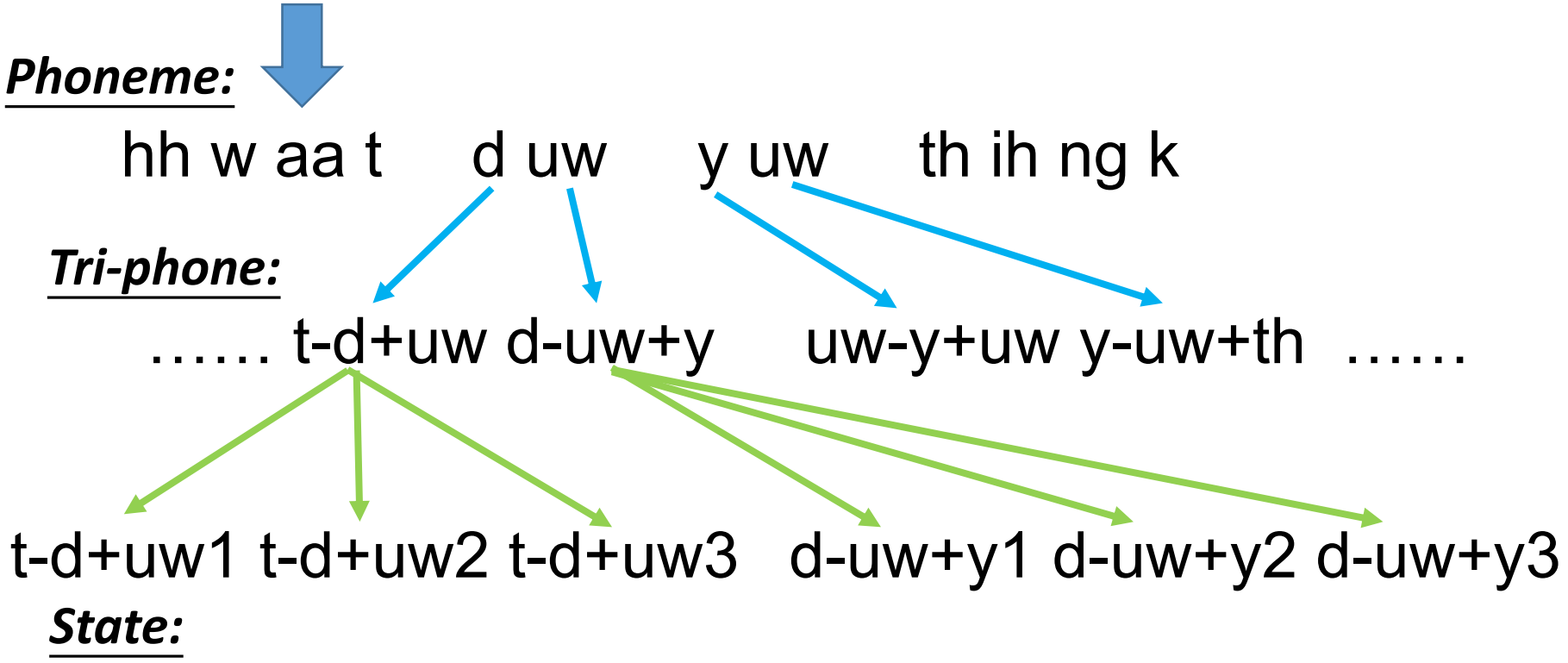
Modularization - Speech

- The hierarchical structure of human languages

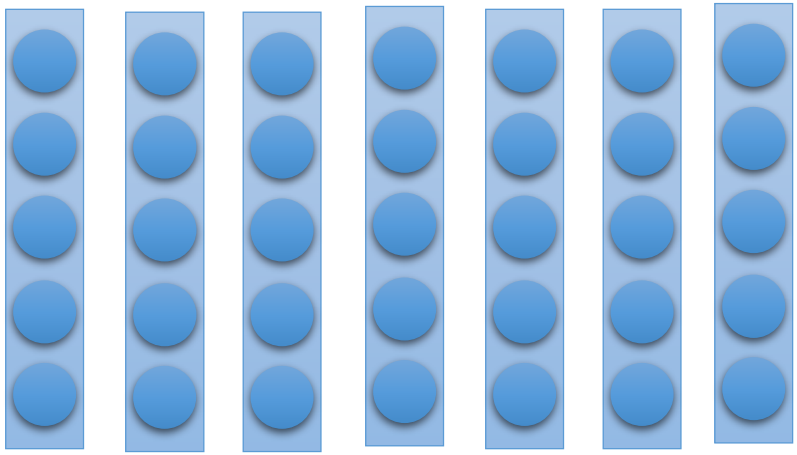
what do you think



Modularization - Speech

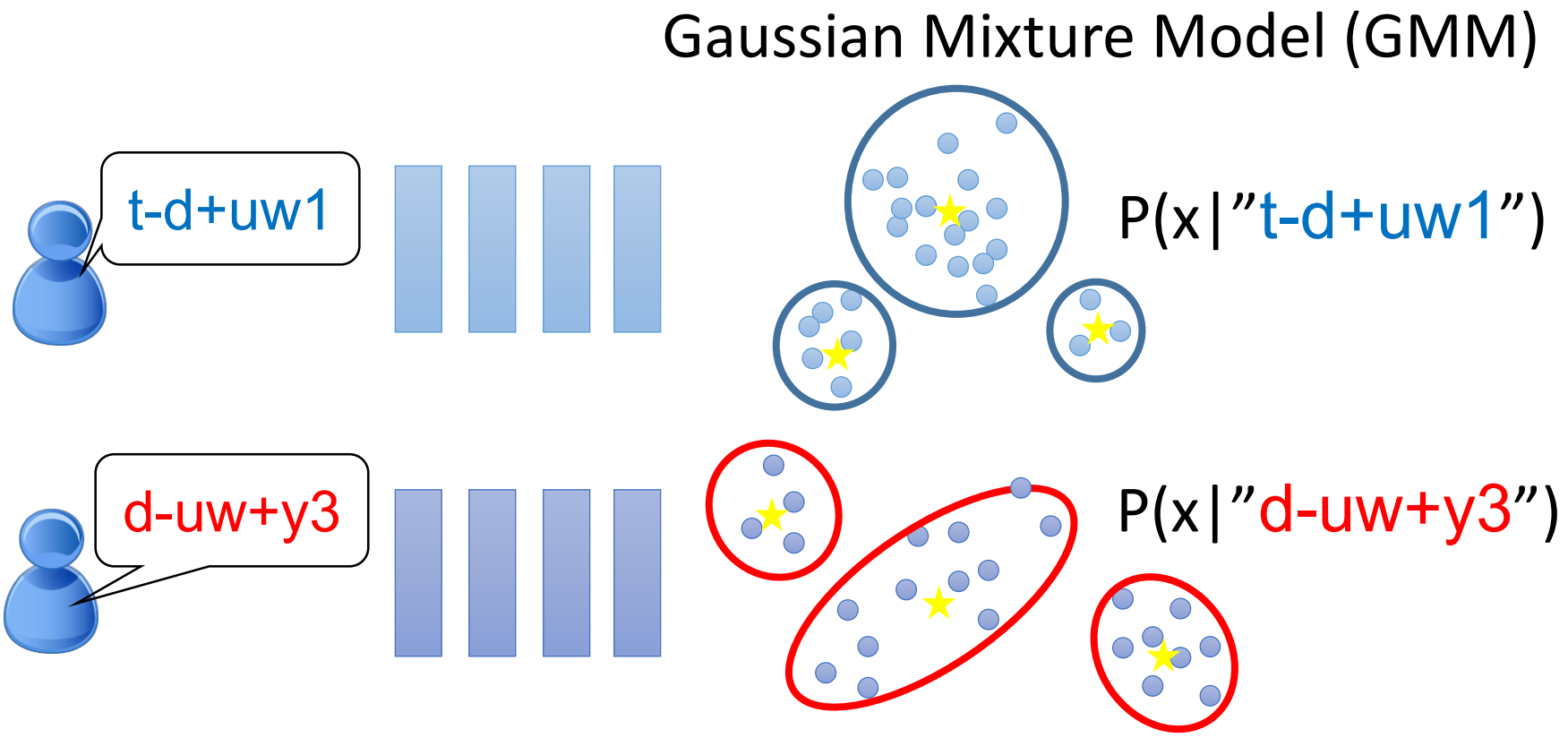
- The first stage of speech recognition
  - Classification: input → acoustic feature, output → state

