Ω

R is the number of training data → Larger R, smaller Ω

M is the "capacity" of your model → Larger M, larger Ω

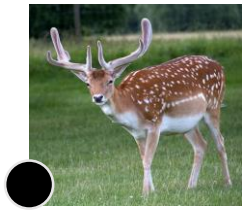
("size" of the function set)

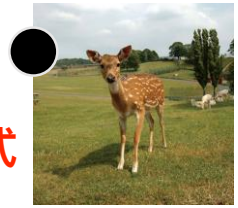
How to measure the "capacity"? VC dimension (d_{VC})

利用vc dimension來evaluate model capacity

如果故意亂教而model都學的起來（overfitting），則待俵他 vc dimension >=3

Given 3 data points





總共有八種不同的label方式

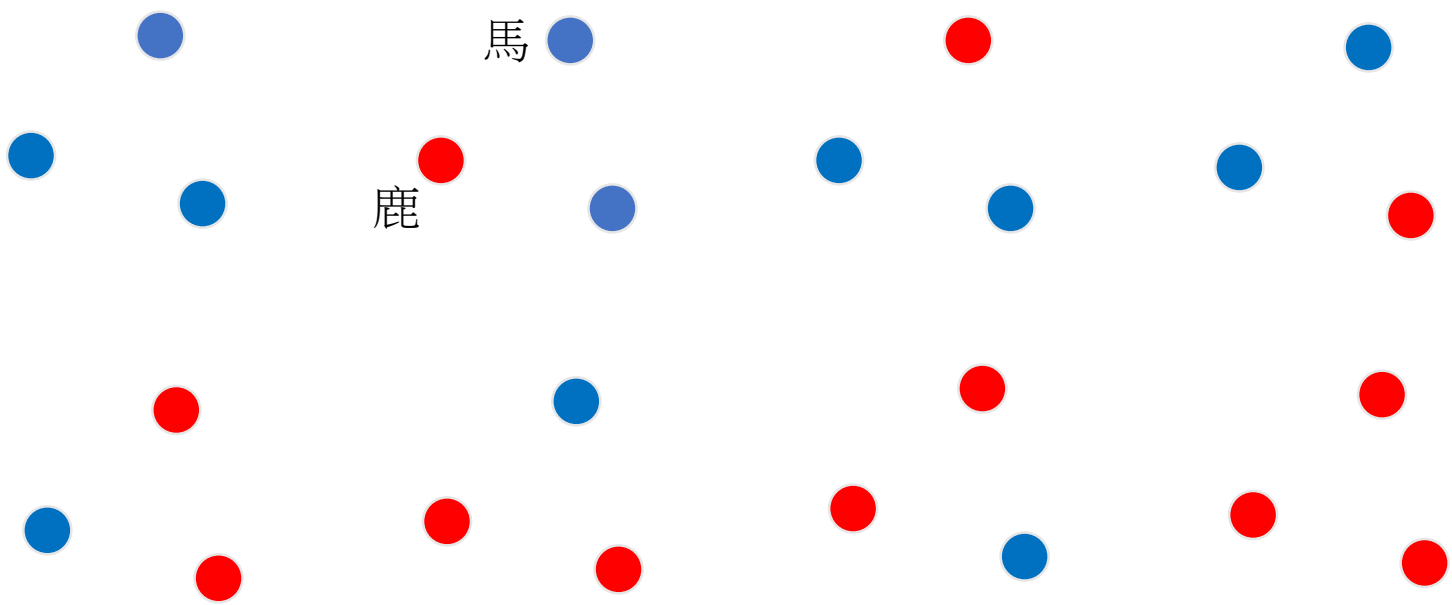
Random label (故意亂教)

Model M can always achieve 0% error rate

(亂教 Model M 都學得會)

