

# Unsupervised Learning:

## Deep Auto-encoder

# Unsupervised Learning

“We expect unsupervised learning to become far more important in the longer term. Human and animal learning is largely unsupervised: we discover the structure of the world by observing it, not by being told the name of every object.”

– LeCun, Bengio, Hinton, Nature 2015

As I've said in previous statements: most of human and animal learning is unsupervised learning. If intelligence was a cake, unsupervised learning would be the cake, supervised learning would be the icing on the cake, and reinforcement learning would be the cherry on the cake. We know how to make the icing and the cherry, but we don't know how to make the cake.

- Yann LeCun, March 14, 2016 (Facebook)

必須同時train Encoder & Decoder

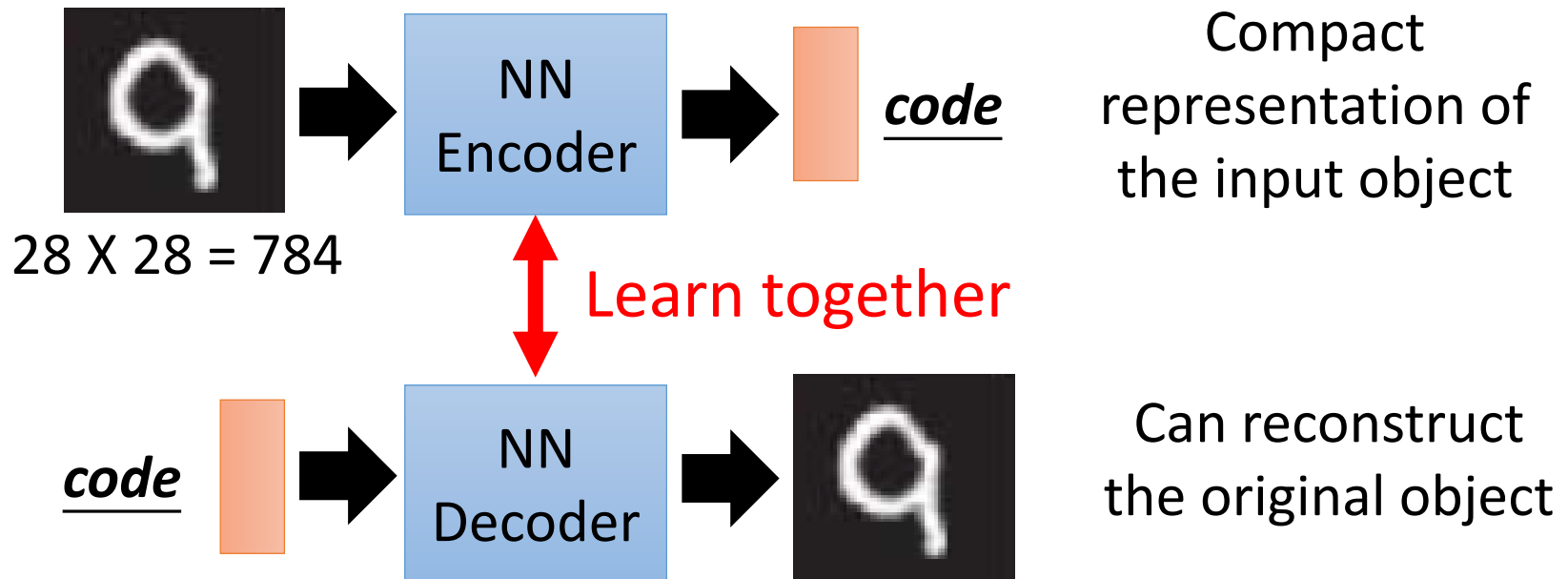
# Auto-encoder

使用neural network降維

遠比PCA複雜，因為他不  
是一個線性的東西

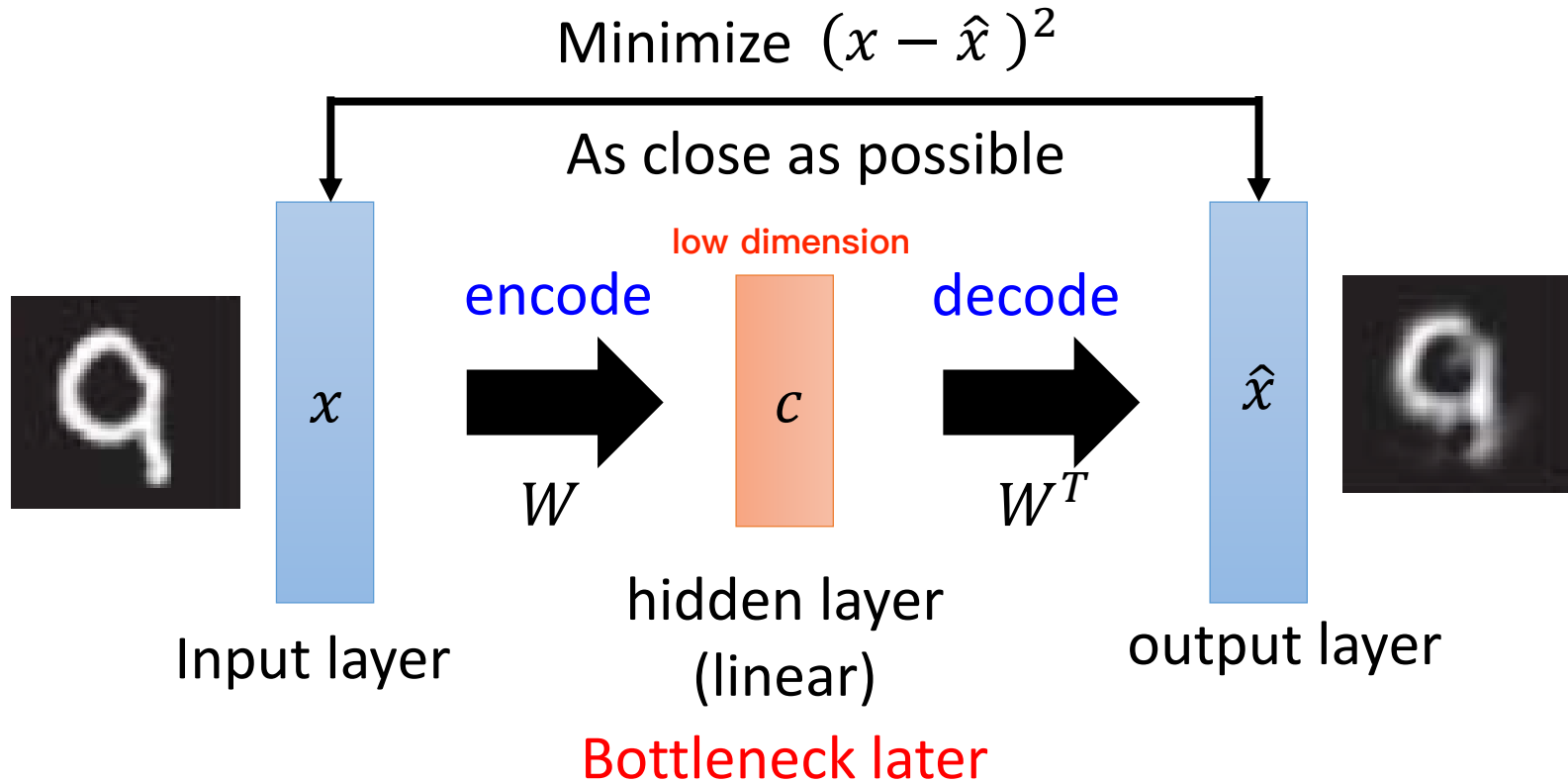
Usually <784

非線性轉換



PCA的W有一個close form solution (Eigen Vector)

# Recap: PCA



Output of the hidden layer is the code

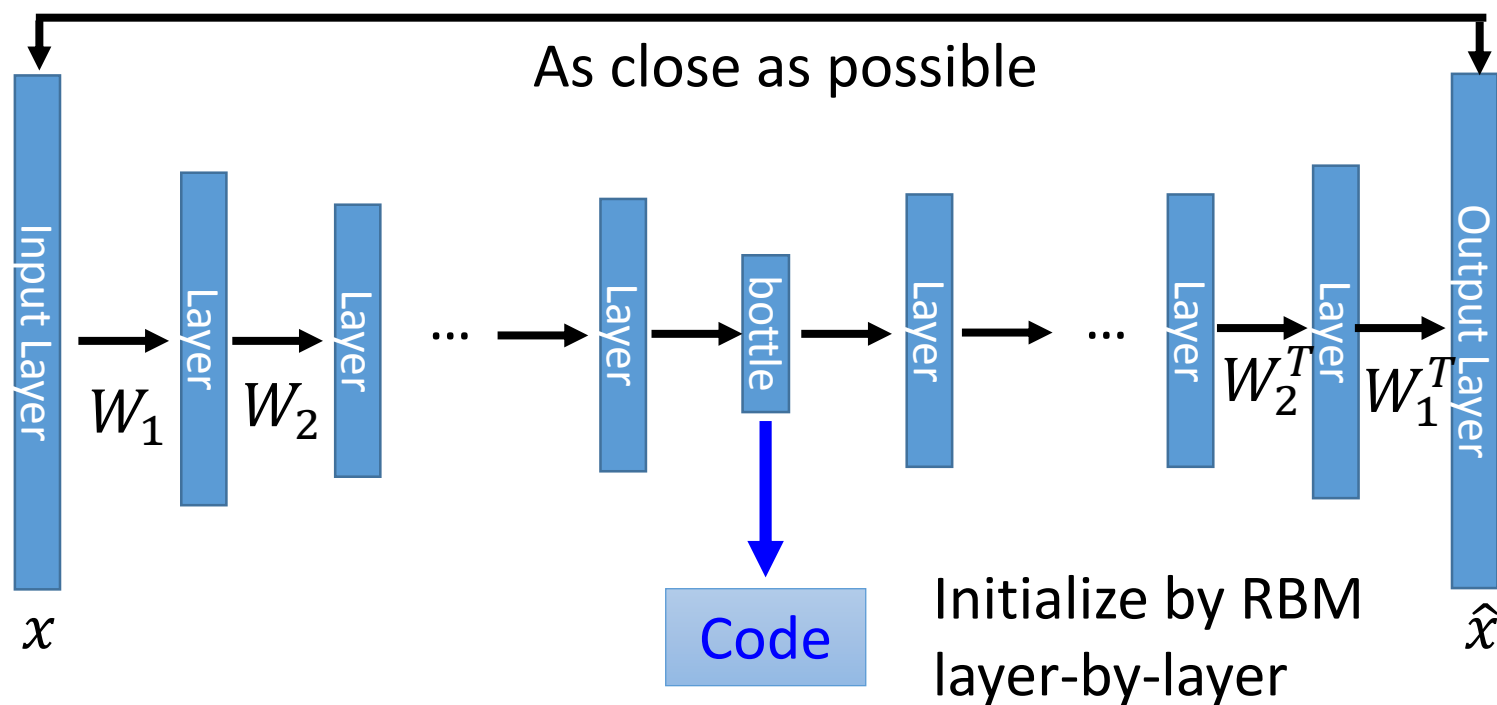
跟PCA比起來就是多增加了許多的hidden layer

# Deep Auto-encoder

Symmetric is not necessary.

