AI Theoretical Basics

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Brief History

AI research starting in the fifties of last century

2 main directions:

- "copy" human brain $\rightarrow$ neural networks

  ⚠ needs very much computing power
  short coming up, AI winter, big coming back ...

- logic-based $\rightarrow$ expert systems

  hype in the late eighties of last century

Logic-based (excursus)

Prolog (programming language)

```
% clauses: facts
mother_child(trude, sally).
father_child(tom, sally).
father_child(tom, erica).
father_child(mike, tom).

% clauses: rules
parent_child(X, Y) :-
   father_child(X, Y).
```

```
parent_child(X, Y) :-
   mother_child(X, Y).

sibling(X, Y) :-
   parent_child(Z, X),
   parent_child(Z, Y),
   not(X = Y).

ancestor(X, Y) :-
   parent_child(X, Y).
```

```
ancestor(X, Y) :-
   parent_child(X, Z),
   ancestor(Z, Y).

% queries
?- sibling(sally, erica).
Yes
?- mother_child(trude, X).
X = sally
```

programs work in both directions :-)

Example based on `https://en.wikipedia.org/wiki/Prolog`

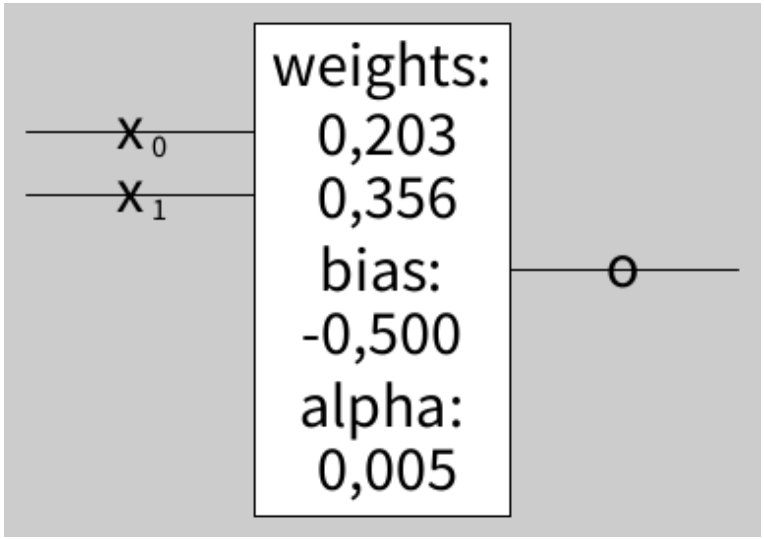
Basic Perceptron

Perceptron (Frank Rosenblatt, 1957): simplified artificial neuronal network

basic version: one artificial neuron

$$o = \begin{cases} 1, & \sum_i w_i \cdot x_i + b > 0 \\ 0, & \text{else} \end{cases}$$

w_i: weights, x_i: inputs, b: bias, o: output

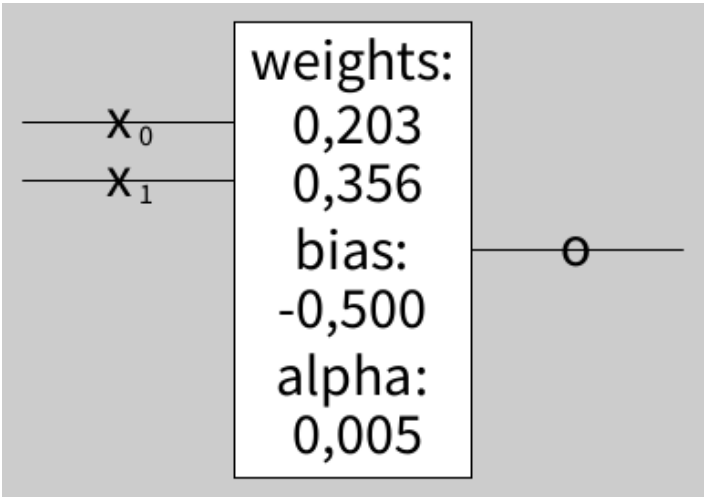


learning = "correctly" adjusting weights

$$w_i^{\text{new}} = w_i^{\text{old}} + \underbrace{\alpha \cdot (t - o) \cdot x_i}_{\Delta w_i}$$

