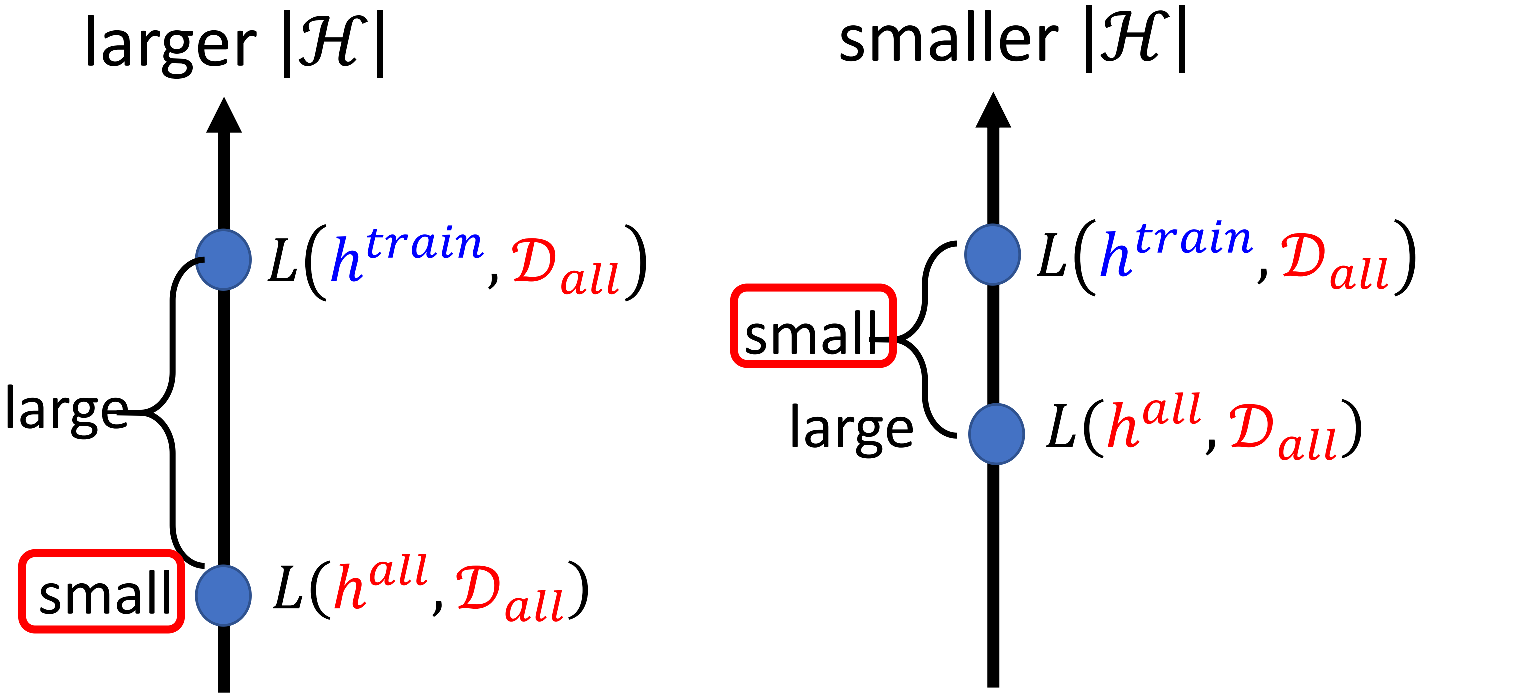
Why Deep Learning?



larger $|\mathcal{H}|$

$L(h^{train}, \mathcal{D}_{all})$

large

small

$L(h^{all}, \mathcal{D}_{all})$

smaller $|\mathcal{H}|$

$L(h^{train}, \mathcal{D}_{all})$

small

large

$L(h^{all}, \mathcal{D}_{all})$

鱼与熊掌可以兼得吗？

Still small loss

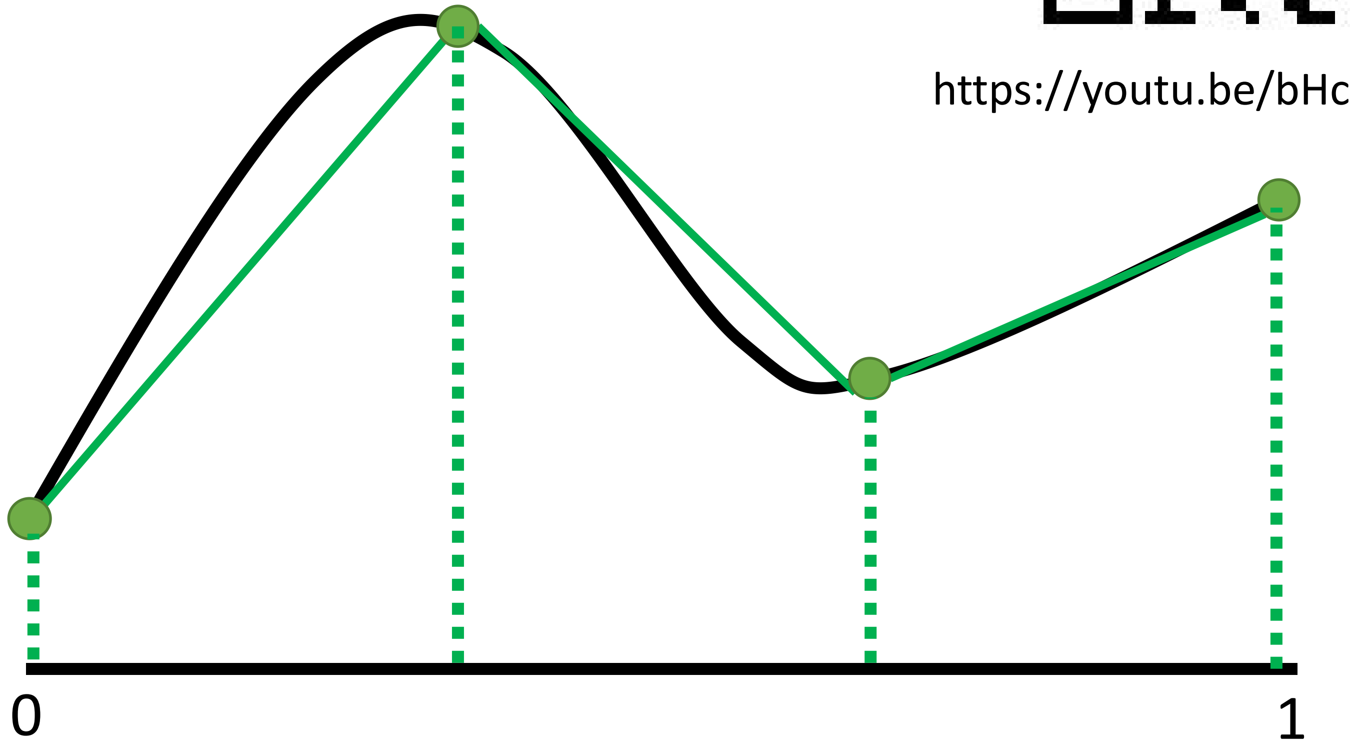
$$h^{all} = arg\min_{h\in\boxed{\mathcal{H}}} \boxed{L(h, \mathcal{D}_{all})}$$

Small (fewer candidates)

