Aula 08 – Redes Neurais Convolucionais

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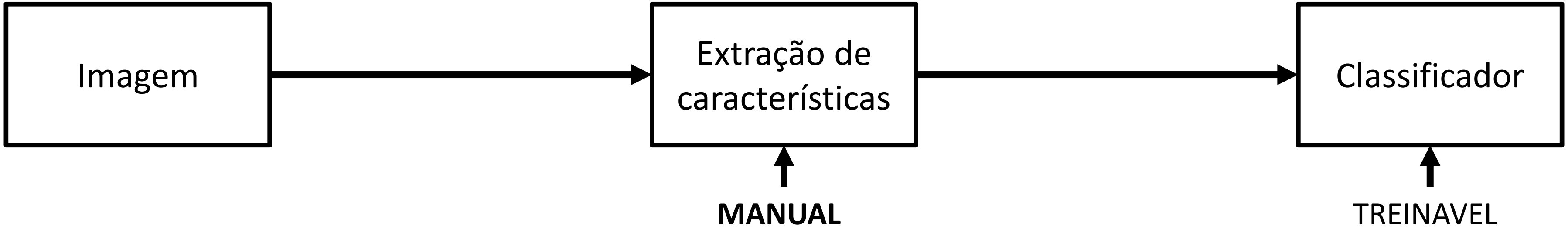
Roteiro

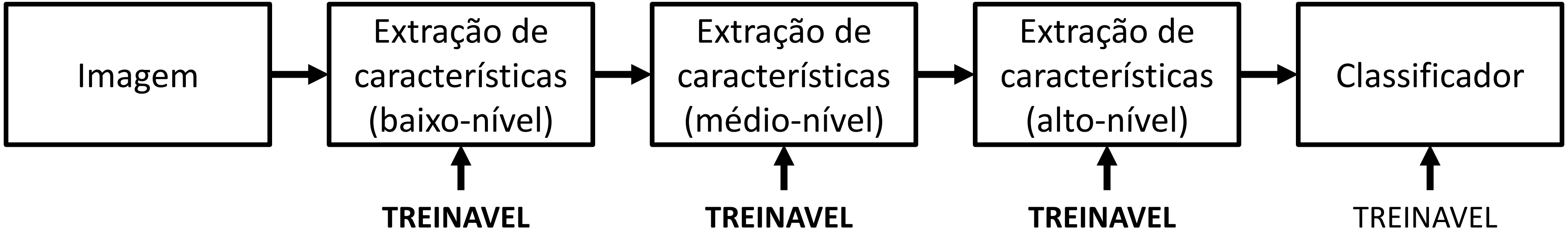
- Pipelines de classificação
- Perceptron de múltiplas camadas (MLP)
- Redes Neurais Convolucionais (CNNs)
- Camada convolucional
- Camada de pooling
- Função de ativação
- Camada completamente conectada
- Camada de saída – softmax
- Função de perda (loss)
- Otimizadores
- Arquiteturas
- Bibliotecas e desenvolvimento
- Conjuntos de imagens