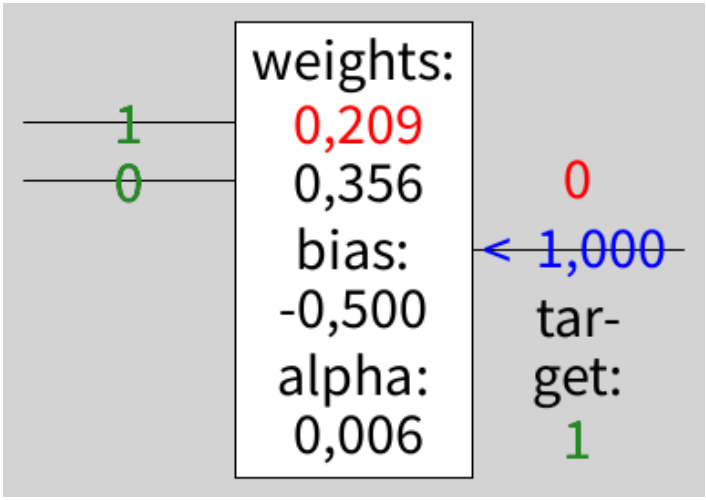
α: learning rate, t: target (correct output)

Train it (1)



OR:

x_1	x_0	t
0	0	0
0	1	1
1	0	1
1	1	1



Train it (2) / limitations of the basic perceptron

AND:

x_1	x_0	t
0	0	0
0	1	0
1	0	0
1	1	1

XOR:

x_1	x_0	t
0	0	0
0	1	1
1	0	1
1	1	0

?

⚠ sometimes it does not convergate, instead it oscillates

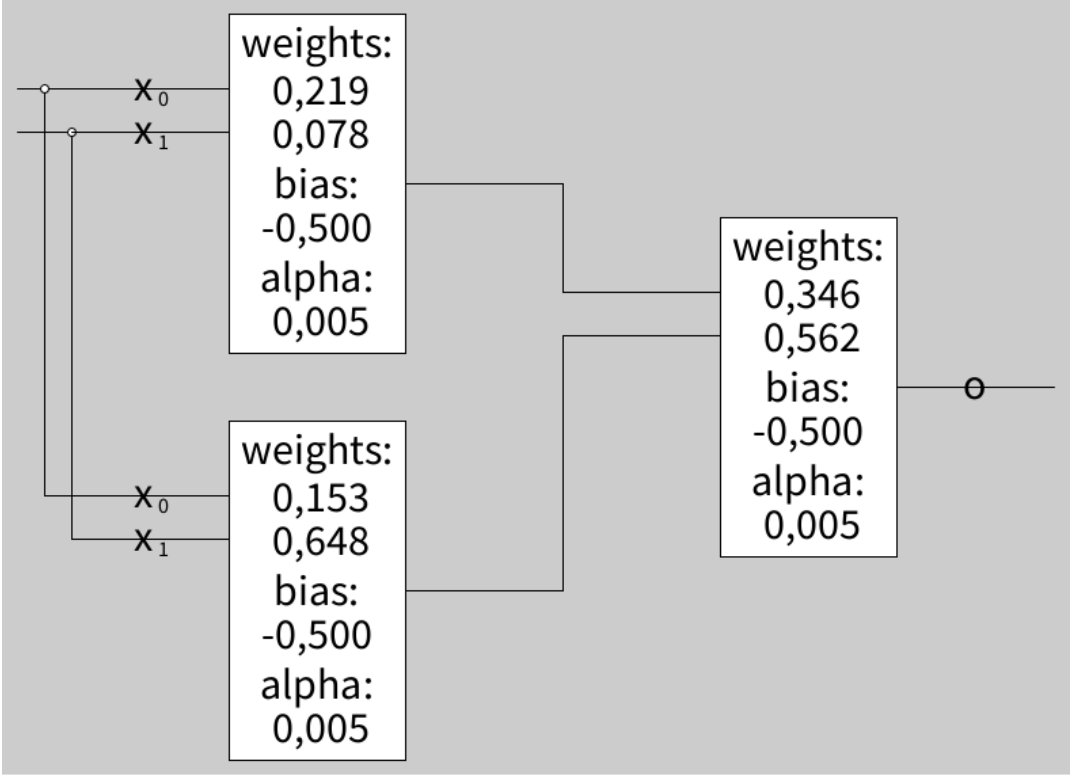
The following might help:

- sending training data not round robin
- varying alpha

But not in all cases — esp. XOR. :-(

Multi-Layer-Perceptron

several artificial neurons in multiple layers



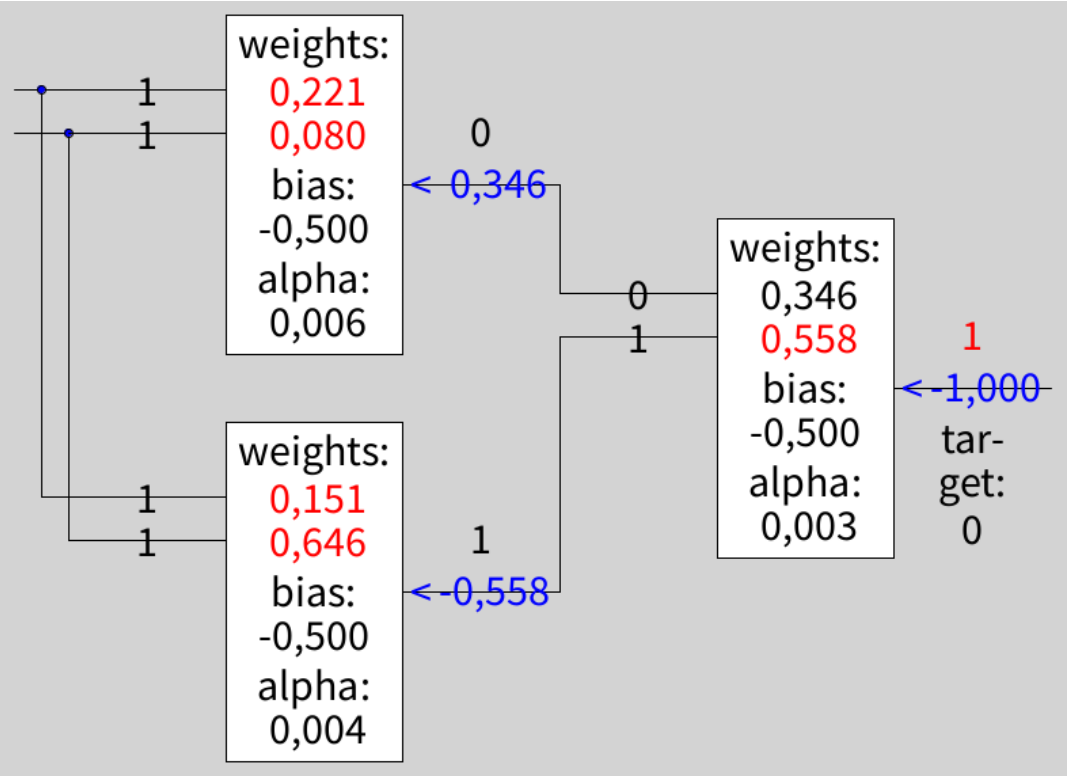
Train it:

$$w_i^{\text{new}} = w_i^{\text{old}} + \underbrace{\alpha \cdot (t - o) \cdot x_i}_{\Delta w_i}$$

– output layer: :-)

– hidden layer(s): t ?

Backpropagation



- use input, calculate forward
- calculate error behind (and adapt weights there)
- propagate error in a clever way back to front (and adapt weights there)

Multi-Layer: different network types

- feedforward neural network
  output can't be input of ahead layers
  ⚠ required for backpropagation

- recurrent neural network
  output can be input of ahead layers
  private crazy idea: make sound with this?

Training data: it's getting great ...

⚠ for each input combination, there is a target value

- 2 inputs $\rightarrow$ 4 input combinations ($\rightarrow$ 16 target functions)

possible input combinations	each column: possible target function (training uses only one of them)						
0, 0	0	0	...	0	0	...	1
0, 1	0	0	...	1	1	...	1
1, 0	0	0	...	1	1	...	1
1, 1	0	1	...	0	1	...	1
		AND		XOR	OR		

- 3 inputs $\rightarrow$ 8 input combinations ($\rightarrow$ 256 target functions)
- 4 inputs $\rightarrow$ 16 input combinations ($\rightarrow$ 65536 target functions)
- n inputs $\rightarrow$ 2^n input combinations ($\rightarrow$ $2^{(2^n)}$ target functions)

text input, just 50 letters, ...