希望layer之間有transpose (減少參數避免overfitting) , 但auto-encoder未必必要

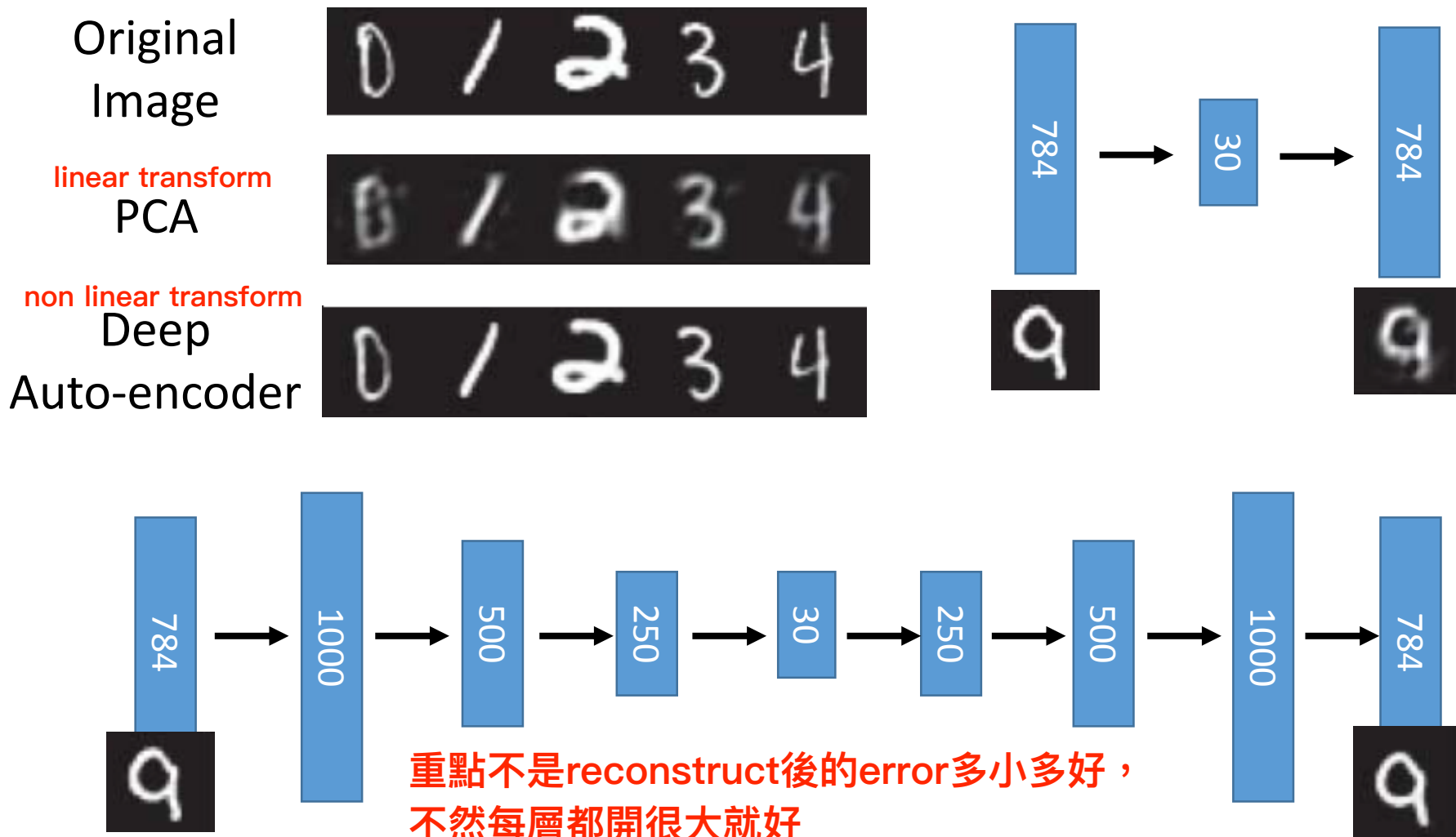
- Of course, the auto-encoder can be deep



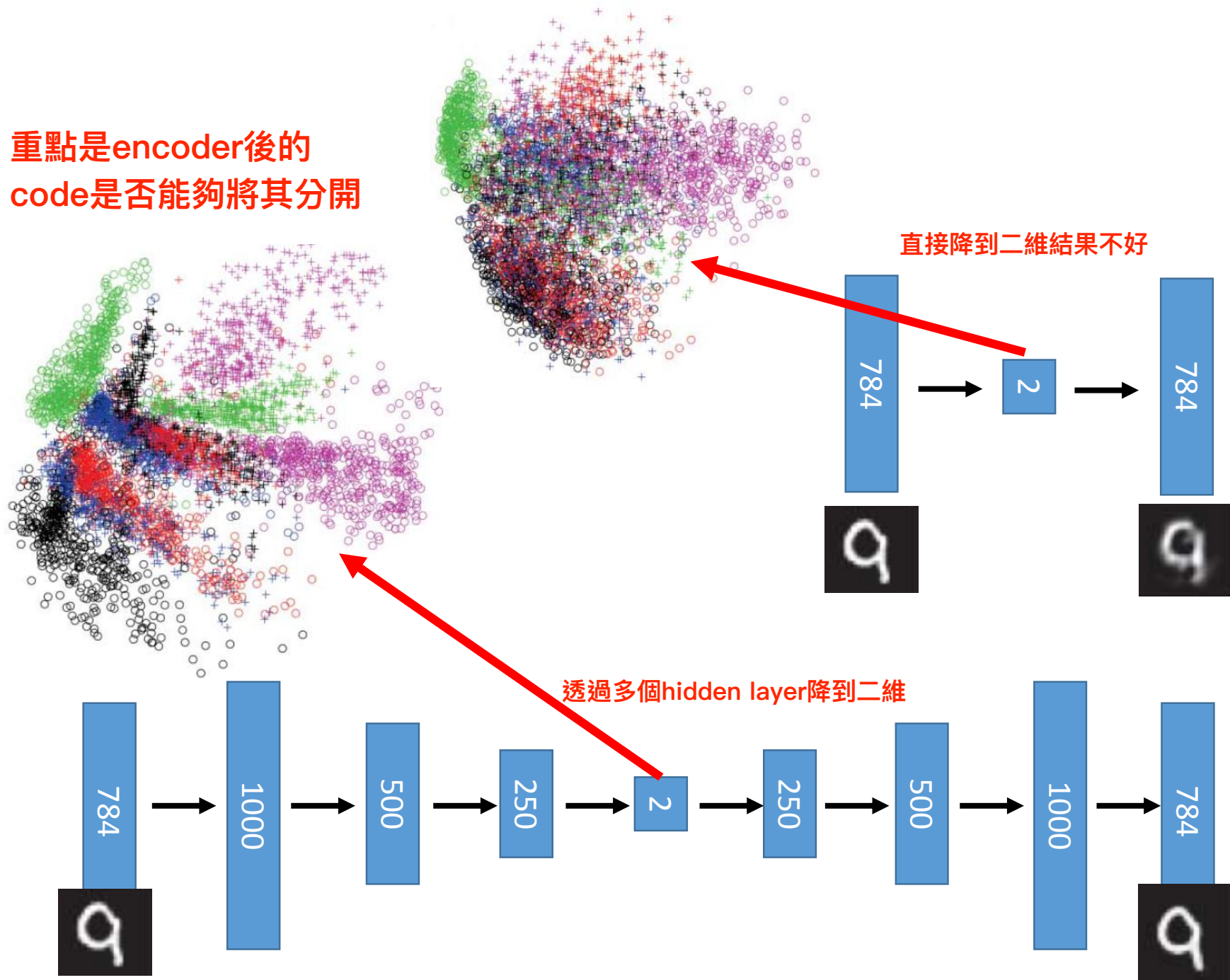
Reference: Hinton, Geoffrey E., and Ruslan R. Salakhutdinov. "Reducing the dimensionality of data with neural networks." *Science* 313.5786 (2006): 504-507

# Deep Auto-encoder

P C A 本身是線性的，因此轉換過程有  
loss value，reconstruct 結果會比較差



重點是encoder後的  
code是否能夠將其分開

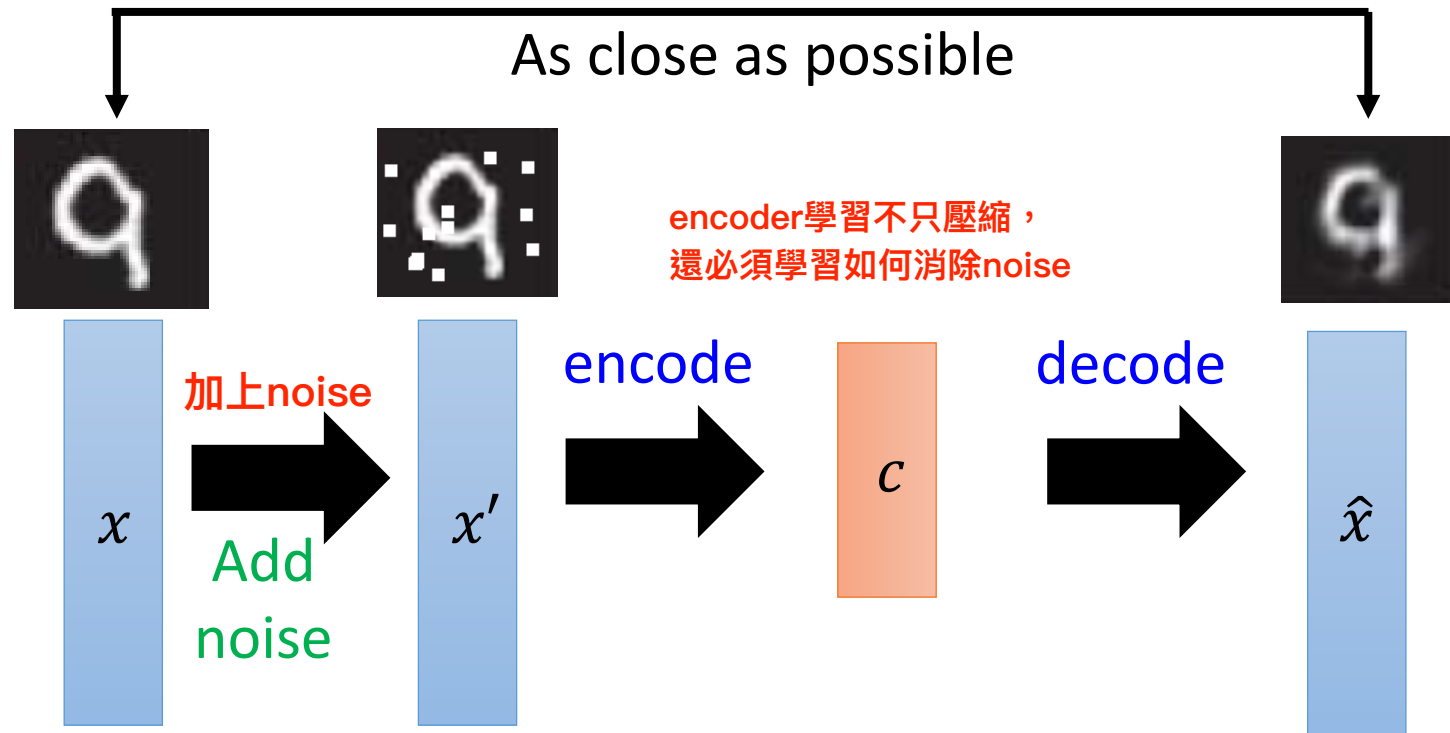


## More: Contractive auto-encoder

# Auto-encoder

Ref: Rifai, Salah, et al. "Contractive auto-encoders: Explicit invariance during feature extraction." *Proceedings of the 28th International Conference on Machine Learning (ICML-11)*. 2011.