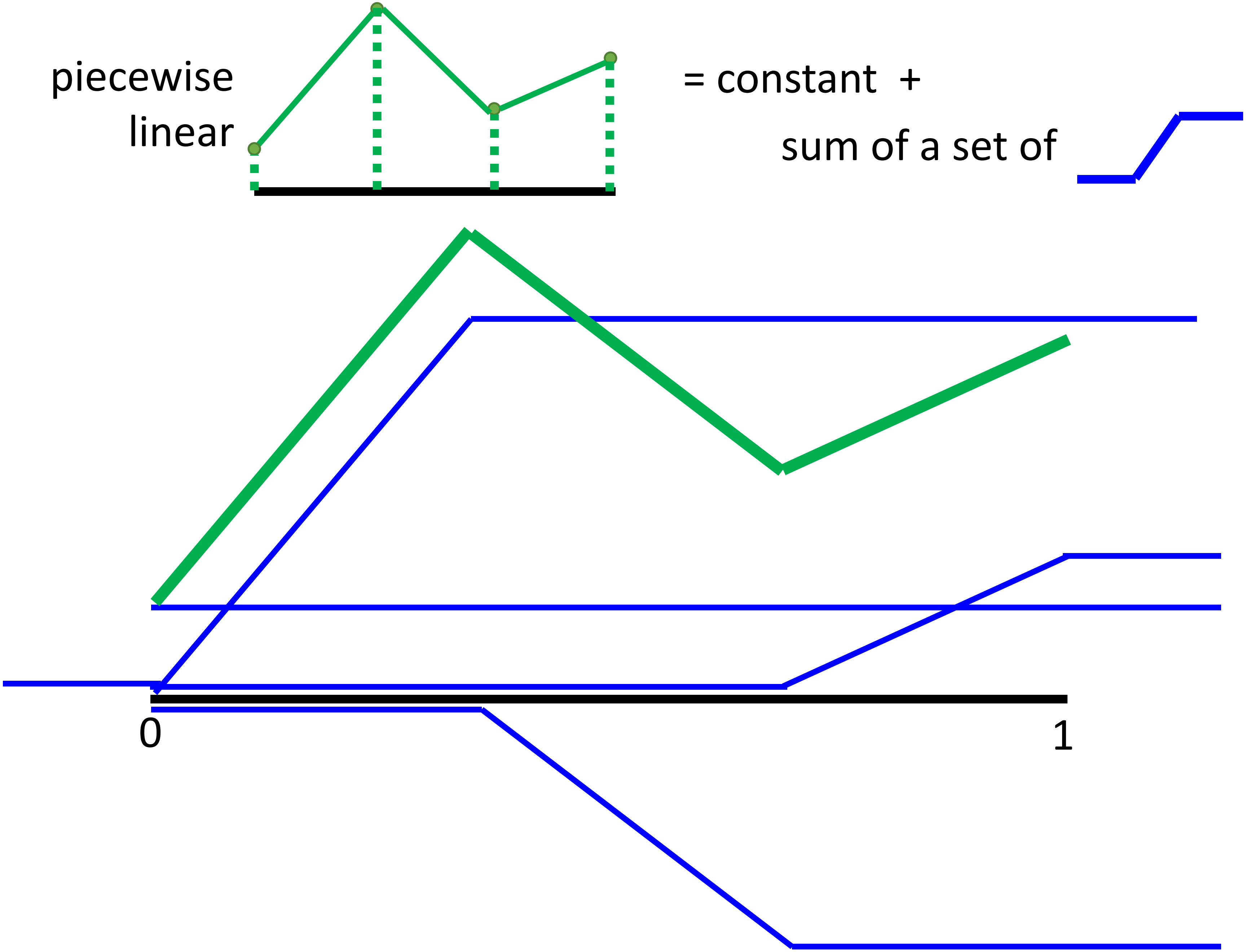
Review: Why Hidden Layer?

Piecewise Linear

https://youtu.be/bHcJCp2Fyxs



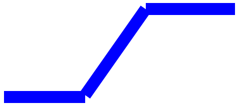
We can have good approximation with sufficient pieces.



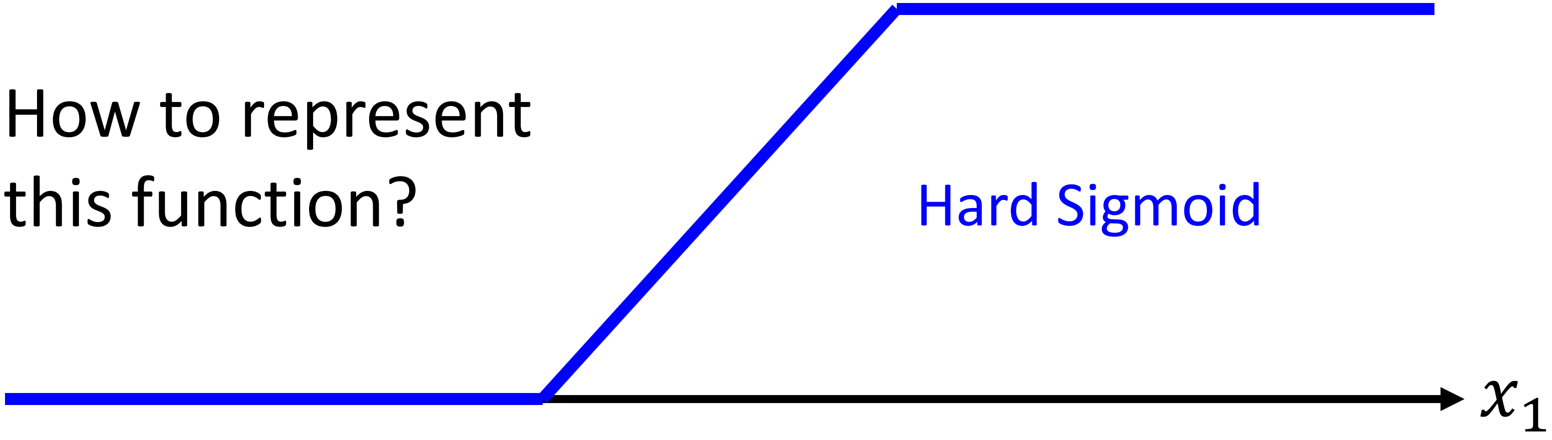
piecewise linear

= constant +

sum of a set of

Piecewise linear = constant + sum of a set of 

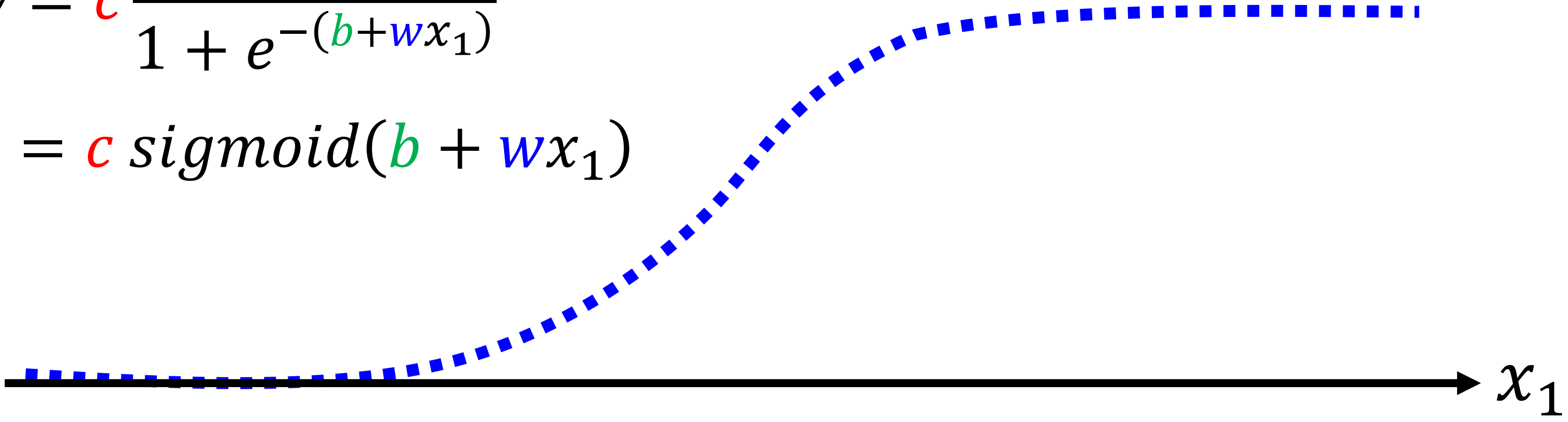
How to represent this function?