Determine the state each acoustic feature belongs to



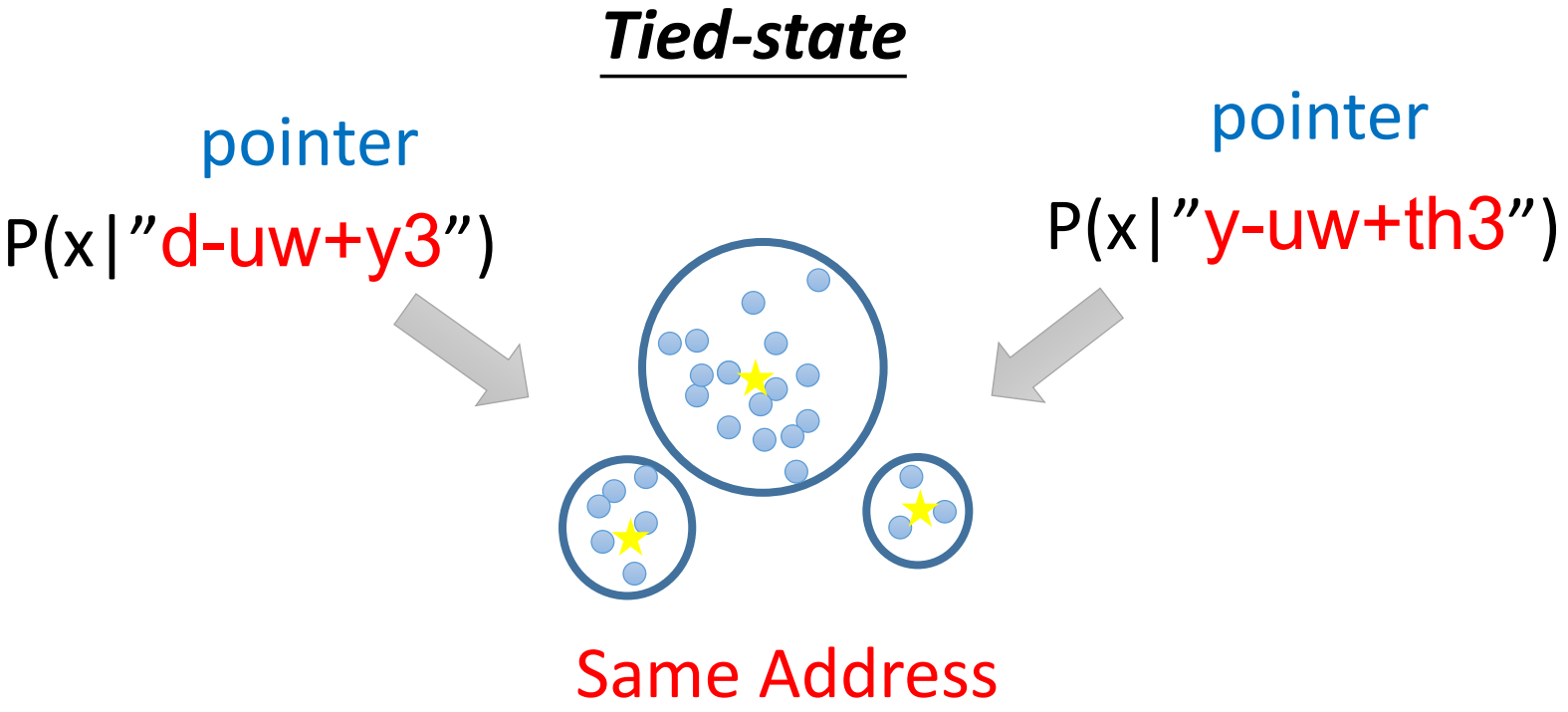
Modularization - Speech

- Each state has a stationary distribution for acoustic features



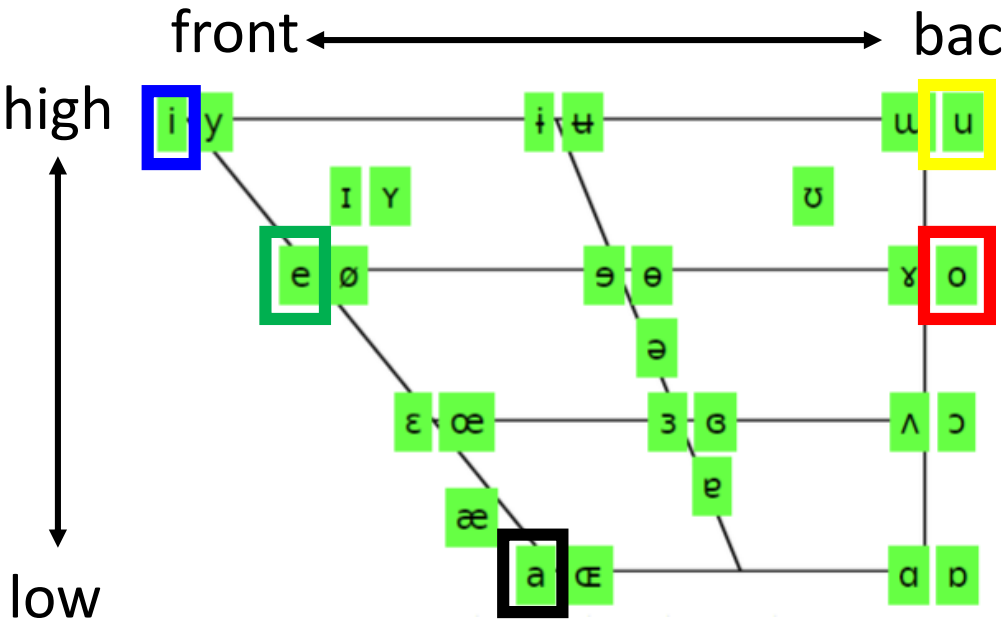
Modularization - Speech

- Each state has a stationary distribution for acoustic features



Modularization - Speech

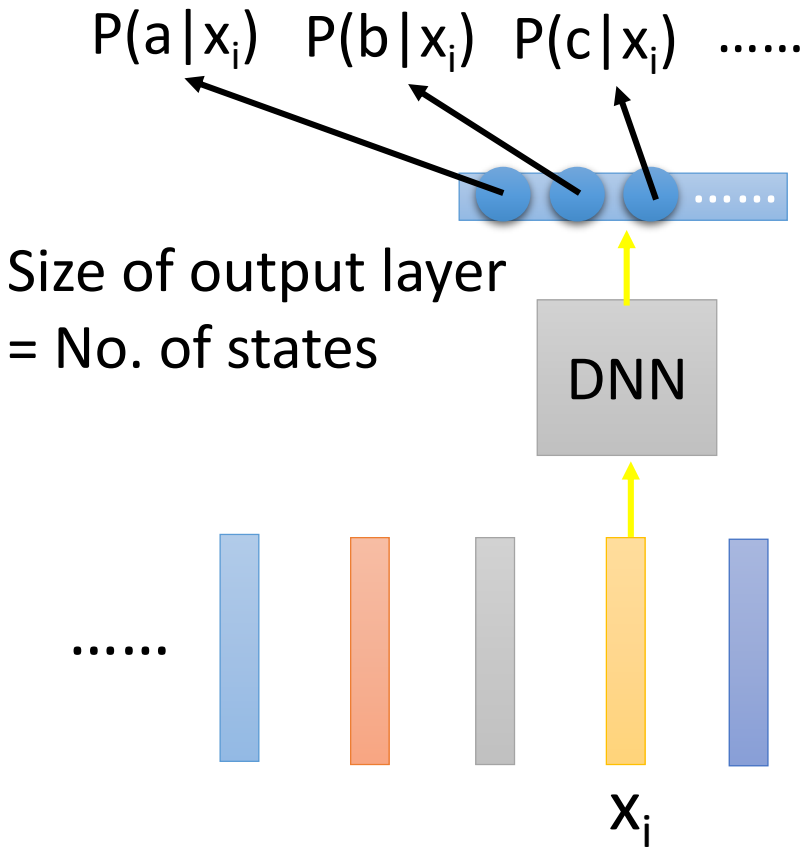
- In HMM-GMM, all the phonemes are modeled independently
  - Not an effective way to model human voice



The sound of vowel is only controlled by a few factors.

http://www.ipachart.com/

Modularization - Speech



- DNN input:

  One acoustic feature

- DNN output:

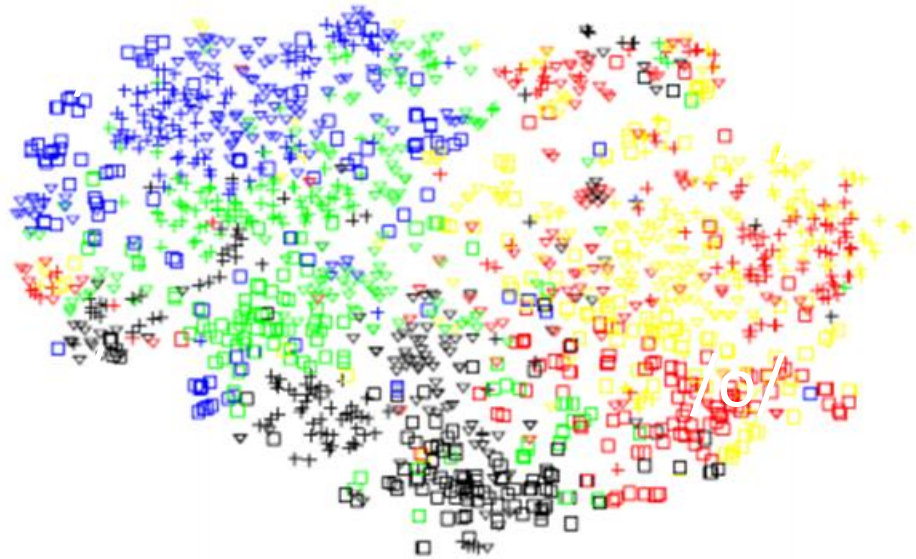
  Probability of each state

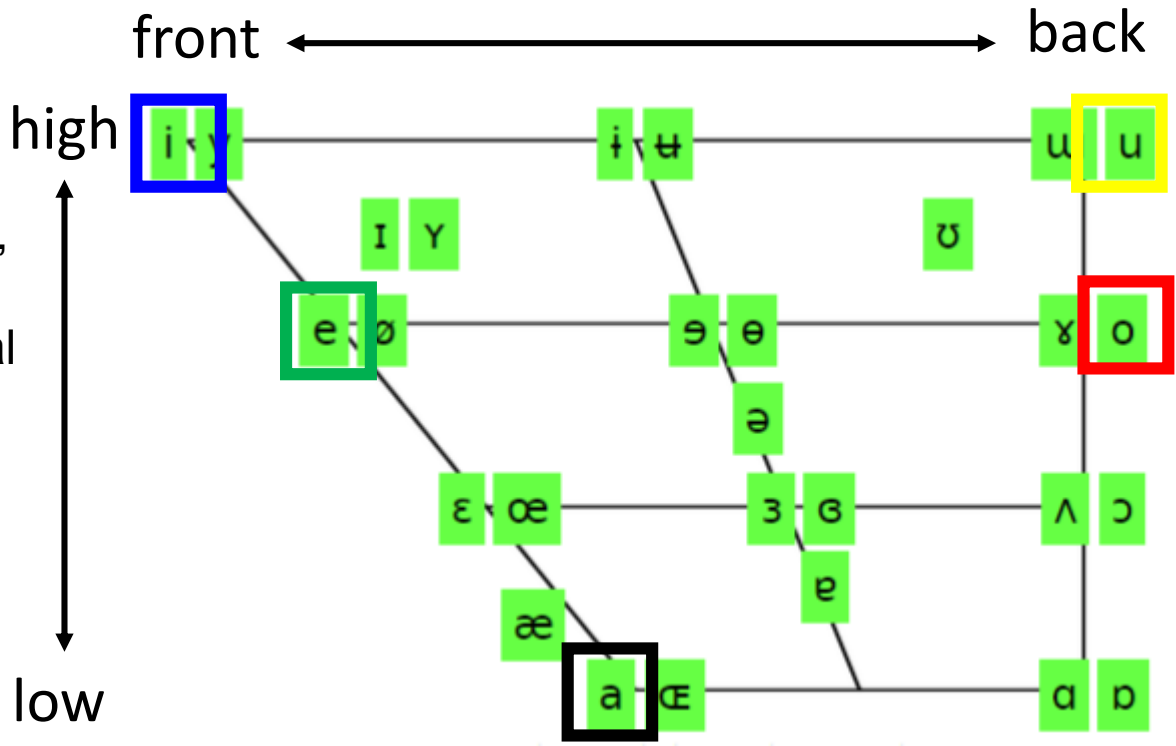
All the states use the same DNN

Modularization

Vu, Ngoc Thang, Jochen Weiner, and Tanja Schultz. "Investigating the Learning Effect of Multilingual Bottle-Neck Features for ASR." *Interspeech*. 2014.

Output of hidden layer reduce to two dimensions





- The lower layers detect the manner of articulation
- All the phonemes share the results from the same set of detectors.
- Use parameters effectively

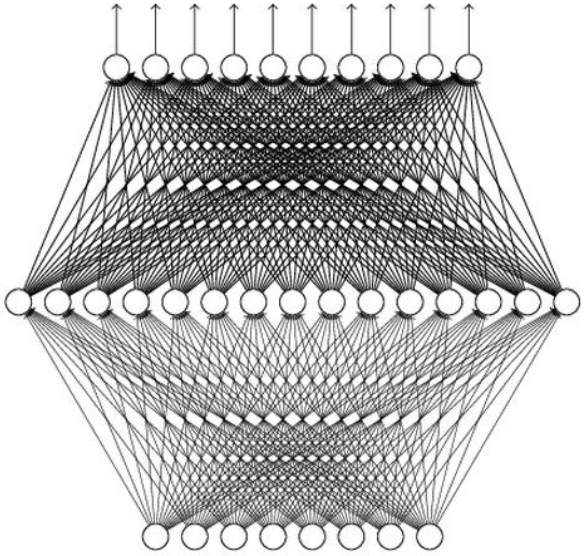
Universality Theorem

Any continuous function f

$$f : R^N \rightarrow R^M$$

Can be realized by a network with one hidden layer

(given **enough** hidden neurons)

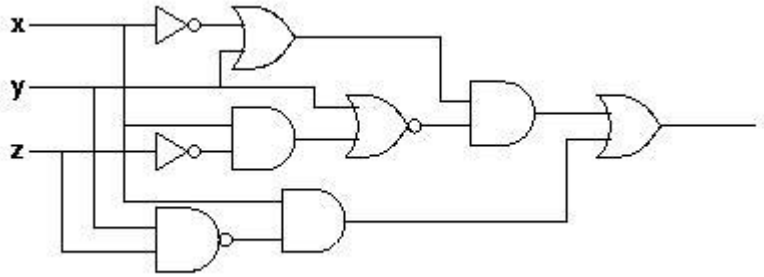


Reference for the reason:
http://neuralnetworksanddeeplearning.com/chap4.html

Yes, shallow network can represent any function.

However, using deep structure is more effective.

Analogy



Logic circuits

- Logic circuits consists of **gates**
- **A two layers of logic gates** can represent **any Boolean function.**
- Using multiple layers of logic gates to build some functions are much simpler

→ less gates needed

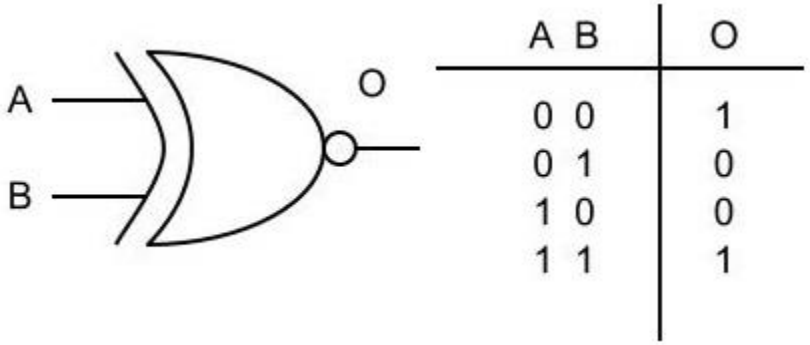
Neural network

- Neural network consists of **neurons**
- **A hidden layer network** can represent **any continuous function.**
- Using multiple layers of neurons to represent some functions are much simpler

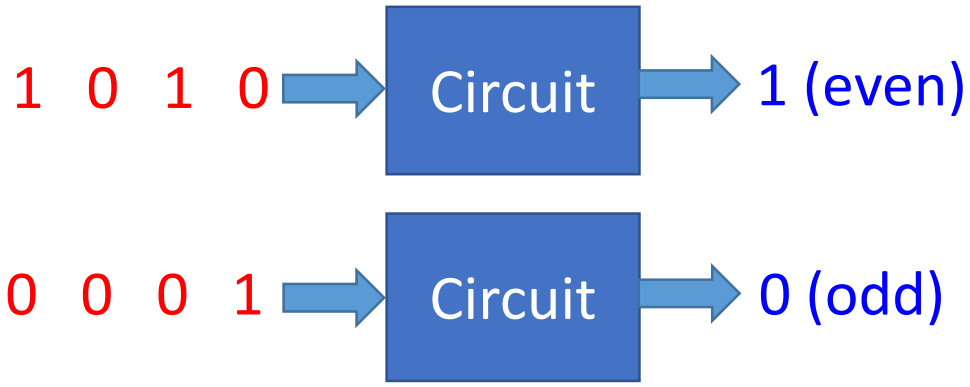
→ less parameters → less data?