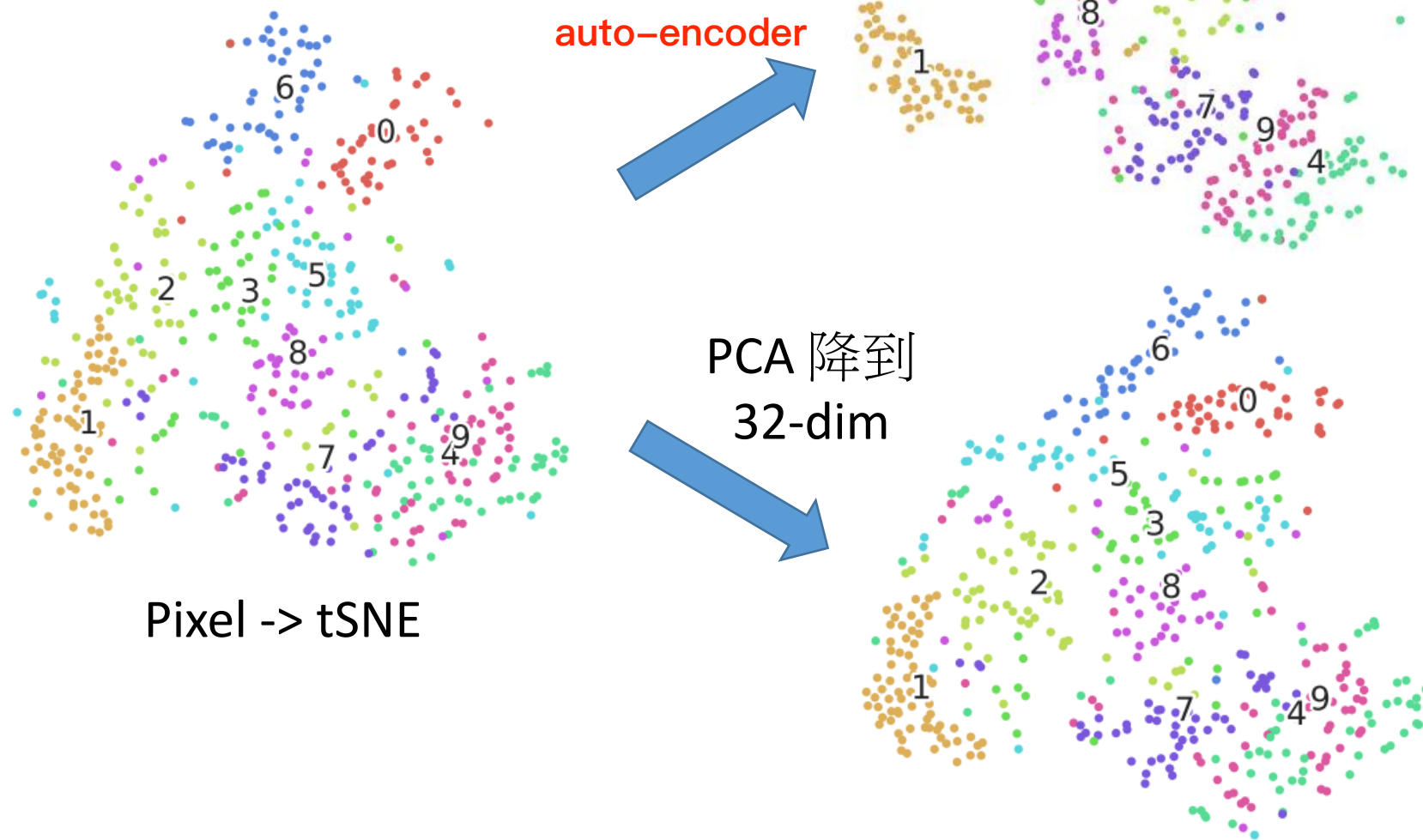
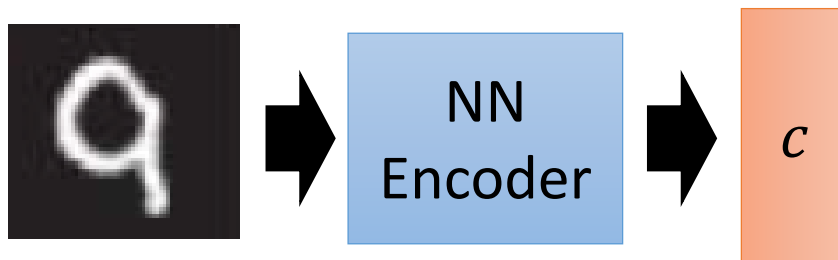
- De-noising auto-encoder



Vincent, Pascal, et al. "Extracting and composing robust features with denoising autoencoders." *ICML*, 2008.



# Deep Auto-encoder - Example



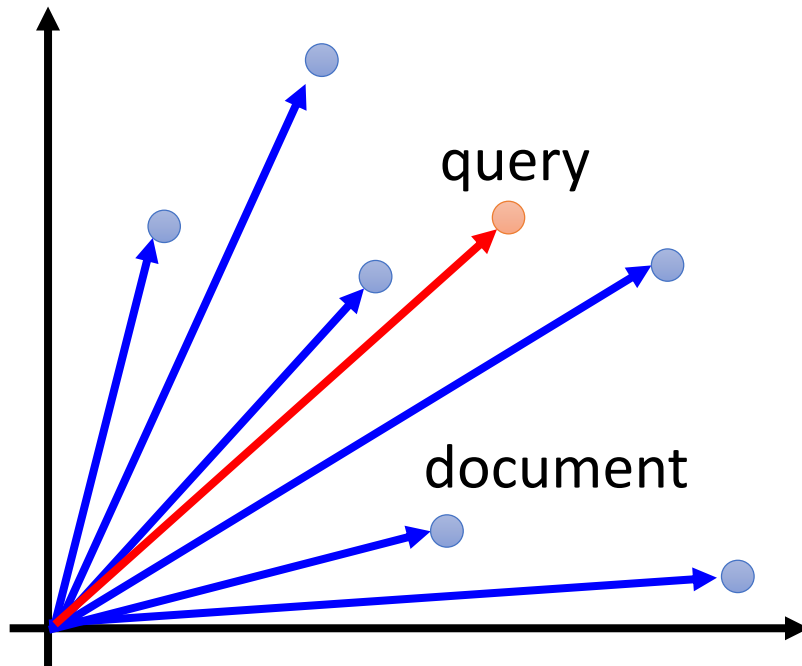
auto-encoder也可以用在文字上

# Auto-encoder – Text Retrieval

開一個很大維的vector，記錄哪些詞彙出現的次數，  
但只能做到字面的比對，但是沒有考慮到語意的關係

## Vector Space Model

similarity：計算每個vector的cos角度差



## Bag-of-word

word string:

"This is an apple"

this	1
is	1
a	0
an	1
apple	1
pen	0
⋮	

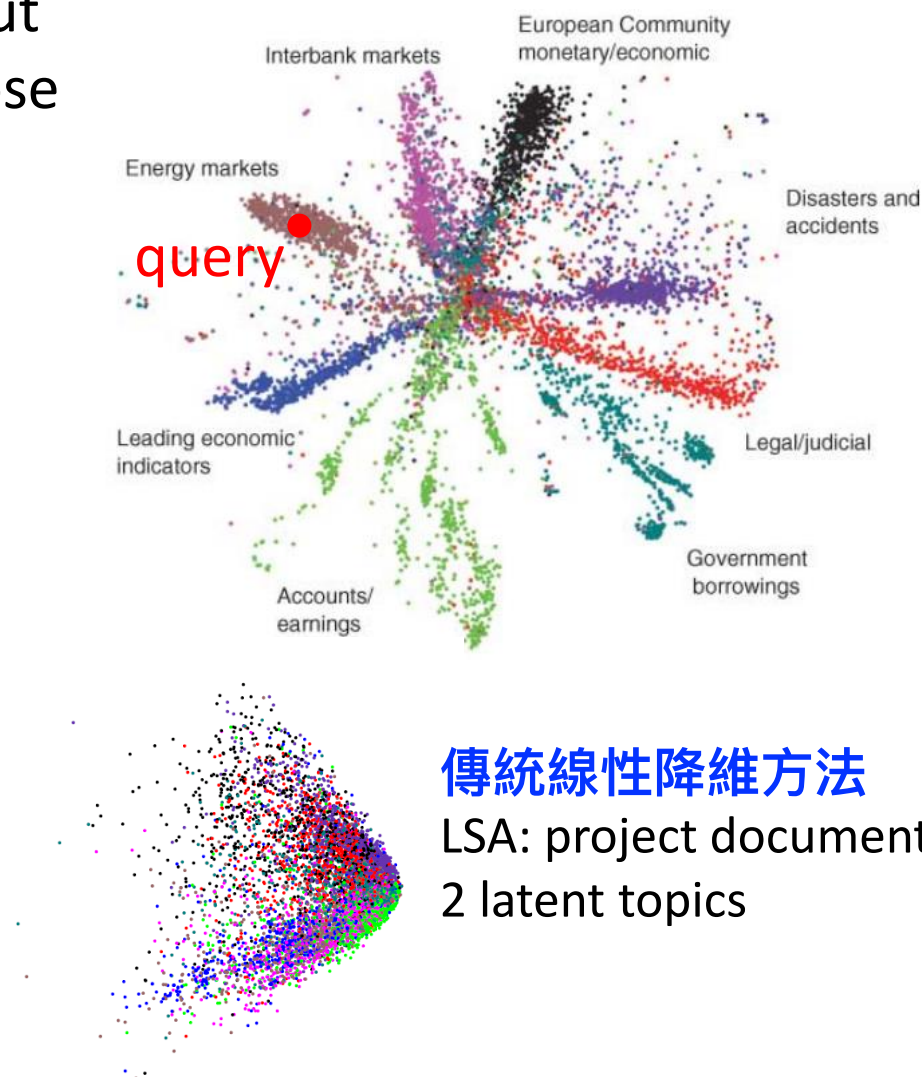
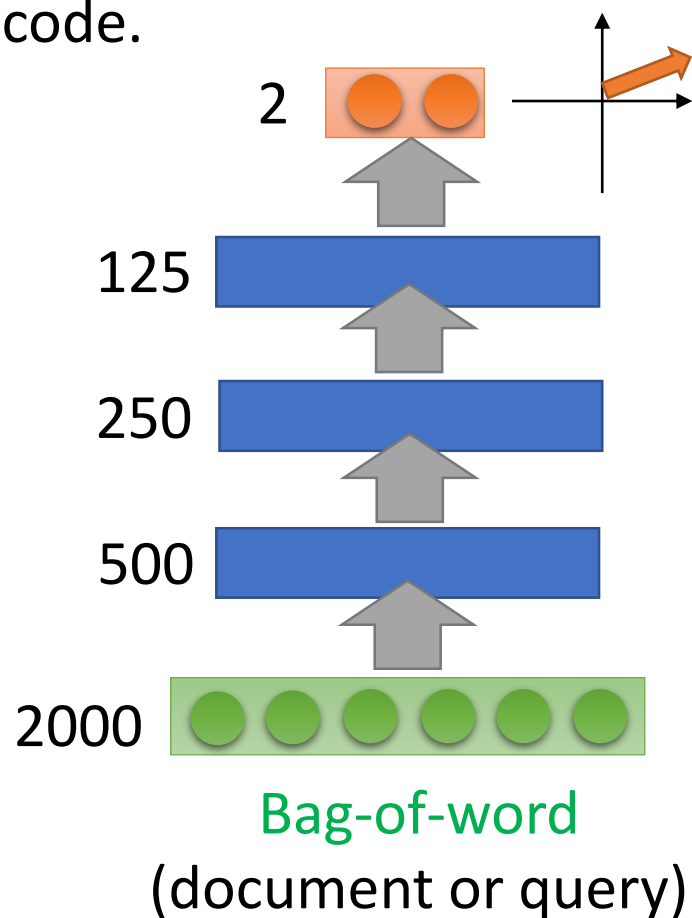
沒有考慮到語意的關係

Semantics are not  
considered.