VC dimension (d_{VC}) of Model M $\geq$ 3

e.g. linear model



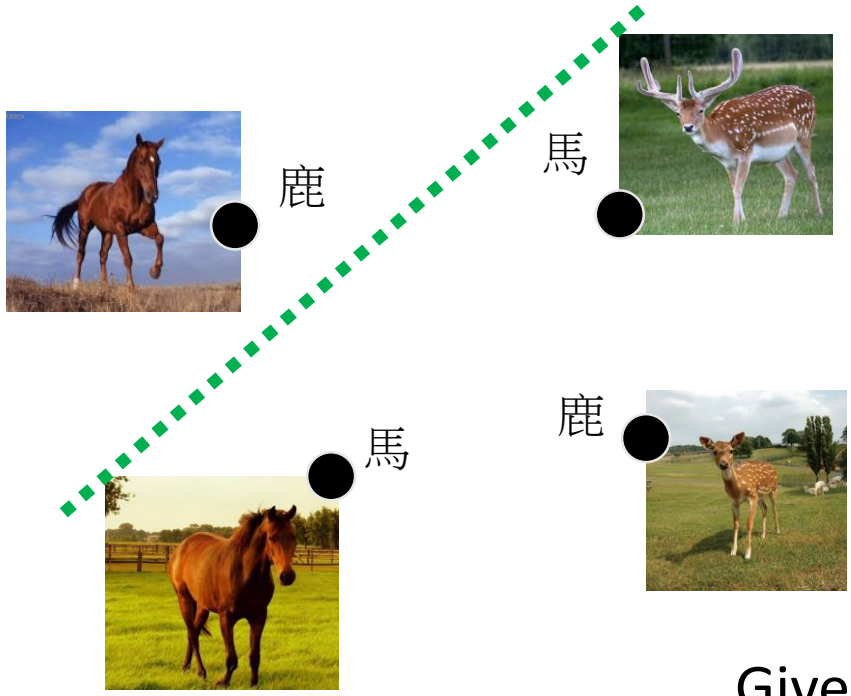
Random label (故意亂教)

There are some cases linear model can not learn.

(知道是來亂的，所以不學)