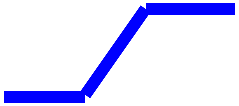


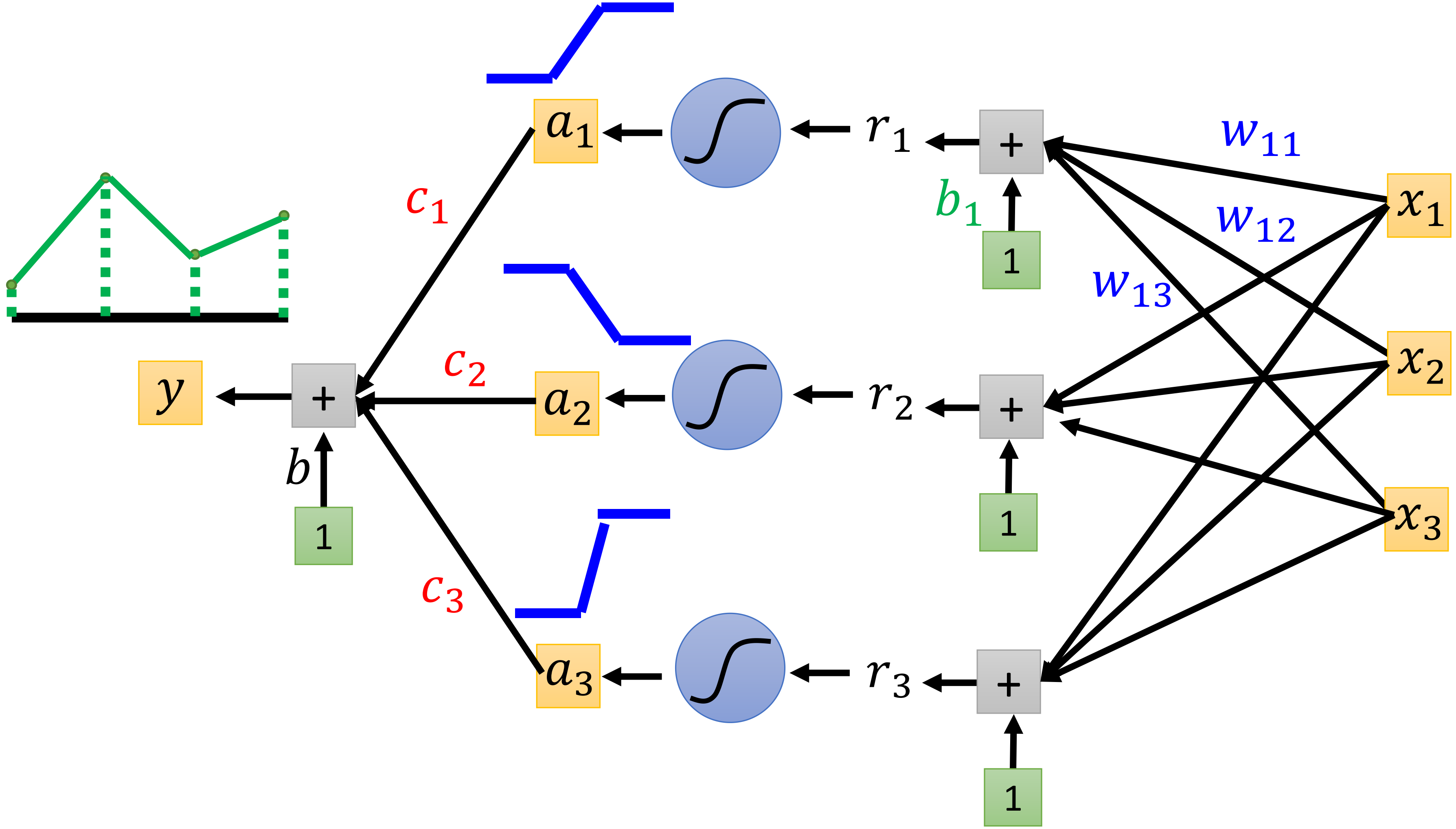
<u>Sigmoid Function</u>

$$y = c\,\frac{1}{1+e^{-(b+wx_1)}}$$

$$= c\;sigmoid(b+wx_1)$$

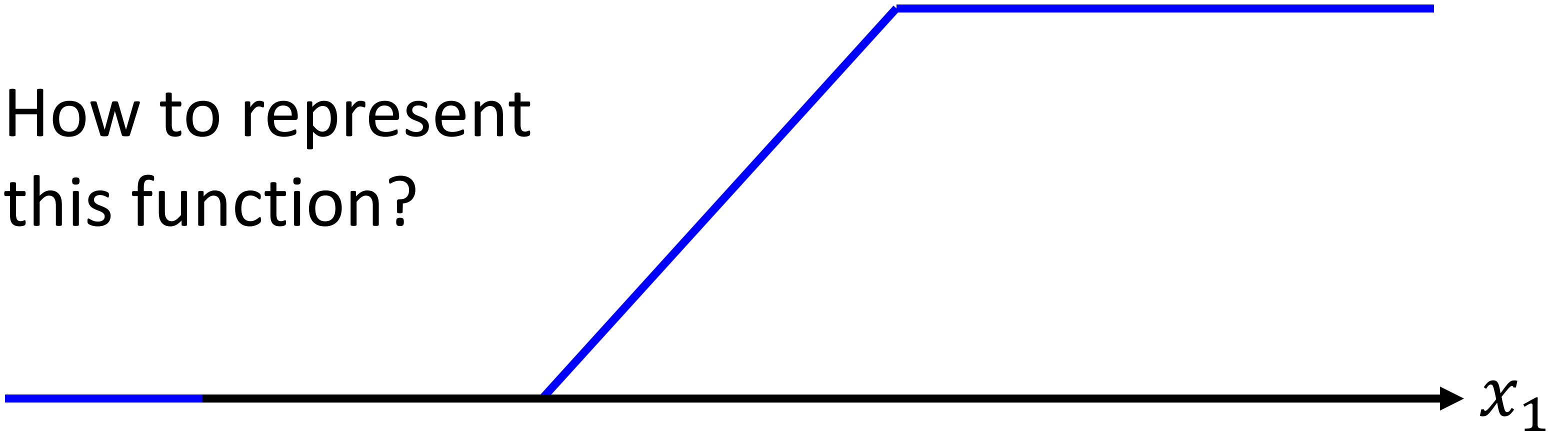


Piecewise linear = constant + sum of a set of 

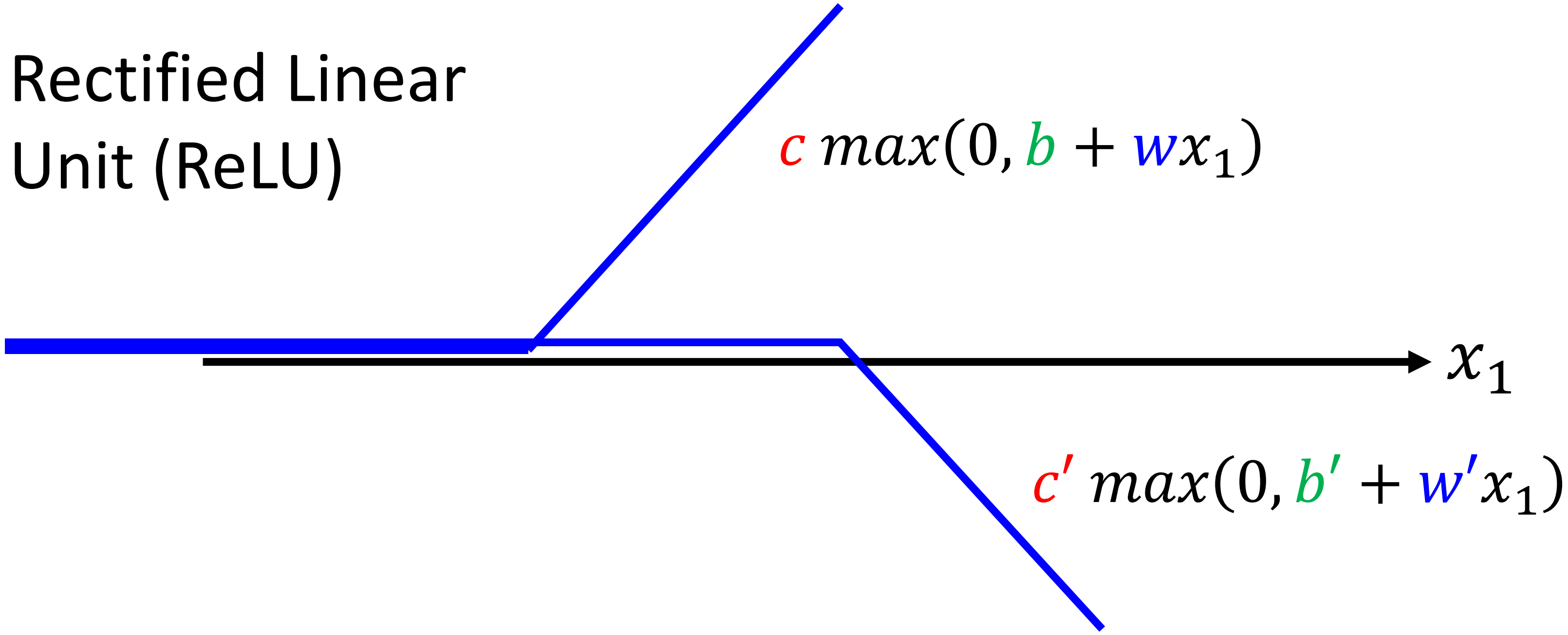


Hard Sigmoid → ReLU

How to represent this function?