Pipelines de classificação

Pipeline clássico de classificação de imagens

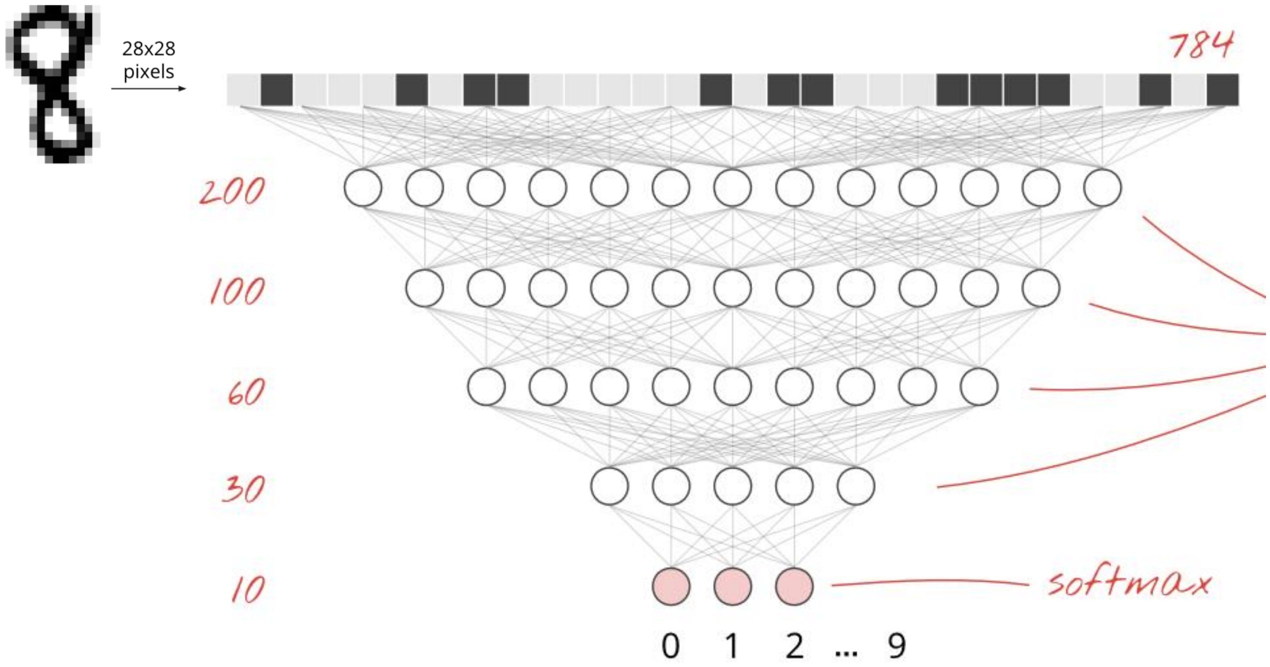


Deep Learning



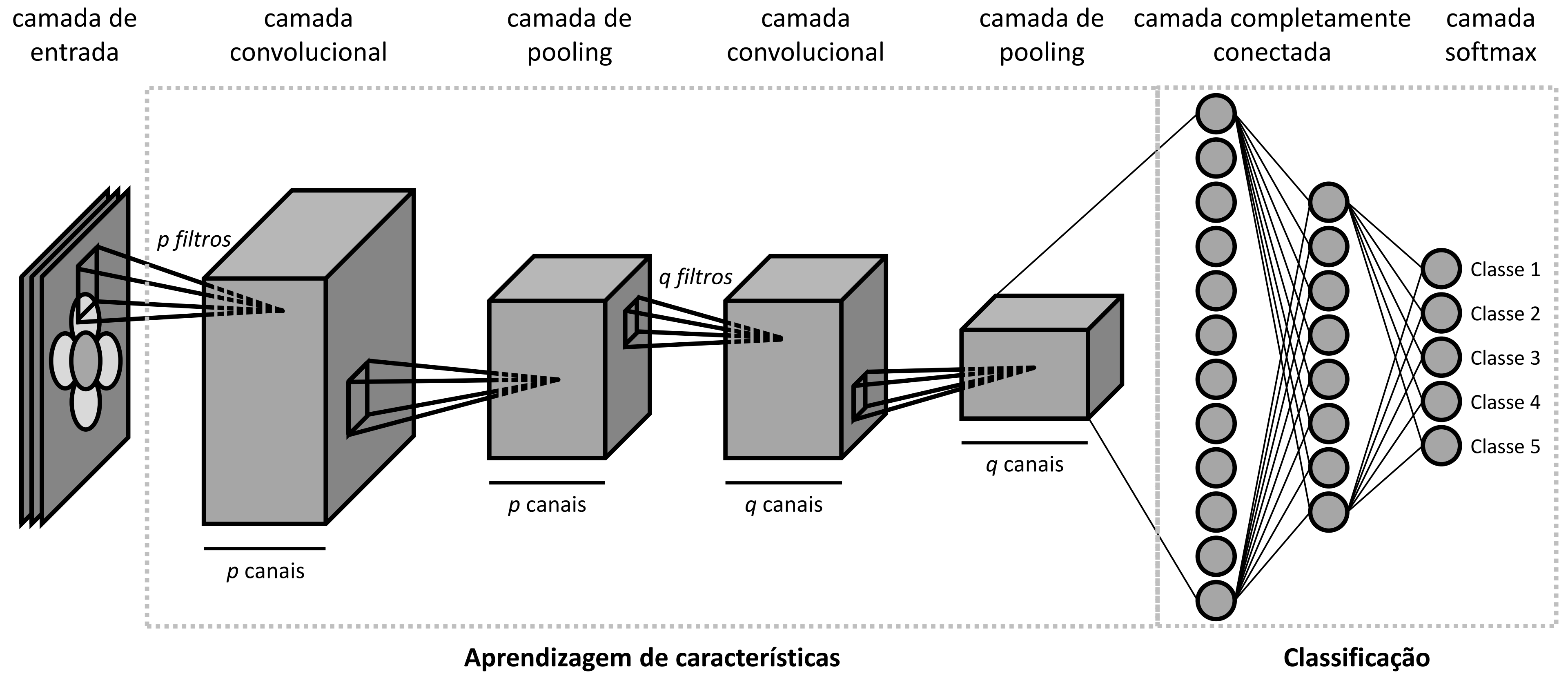
Yann LeCun's Deep Learning Course at CDS - SPRING 2021

Perceptron de múltiplas camadas (MLP)



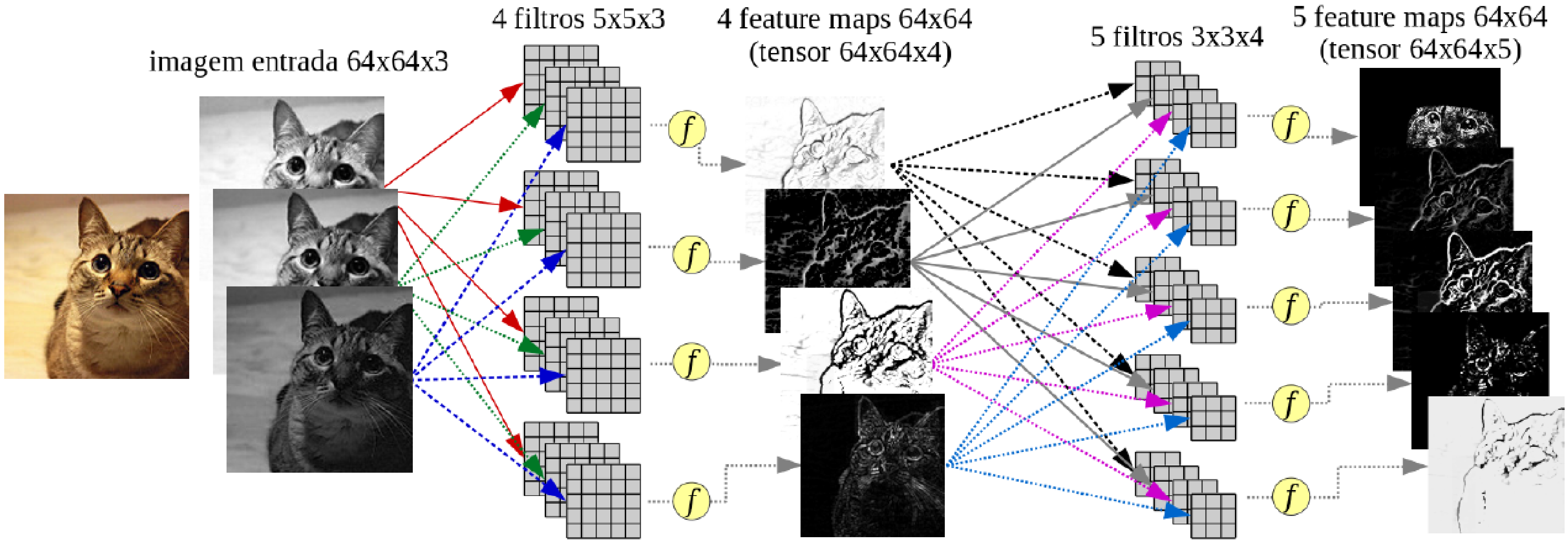
Learn TensorFlow and deep learning, without a Ph.D.

