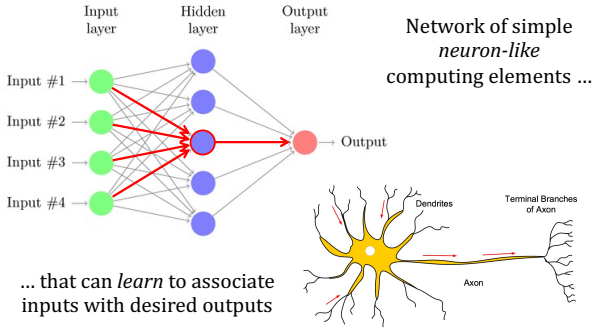
What is an artificial neural network?

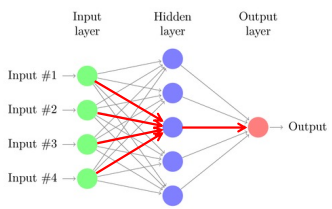


Network of simple *neuron-like* computing elements …

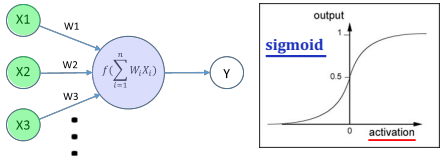
… that can *learn* to associate inputs with desired outputs

1

Artificial neural networks



feedforward processing →



$w_1 * X_1 + w_2 * X_2 + \ldots + w_n * X_n + b > 0$

activation ***bias***

network weights can be ***learned*** from training examples
(mapping from inputs to correct outputs)

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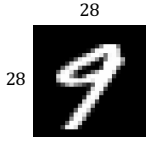
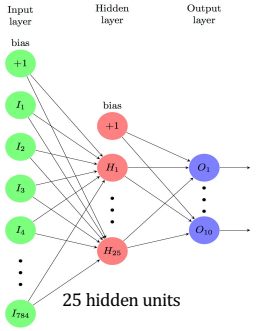
Example: learning handwritten digits

MNIST database:
3000 28x28 images of handwritten digits



sample image from MNIST database



one input unit for each pixel

25 hidden units

one output unit for each digit

select output unit with maximum response
e.g. 9

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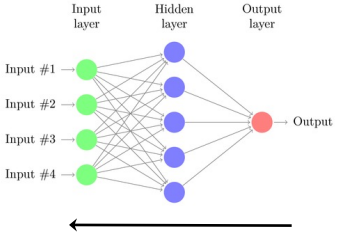
Learning to recognize input patterns

feedforward processing →



← *backpropagation* algorithm to learn network weights

network weights can be ***learned*** from training examples
(mapping from inputs to correct outputs)

backpropagation:
iterative algorithm that progressively reduces error between computed and desired output until performance is satisfactory

on each iteration:

- compute output of current network and assess performance
- compute weight adjustments from hidden to output layer that can reduce output errors
- compute weight adjustments from input to hidden units that can enhance hidden layer
- change network weights, using *rate parameter*

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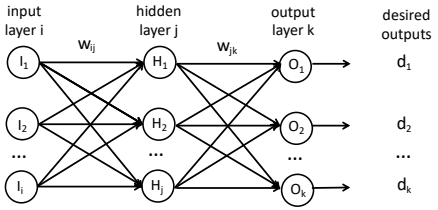
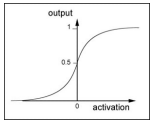
Backpropagation algorithm





$$f(x) = \frac{1}{1+e^{-x}}$$

$f'(x) = f(x) * (1- f(x))$

For each training sample, determine what weight changes would improve performance of the network:

Δw_{jk} = <rate parameter> * <current output of unit H_j> * <slope of O_k> * <benefit of adjusting O_k>

$\Delta w_{jk} = r * H_j * (O_k(1 - O_k)) * (O_k - d_k)$

$\Delta w_{ij} = r * I_i * (H_j(1 - H_j)) * b_j$ < b_j is benefit of adjusting H_j>

$b_j = \Sigma_k w_{jk} * (O_k(1 - O_k)) * (O_k - d_k)$

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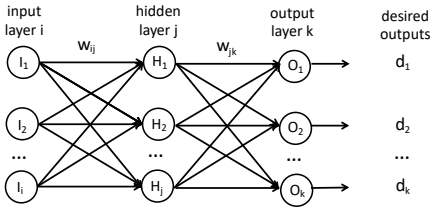
Backpropagation algorithm



note about rate parameter:

- if too small, network may take a very long time to converge
- if too large, network behavior oscillates around best solution

(1) for each training sample, determine all the weight changes Δw_{jk} and Δw_{jk} that would improve performance of the network

(2) add up the weight changes for all training examples and change all the weights at once

(3) repeat steps (1) and (2) until overall performance is satisfactory e.g. *small cost* = $\Sigma_k (O_k - d_k)^2$

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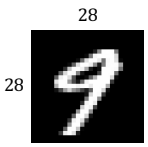
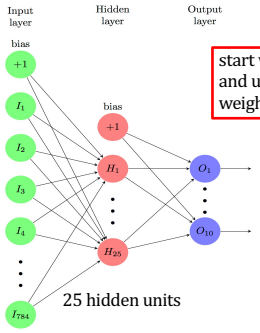
Example: learning handwritten digits

MNIST database:
3000 28x28 images of handwritten digits



sample image from MNIST database



one input unit for each pixel

25 hidden units

start with random initial weights and use backpropagation to learn weights to recognize digits

one output unit for each digit

select output unit with maximum response
e.g. 9

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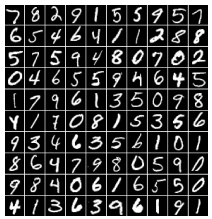
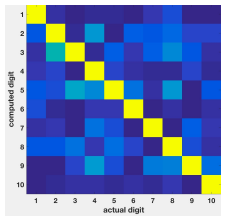
Results: learning handwritten digits



correct examples

wrong examples



confusion matrix

overall classification accuracy: 87.1%

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