VC dimension (d_{VC}) of Linear Model < 4

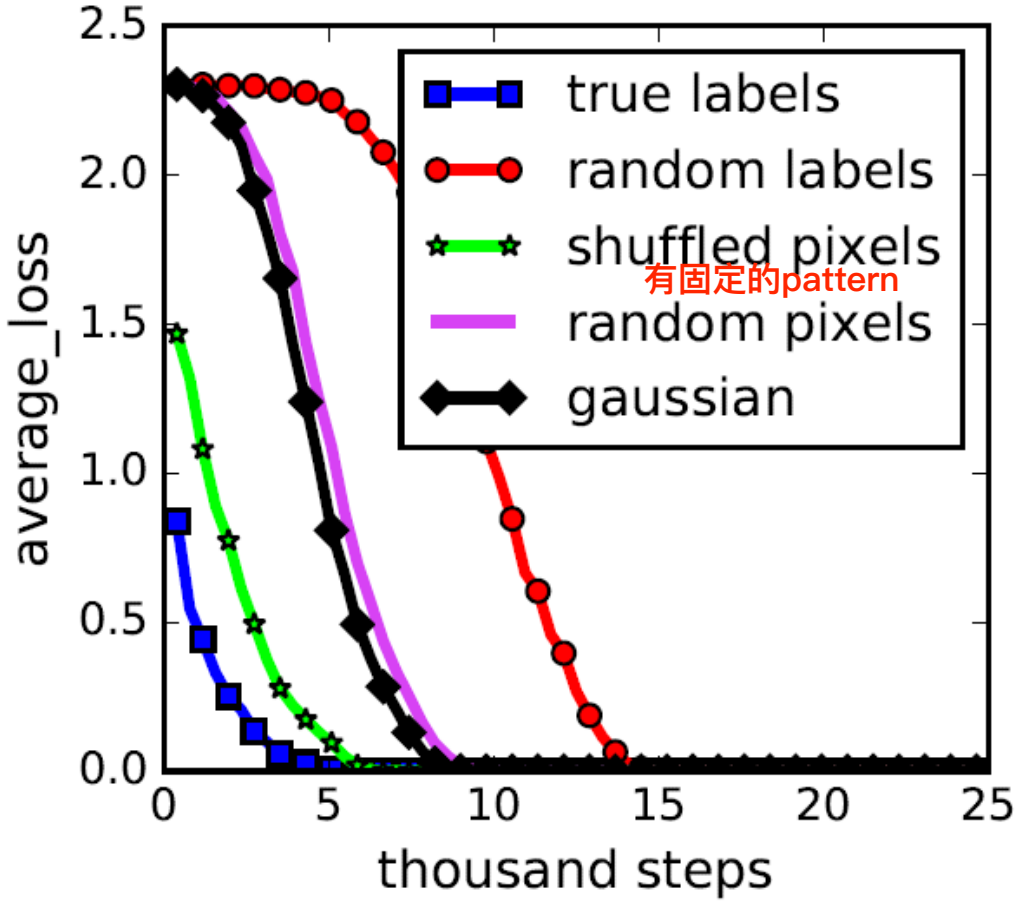
linear model解不了，但deep network是可以解的



Given 4 data points

What is the capacity of deep models?

Inception model on the CIFAR10



Chiyuan Zhang, Samy Bengio, Moritz Hardt, Benjamin Recht, Oriol Vinyals, "Understanding deep learning requires rethinking generalization", ICLR 2017

Overparameterized Network?

No matter the data distribution

With probability $1-\delta$

$$E_{test} \leq E_{train} + \Omega(R, M, \delta)$$

假設今天有兩個model都可以達到training error = 0
則我們當然選擇model capacity較小的來做為我們的model

Smaller δ, larger Ω

R is the number of training data → Larger R, smaller Ω

M is the "capacity" of your model → Larger M, larger Ω

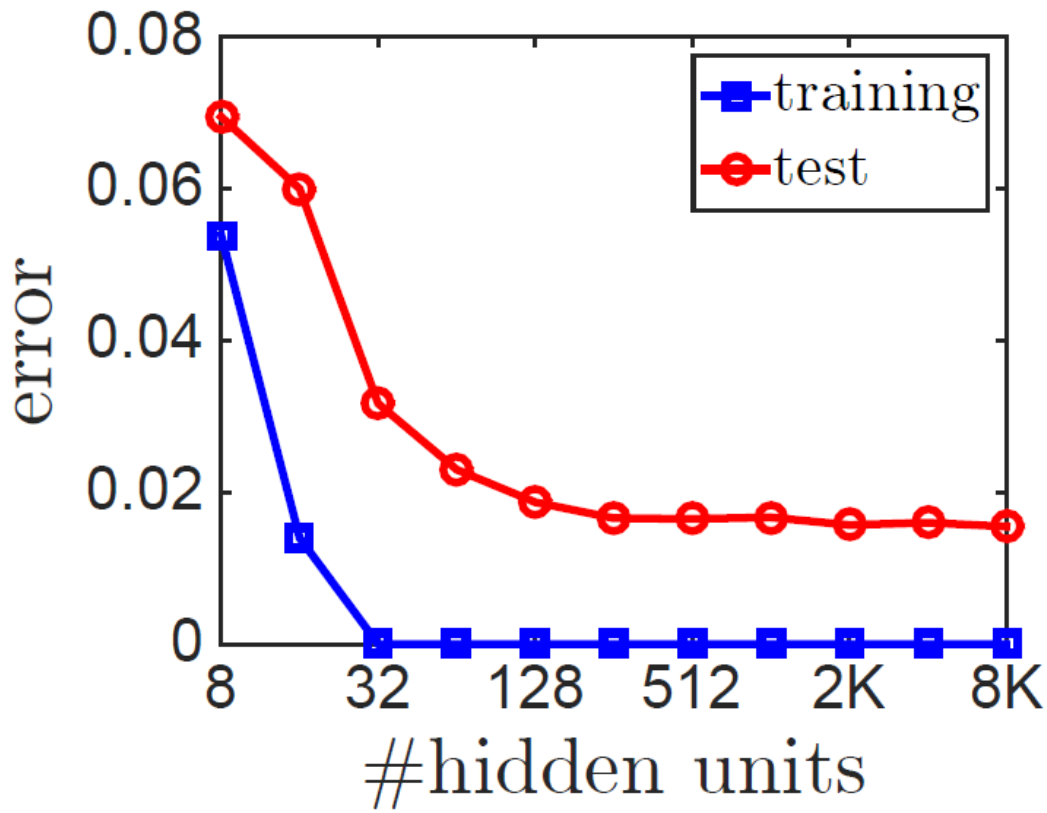
("size" of the function set)

If two models have the same E_{train} → Select the one with smaller capacity

Demo

Overparameterized Network?