疊一個auto-encoder，將Bag of Word降維成二維

# Auto-encoder – Text Retrieval

The documents talking about the same thing will have close code.



# Auto-encoder – 影像搜尋

## Similar Image Search

Retrieved using Euclidean distance in pixel intensity space

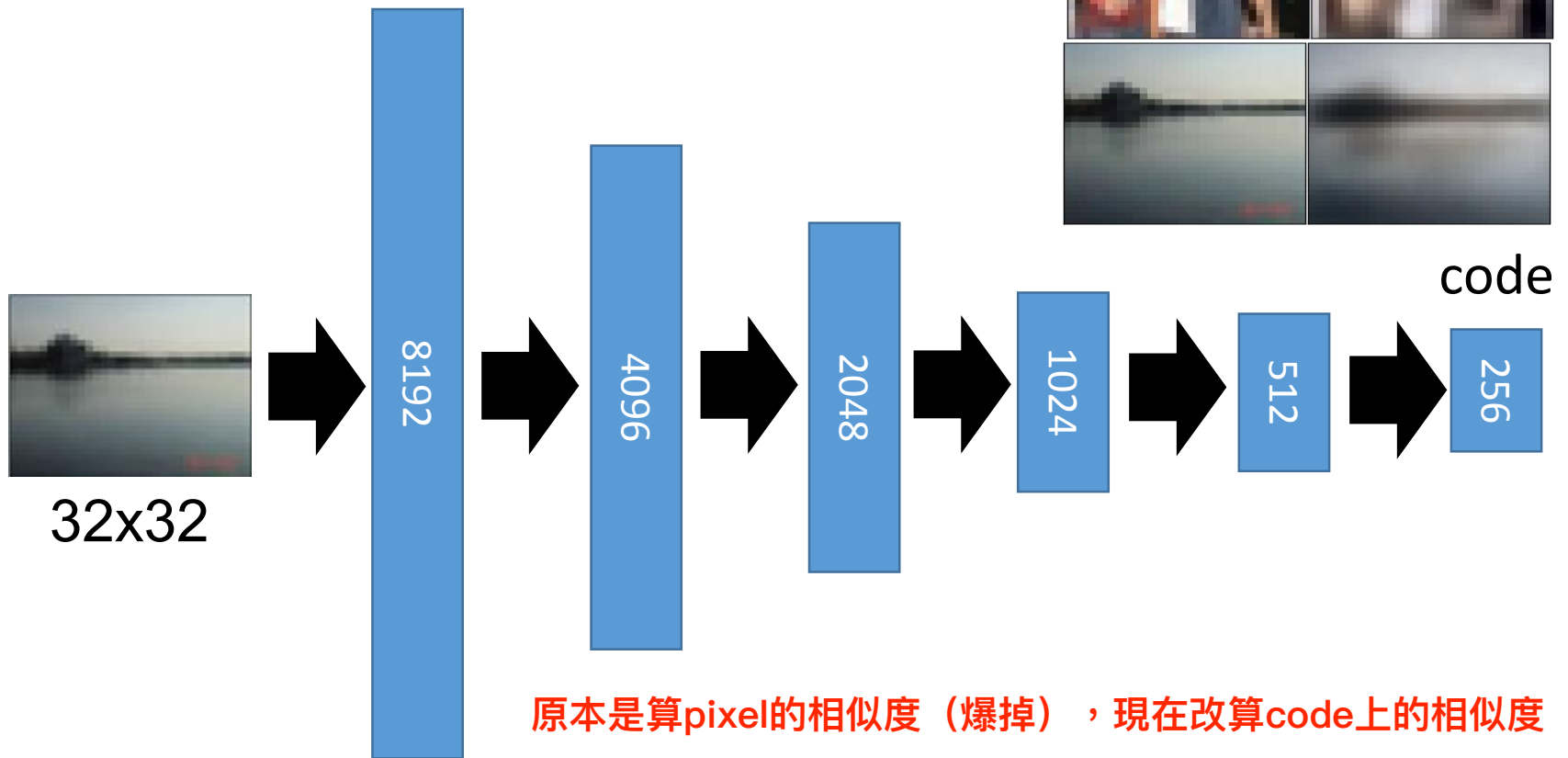


用每個pixel算euclidean  
distance相似度會爆掉

(Images from Hinton's slides on Coursera)

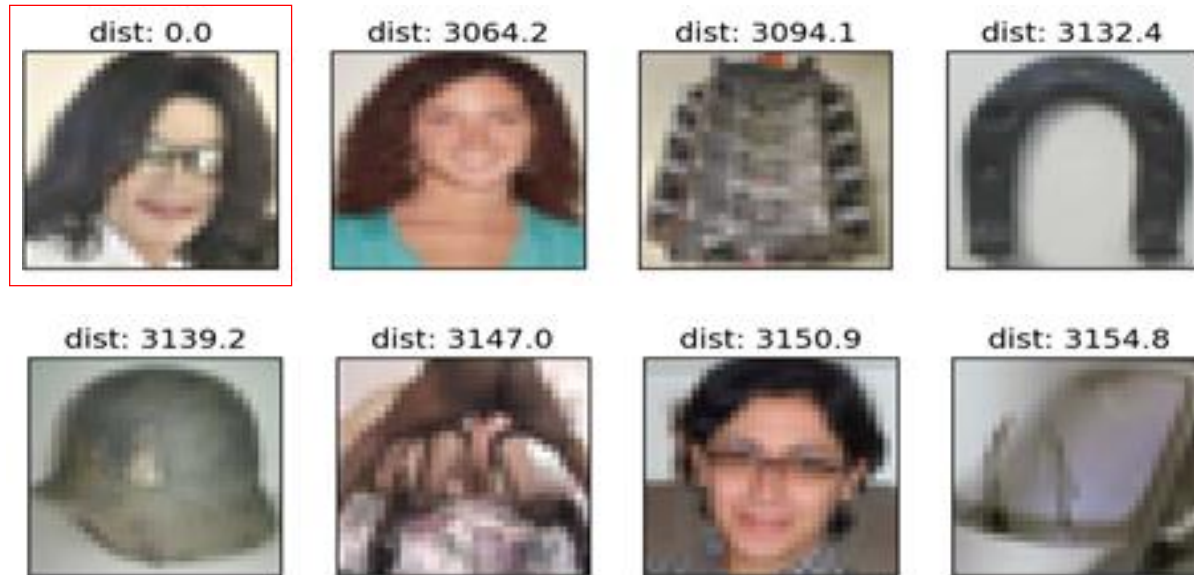
Reference: Krizhevsky, Alex, and Geoffrey E. Hinton. "Using very deep autoencoders for content-based image retrieval." *ESANN*. 2011.

# Auto-encoder – Similar Image Search



(crawl millions of images from the Internet)

