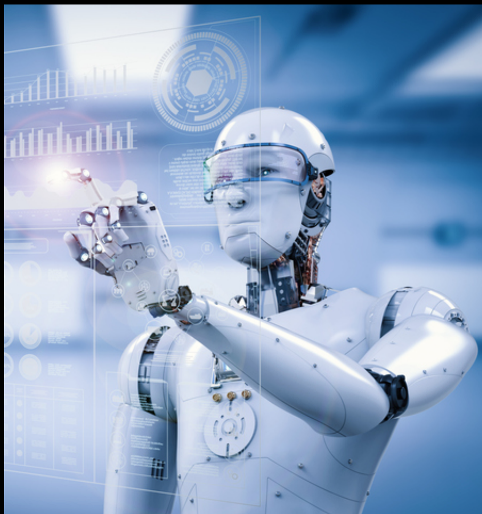
CS 66: Machine Learning

Prof. Sara Mathieson

Spring 2019

SWARTHMORE

MACHINE LEARNING



What society thinks I do

$$\nabla_w \mathcal{L}(w,b,\alpha) = w - \sum_{i=1}^{m} \alpha_i y^{(i)} x^{(i)} = 0$$

This implies that

$$w = \sum_{i=1}^{m} \alpha_i y^{(i)} x^{(i)}.$$

As for the derivative with respect to b, we obtain

$$\frac{\partial}{\partial b}\mathcal{L}(w,b,\alpha) = \sum_{i=1}^{m} \alpha_i y^{(i)} = 0.$$

If we take the definition of w in Equation (9) and plug that back int
Lagrangian (Equation 8), and simplify, we get

$$\mathcal{L}(w,b,\alpha) = \sum_{i=1}^{m} \alpha_i - \frac{1}{2} \sum_{i,j=1}^{m} y^{(i)} y^{(j)} \alpha_i \alpha_j (x^{(i)})^T x^{(j)} - b \sum_{i=1}^{m} \alpha_i y^{(i)}.$$

But from Equation (10), the last term must be zero, so we obtain

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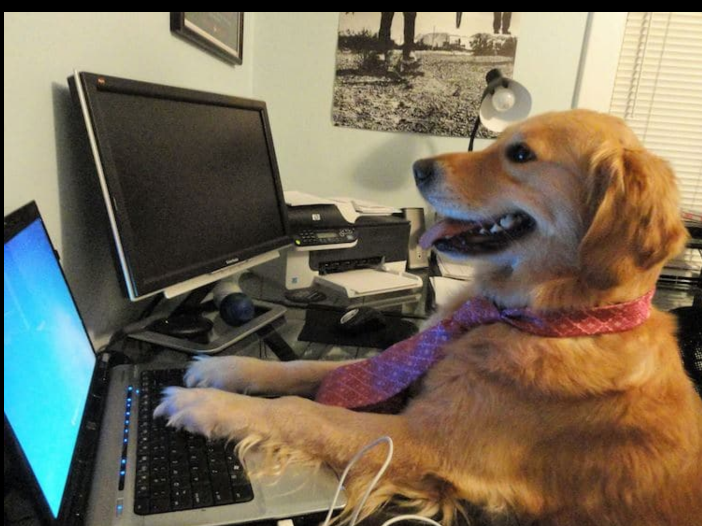
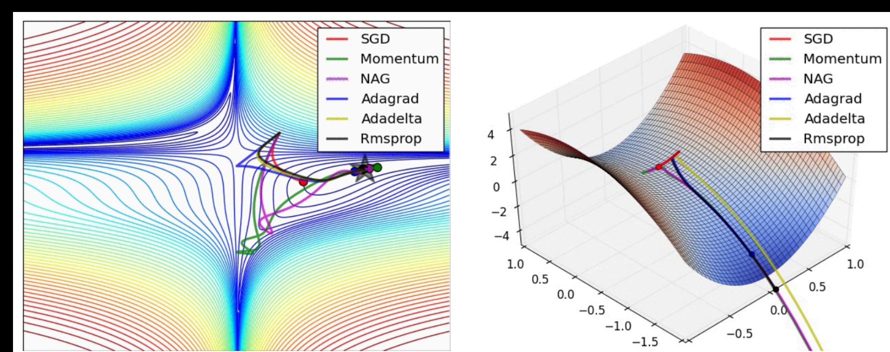
What my boss thinks I do

What other computer scientists think I do



What mathematicians think I do



What I think I do

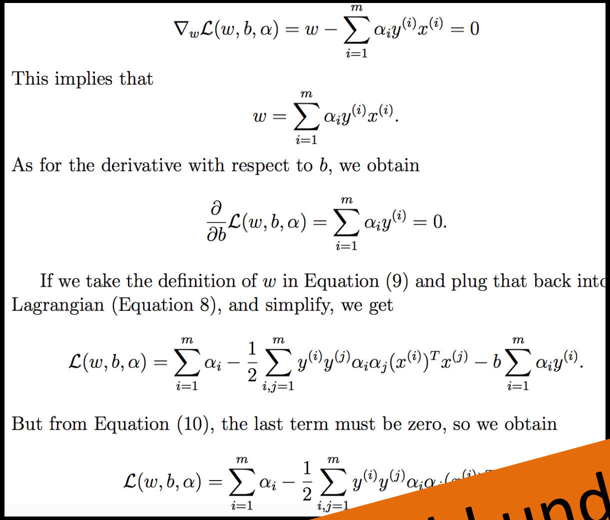
```
>>> from sklearn import svm
>>> import tensorflow as tf
```

What I really do

Adapted from: "Know Your Meme"

MACHINE LEARNING

What society thinks I do



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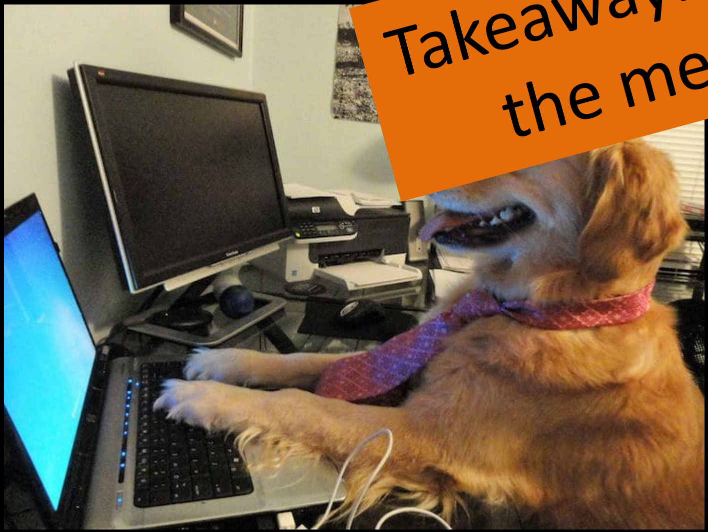
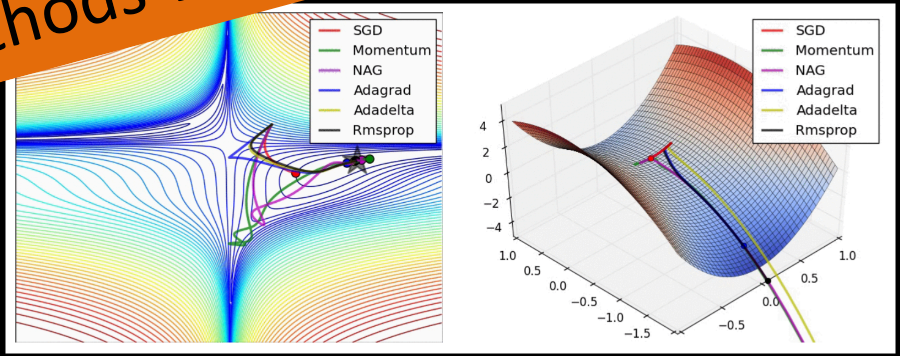
Wha

t other computer scientists think I do

Takeaway: we should understand the methods we are using!