當hidden layer unit增加的時候, 竟然還可以降低testing error

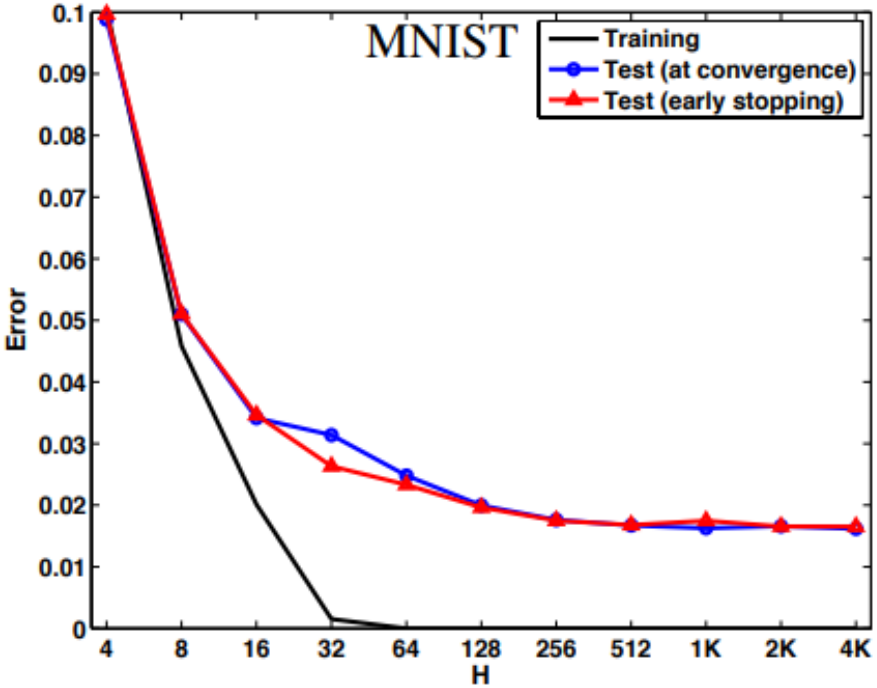


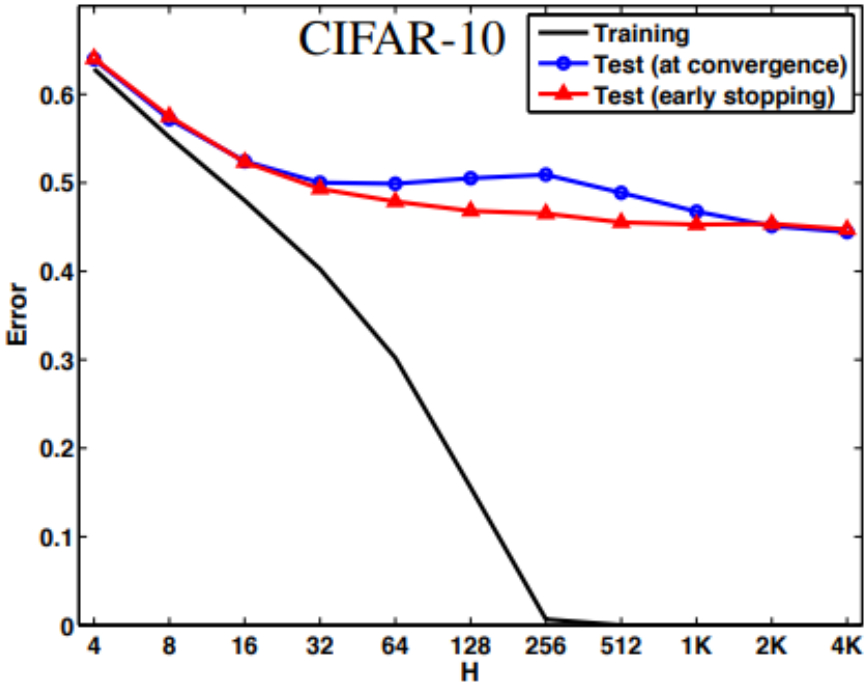
MNIST

https://arxiv.org/abs/1706.08947

Overparameterized Network?