# Retrieved using Euclidean distance in pixel intensity space

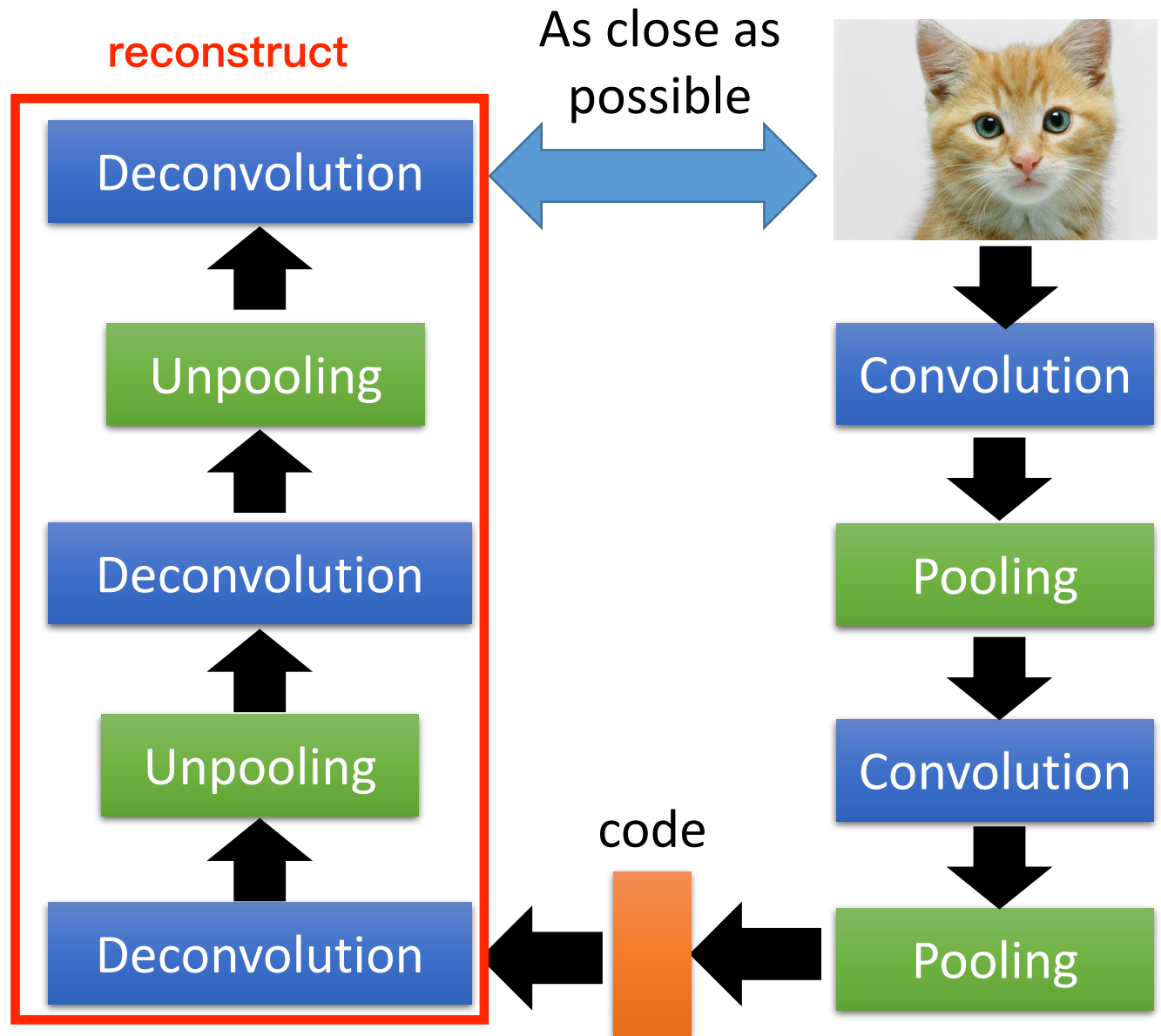


上面使用pixel euclidean效果超差  
retrieved using 256 codes



但使用auto-encoder找出code後繼算相似度可辨識人臉

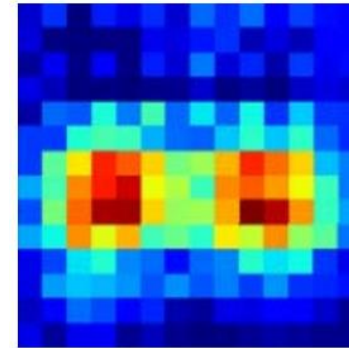
# Auto- encoder for CNN



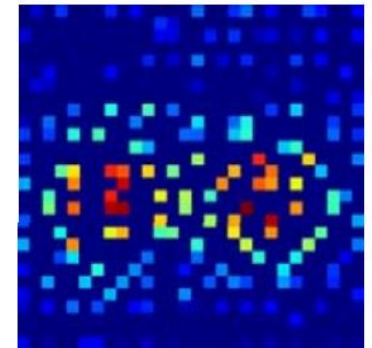


# CNN -Unpooling

做Unpooling即是maxPooling的相反



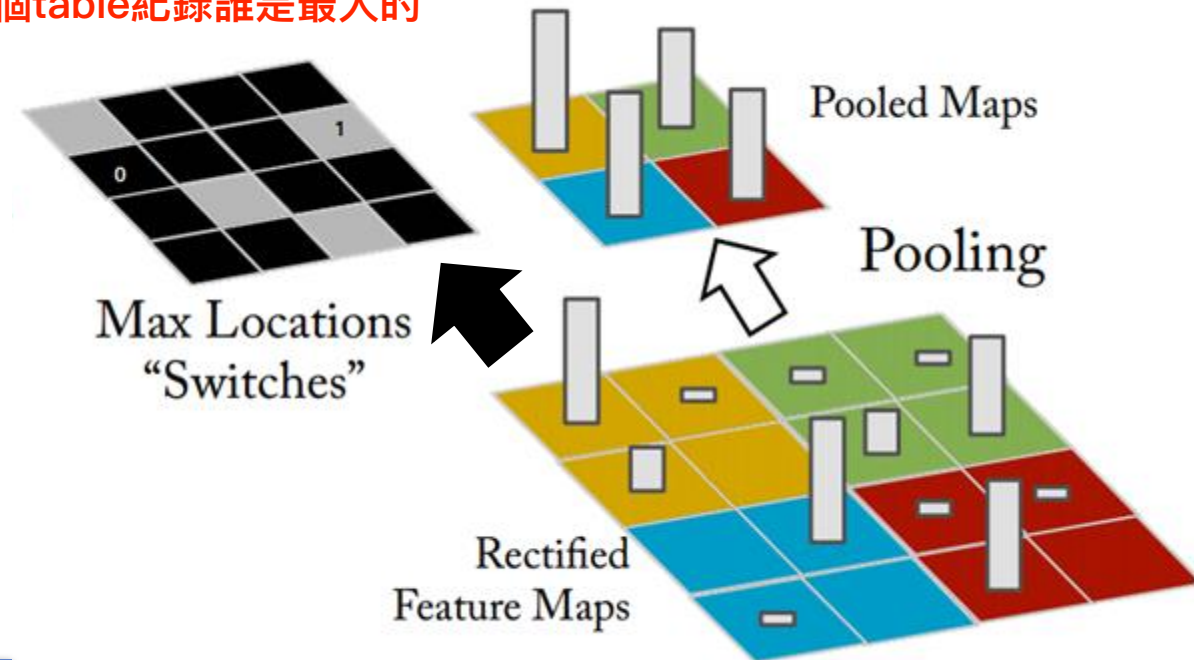
14 x 14



28 x 28

存一個table紀錄誰是最大的

針對每一個pooling block  
把最大值放在記錄好的位  
子，其餘三個補零



Alternative: simply  
repeat the values

Source of image :

[https://leonardoaraujosantos.gitbooks.io/artificial-intelligence/content/image\\_segmentation.html](https://leonardoaraujosantos.gitbooks.io/artificial-intelligence/content/image_segmentation.html)

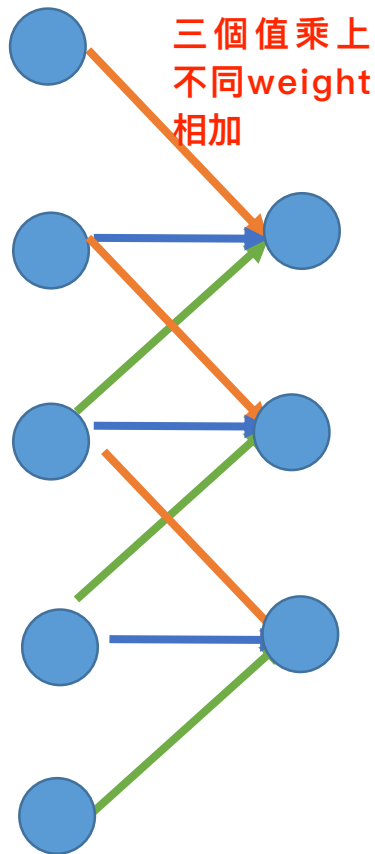


# CNN

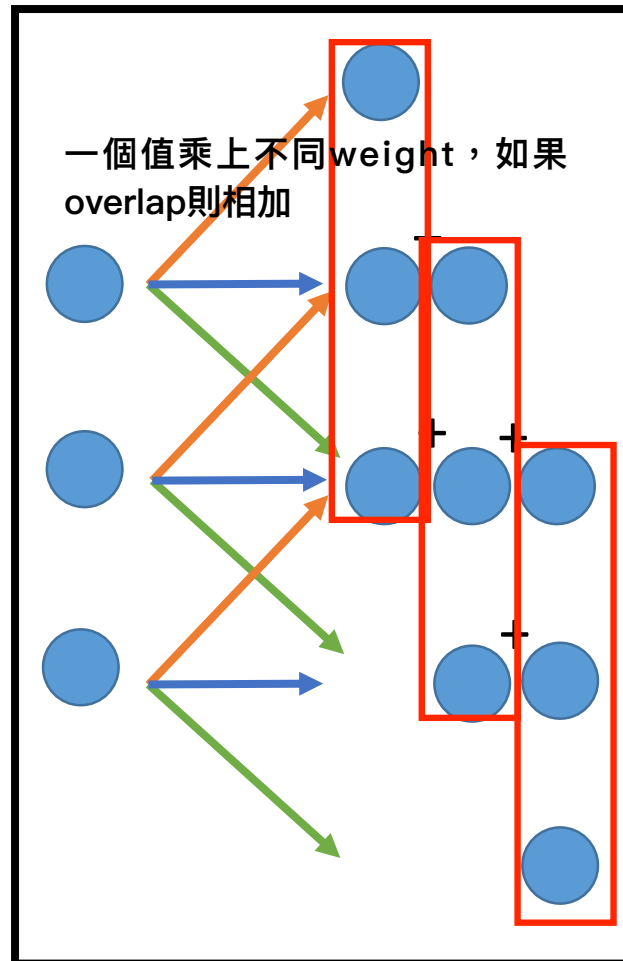
## - Deconvolution

Actually, deconvolution is convolution.