What mathematicians think I do



What I think I do

```
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```

What I really do

Lab 7 getting started

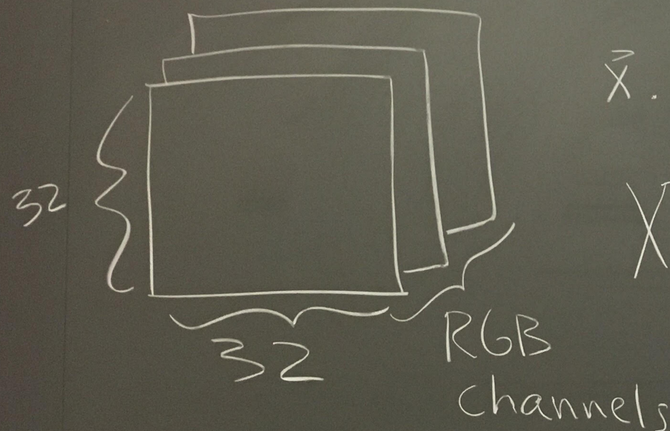
- It is helpful to have our data be zero-centered, so we will subtract off the mean

- It is also helpful to have the features be on the same scale, so we will divide by the standard deviation

- We will compute the mean and std with respect to the *training data*, then apply the same transformation to all datasets

Lab 7 getting started

- Input is now itself a multi-dimensional array
- For images, often the shape of each image will be (width, height, 3) for RGB channels
- Need to “*flatten*” or “unravel” for fully connected networks



$\vec{x}.\text{shape} = (32, 32, 3)$

$X.\text{shape} = (n, \underbrace{32, 32, 3})$