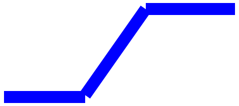


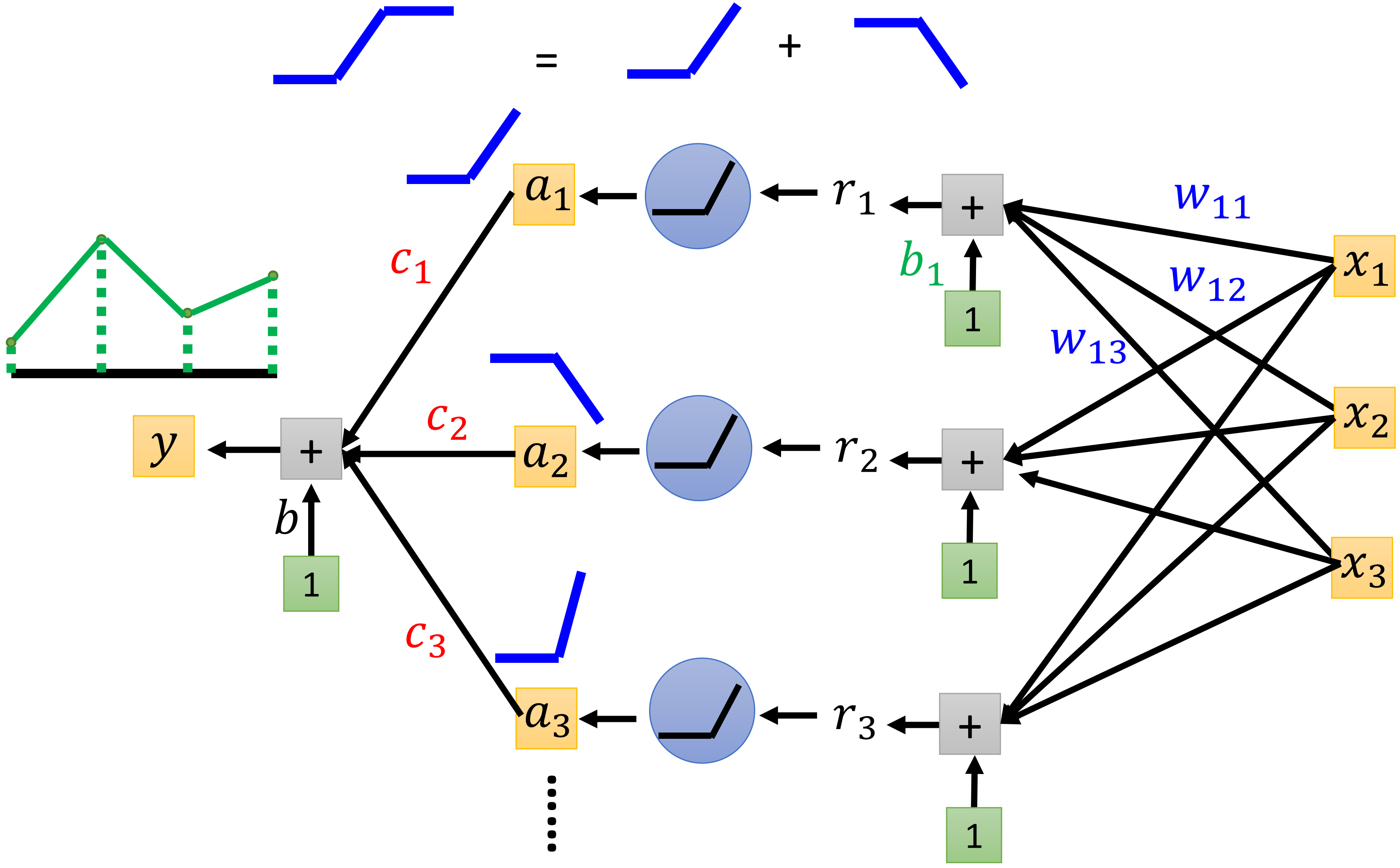
Rectified Linear Unit (ReLU)



$c\ max(0, b + wx_1)$

$c'\ max(0, b' + w'x_1)$

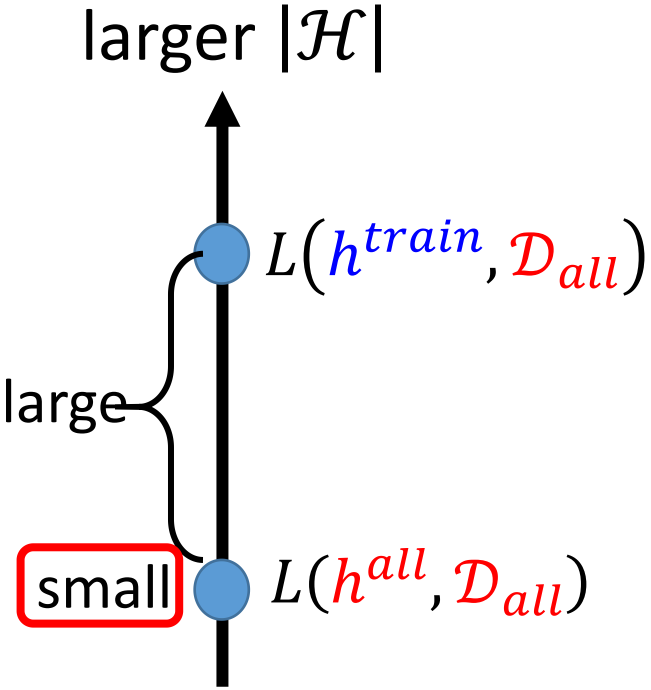
Piecewise linear = constant + sum of a set of 



Why we want "***Deep***" network, not "***Fat***" network?

Deeper is Better?

Layer X Size	Word Error Rate (%)
1 X 2k	24.2
2 X 2k	20.4
3 X 2k	18.4
4 X 2k	17.8
5 X 2k	17.2
7 X 2k	17.1