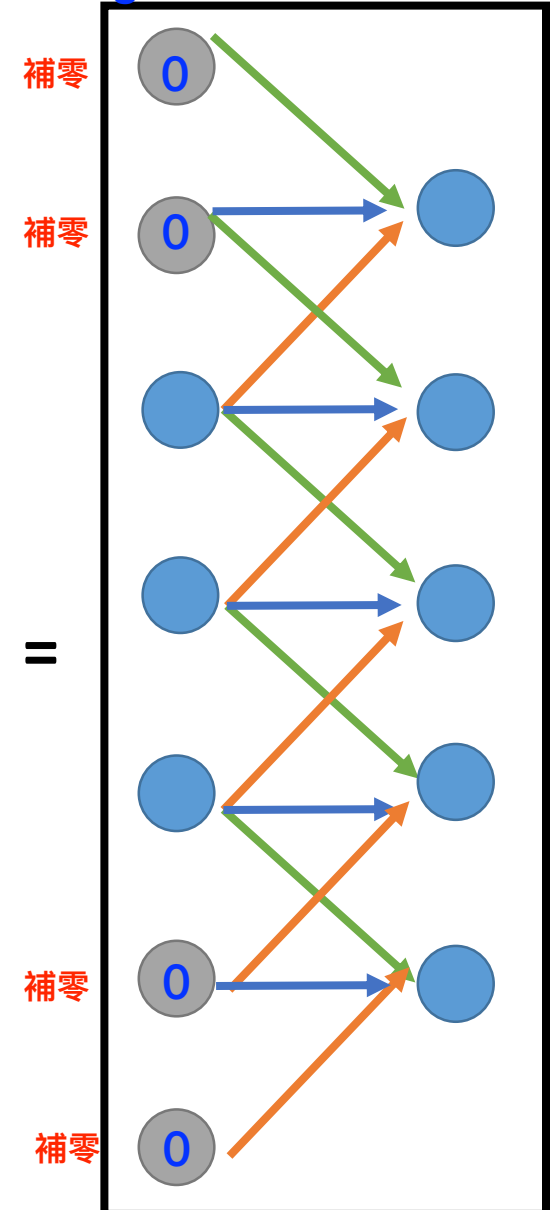
相當於convolution，只是weight不同且旁邊需要補零



Convolution



De-Convolution

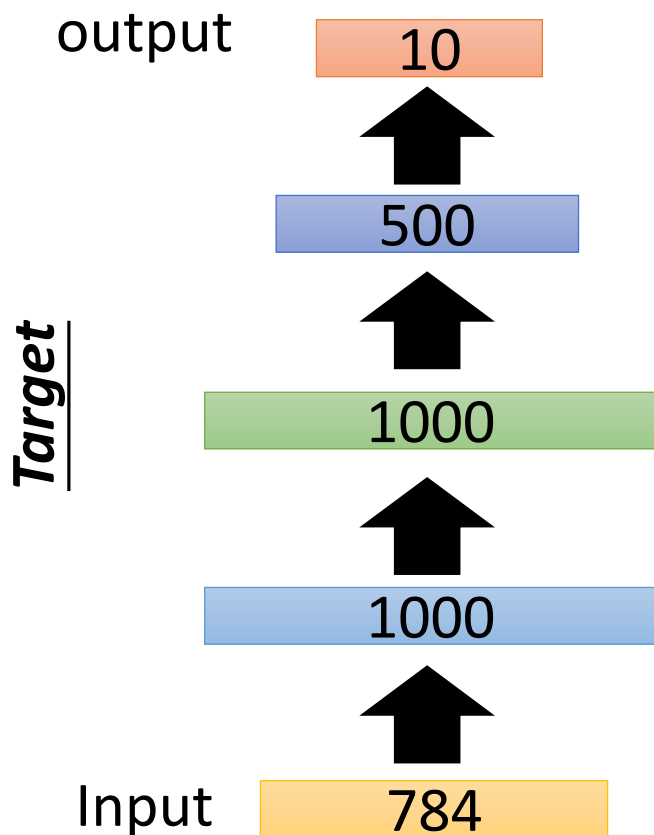


# Auto-encoder – Pre-training DNN

unsupervised

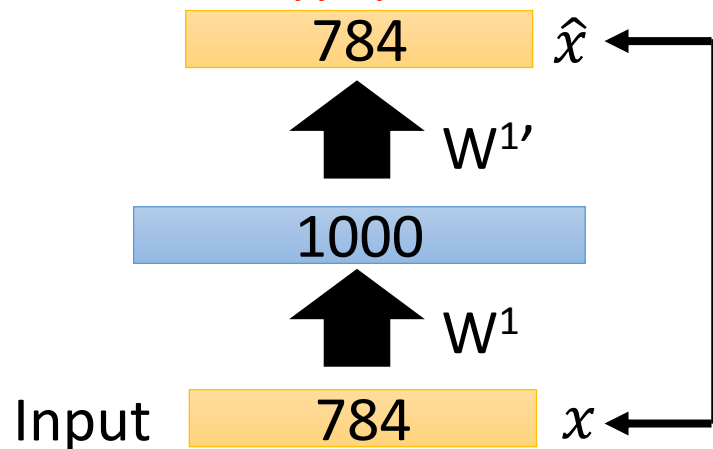
這個情境特別適合semi-supervised learning

- Greedy Layer-wise Pre-training *again*



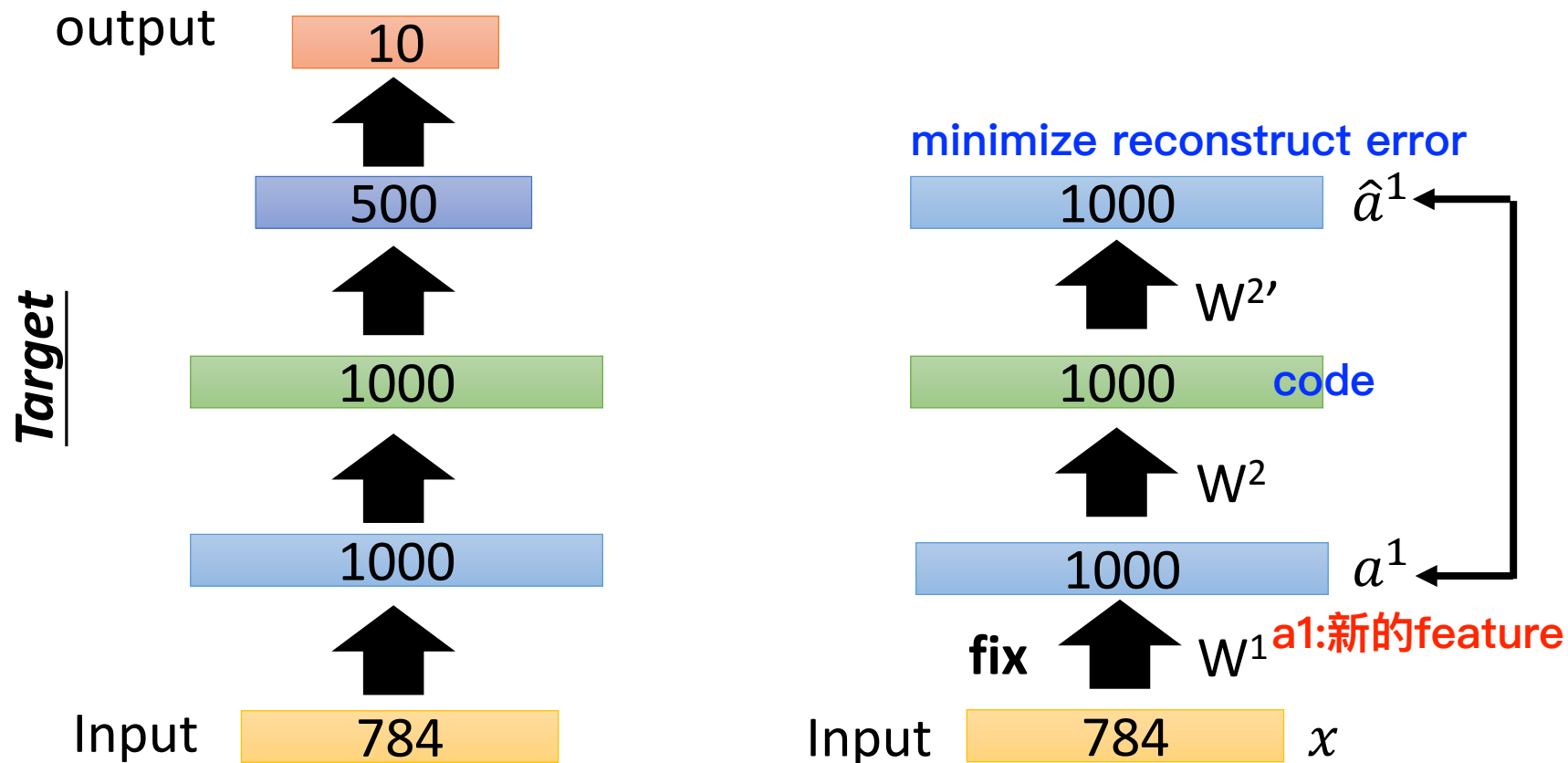
當bottleneck是high dimensional（為了配合target network），因此需要加上 regularization or de-noise auto-encoder  
先使用auto-encoder做一些pre-processing

auto-encoder的pre processing  
這邊如果要train好要加一些regularization或是noise  
避免他只是直接copy input