Redes Neurais Convolucionais (CNNs)



CAMADA CONVOLUCIONAL

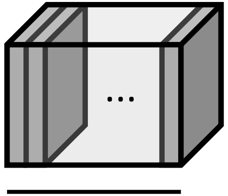
Camada convolucional



Moacir Ponti. http://conteudo.icmc.usp.br/pessoas/moacir/p17sibgrapi-tutorial/

Camada convolucional

M^{l-1}

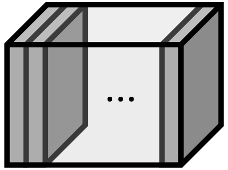


D canais

Camada convolucional

Camada convolucional C^l

M^{l-1}

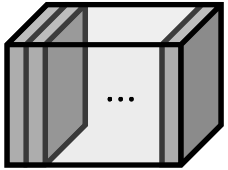


k=1

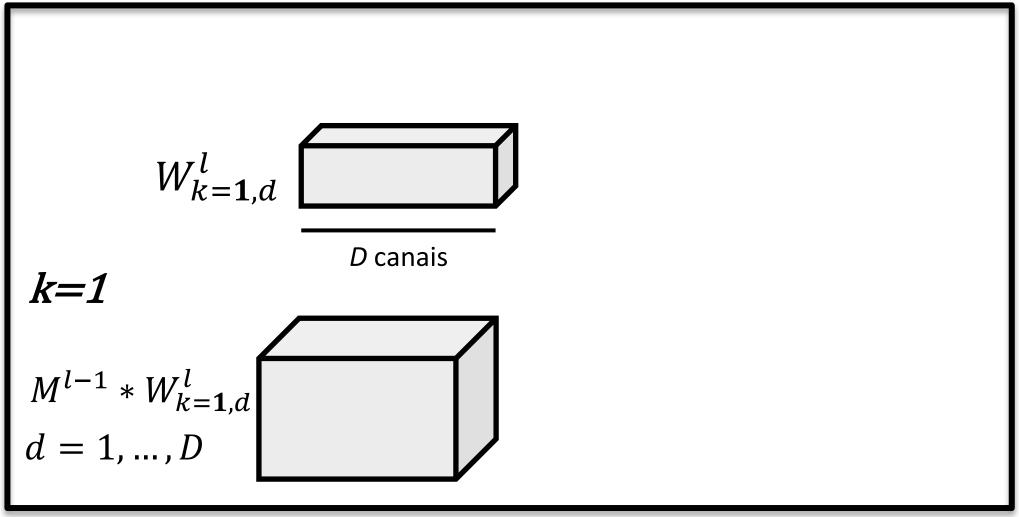
Camada convolucional

Camada convolucional C^l

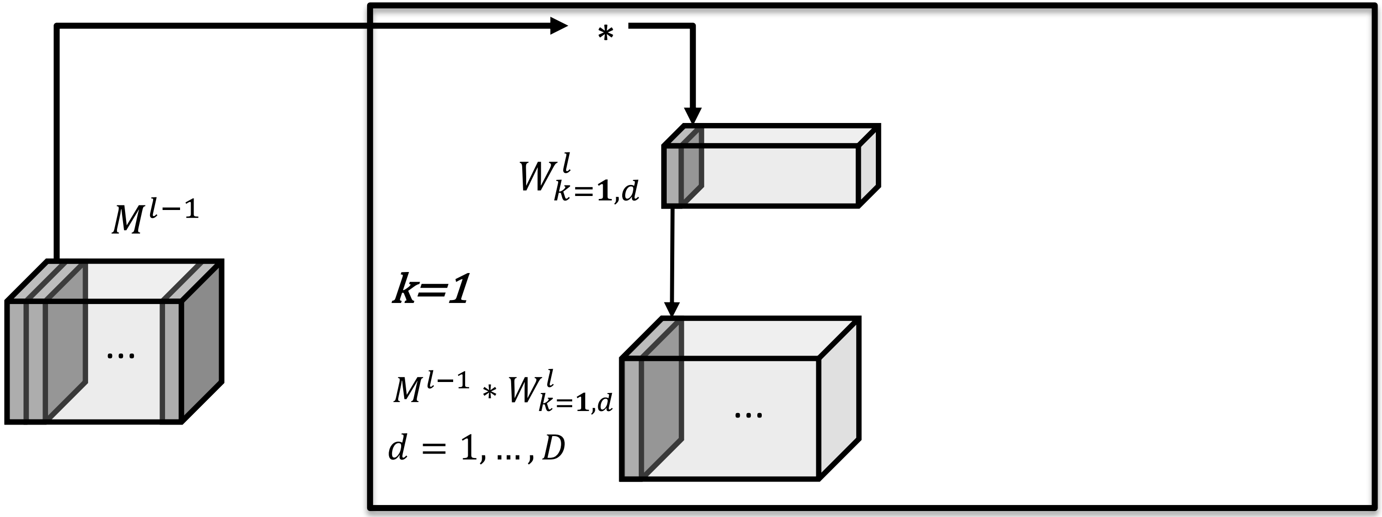
M^{l-1}



D canais