larger $|\mathcal{H}|$
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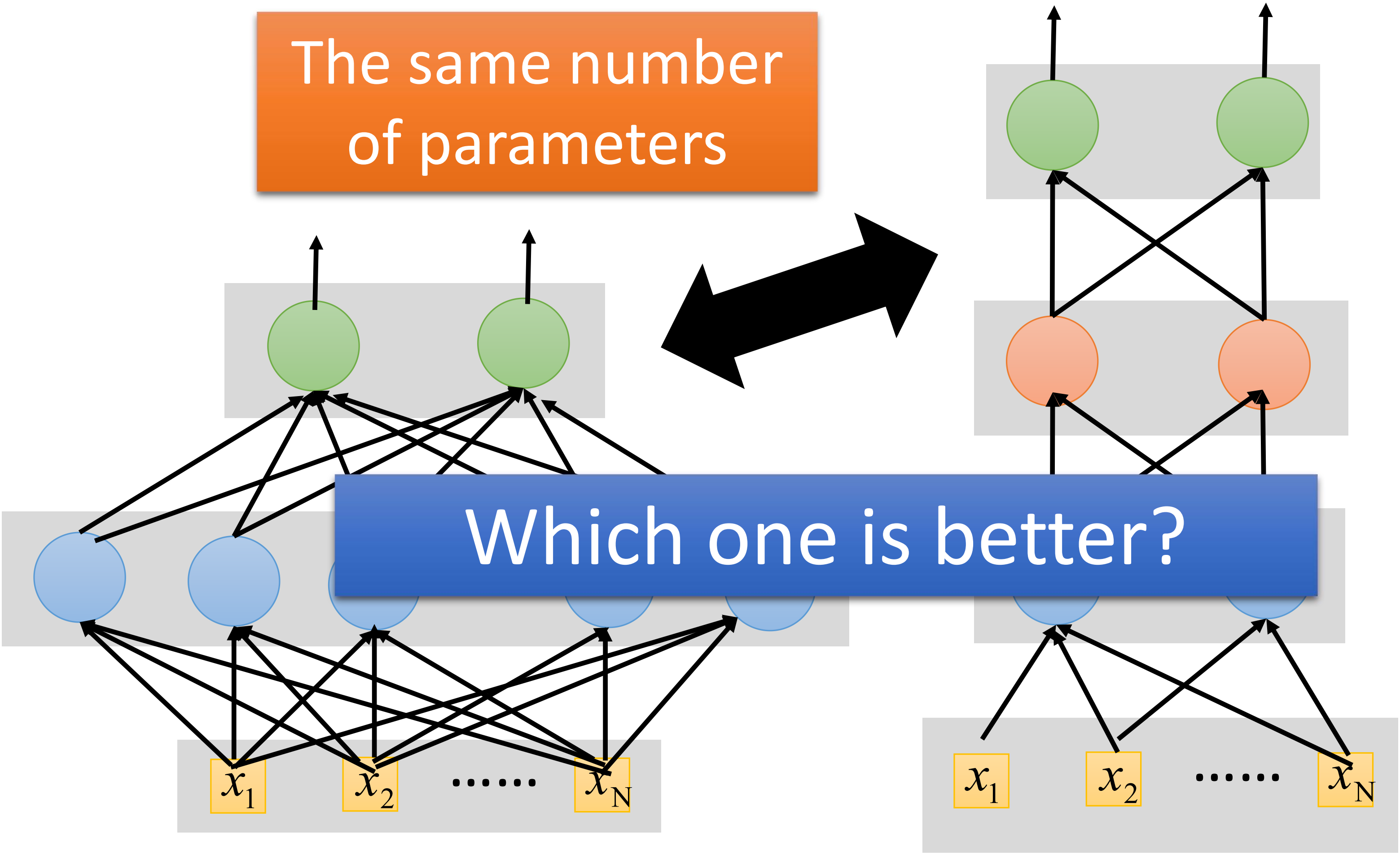
large
small
$L(h^{all}, \mathcal{D}_{all})$

Seide Frank, Gang Li, and Dong Yu. "Conversational Speech Transcription Using Context-Dependent Deep Neural Networks." *Interspeech*. 2011.

Fat + Short v.s. Thin + Tall



The same number of parameters

Which one is better?

Shallow

Deep

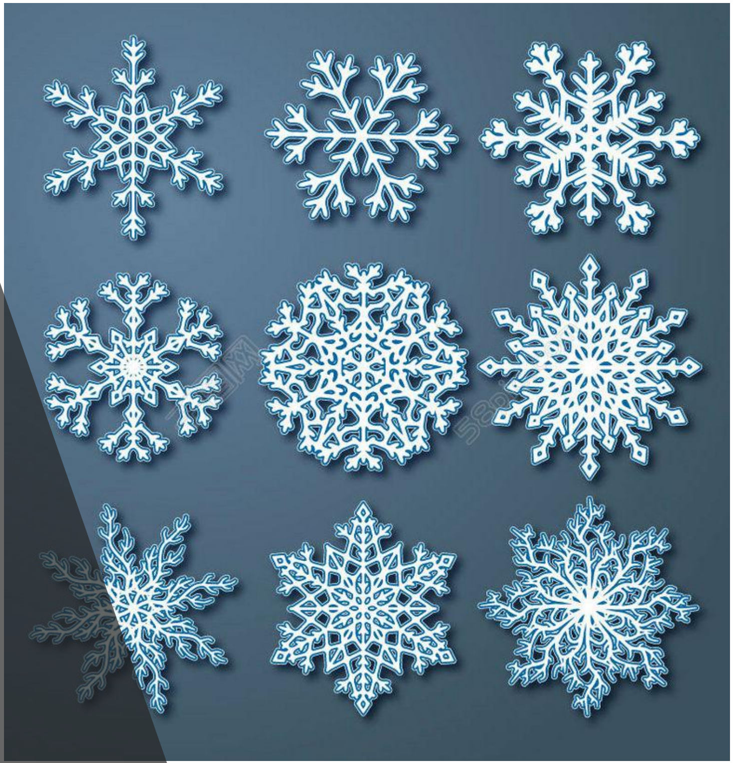
Fat + Short v.s. Thin + Tall

Layer X Size	Word Error Rate (%)	Layer X Size	Word Error Rate (%)
1 X 2k	24.2		
2 X 2k	20.4		
3 X 2k	18.4		
4 X 2k	17.8		
5 X 2k	17.2	1 X 3772	22.5
7 X 2k	17.1	1 X 4634	22.6
		1 X 16k	22.1

Why?

Seide Frank, Gang Li, and Dong Yu. "Conversational Speech Transcription Using Context-Dependent Deep Neural Networks." *Interspeech*. 2011.

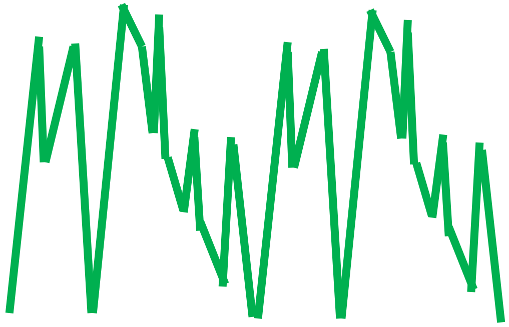
Why we need deep?

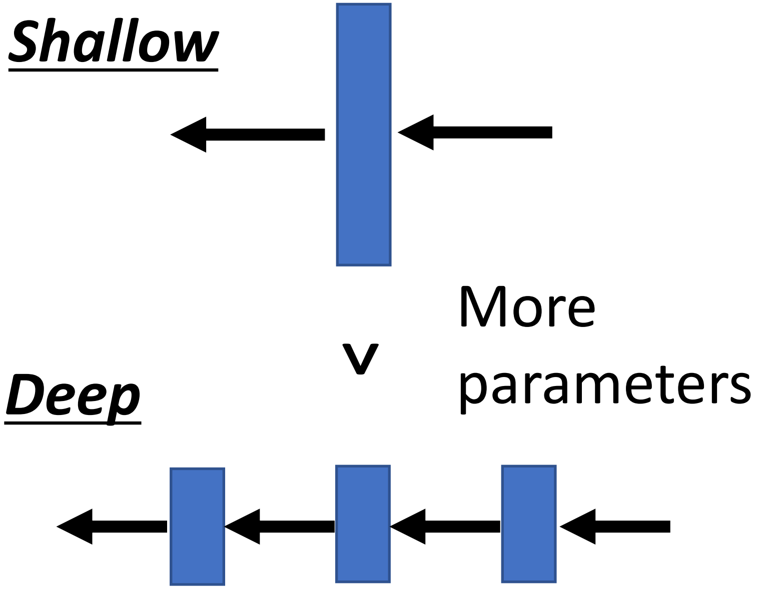


Why we need deep?

Yes, one hidden layer can represent any function.

However, using deep structure is more effective.