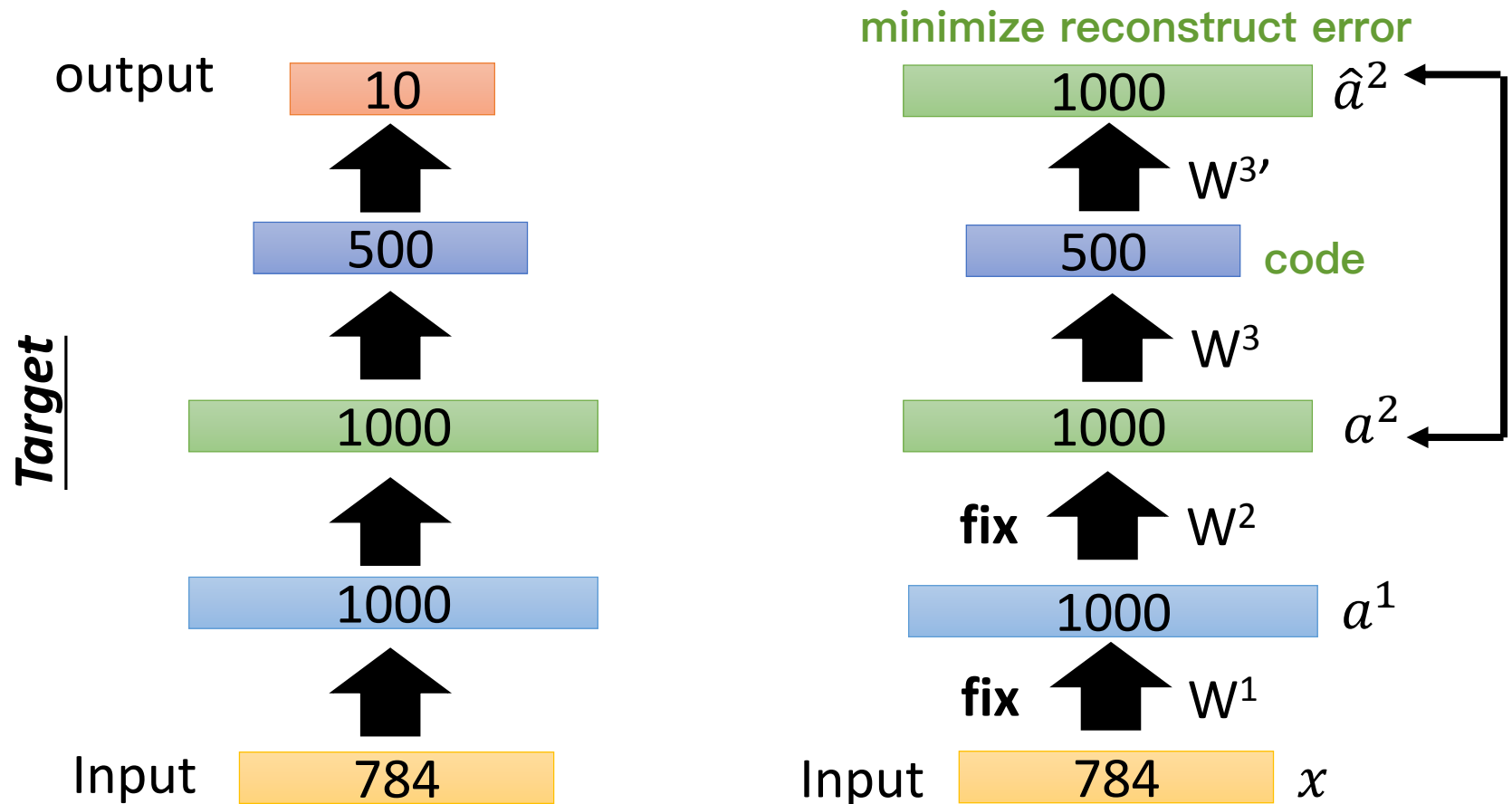
# Auto-encoder – Pre-training DNN

- Greedy Layer-wise Pre-training *again*



# Auto-encoder – Pre-training DNN

- Greedy Layer-wise Pre-training *again*



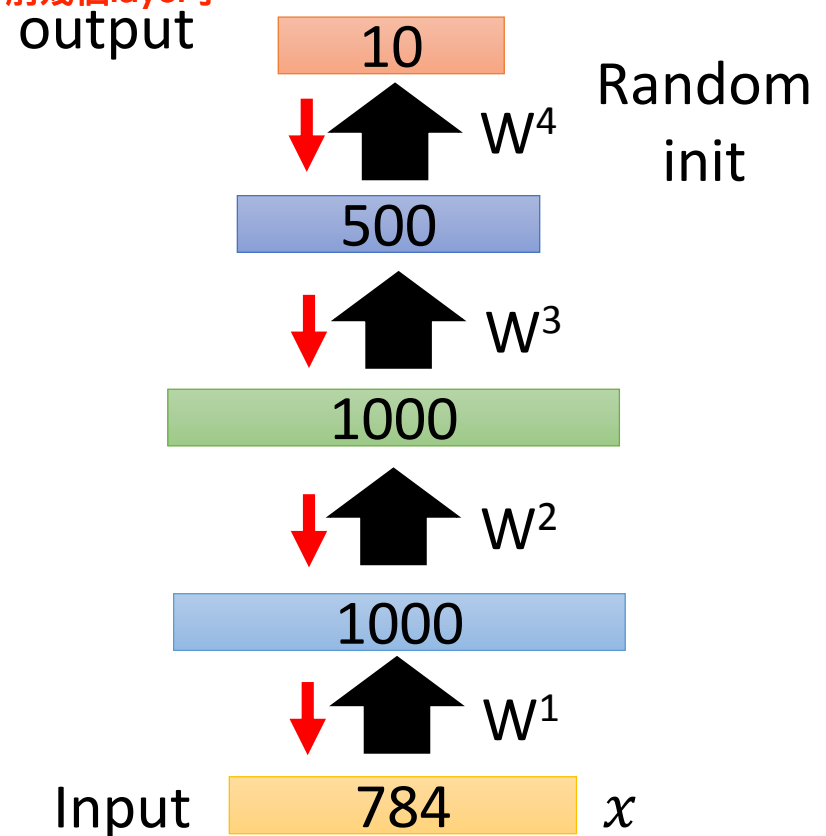
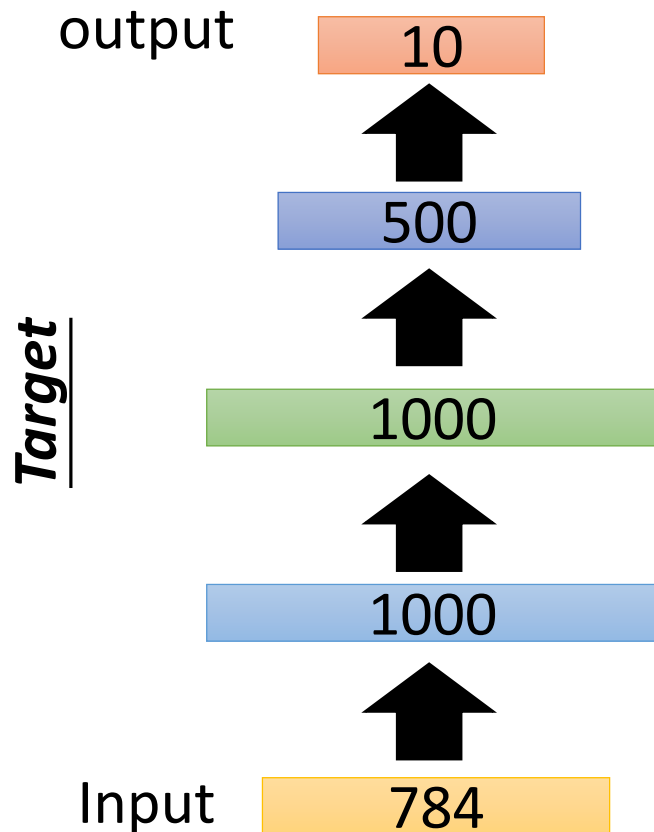
# Auto-encoder – Pre-training DNN

這時候就可以將 $w_1, w_2, w_3$ 當做initial weight，而 $w_4$ 在用random做  
back propagation 做fine tune

- Greedy Layer-wise Pre-training *again*

在pre-training的時候就已經訓練好前幾個layer了

Find-tune by  
backpropagation



# Learning More

## - Restricted Boltzmann Machine

不是DNN

- Neural networks [5.1] : Restricted Boltzmann machine – definition
  - [https://www.youtube.com/watch?v=p4Vh\\_zMw-HQ&index=36&list=PL6Xpj9I5qXYEcOhn7TqghAJ6NAPrNmUBH](https://www.youtube.com/watch?v=p4Vh_zMw-HQ&index=36&list=PL6Xpj9I5qXYEcOhn7TqghAJ6NAPrNmUBH)
- Neural networks [5.2] : Restricted Boltzmann machine – inference
  - [https://www.youtube.com/watch?v=lekCh\\_i32iE&list=PL6Xpj9I5qXYEcOhn7TqghAJ6NAPrNmUBH&index=37](https://www.youtube.com/watch?v=lekCh_i32iE&list=PL6Xpj9I5qXYEcOhn7TqghAJ6NAPrNmUBH&index=37)
- Neural networks [5.3] : Restricted Boltzmann machine - free energy
  - [https://www.youtube.com/watch?v=e0Ts\\_7Y6hZU&list=PL6Xpj9I5qXYEcOhn7TqghAJ6NAPrNmUBH&index=38](https://www.youtube.com/watch?v=e0Ts_7Y6hZU&list=PL6Xpj9I5qXYEcOhn7TqghAJ6NAPrNmUBH&index=38)

# Learning More

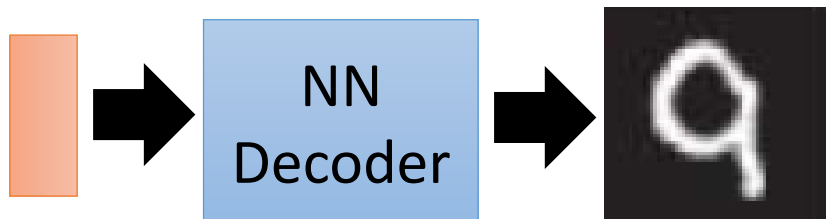
## - Deep Belief Network

不是DNN

- Neural networks [7.7] : Deep learning - deep belief network
  - <https://www.youtube.com/watch?v=vkb6AWYXZ5I&list=PL6Xpj9I5qXYEcOhn7TqghAJ6NAPrNmUBH&index=57>
- Neural networks [7.8] : Deep learning - variational bound
  - <https://www.youtube.com/watch?v=pStDscJh2Wo&list=PL6Xpj9I5qXYEcOhn7TqghAJ6NAPrNmUBH&index=58>
- Neural networks [7.9] : Deep learning - DBN pre-training
  - <https://www.youtube.com/watch?v=35MUIYCColk&list=PL6Xpj9I5qXYEcOhn7TqghAJ6NAPrNmUBH&index=59>

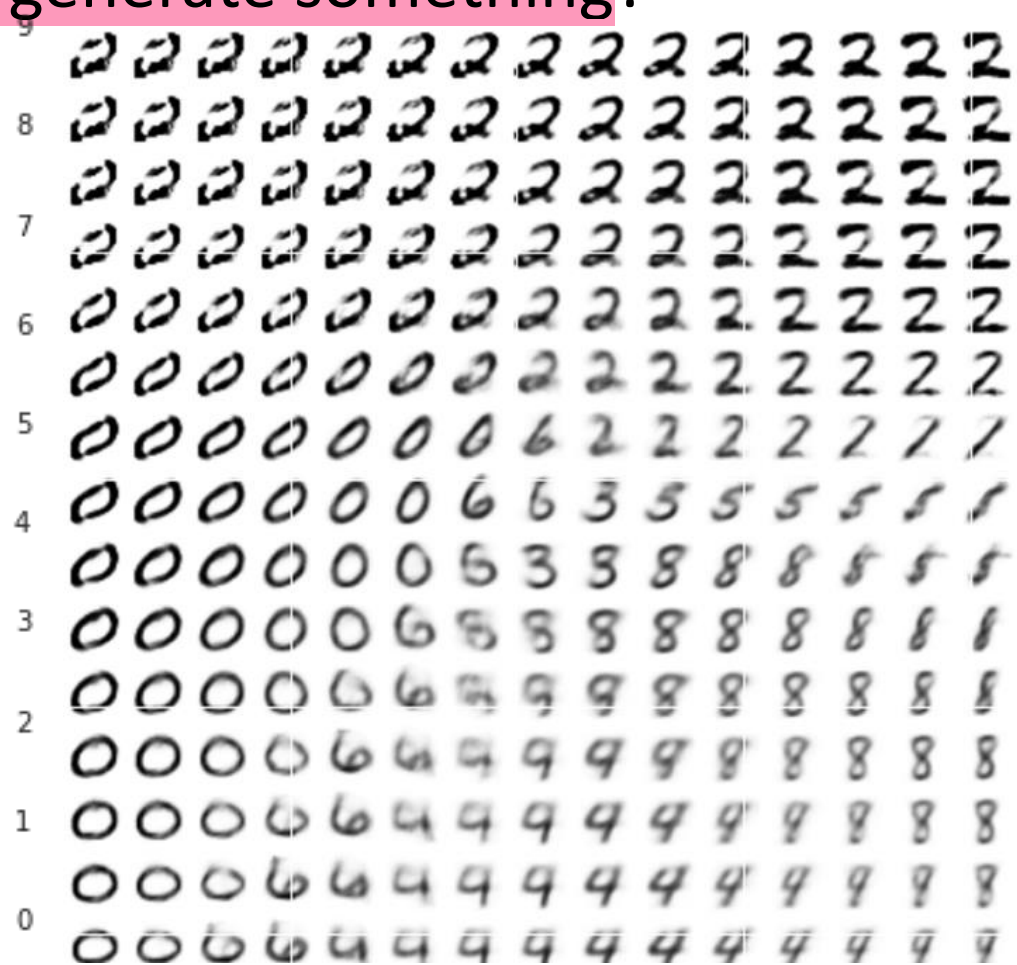
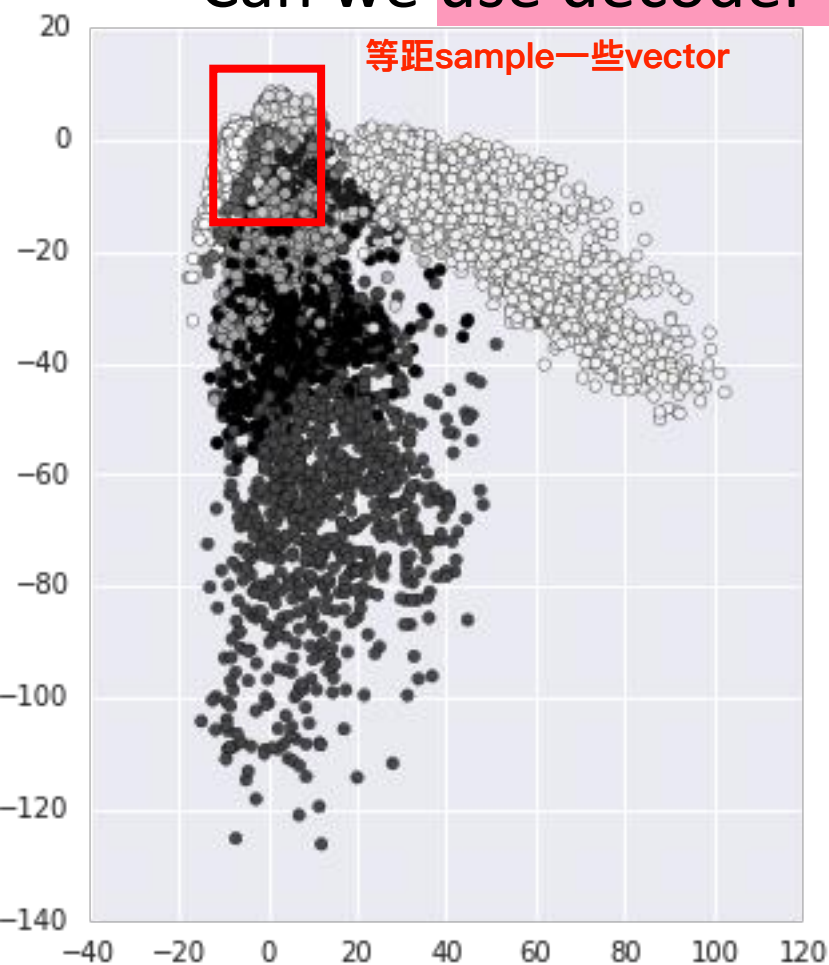
Next .....

code



可以用decoder來產生圖片

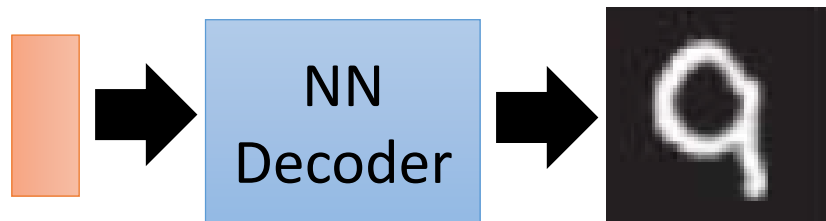
- Can we use decoder to generate something?