"flatten", "unravel"

$32 \cdot 32 \cdot 3 = \underbrace{3072}_{p}$

Lab 7 getting started

- So far in this class, we have considered *stochastic gradient descent*, where one data point is used to compute the gradient and update the weights
- On the flipside is *batch gradient descent*, where we compute the gradient with respect to all the data, and then update the weights
- A middle ground uses *mini-batches* of examples before updating the weights. This is the approach we will use in Lab 7.

Outline for April 8

- Choice of weight initialization
- Regularization
- Autoencoders and unsupervised pre-training
- Begin: convolutional neural networks

  - Lab 7 check-in (fully connected NN part) on WED
  - Lab 7 due Monday (week from today)
  - Office hours TODAY 12:30-2pm

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Weight initialization

- All 0's initialization is bad! Causes nodes to compute the same outputs, so then the weights go through the same updates during gradient descent

- Need asymmetry! => usually use small random values

Weight initialization

- Issue: nodes with more randomly initialized inputs will have a higher variance in their output

- Solution: divide by the sqrt(n) where n is the "fan-in" (number of inputs)

More info:
http://cs231n.github.io/neural-networks-1/

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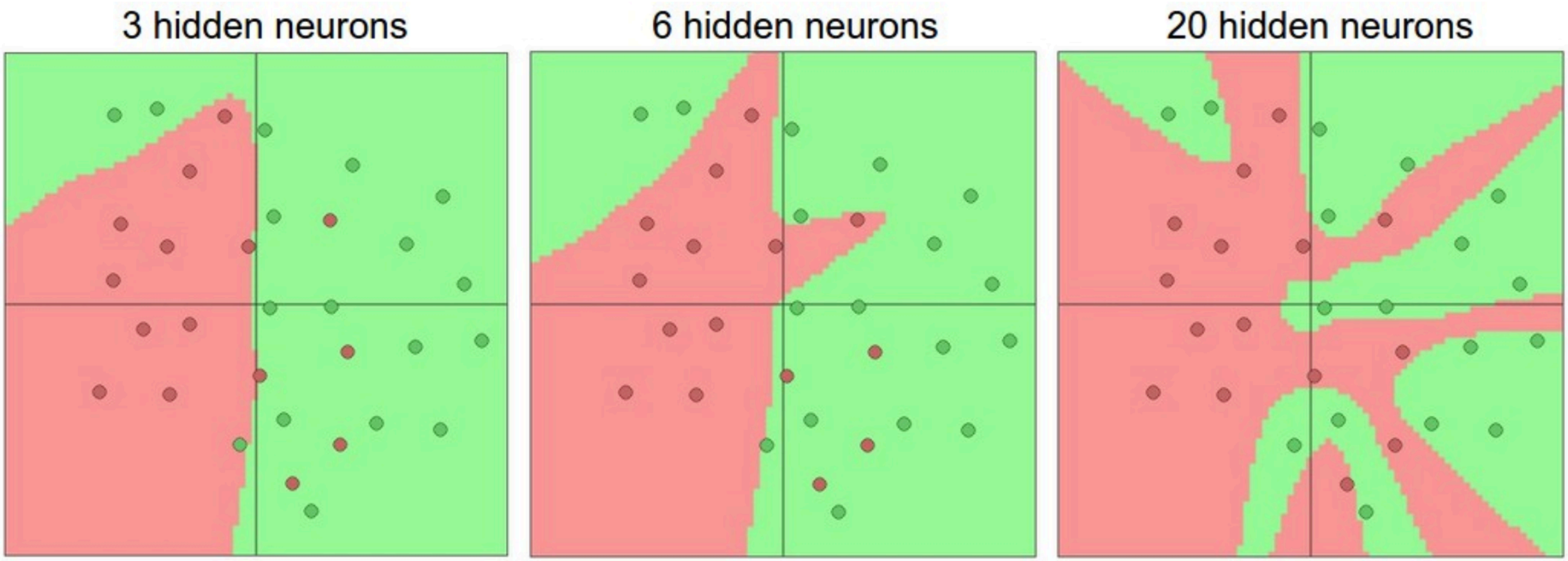
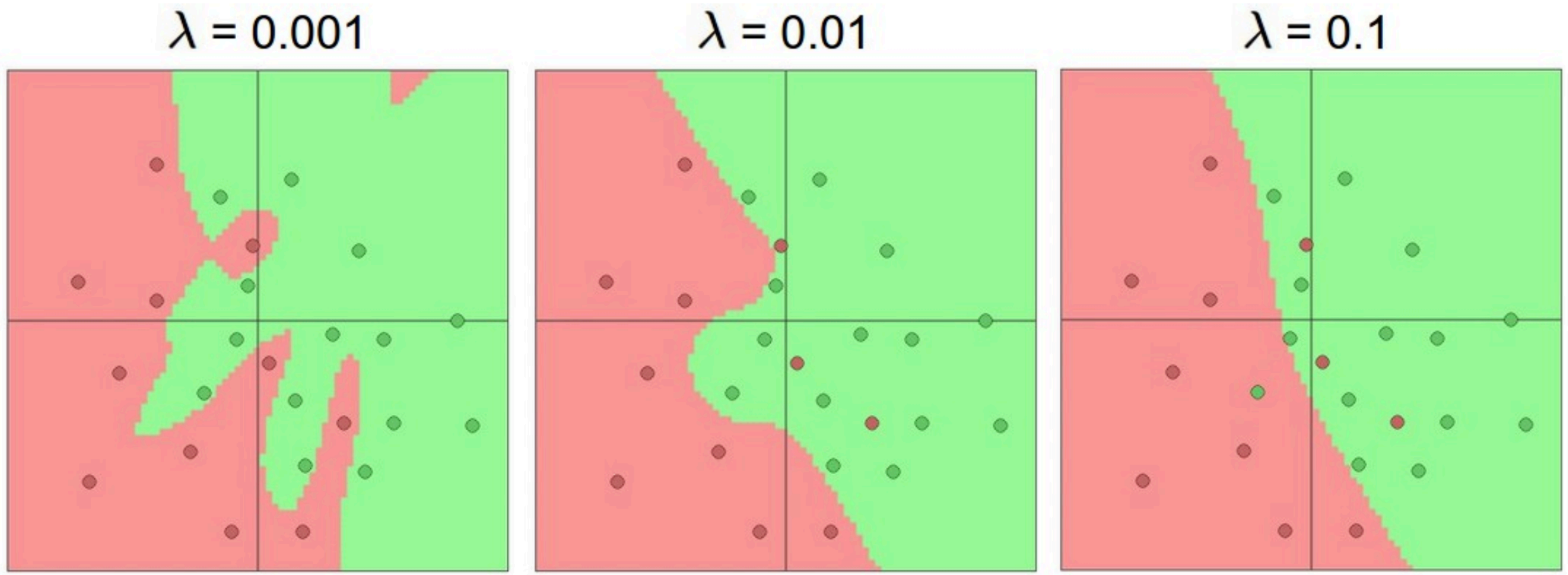
More hidden units can contribute to overfitting



Larger Neural Networks can represent more complicated functions. The data are shown as circles colored by their class, and the decision regions by a trained neural network are shown underneath. You can play with these examples in this ConvNetsJS demo.