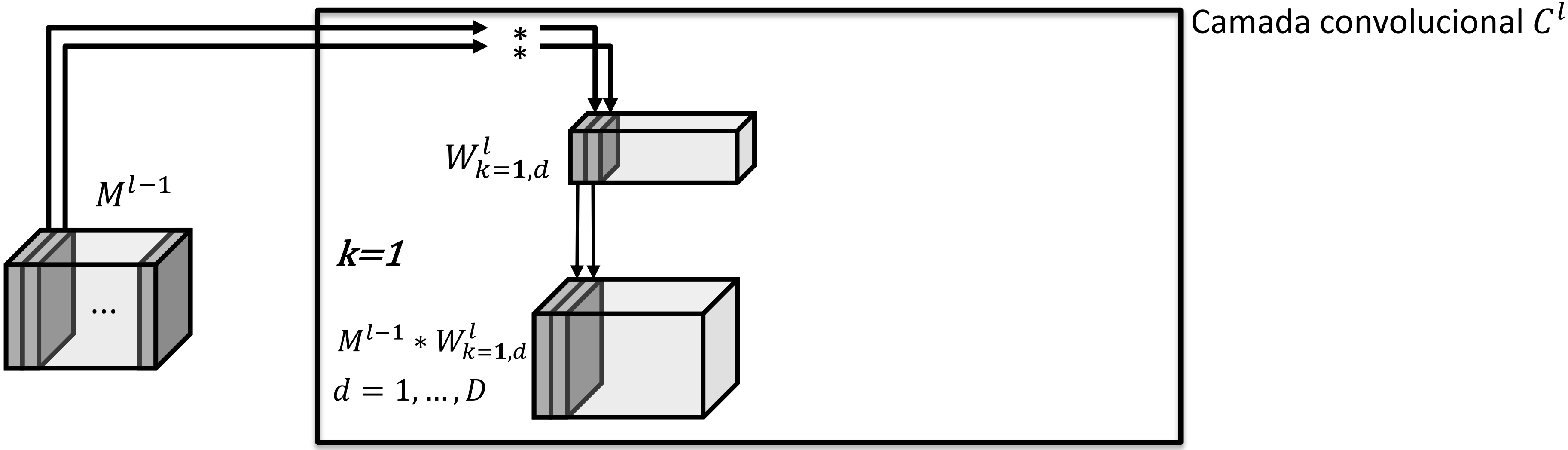


Camada convolucional

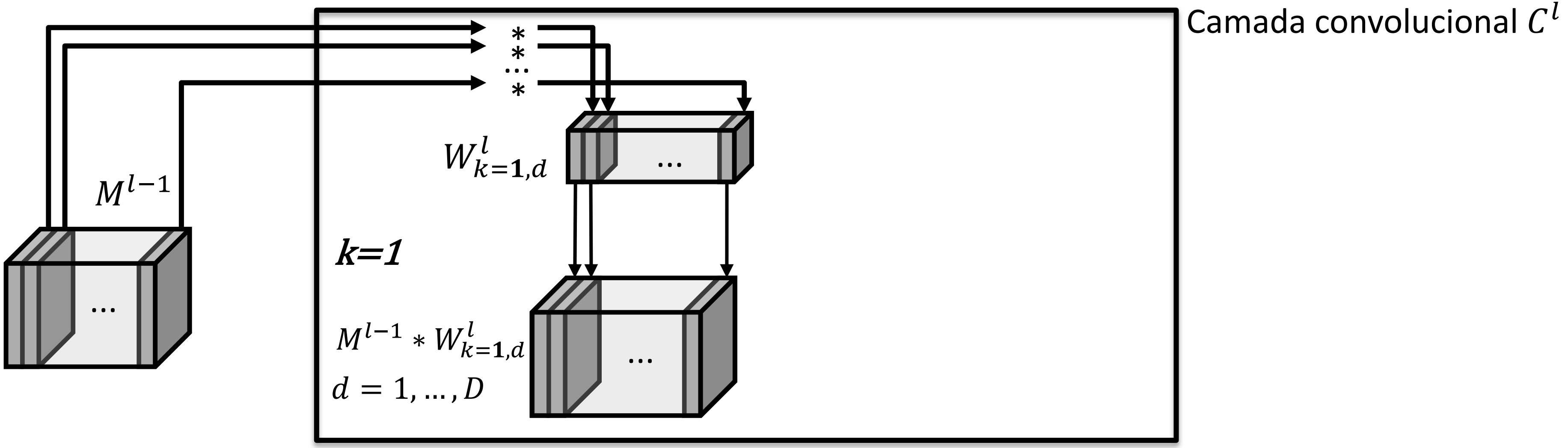


Camada convolucional C^l

Camada convolucional

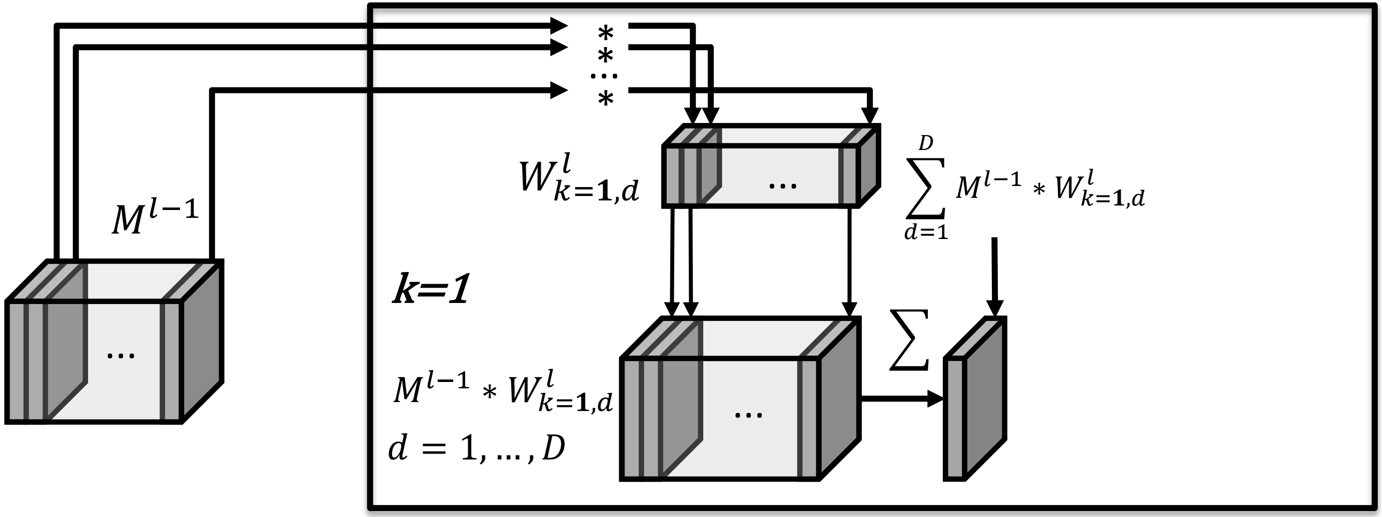


Camada convolucional

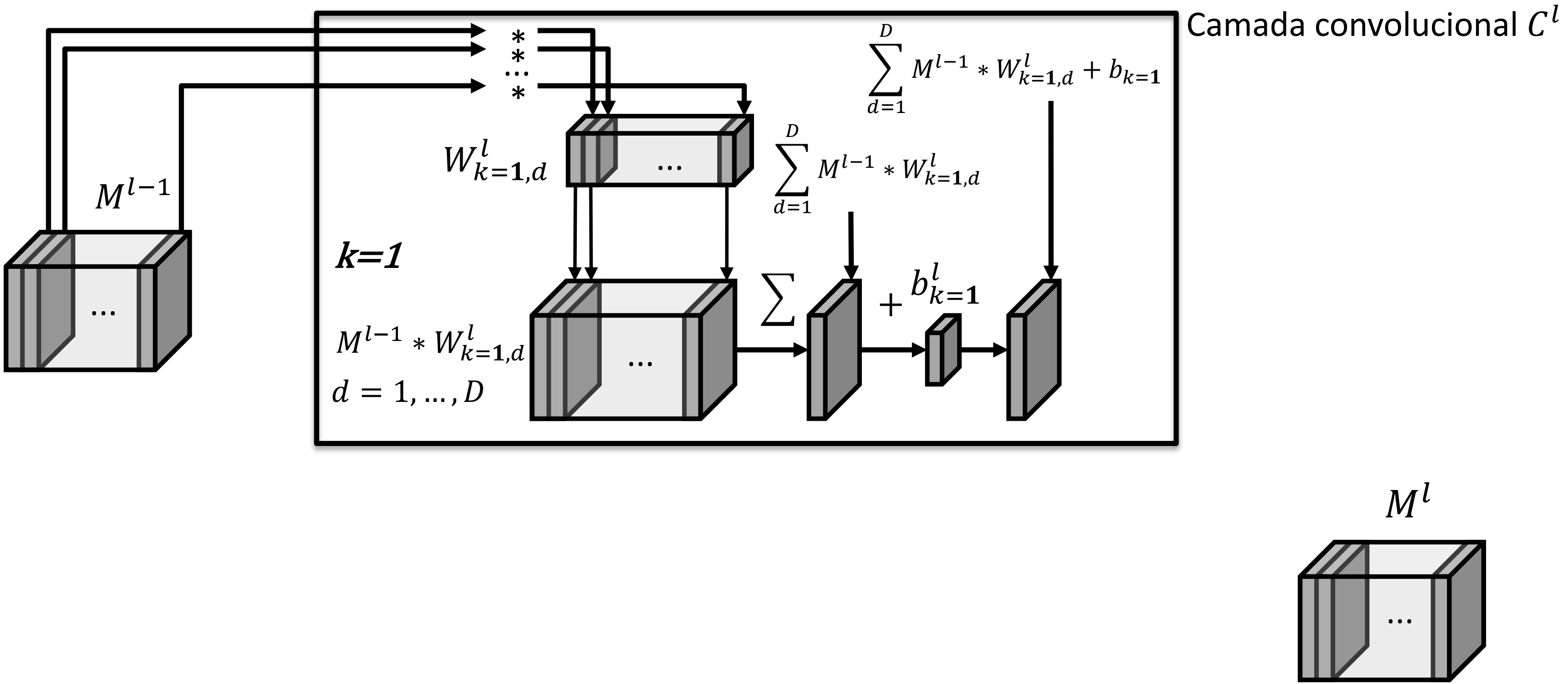


Camada convolucional