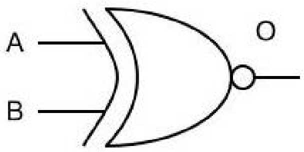
Shallow

v

More parameters

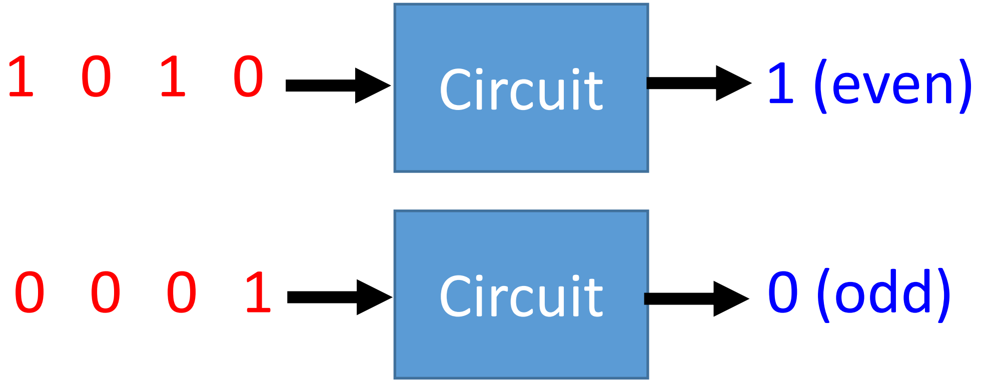
Deep

Analogy – Logic Circuits



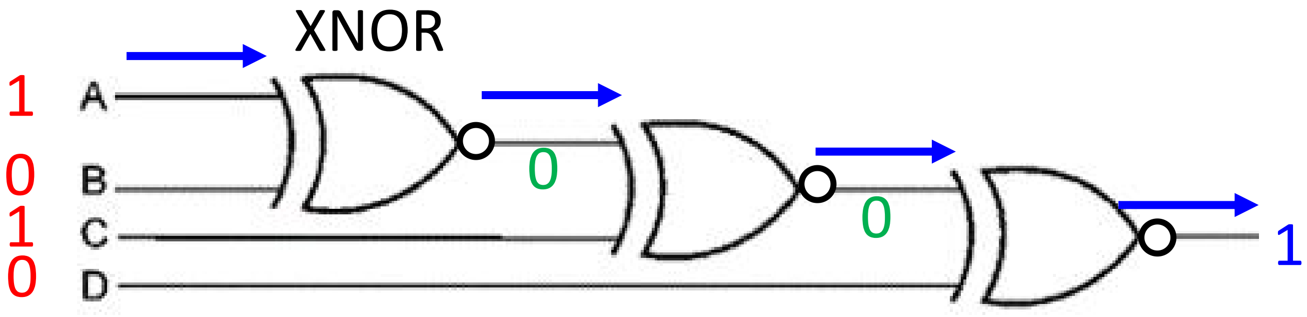
A	B	O
0	0	1
0	1	0
1	0	0
1	1	1

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



For input sequence with d bits,

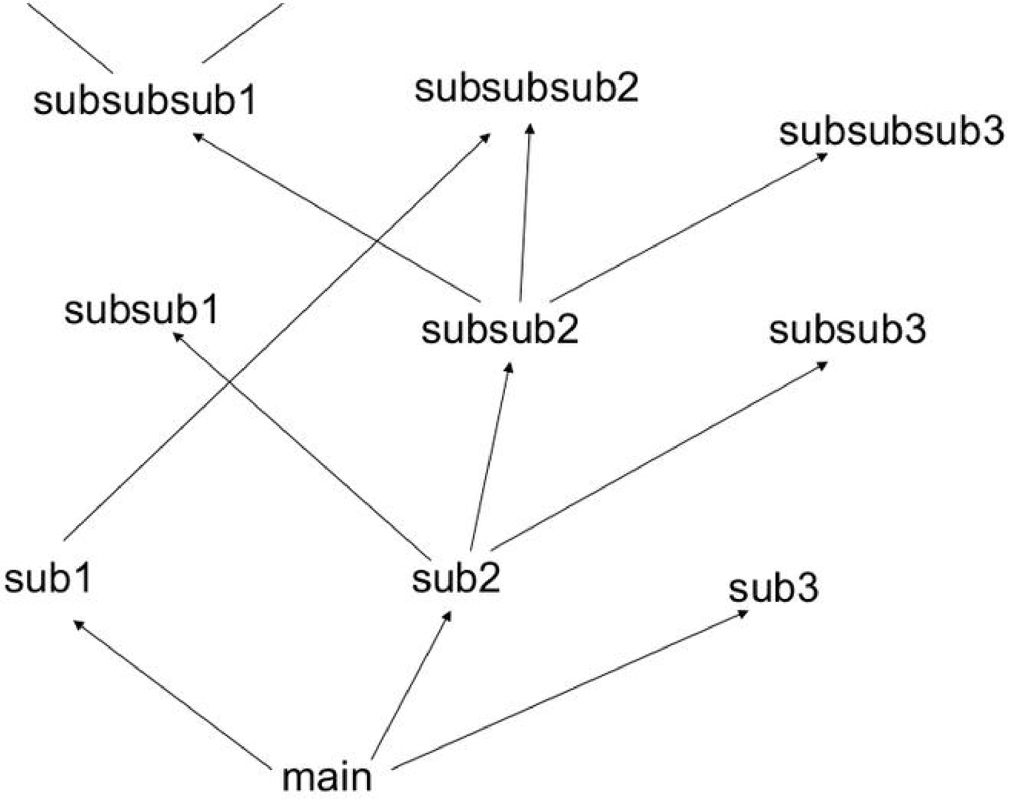
Two-layer circuit need $O(2^d)$ gates.



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

Analogy – Programming

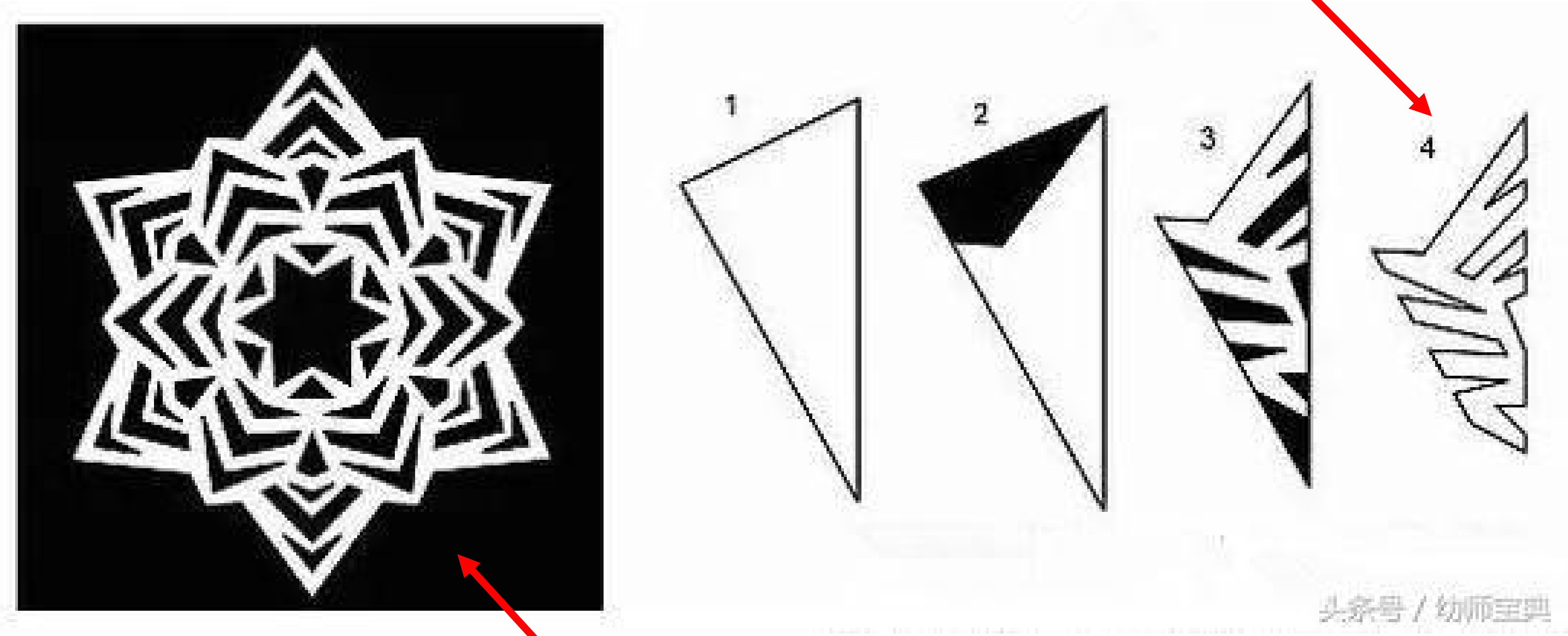
Don't put everything in your main function.