Image from: http://cs231n.github.io/neural-networks-1/

However! It is always better to use a larger network and regularize in other ways



The effects of regularization strength: Each neural network above has 20 hidden neurons, but changing the regularization strength makes its final decision regions smoother with a higher regularization. You can play with these examples in this ConvNetsJS demo.

Image from: http://cs231n.github.io/neural-networks-1/

Handout 15

① (a) sigmoid $\boxed{\frac{1}{2}}$ (b)

tanh $\boxed{0}$

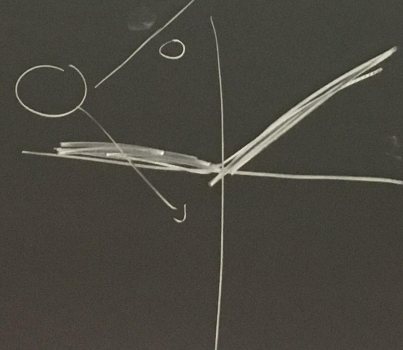
ReLU $\boxed{0}$

$$\sigma'(0) = \frac{1}{4} = \frac{1}{2}\cdot\frac{1}{2}$$

$$\xrightarrow[\boxed{-\frac{3}{4}}]{0} \sigma \xrightarrow[-3]{\frac{1}{2}}$$

(c) $\boxed{\xrightarrow[0]{-1} \text{relu} \xrightarrow[-3]{0}}$

bad if we can't move on from this.



② 1 2 3 } class label

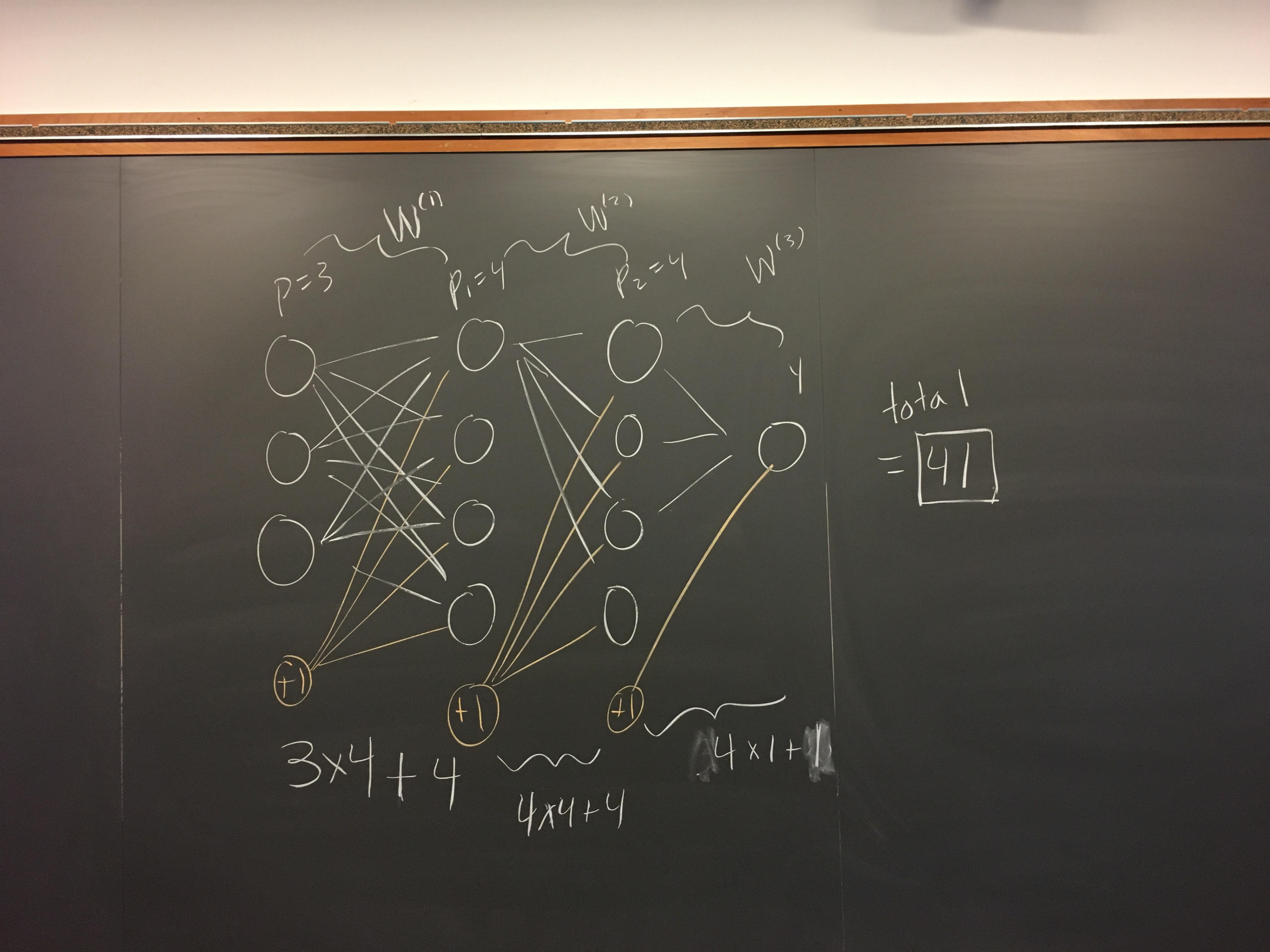
$$y = [0, 1, 0]$$

$$\hat{y} = \left[\frac{1}{4}, \frac{1}{2}, \frac{1}{4}\right] \text{ or } \hat{y} = \left[\frac{3}{8}, \frac{1}{8}, \frac{1}{2}\right]$$

$$H(y, \hat{y}) = -\log_2\left(\frac{1}{2}\right) = \boxed{1}$$

second

$$H(y, \hat{y}) = -\log_2\left(\frac{1}{8}\right) = \boxed{3} \cdot \frac{1}{1}$$


$W^{(1)}$
$W^{(2)}$
$W^{(3)}$
$p=3$
$p_1=4$
$p_2=4$
y
+1
+1
+1
$3\times4+4$
$4\times4+4$
$4\times1+1$
total
$=\boxed{41}$

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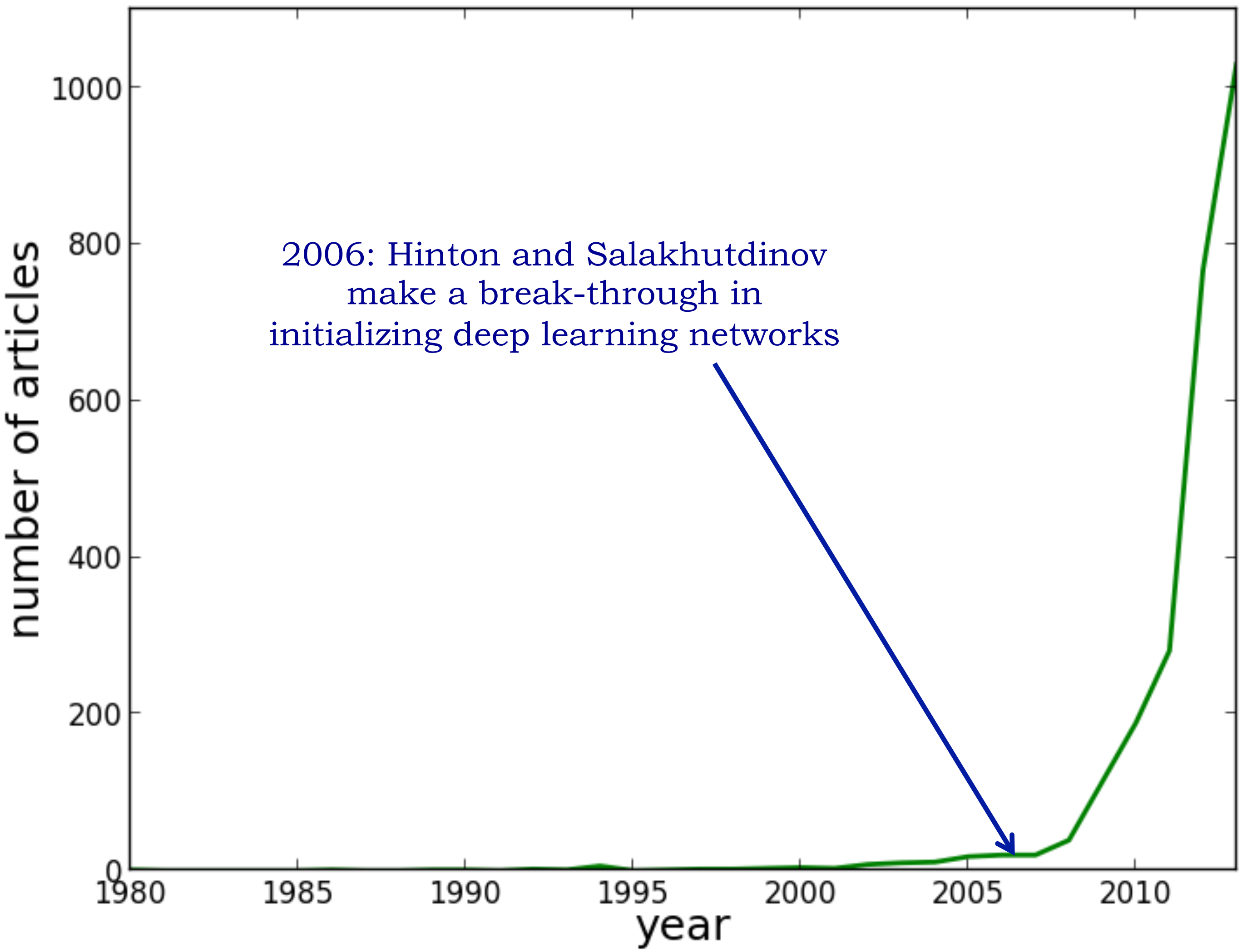
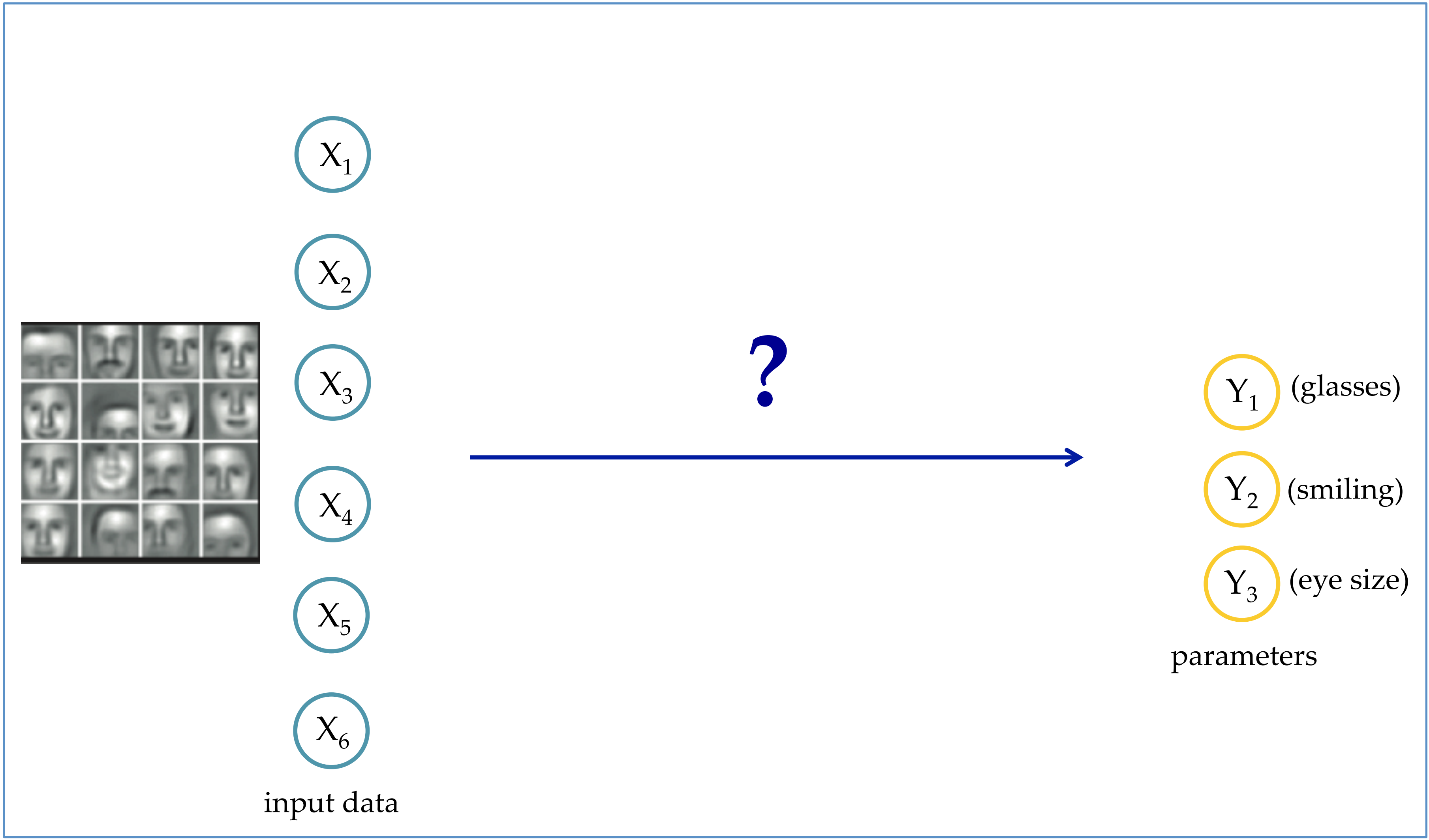
What was this breakthrough in deep learning?