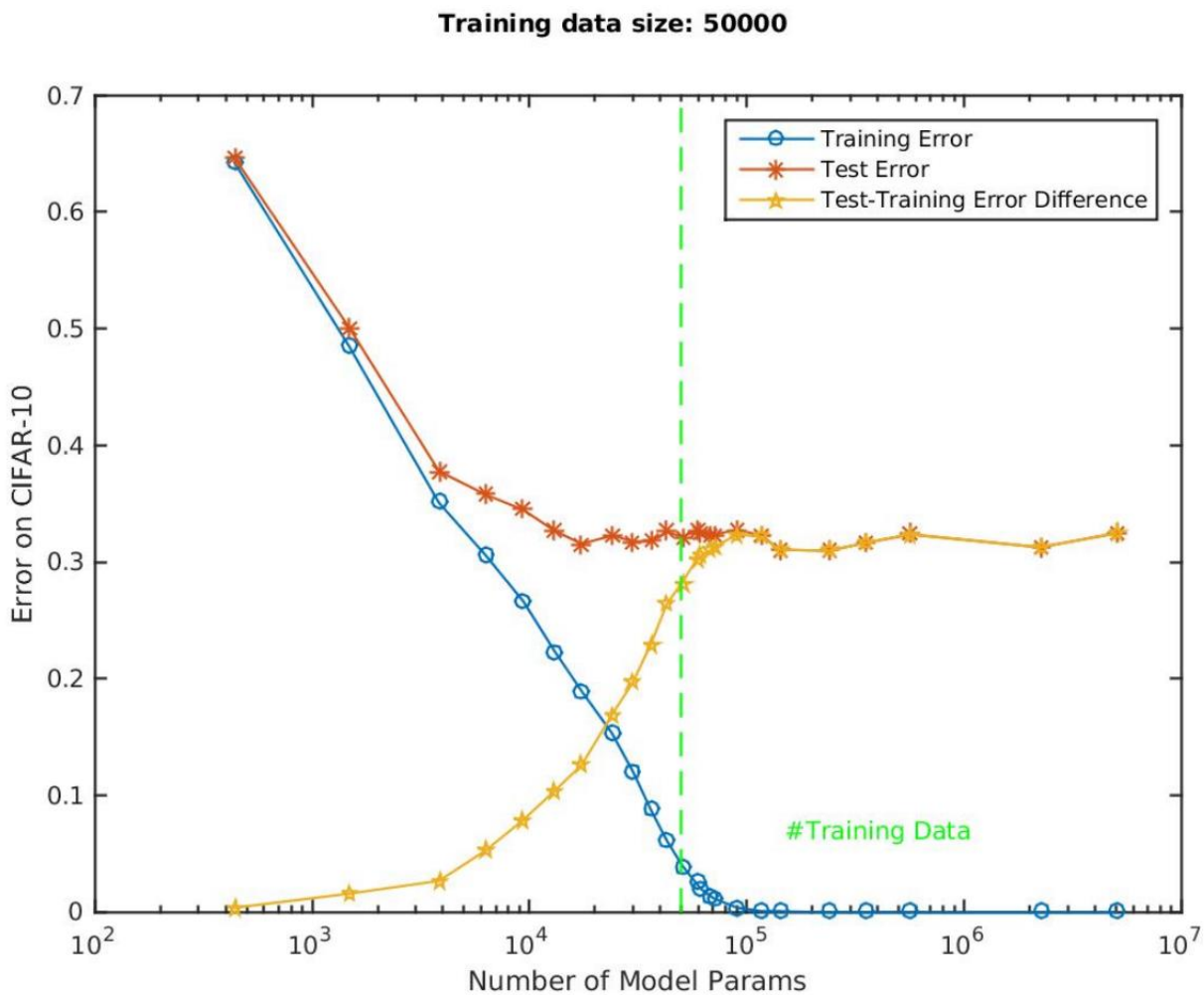
當hidden layer unit增加的時候, 即使達到training error = 0, 竟然還可以降低testing error