This page is for EE background.

Analogy

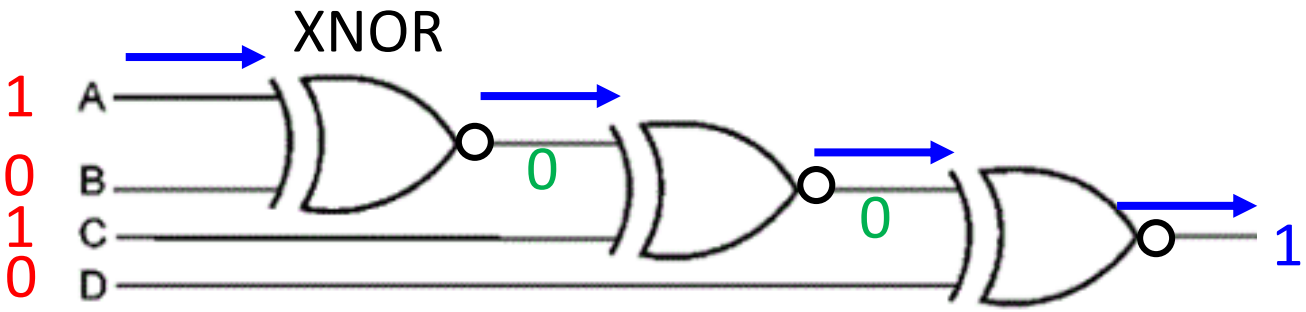


- E.g. ***parity check***



For input sequence with d bits,

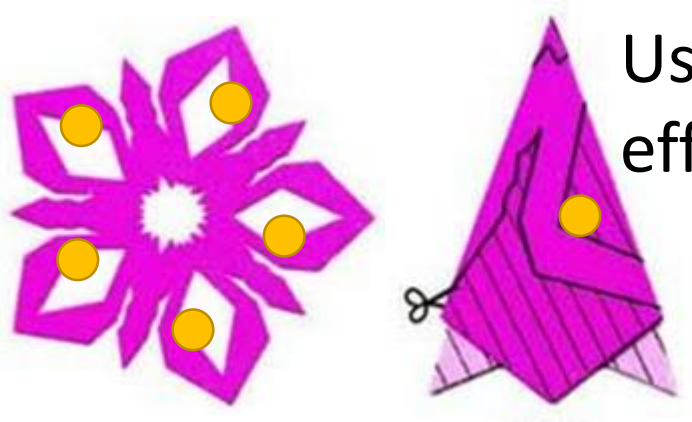
Two-layer circuit need $O(2^d)$ gates.



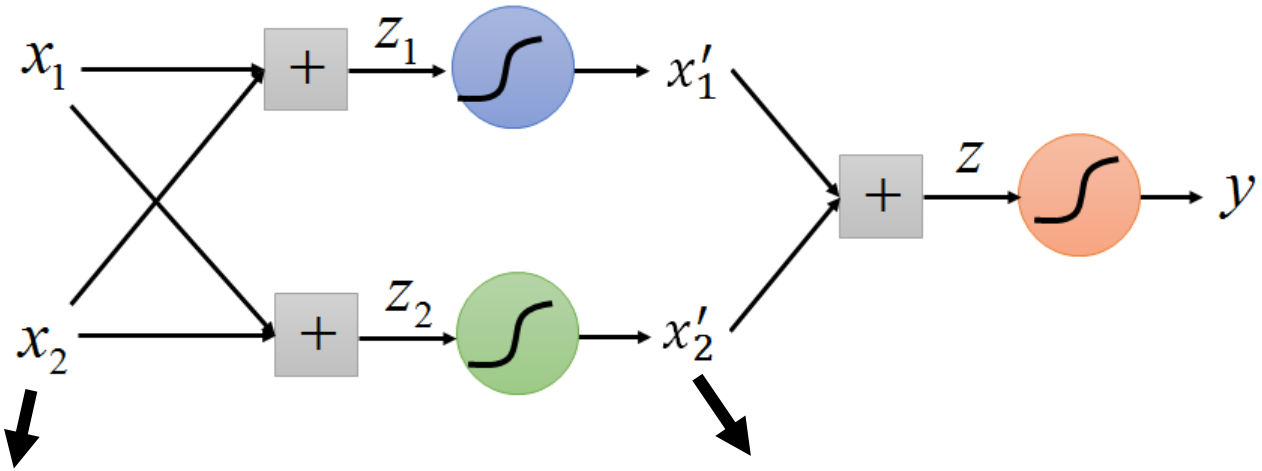
With multiple layers, we need only O(d) gates.