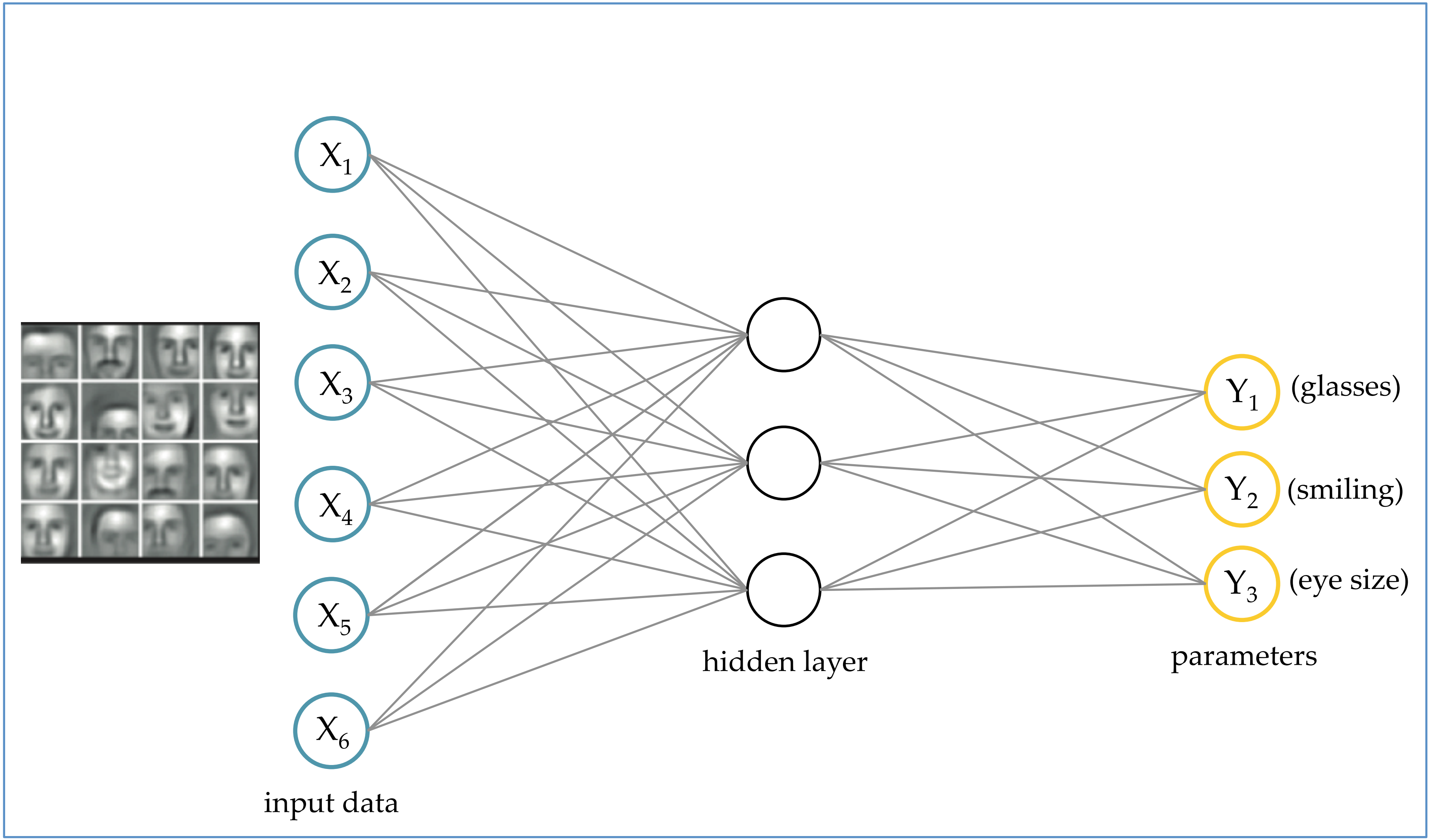


Images on next slides from
Hinton & Salakhutdinov (2006)

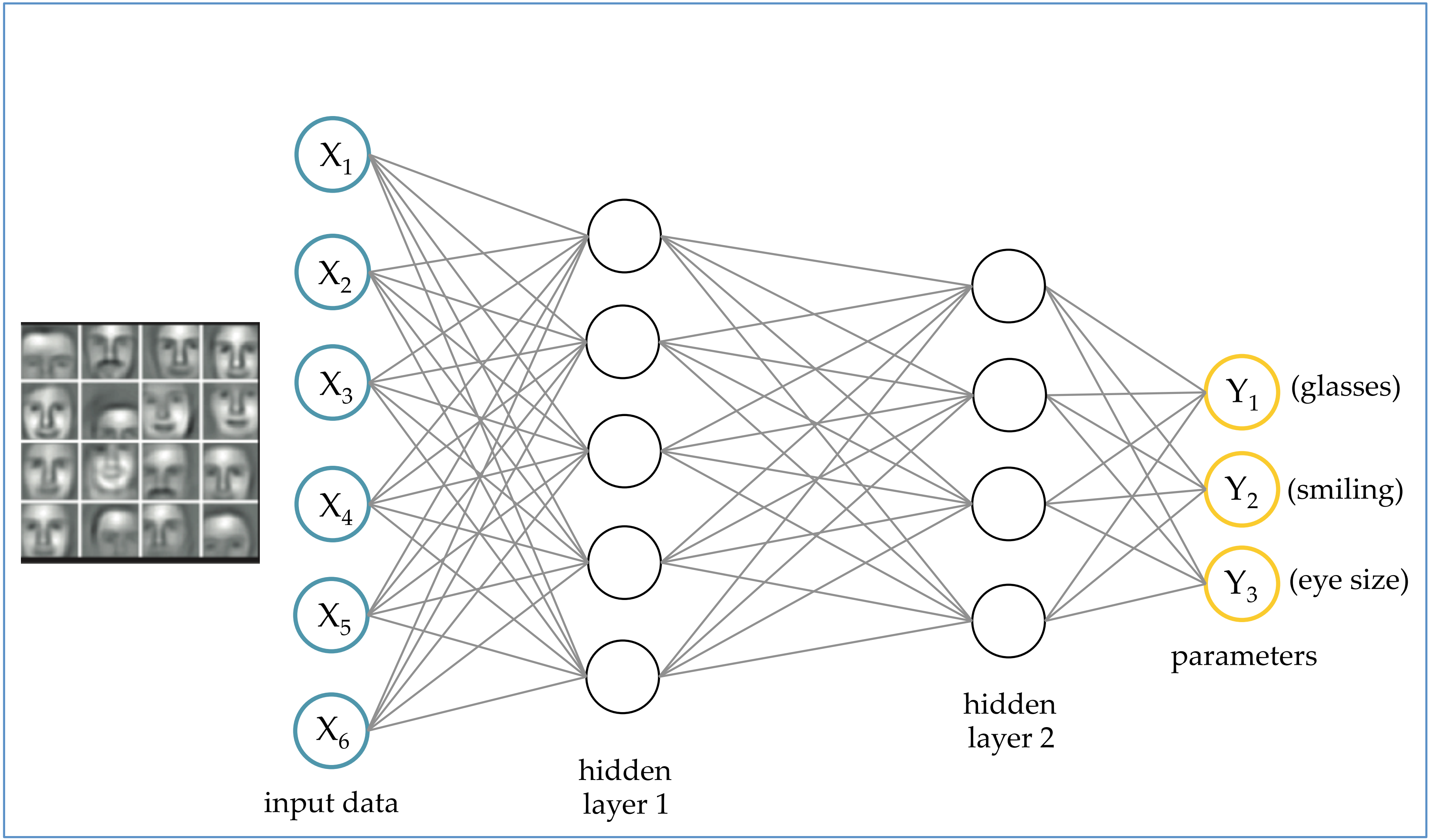
Goal: find a function between input and output



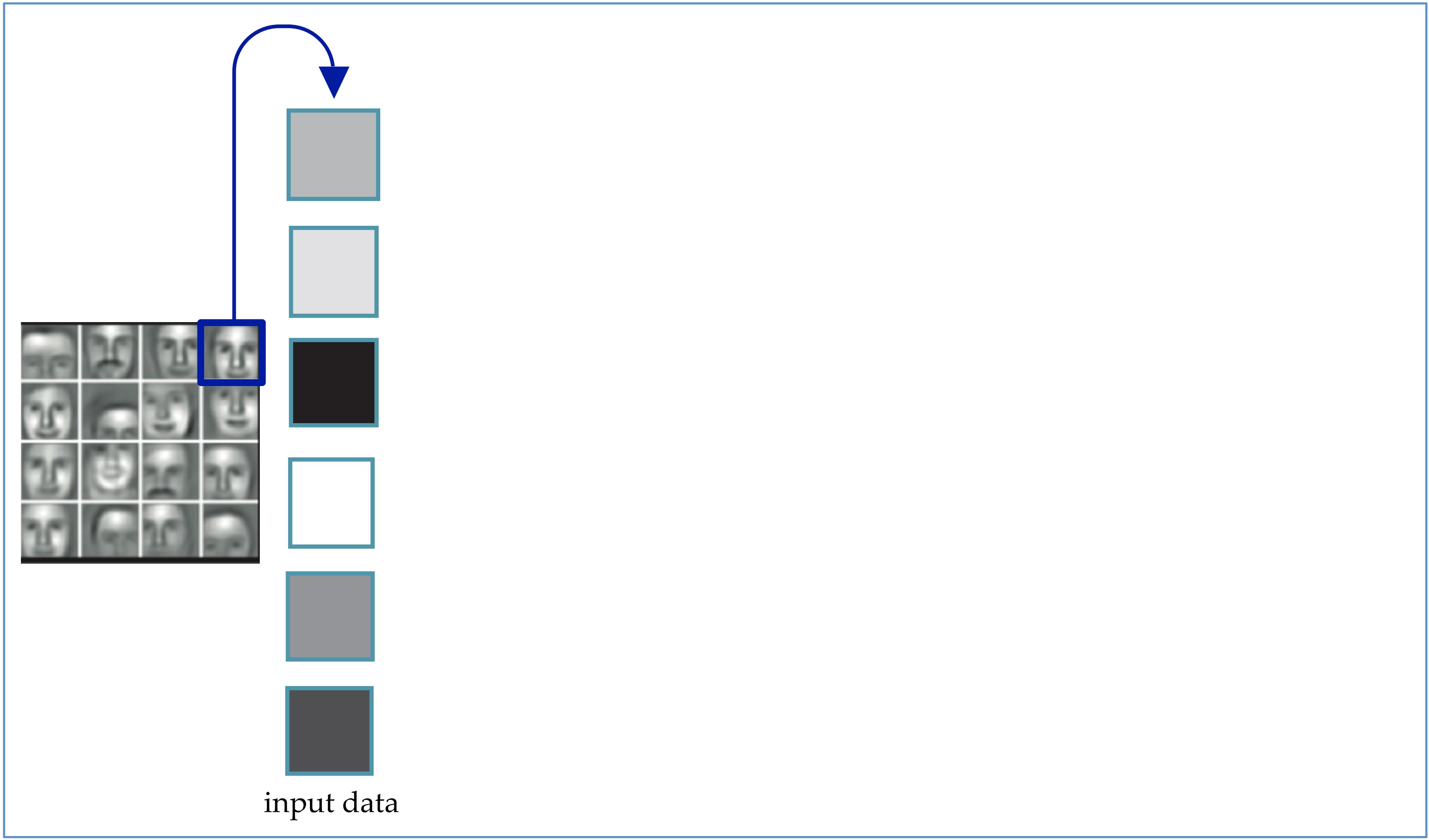
First idea: one hidden layer



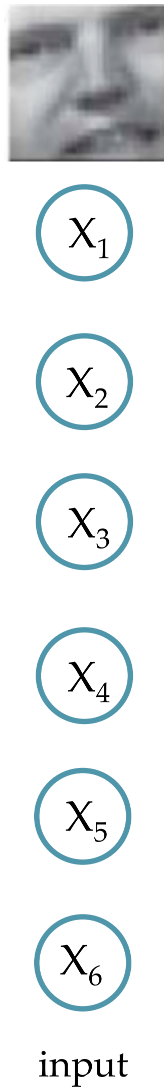
Second idea: more hidden layers ("deep" learning)



Flatten pixels of image into a single vector



Detour to autoencoders



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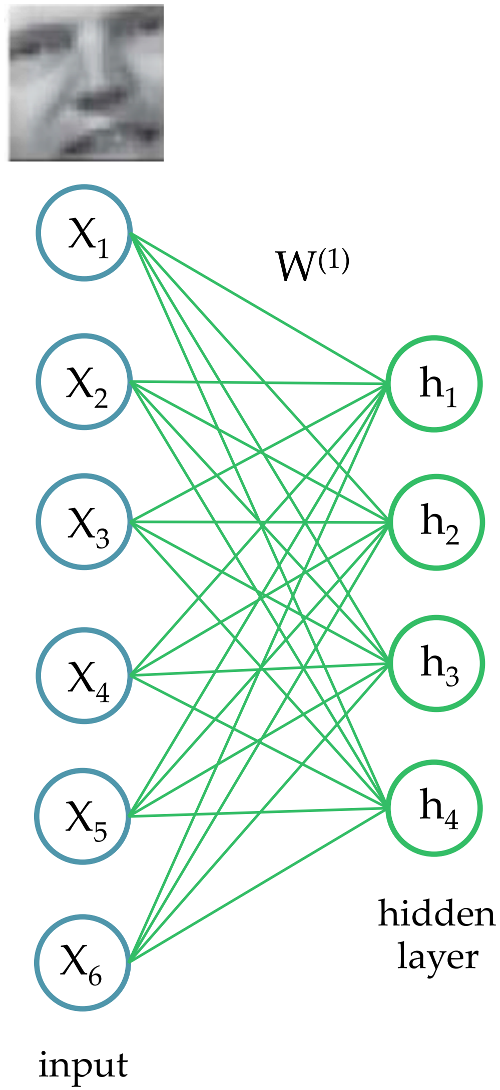
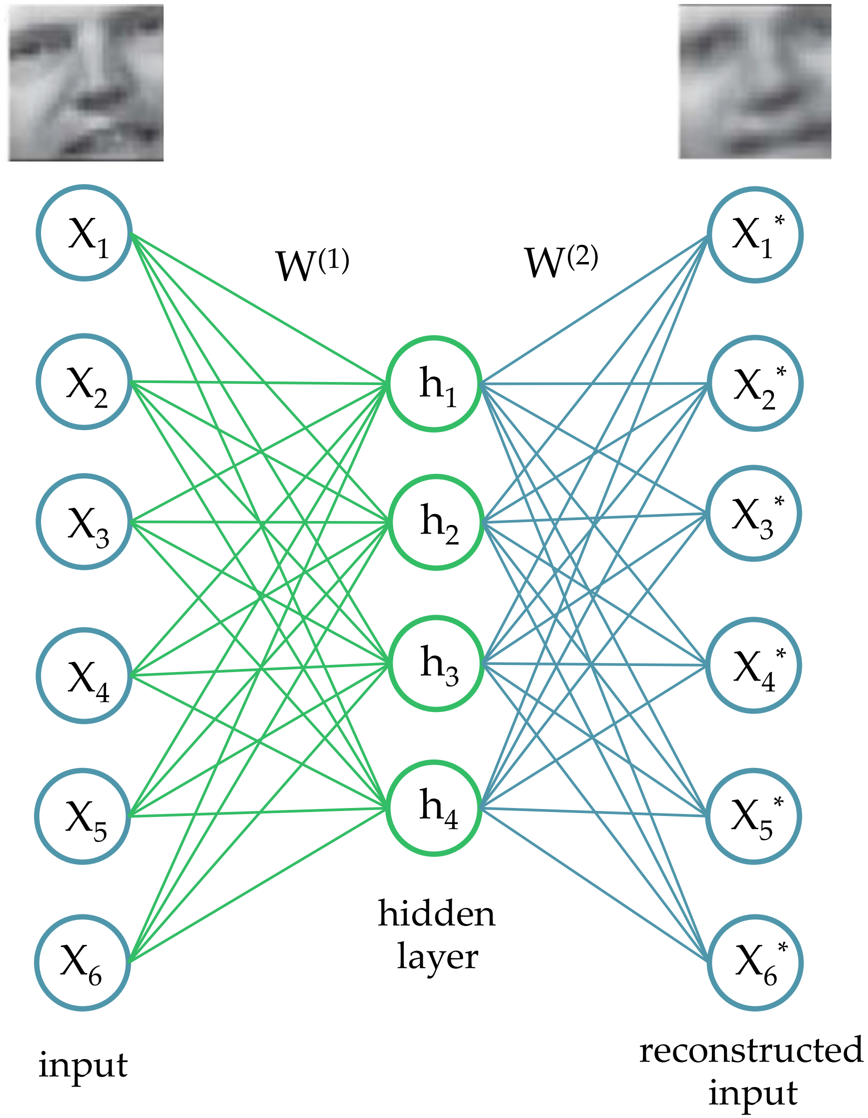
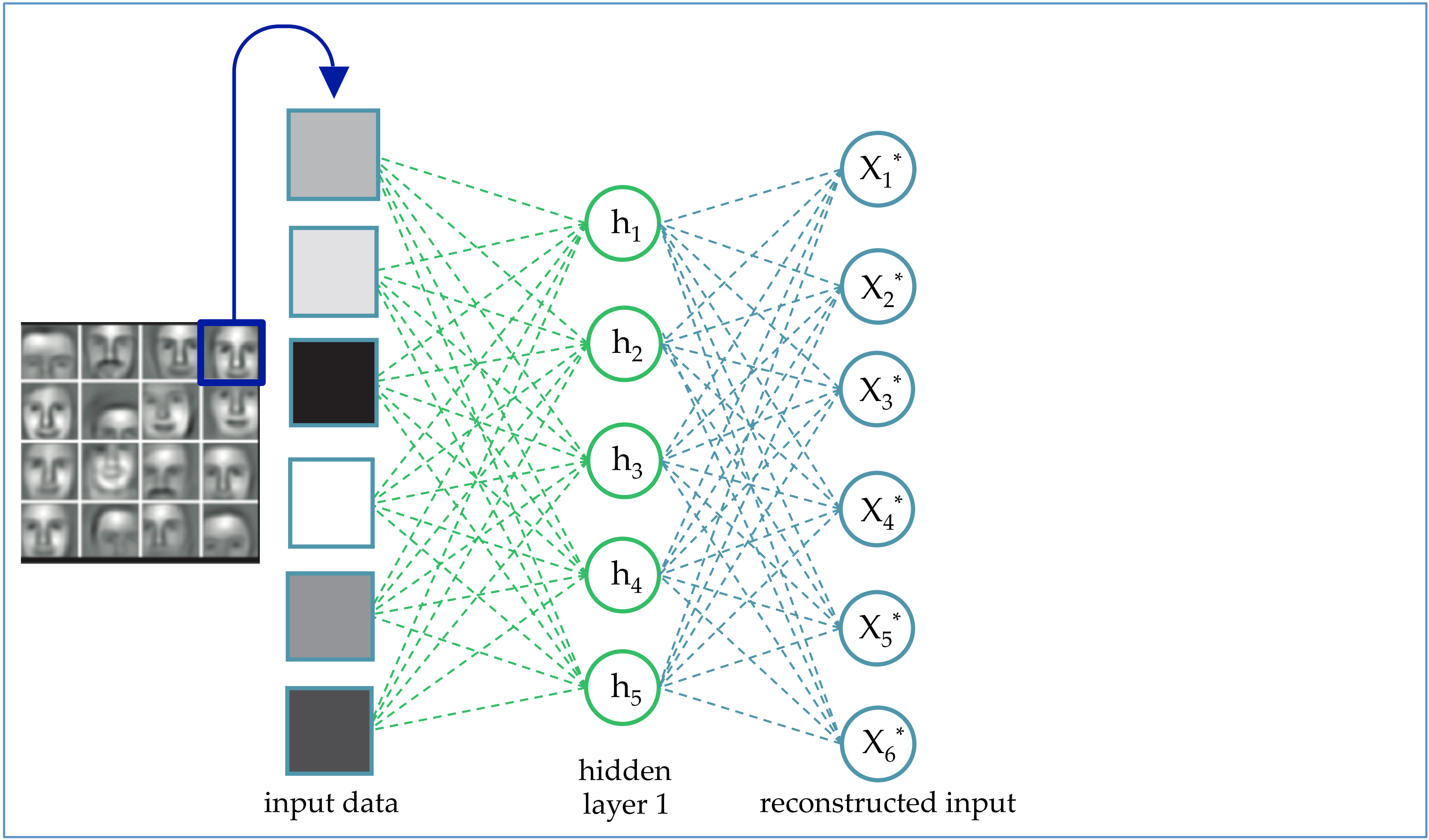


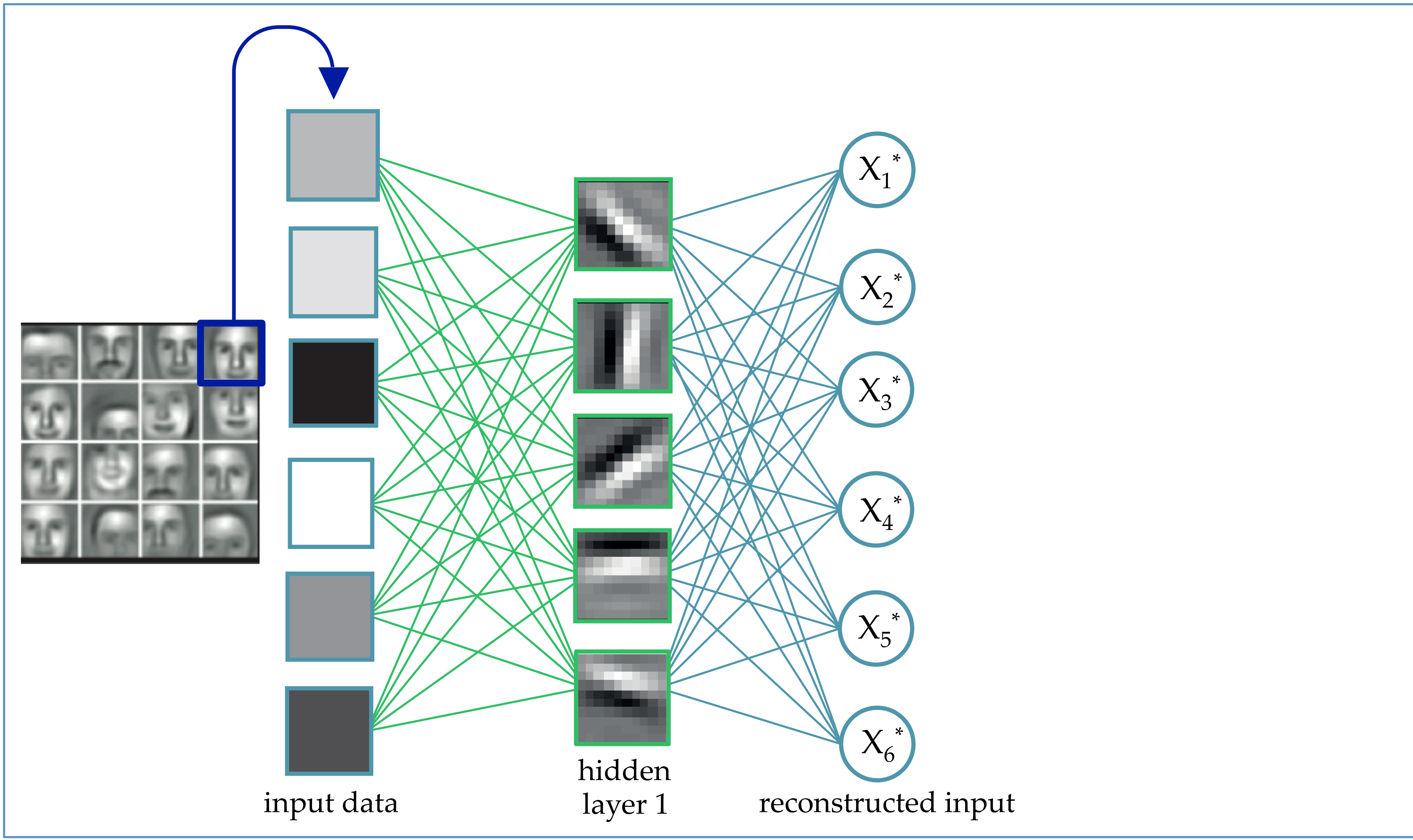
Detour to autoencoders



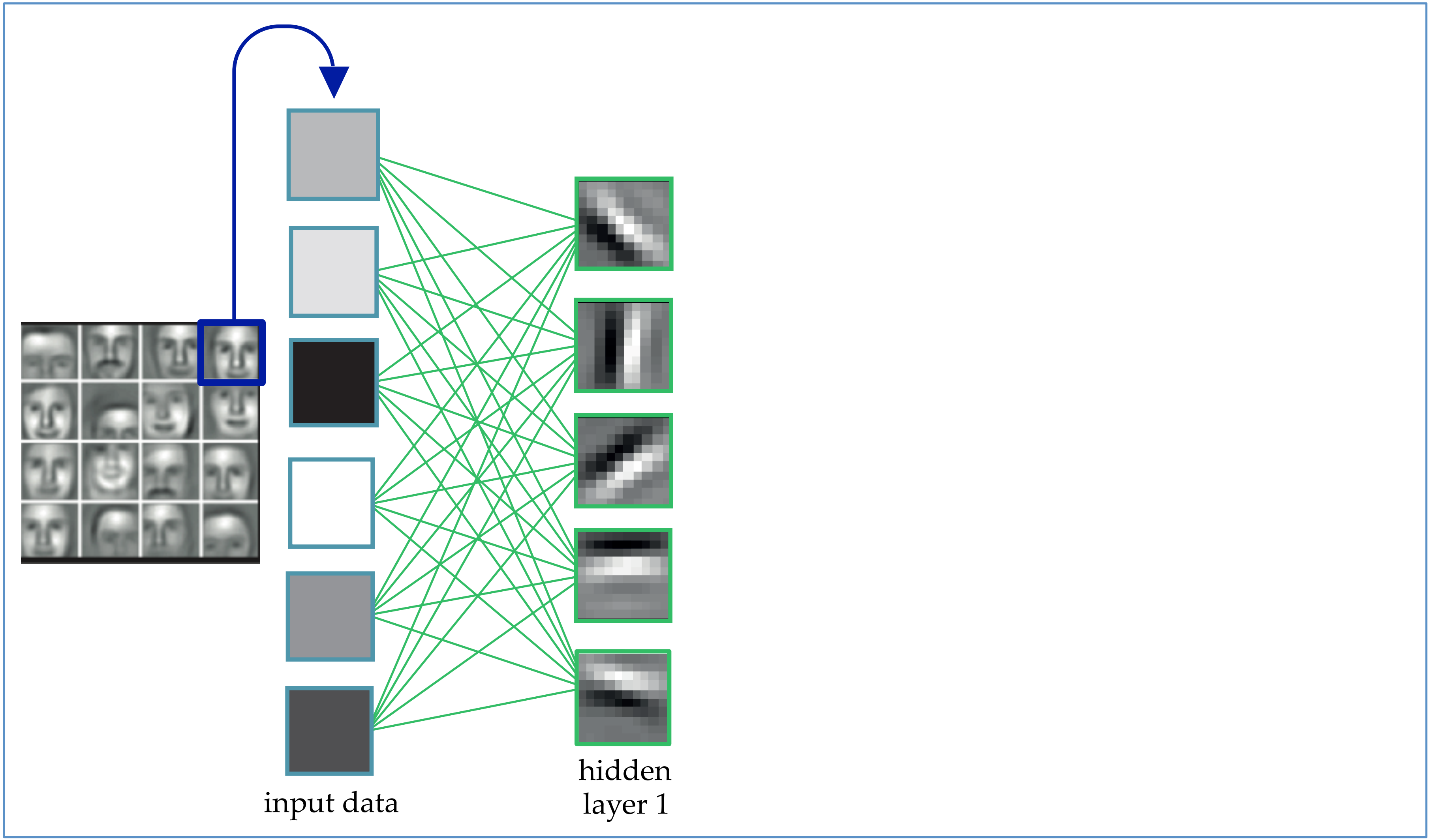
Use unsupervised pre-training to find a function from the input to itself



Hidden units can be interpreted as edges