Supervised vs. Unsupervised Learning

as above, with well known target function: supervised learning

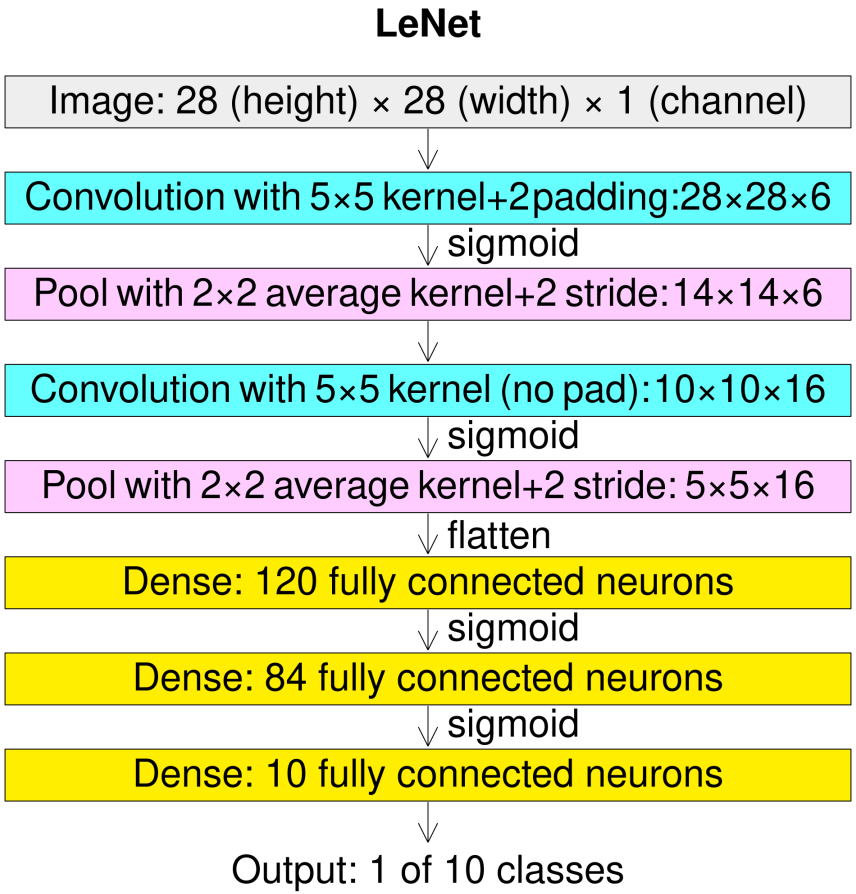
"no" explicit target function: unsupervised learning:

search for even unknown correlations between input data
"target": optimization based on some metric

– segment into clusters
– find outliers
– find principal components (to simplify by dropping the rest)

Convolutional Neural Network

advanced architecture with specialized feedforward subnetworks with spezialized aggregation of their results



- convolution layers:
  combine 2 functions to 1 function
- pooling layers:
  reduce dimensions of data (take max or average of a cluster)
- dense layers:
  fully connected neurons (sigmoid or tanh or ReLu function)

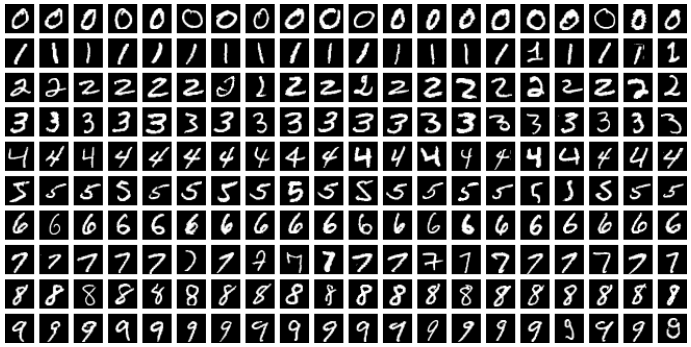
picture source: `https://en.wikipedia.org/wiki/Convolutional_neural_network`