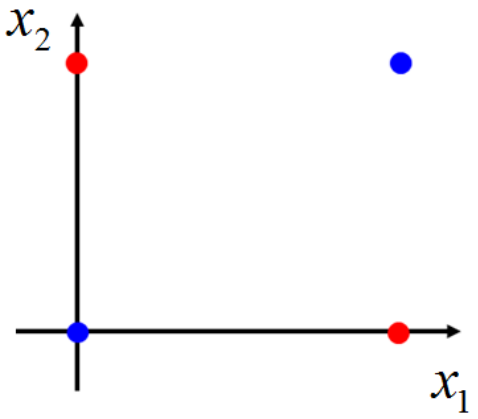
More Analogy

More Analogy

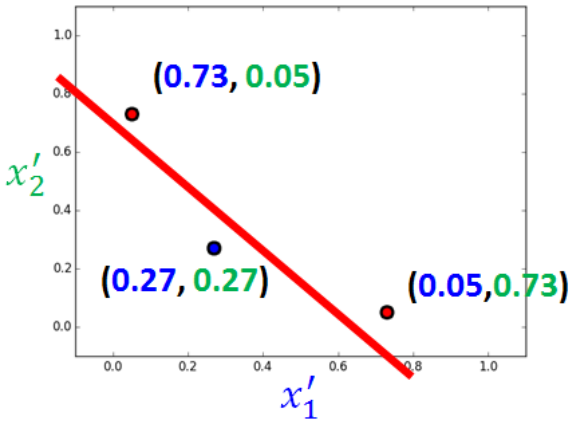


Use data effectively





Folding the space

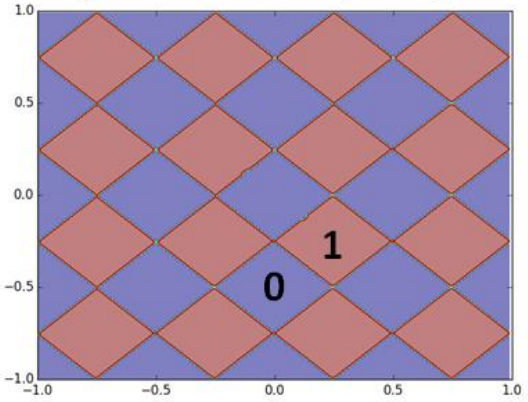


More Analogy - Experiment

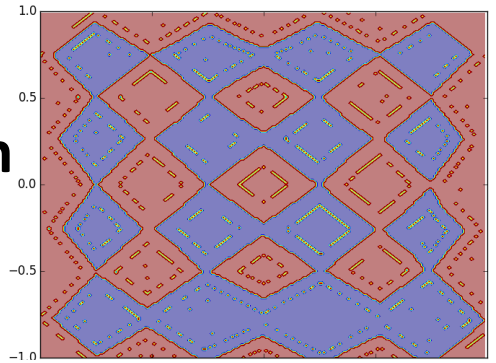
Different numbers of training examples

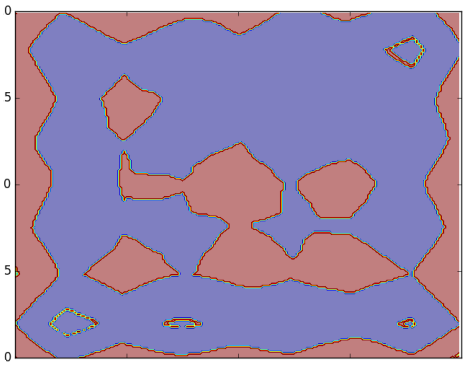
10,0000 2,0000

$f : R^2 \rightarrow \{0,1\}$

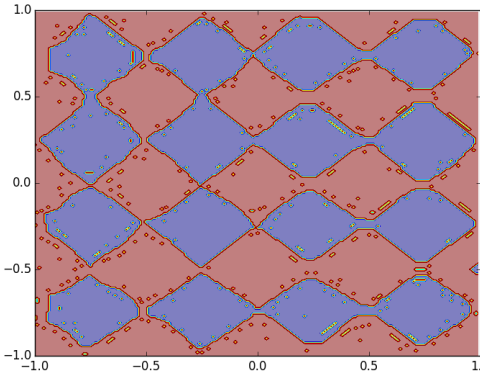


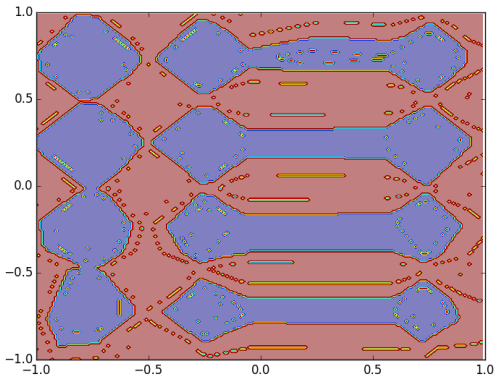
1 hidden layer





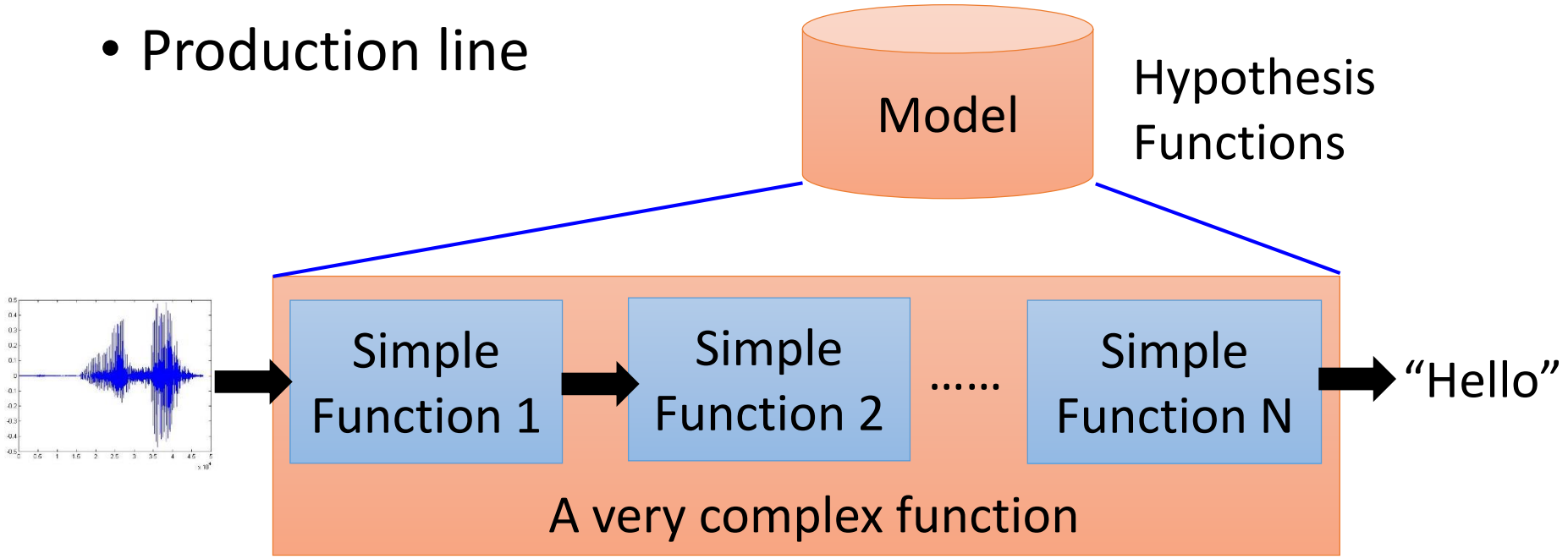
3 hidden layers





End-to-end Learning

- Production line

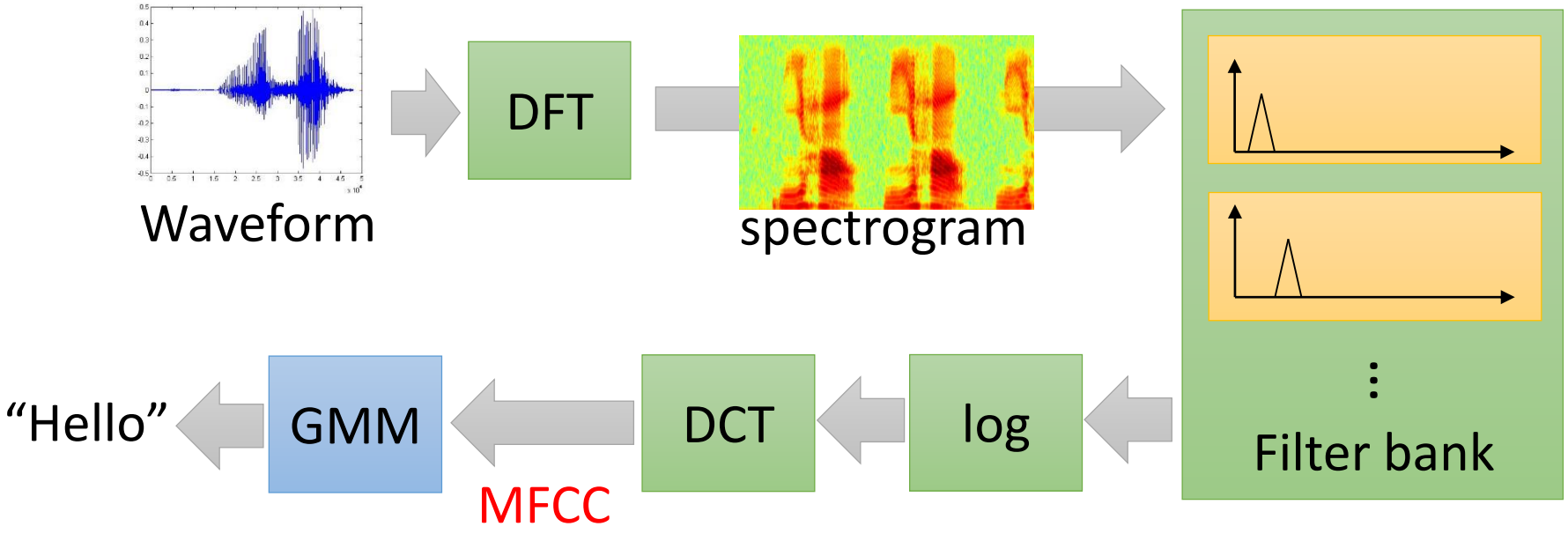


End-to-end training:

What each function should do is learned automatically

End-to-end Learning - Speech Recognition

- Shallow Approach

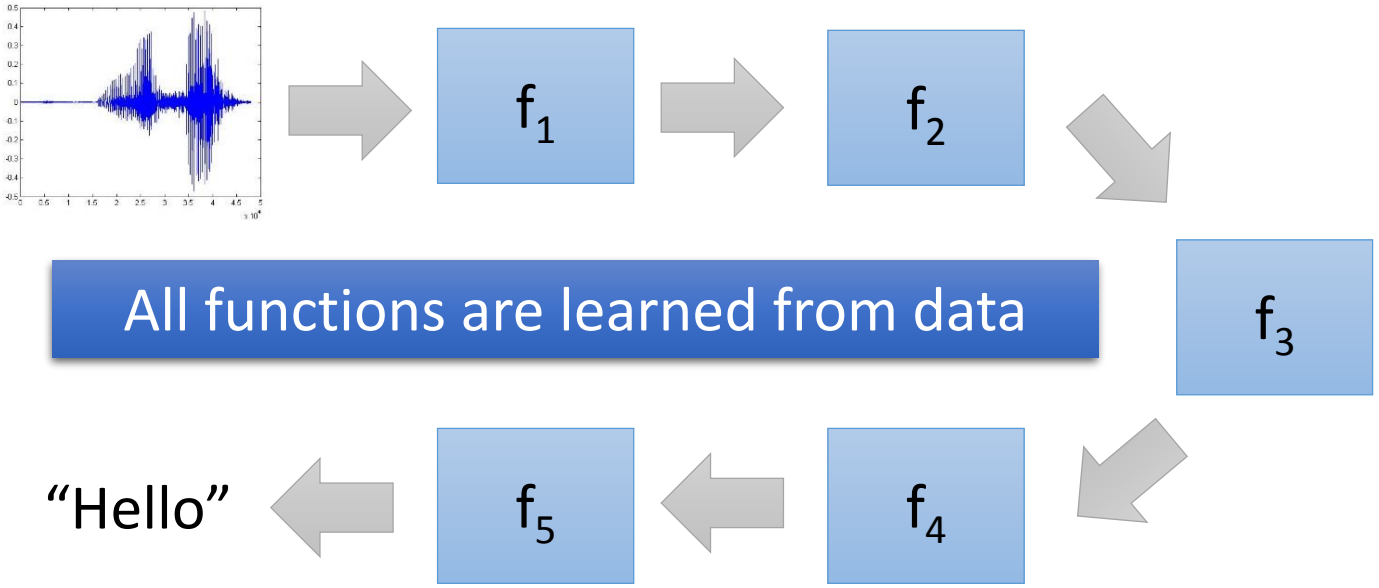


Each box is a simple function in the production line:

:hand-crafted :learned from data

End-to-end Learning - Speech Recognition

- Deep Learning

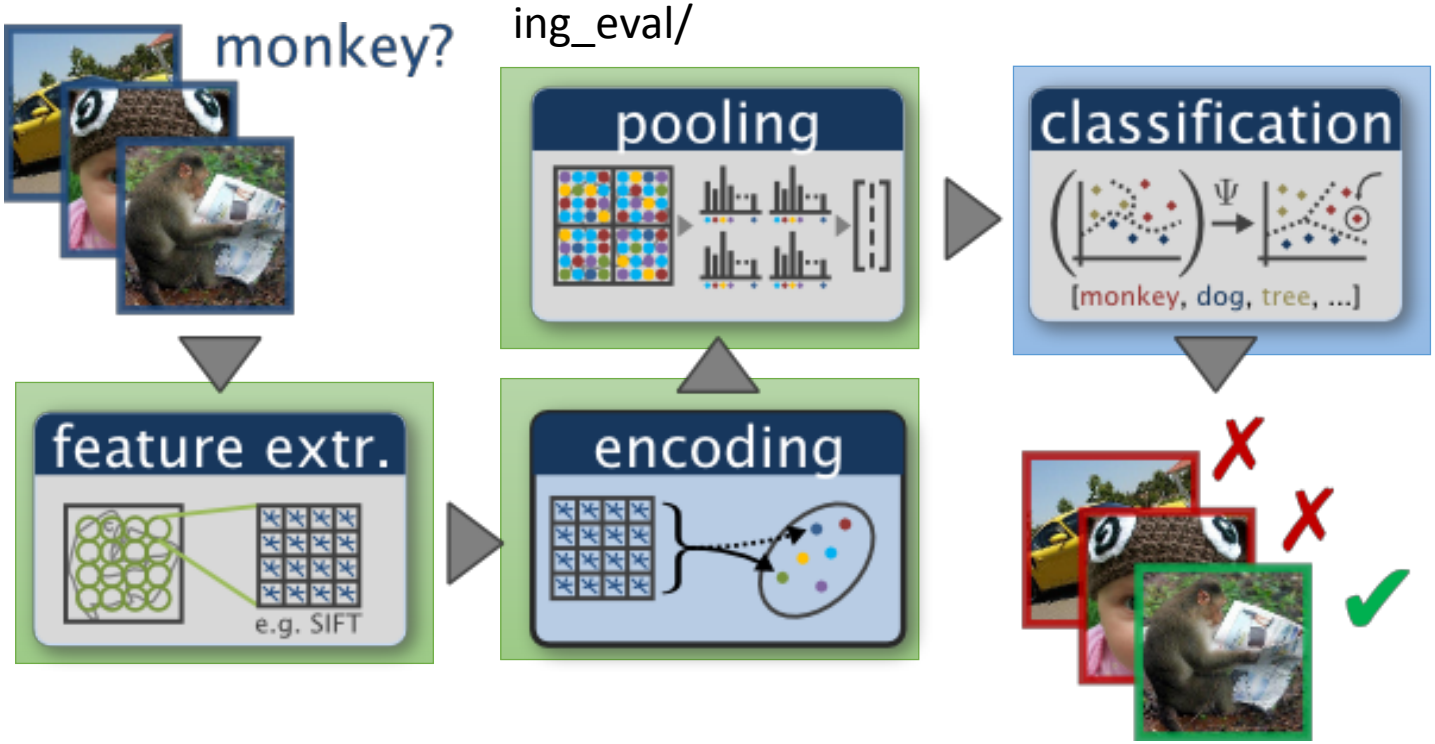


Less engineering labor, but machine learns more

End-to-end Learning - Image Recognition

- Shallow Approach

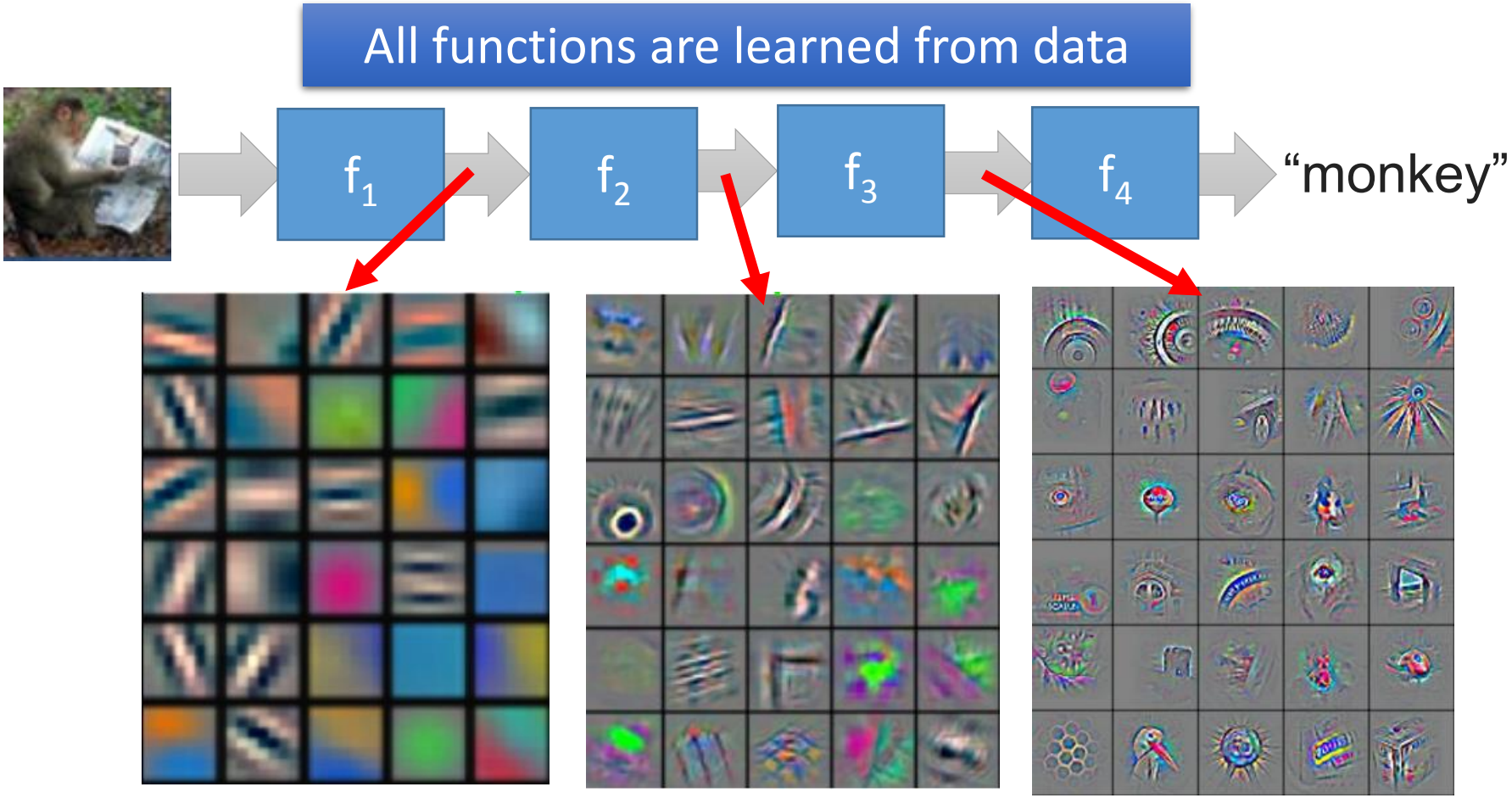
http://www.robots.ox.ac.uk/~vgg/research/encoding_eval/



End-to-end Learning - Image Recognition

Reference: Zeiler, M. D., & Fergus, R. (2014). Visualizing and understanding convolutional networks. In *Computer Vision–ECCV 2014* (pp. 818-833)