Now: throw away reconstruction and input



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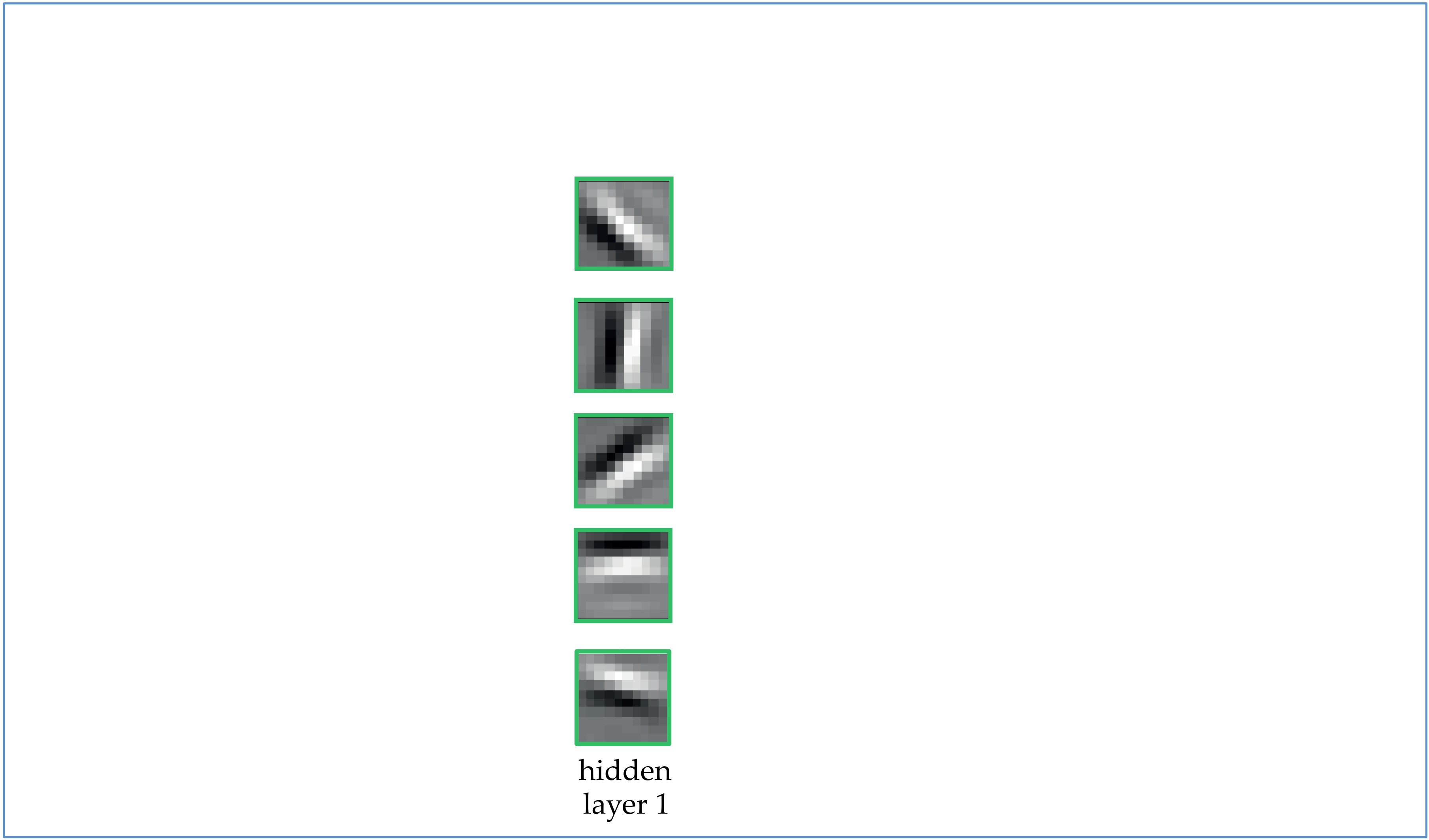
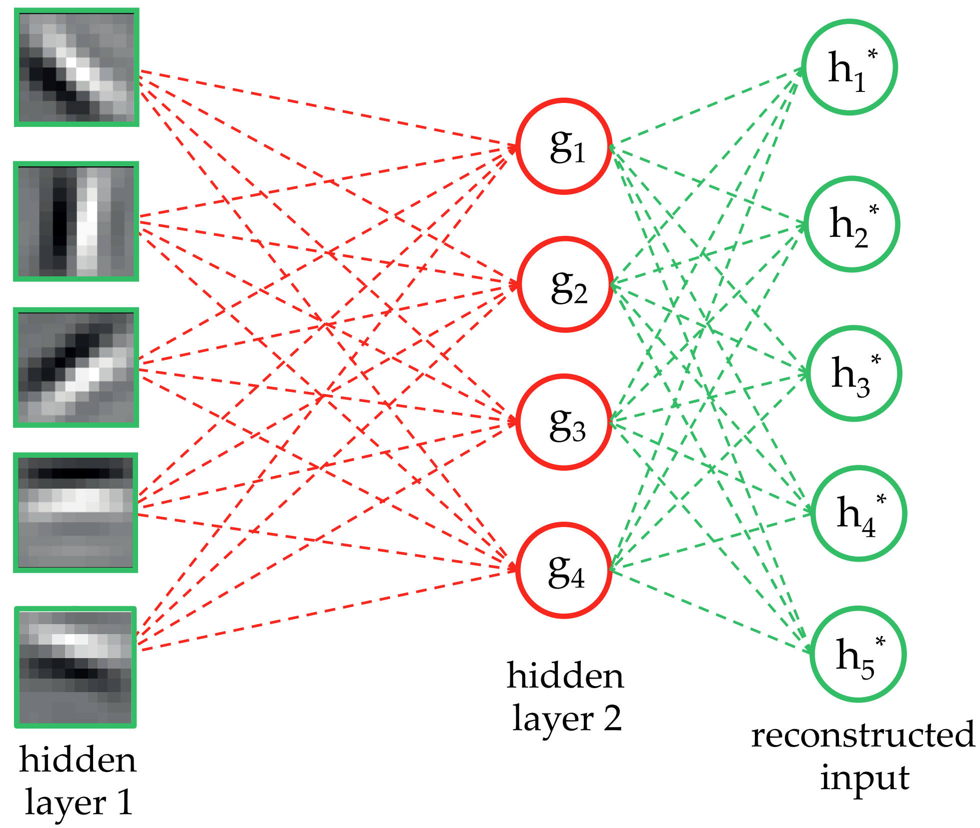


Then repeat the entire process for each layer



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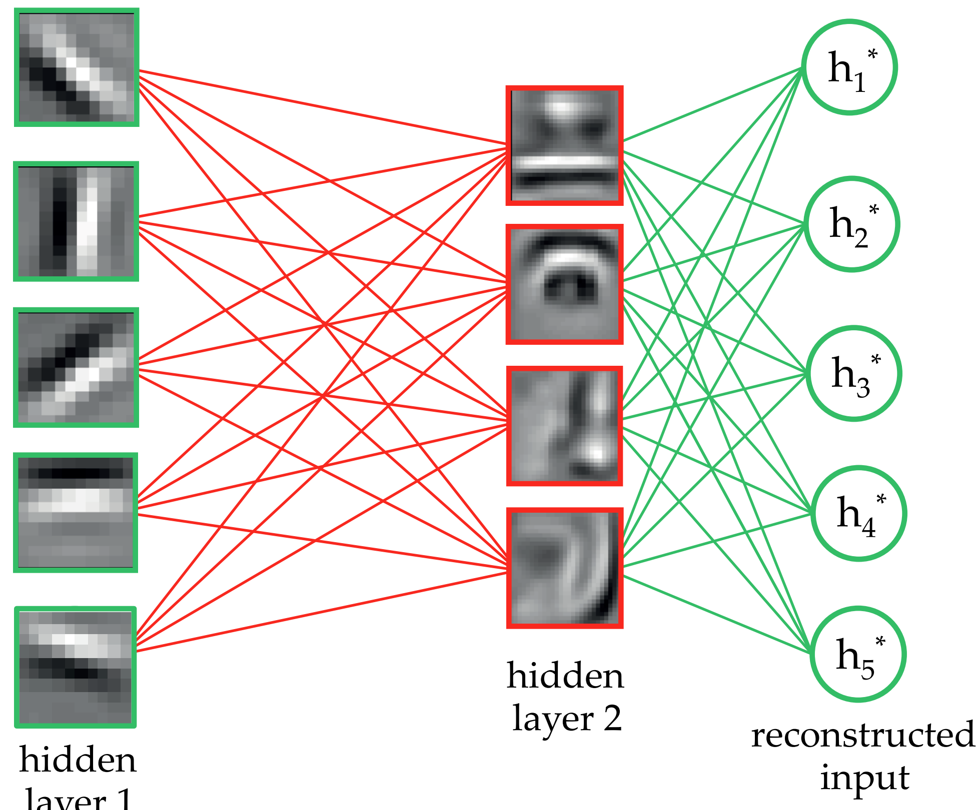

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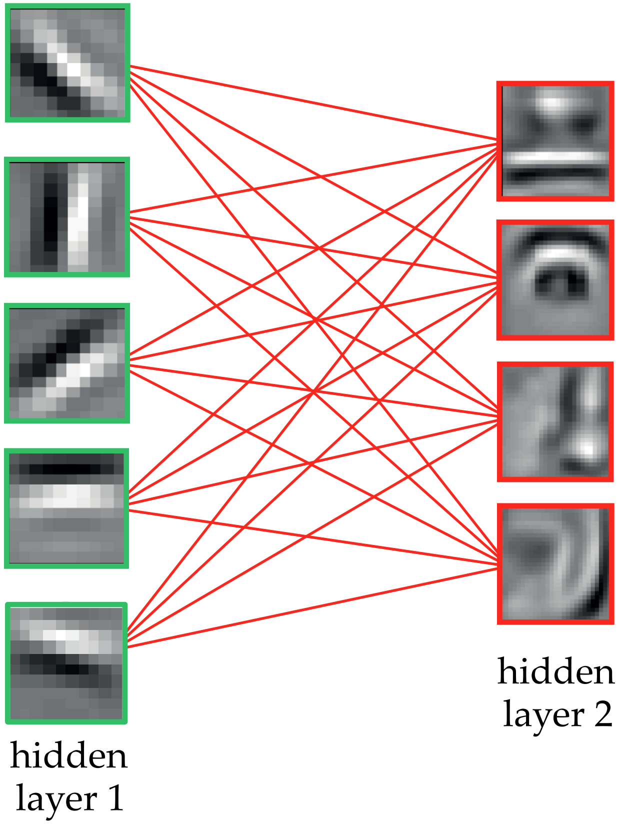

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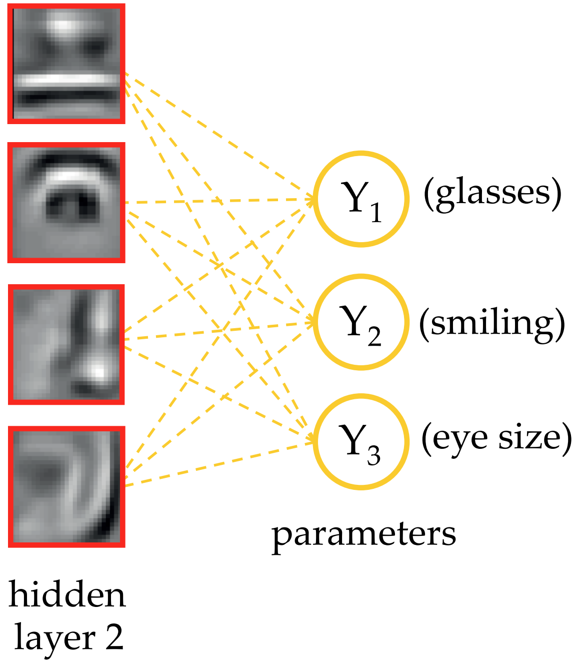
In the last layer, use the outputs (supervised)



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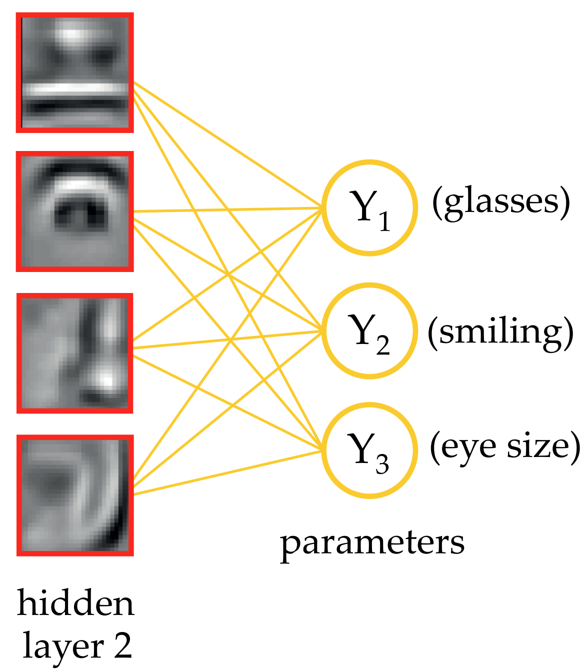
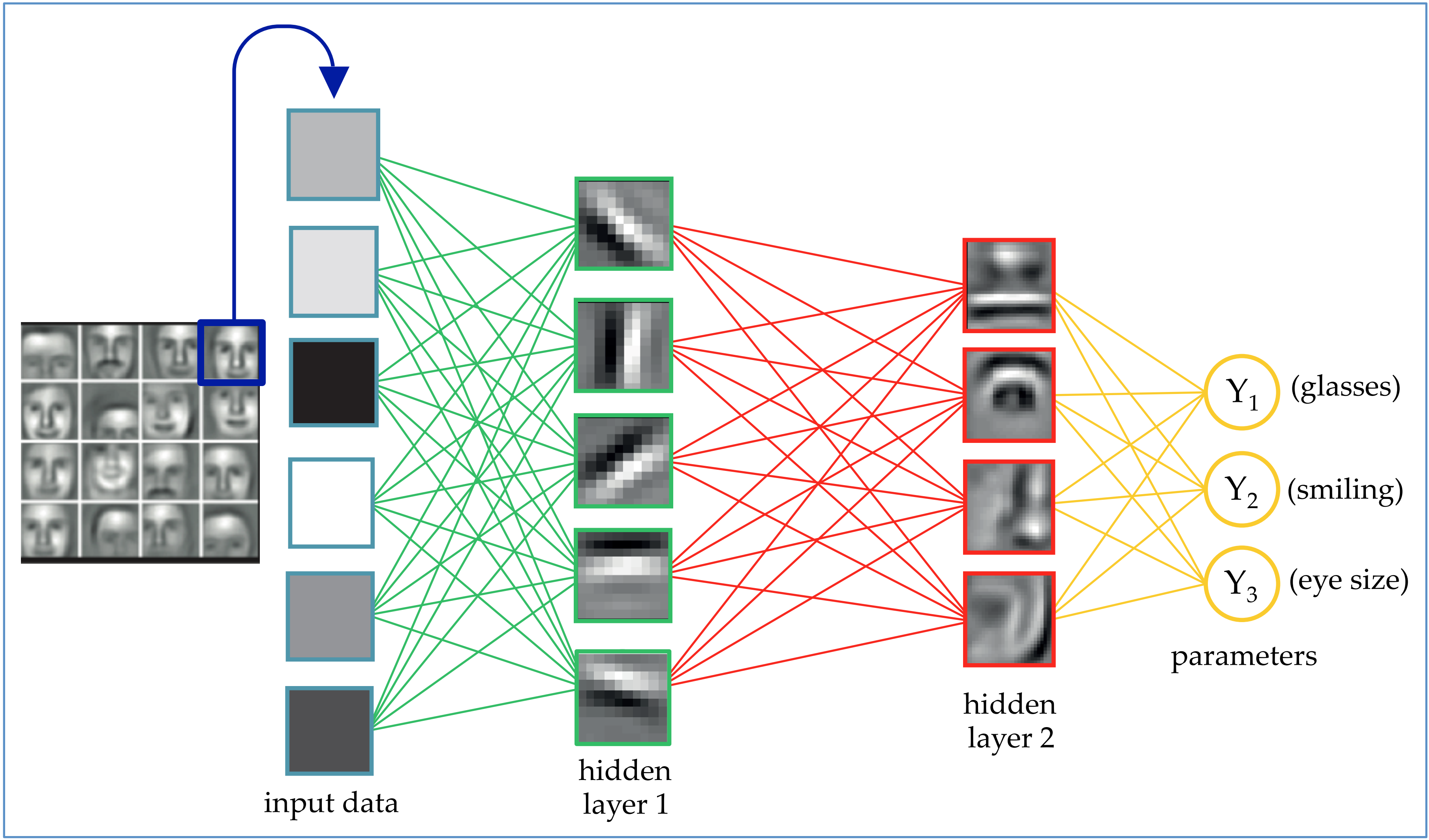


Finally, “fine-tune” the entire network!



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Next time!