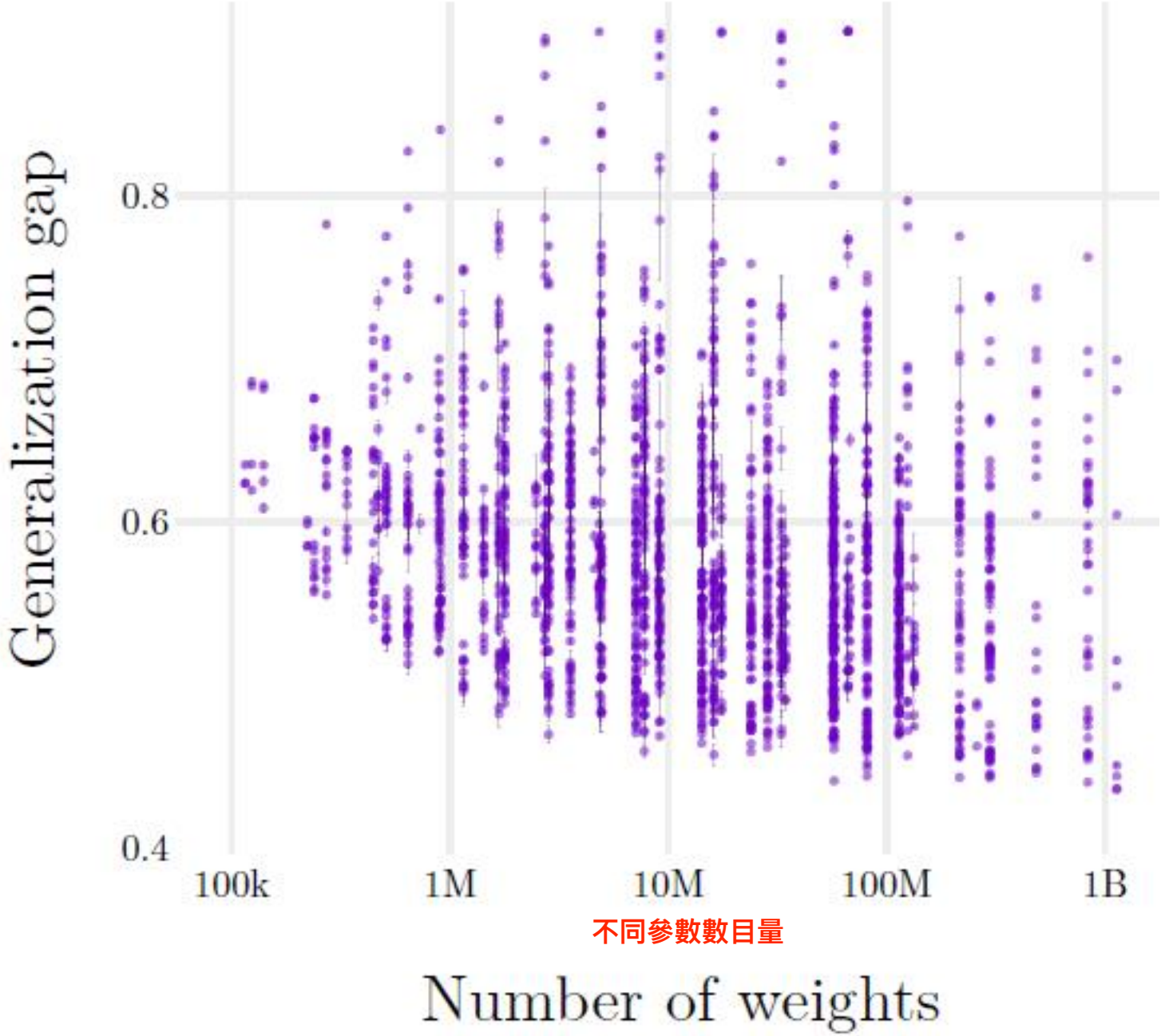


https://arxiv.org/pdf/1412.6614.pdf

Overparameterized Network?