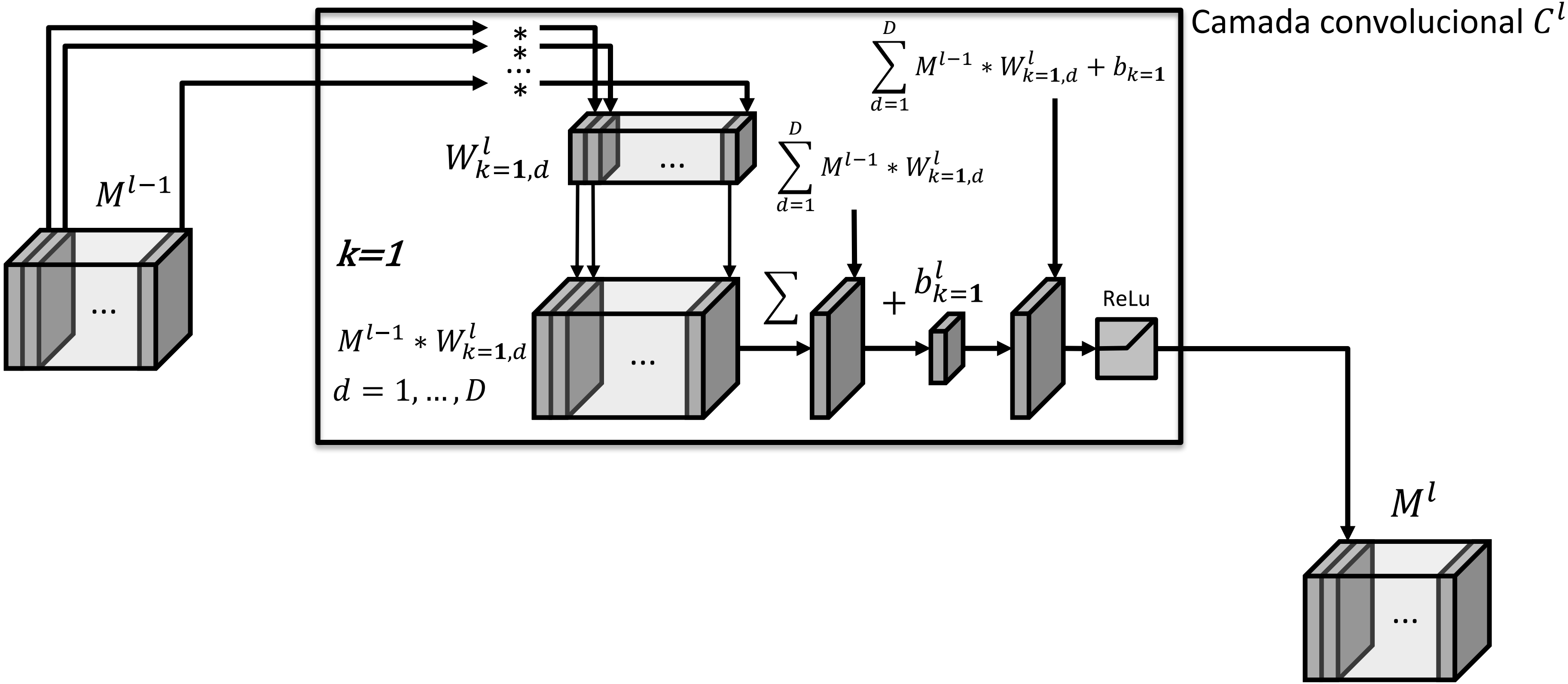
Camada convolucional C^l

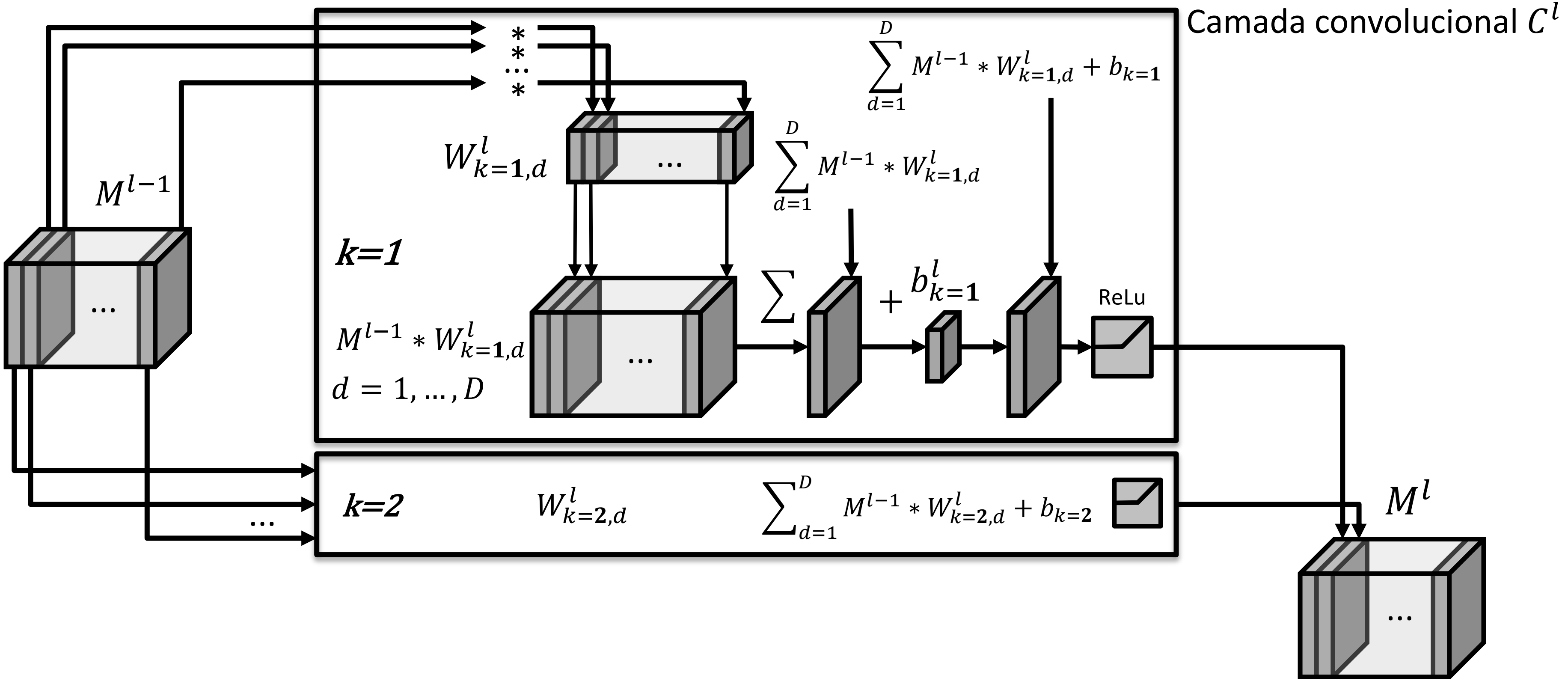


Camada convolucional

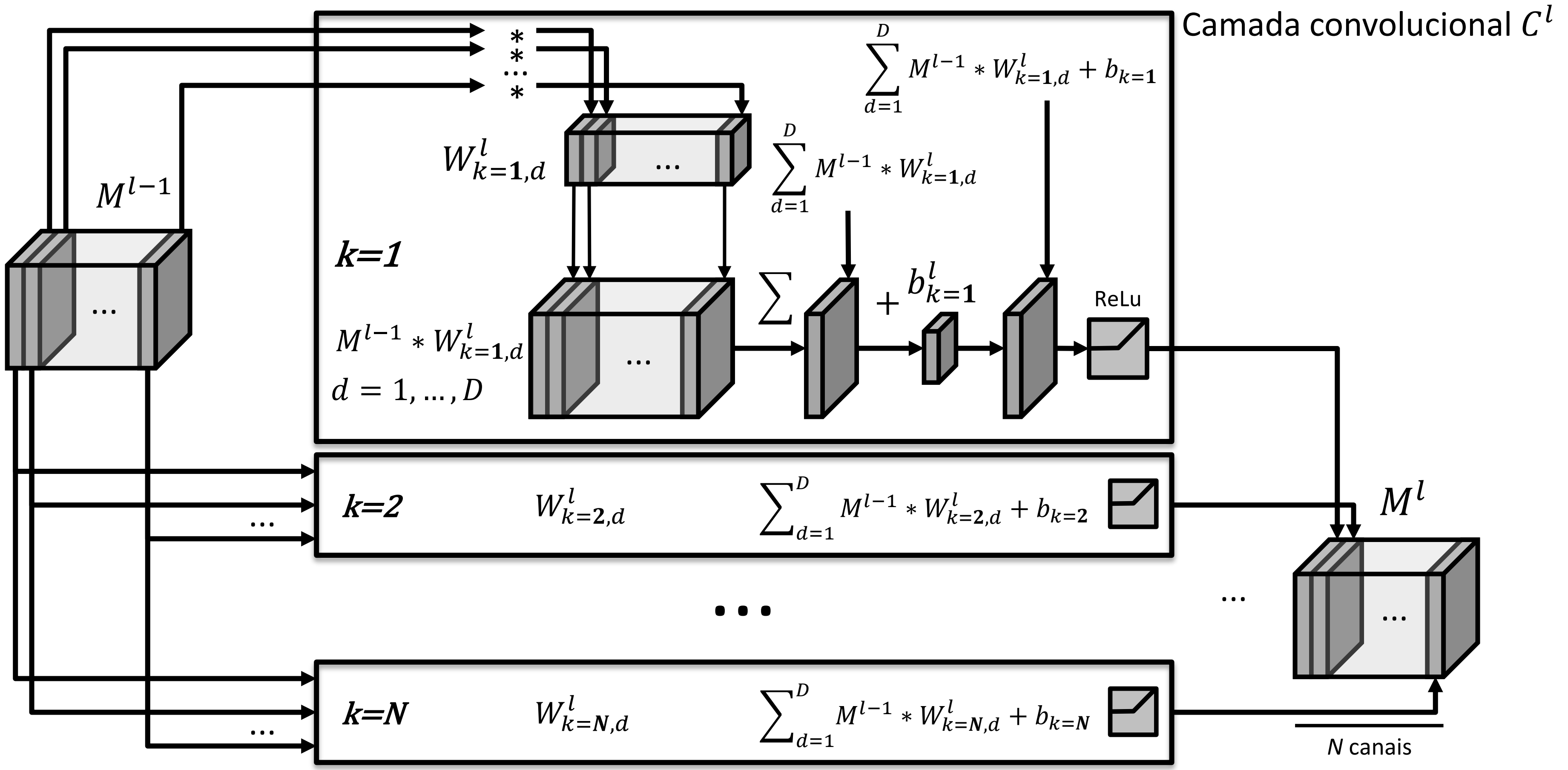


Camada convolucional




Camada convolucional C^l
$\sum_{d=1}^{D} M^{l-1} * W^l_{k=\mathbf{1},d} + b_{k=\mathbf{1}}$
$W^l_{k=\mathbf{1},d}$
$\sum_{d=1}^{D} M^{l-1} * W^l_{k=\mathbf{1},d}$
M^{l-1}
k=1
$\sum$
$+\ b^l_{k=\mathbf{1}}$
ReLu
$M^{l-1} * W^l_{k=\mathbf{1},d}$
$d = 1, \ldots, D$
k=2
$W^l_{k=\mathbf{2},d}$
$\sum_{d=1}^{D} M^{l-1} * W^l_{k=\mathbf{2},d} + b_{k=\mathbf{2}}$
M^l