LeNet

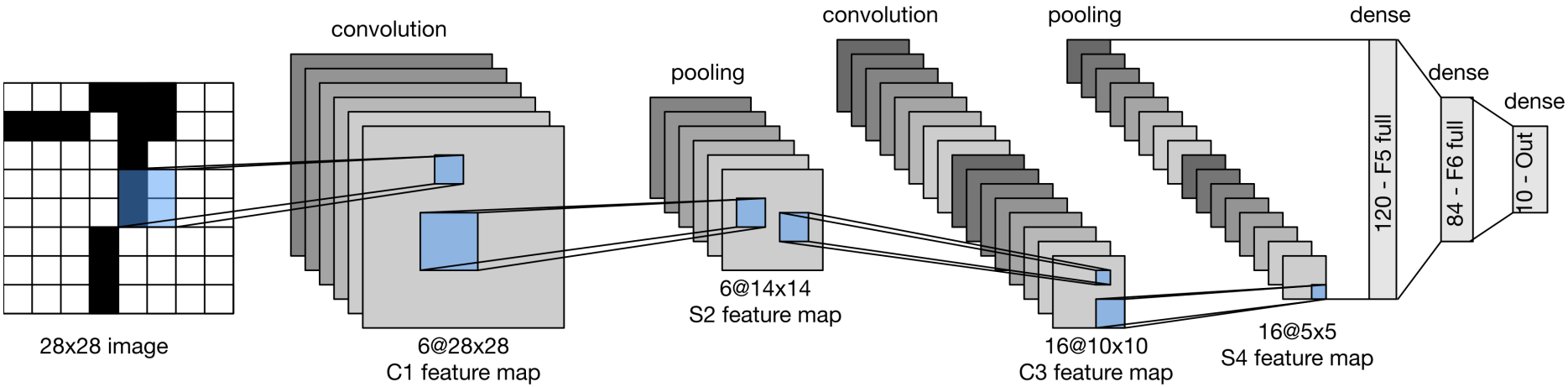
LeNet:

– 1988-1998, AT&T Bell Laboratories

– to identify handwritten digits and letters, esp. in banking applications



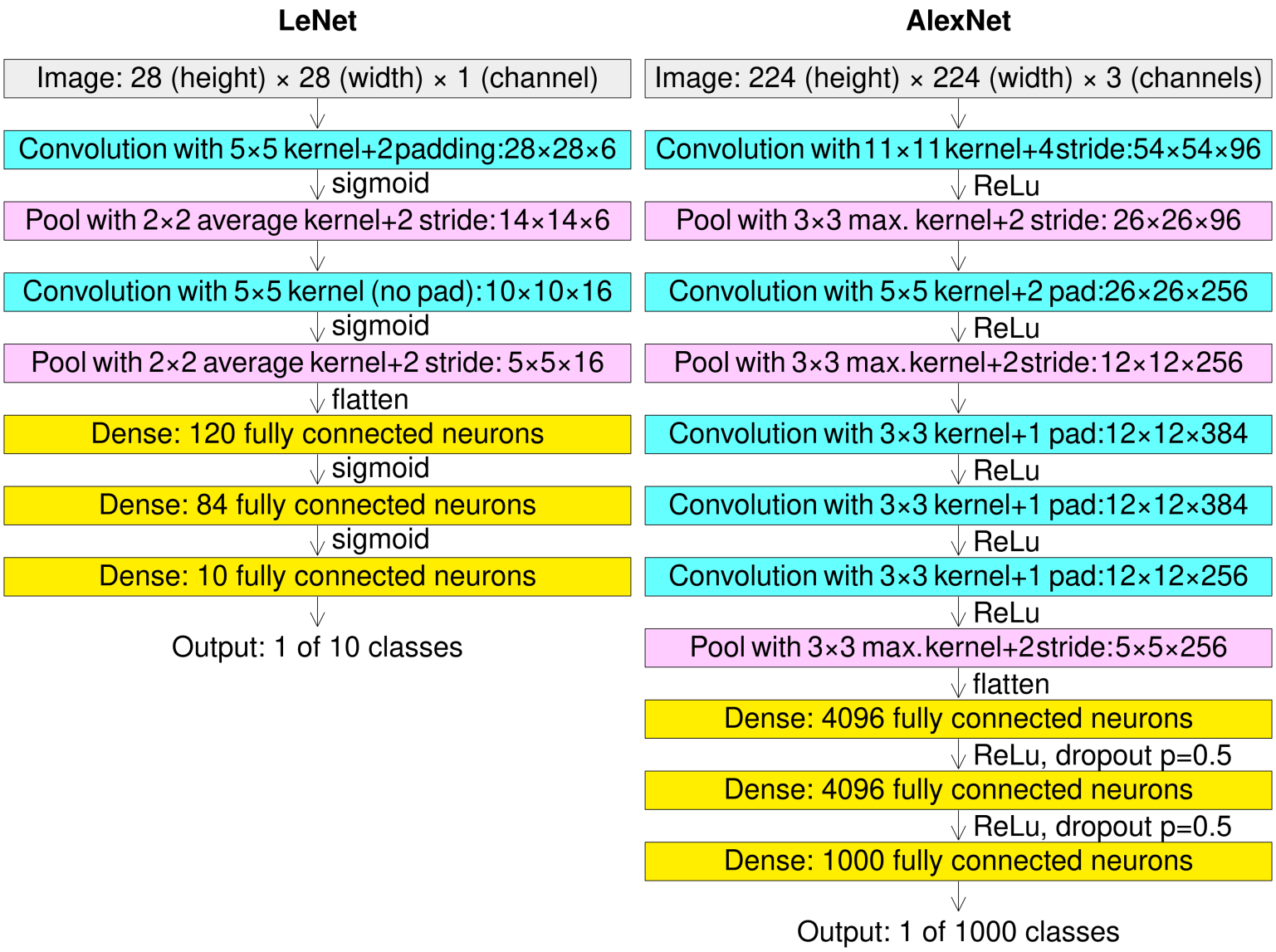
Training data



Architecture

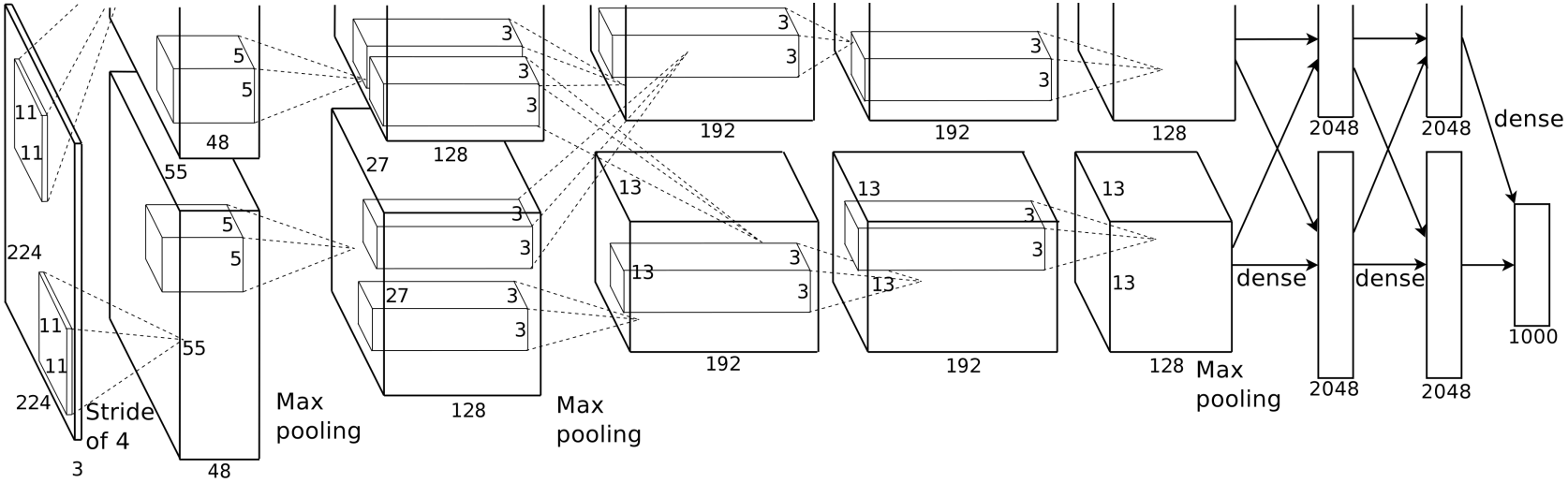
picture sources: `https://en.wikipedia.org/wiki/LeNet`

LeNet (1995) / AlexNet (2012)



source: `https://en.wikipedia.org/wiki/Convolutional_neural_network`

AlexNet



picture source: `https://en.wikipedia.org/wiki/AlexNet`

– 2012, University of Toronto

– for image classification tasks, wins a contest and influenced a large number of subsequent work

– training set: 1.2 million images, training for 90 epochs, 5 to 6 days
2 Nvidia GPUs (split up due to memory requirements)
each forward pass of AlexNet required approximately 1.43 GFLOPs
(theoretically 2,200 forward passes per second possible)