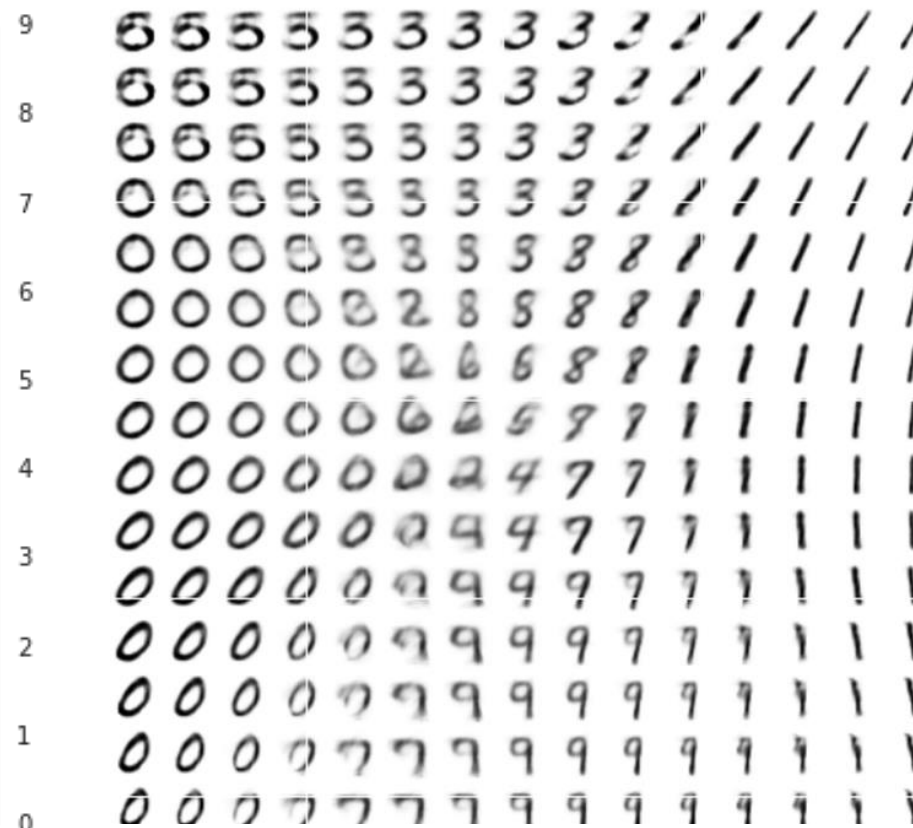
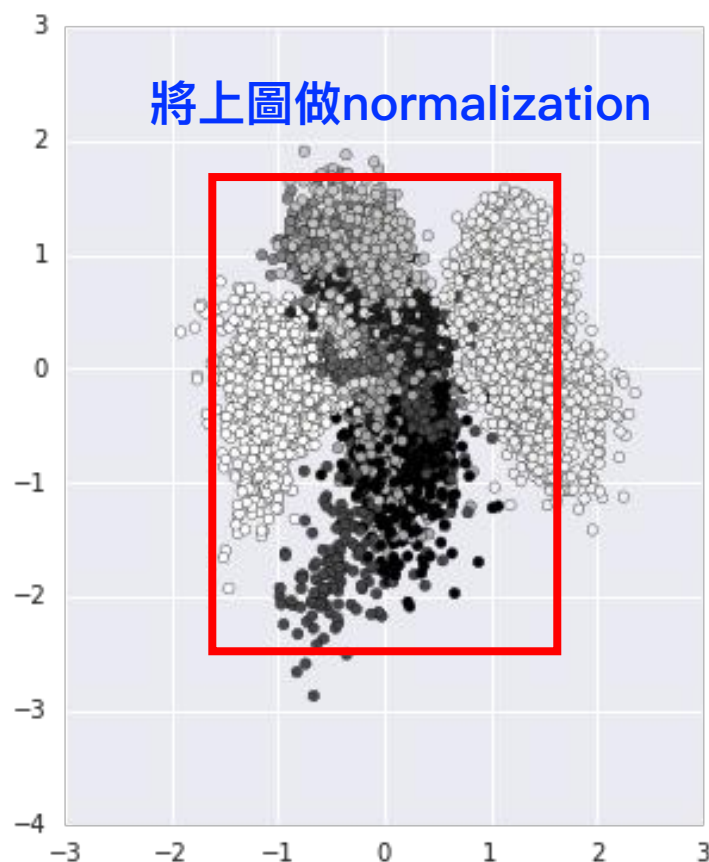
Next .....

code



左右代表圓圈，上下代表有沒有旋轉角度

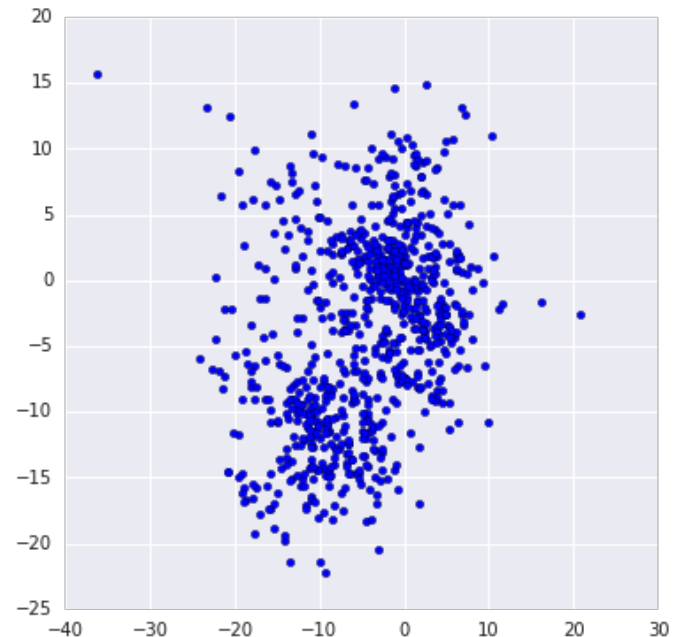
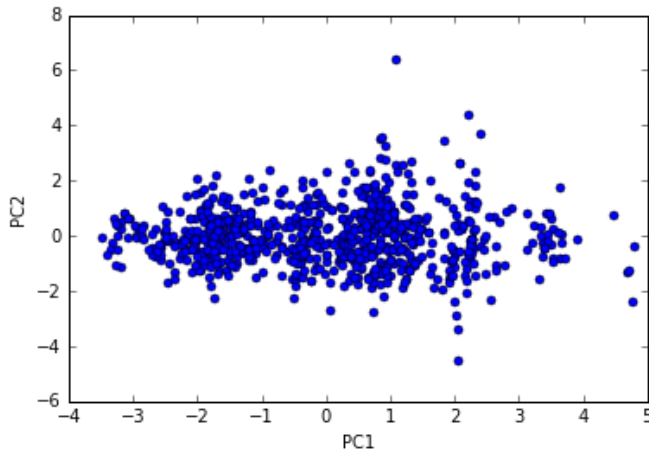
- Can we use decoder to generate something?



# Appendix

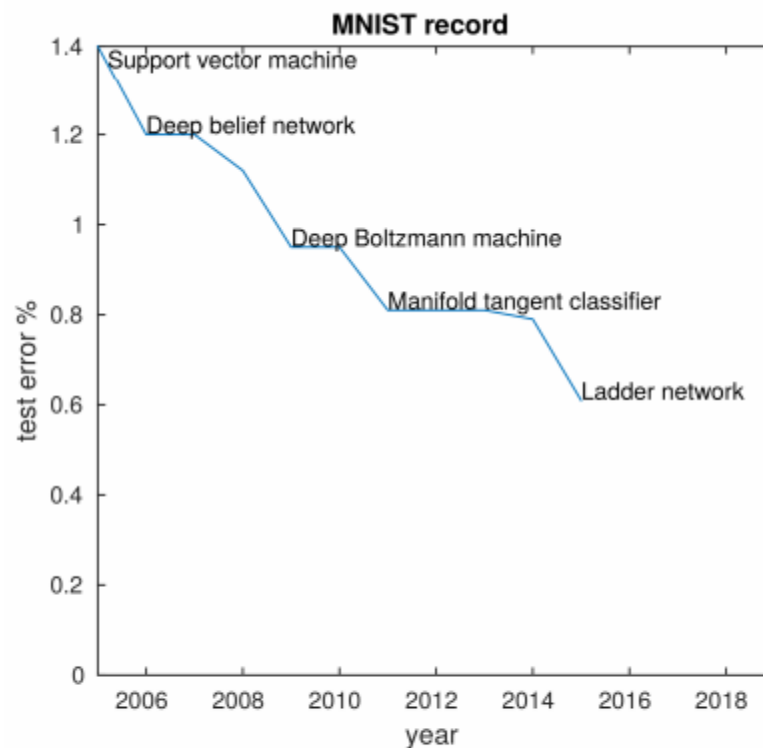
# Pokémon

- <http://140.112.21.35:2880/~tlkagk/pokemon/pca.html>
- <http://140.112.21.35:2880/~tlkagk/pokemon/auto.html>
- The code is modified from
  - <http://jkunst.com/r/pokemon-visualize-em-all/>



# Add: Ladder Network

- <http://rinuboney.github.io/2016/01/19/ladder-network.html>
- [https://mycourses.aalto.fi/pluginfile.php/146701/mod\\_resource/content/1/08%20semisup%20ladder.pdf](https://mycourses.aalto.fi/pluginfile.php/146701/mod_resource/content/1/08%20semisup%20ladder.pdf)
- <https://arxiv.org/abs/1507.02672>



Yearly progress in permutation-invariant MNIST.

A. Rasmus, H. Valpola, M. Honkala, M. Berglund, and T. Raiko.

Semi-Supervised Learning with Ladder Network. To appear in NIPS 2015.