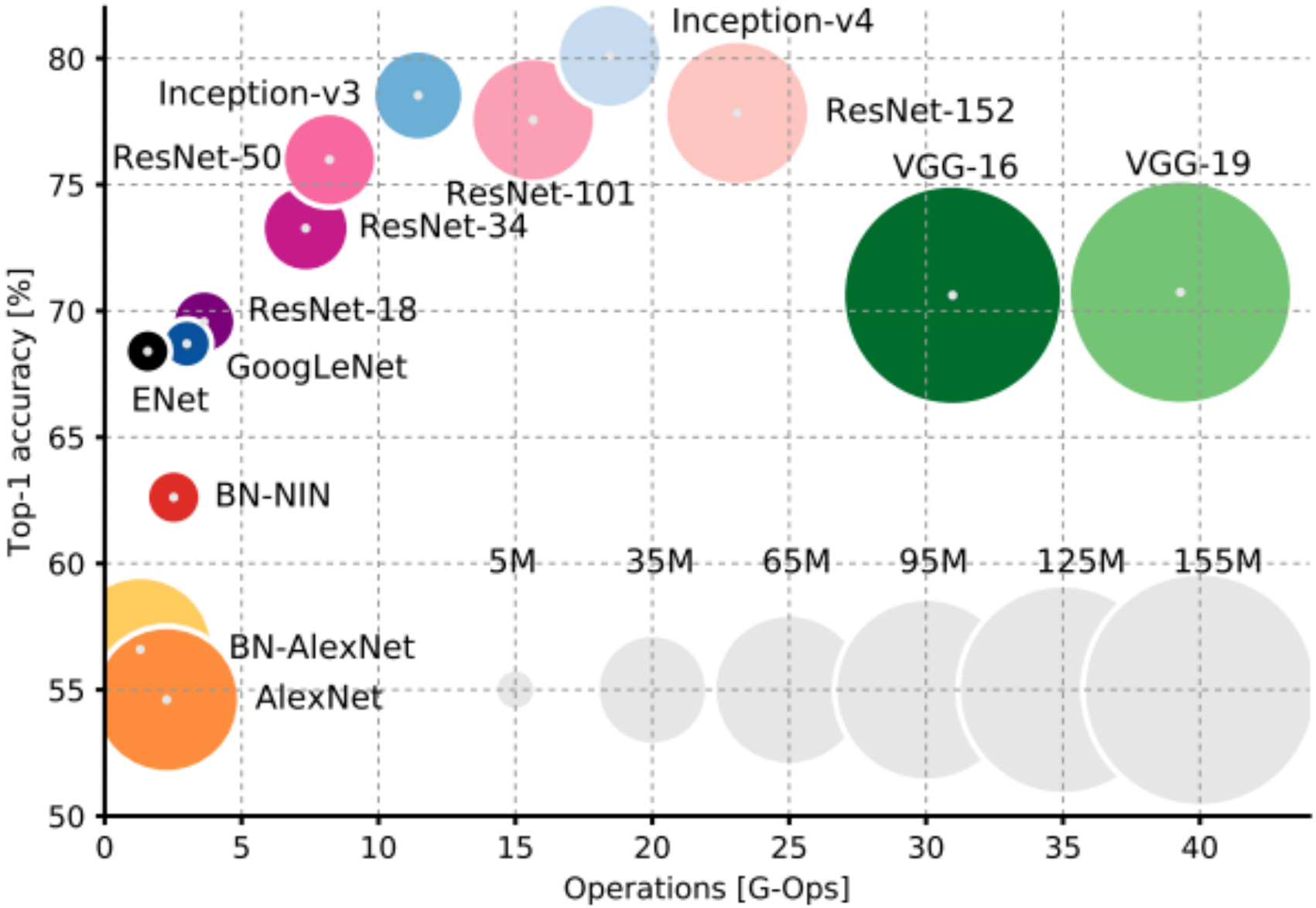
https://arxiv.org/abs/1801.00173



CIFIR-10, 100%
training accuracy

https://arxiv.org/pdf/1802.08760.pdf

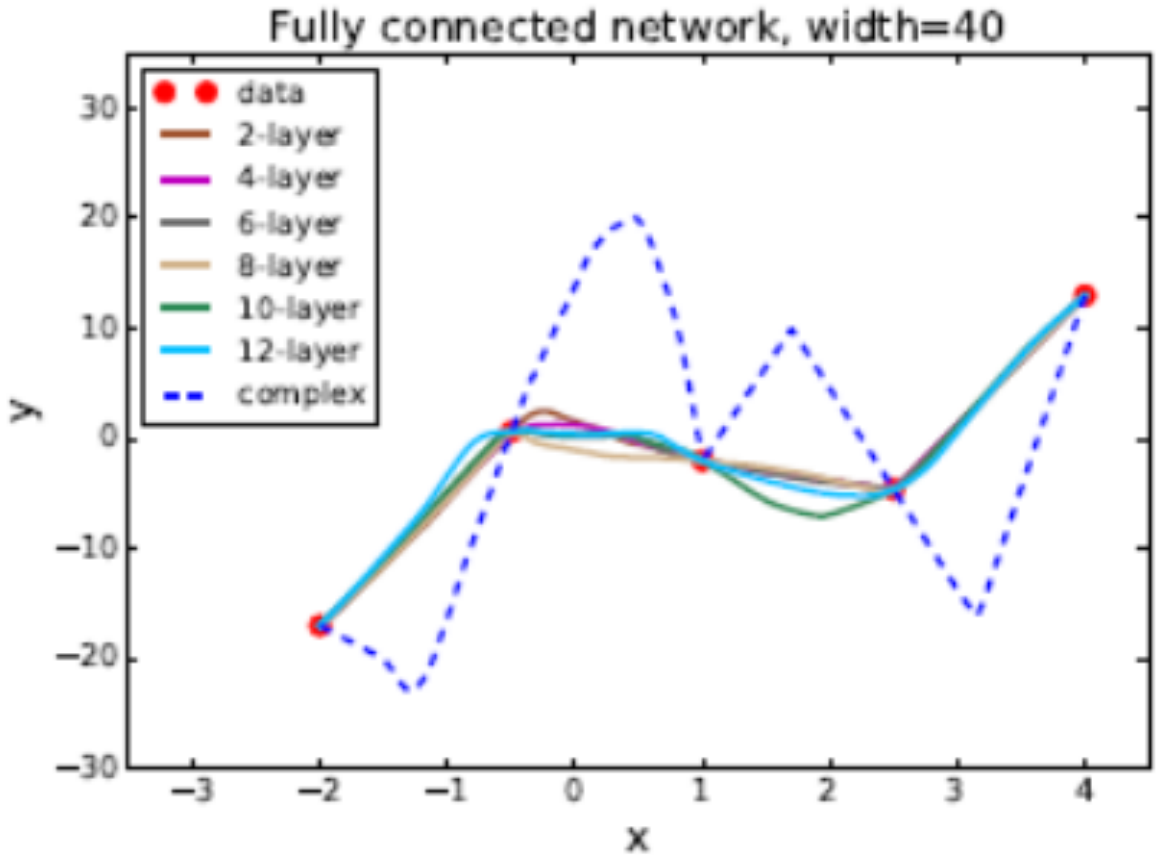
隨著參數越來越多 正確率越來越高



https://arxiv.org/abs/1605.07678

Network regularizes itself?

即使model capacity變大，他仍然regular在平滑的曲線上



https://arxiv.org/pdf/1706.10239.pdf

Concluding Remarks

- The capacity of deep model is large.
- However, it does not overfit!
- The reason is not clear yet.

如果用gradient based來train model可能會自帶regularization，因為一開始的initial參數都很小（接近原點），而regularization就是希望參數能夠接近原點