- Deep Learning



Complex Task …

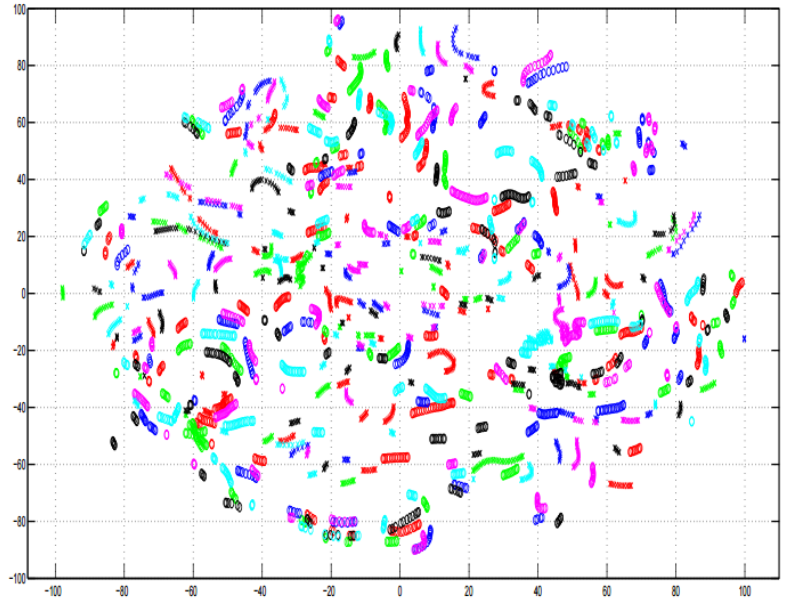
- Very similar input, different output

- Very different input, similar output

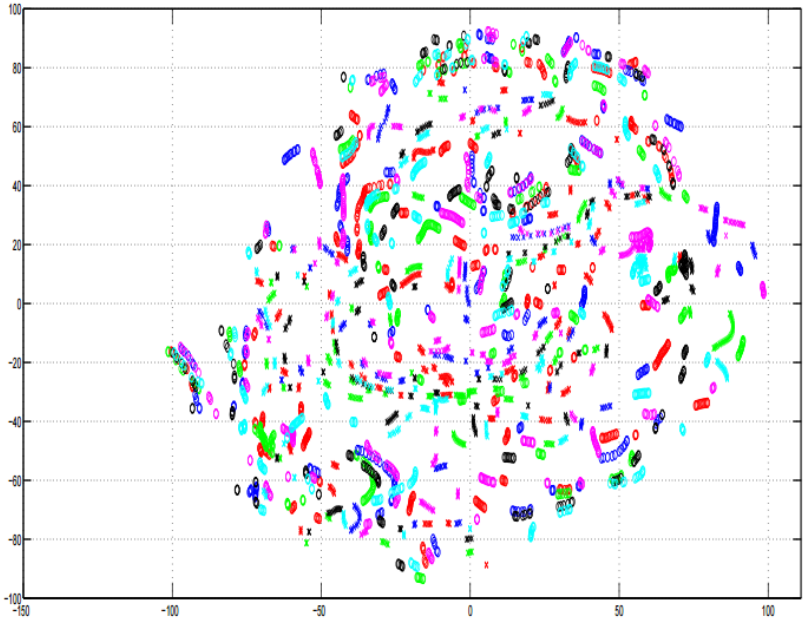
Complex Task …

A. Mohamed, G. Hinton, and G. Penn, "Understanding how Deep Belief Networks Perform Acoustic Modelling," in ICASSP, 2012.

- Speech recognition: Speaker normalization is automatically done in DNN



Input Acoustic Feature (MFCC)



1-st Hidden Layer

Complex Task …

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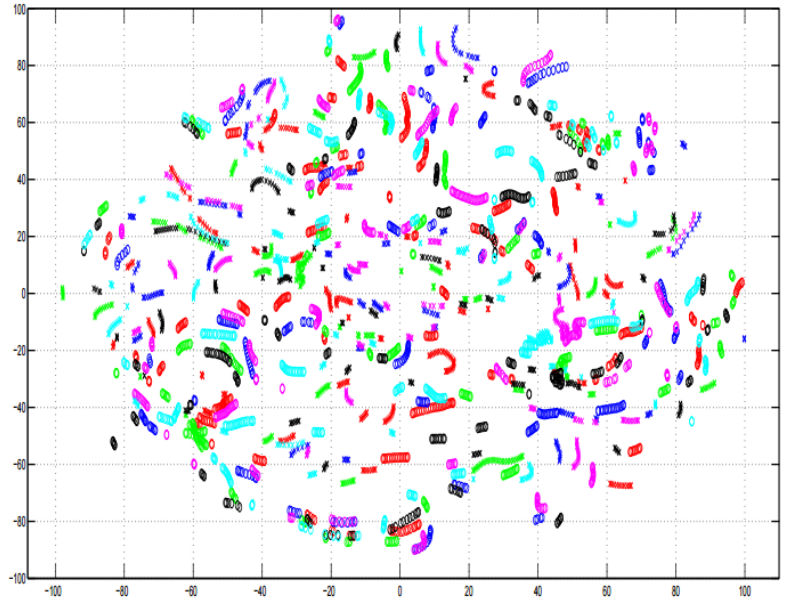
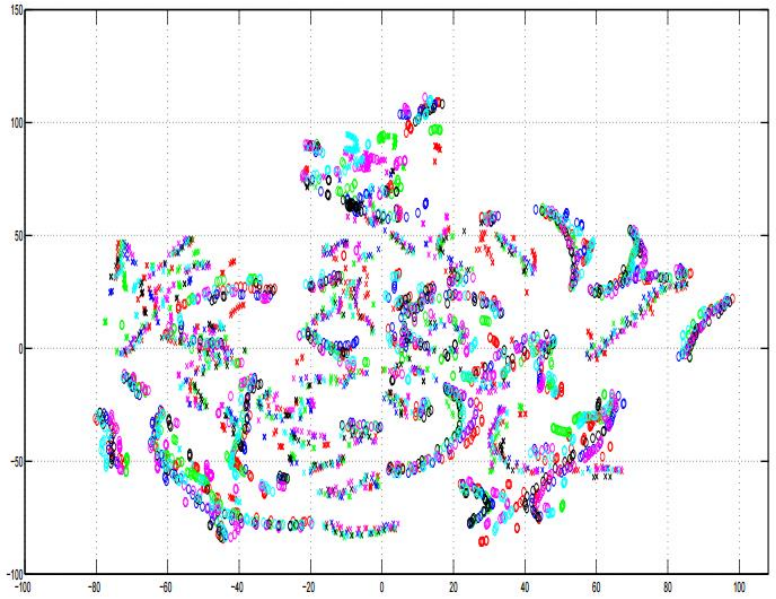
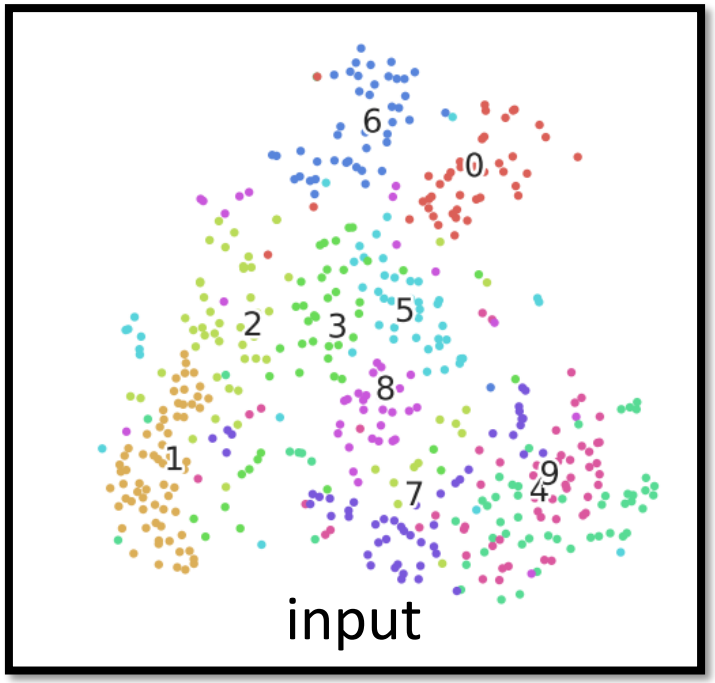


Input Acoustic Feature (MFCC)