http://rinuboney.github.io/2015/10/18/theoretical-motivations-deep-learning.html

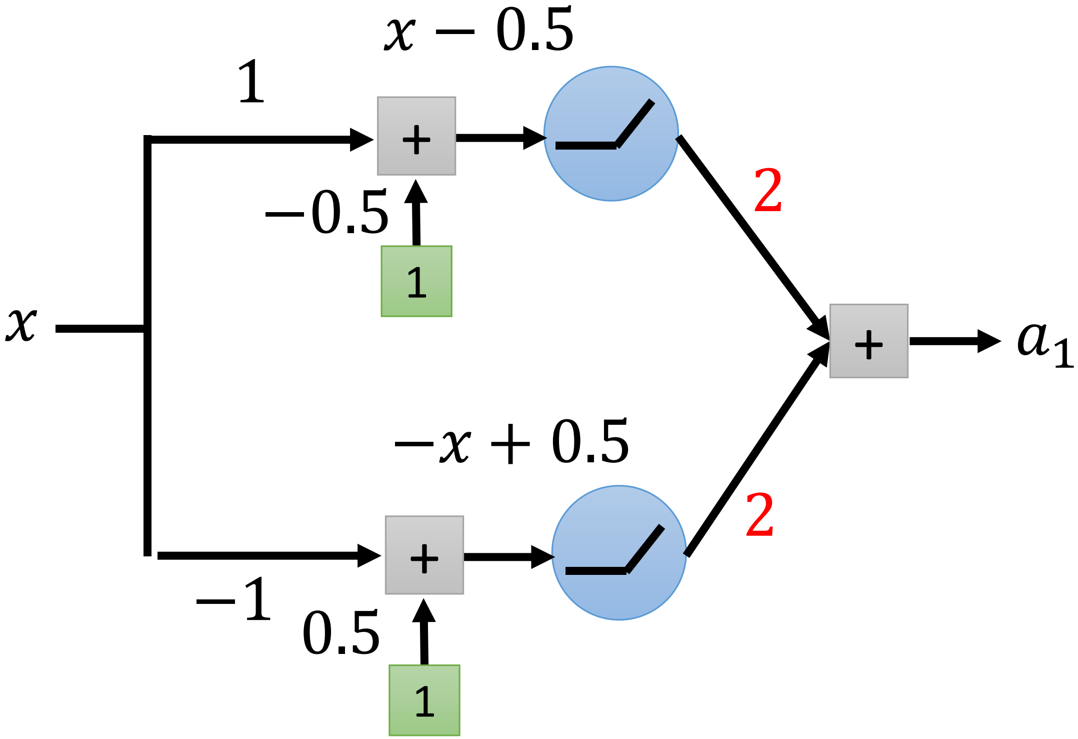
More Analogy

比較有效率

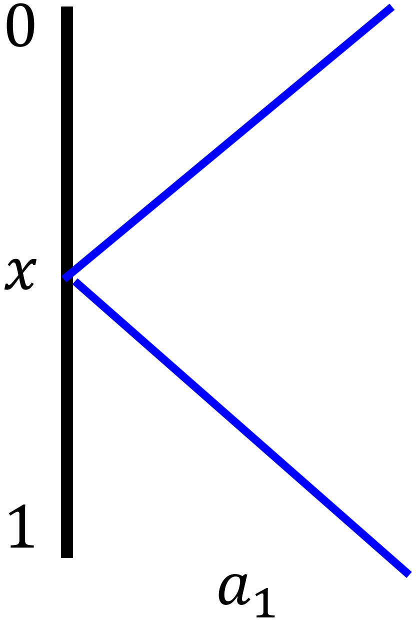


剪很多刀

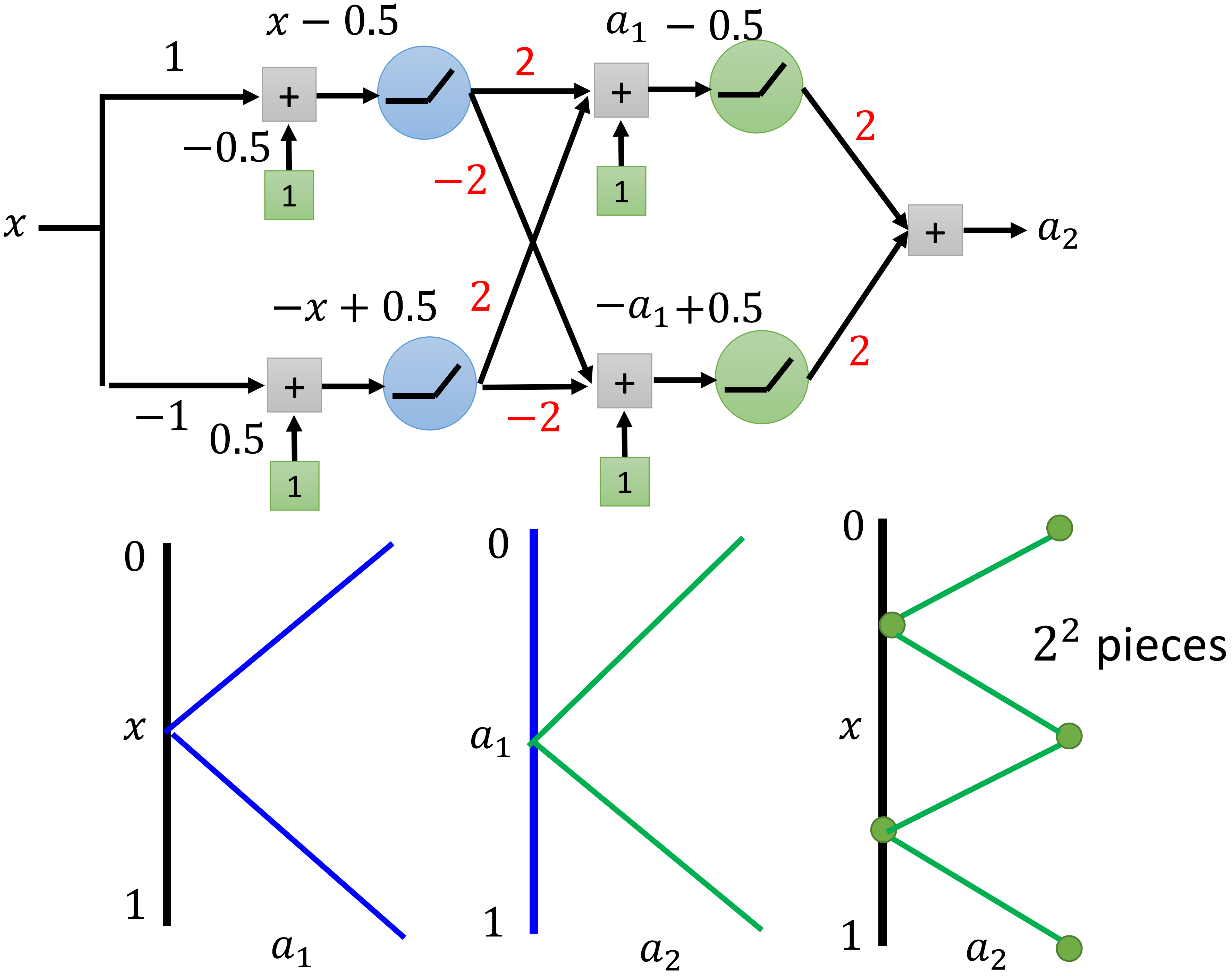
- 以下三頁投影片上課時的數字有誤，已經將修改部的分套上紅色，感謝同學指出錯誤



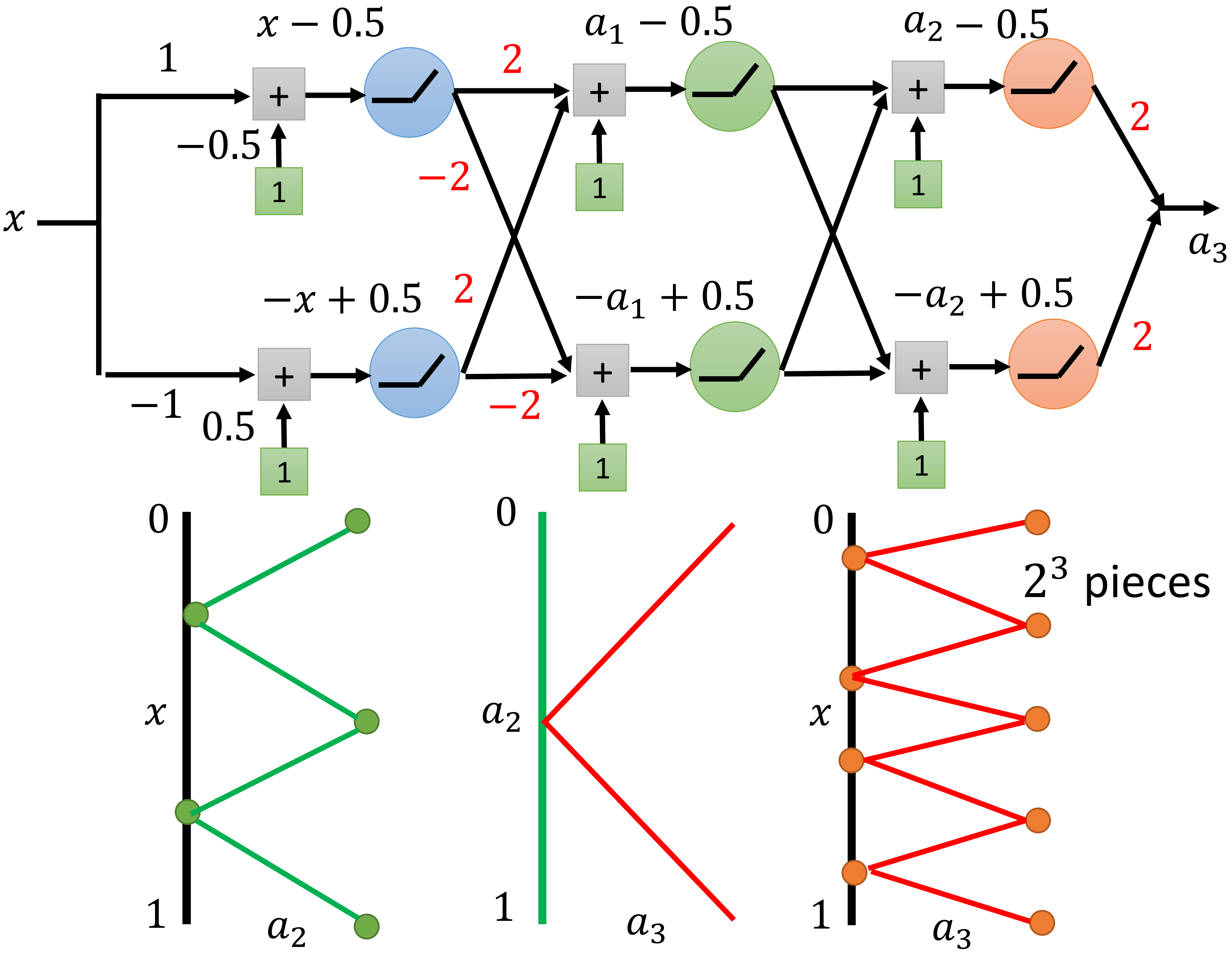
$x - 0.5$
1
+
-0.5
1
2
x
+
a_1
$-x + 0.5$
+
2
-1
0.5
1



0
x
1
a_1

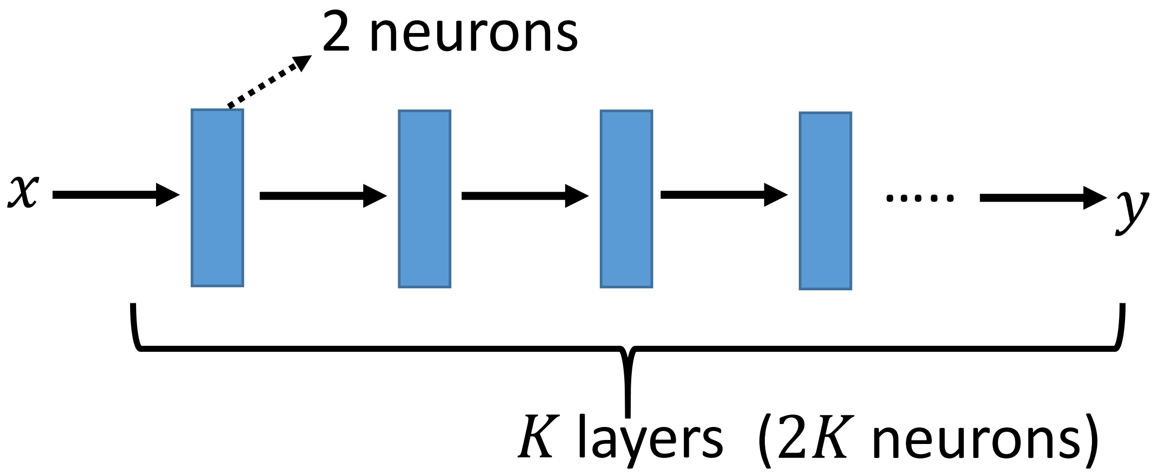

x
1
$x - 0.5$
-0.5
1
+
2
-2
$a_1 - 0.5$
+
1
2
+
a_2
$-x + 0.5$
2
$-a_1 + 0.5$
+
1
2
-1
0.5
1
-2
+
1
0
x
1
a_1
0
a_1
1
a_2
0
x
1
a_2

2^2 pieces


x
1
−0.5
1
$x - 0.5$
−1
0.5
1
$-x + 0.5$
2
−2
2
−2
$a_1 - 0.5$
1
$-a_1 + 0.5$
1
$a_2 - 0.5$
1
$-a_2 + 0.5$
1
2
2
a_3
0
x
1
a_2
0
a_2
1
a_3
0
x
1
a_3

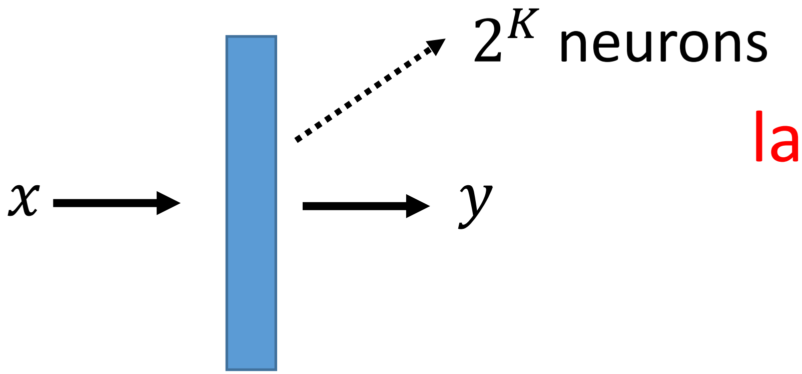
2^3 pieces

Deep

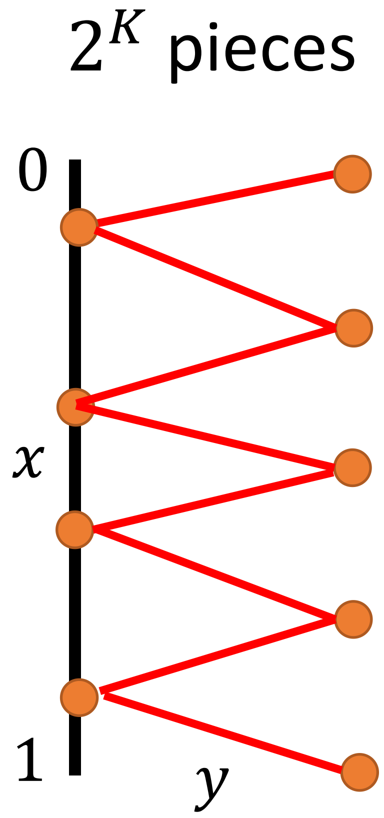


smaller $|\mathcal{H}|$

Shallow



larger $|\mathcal{H}|$



Thinks more ……

- Deep networks outperforms shallow ones when the required functions are complex and regular.

Image, speech, etc. have this characteristics.

- Deep is exponentially better than shallow even when $y = x^2$.

https://youtu.be/FN8jclCrqY0

https://youtu.be/qpuLxXrHQB4

深度學習是一個讓
魚與熊掌可以兼得的方法

Still small loss

$$h^{all} = arg\min_{h \in \boxed{\mathcal{H}}} \boxed{L(h, \mathcal{D}_{all})}$$

Small (fewer candidates)