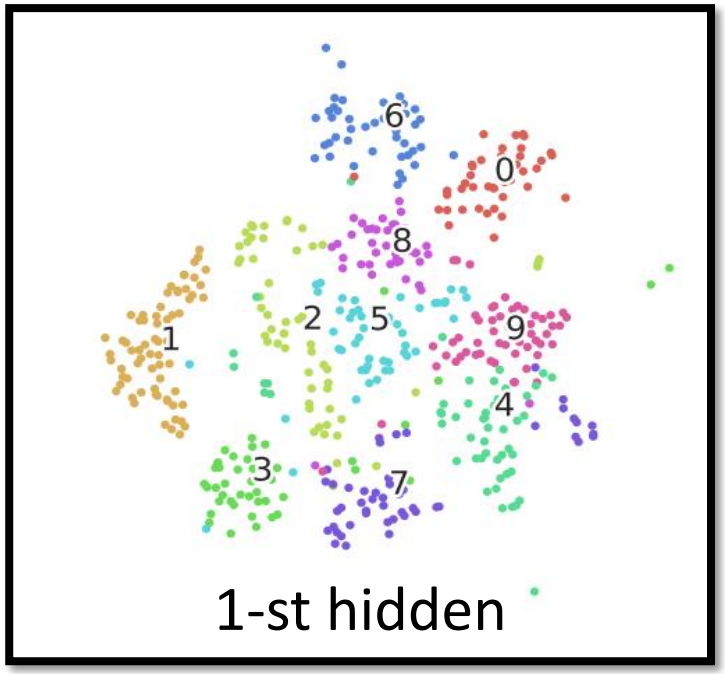


8-th Hidden Layer

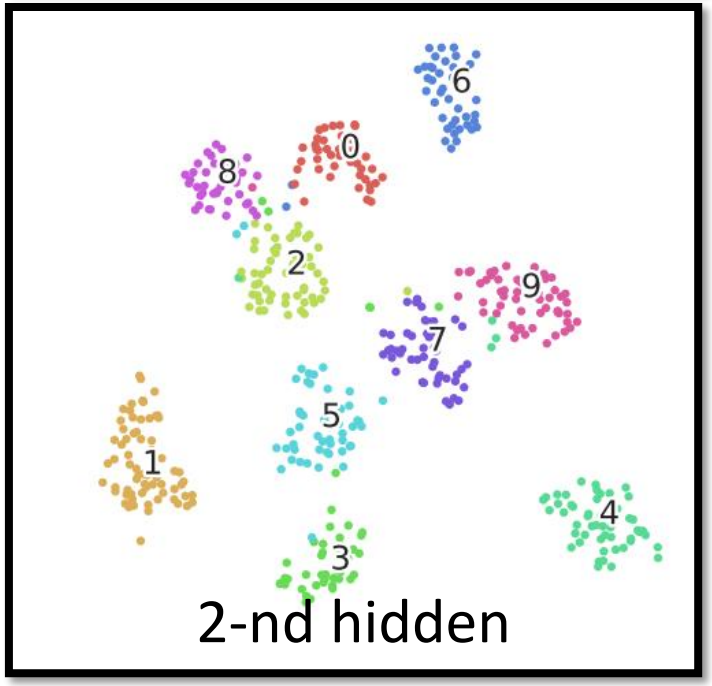
MNIST



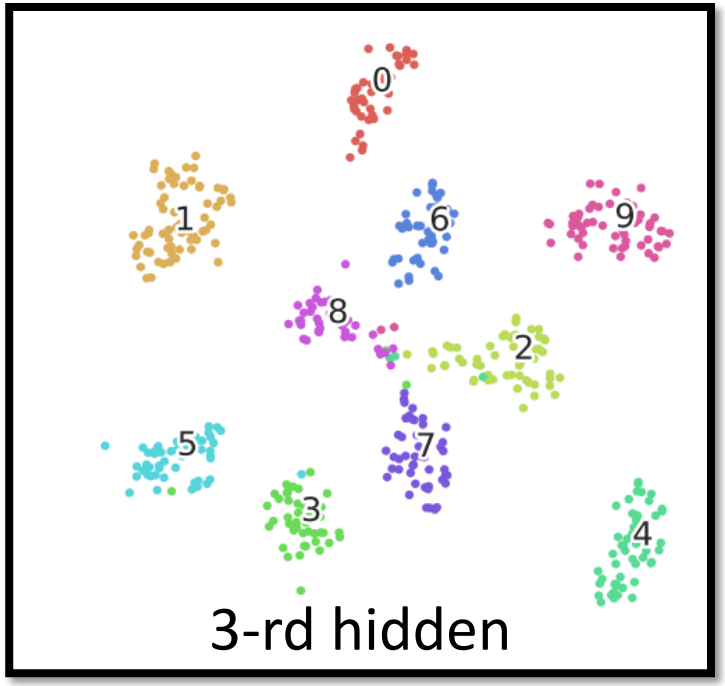
input



1-st hidden



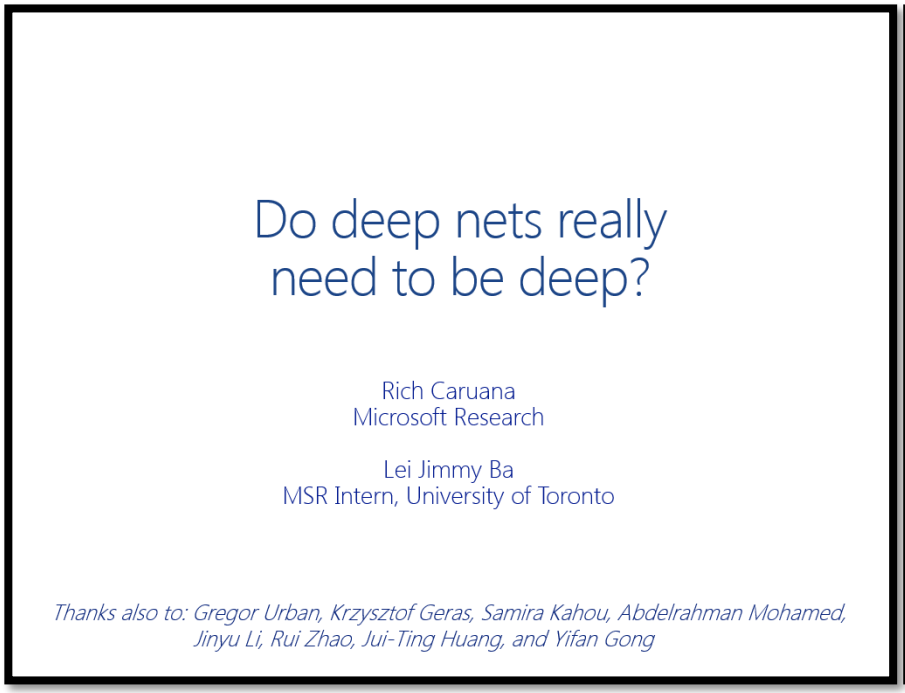
2-nd hidden

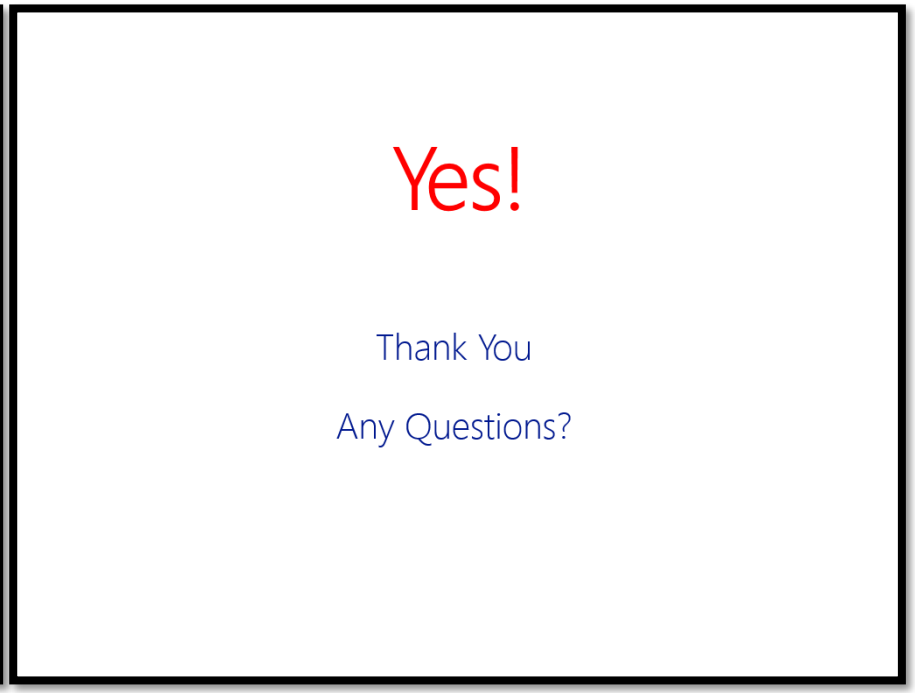


3-rd hidden

To learn more …

- Do Deep Nets Really Need To Be Deep? (by Rich Caruana)
- http://research.microsoft.com/apps/video/default.aspx?id=232373&r=1





keynote of Rich Caruana at ASRU 2015

To learn more …

- Deep Learning: Theoretical Motivations (*Yoshua Bengio*)
  - http://videolectures.net/deeplearning2015_bengio_theoretical_motivations/
- Connections between physics and deep learning
  - https://www.youtube.com/watch?v=5MdSE-N0bxs
- Why Deep Learning Works: Perspectives from Theoretical Chemistry
  - https://www.youtube.com/watch?v=kIbKHIPbxiU