Camada convolucional



Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

x[:,:,1] * w0[:,:,1]

x[:,:,2] * w0[:,:,2]

b0

1

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

x[:,:,1] * w1[:,:,1]

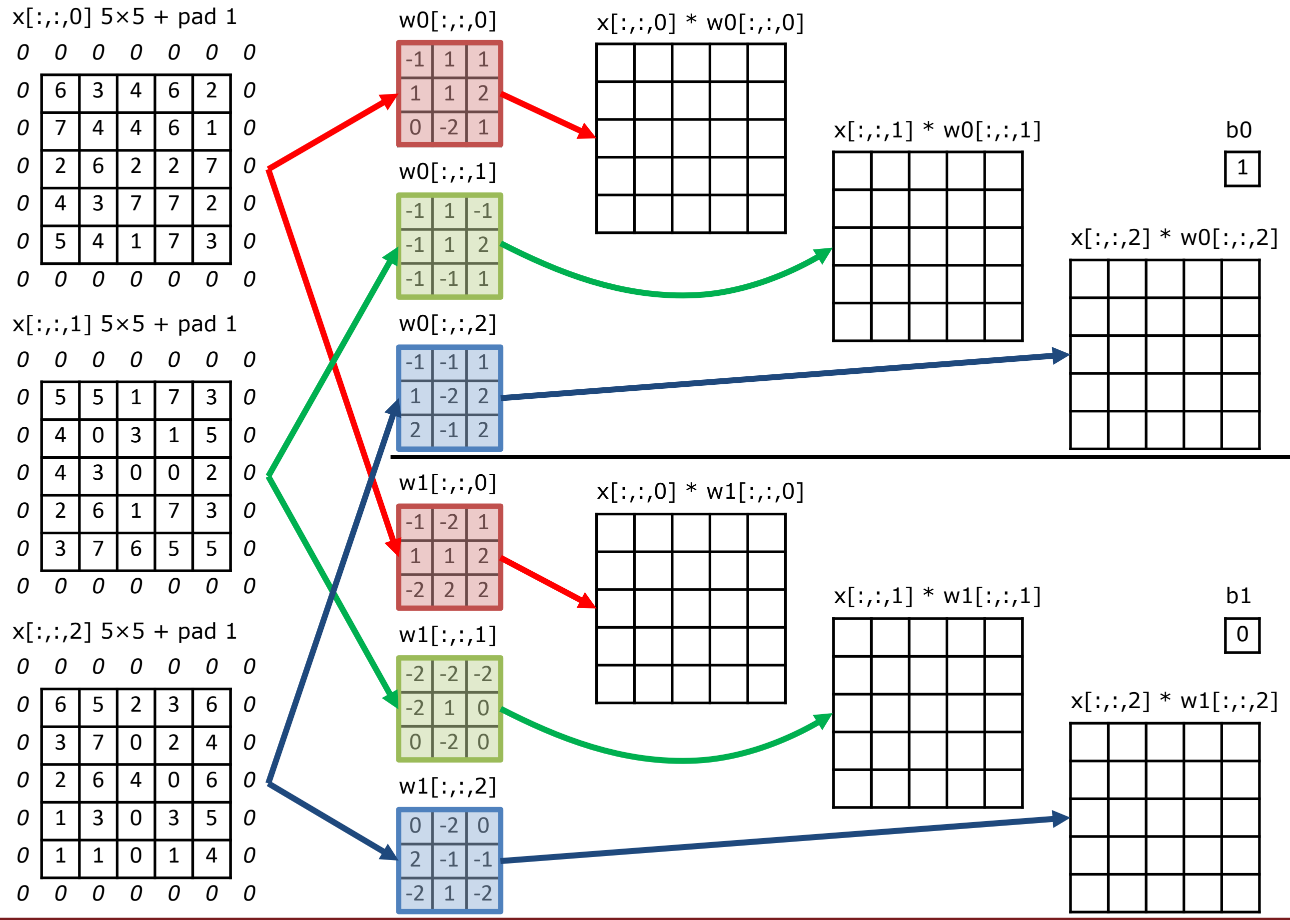
x[:,:,2] * w1[:,:,2]

b1

0

Camada convolucional

https://cs231n.github.io/convolutional-networks/



Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

x[:,:,1] * w0[:,:,1]

x[:,:,2] * w0[:,:,2]

b0

1

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

x[:,:,1] * w1[:,:,1]

x[:,:,2] * w1[:,:,2]

b1

0

Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12				

x[:,:,1] * w0[:,:,1]

4				

b0

1

x[:,:,2] * w0[:,:,2]

-17				

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9				

x[:,:,1] * w1[:,:,1]

-13				

b1

0

x[:,:,2] * w1[:,:,2]

-2				

Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26			

x[:,:,1] * w0[:,:,1]

4	7			

x[:,:,2] * w0[:,:,2]

-17	0			

b0

1

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14			

x[:,:,1] * w1[:,:,1]

-13	-11			

x[:,:,2] * w1[:,:,2]

-2	-21			

b1

0

Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18		

x[:,:,1] * w0[:,:,1]

4	7	6		

b0

1

x[:,:,2] * w0[:,:,2]

-17	0	14		

---

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6		

x[:,:,1] * w1[:,:,1]

-13	-11	-21		

b1

0

x[:,:,2] * w1[:,:,2]

-2	-21	-1		

Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18	25	

x[:,:,1] * w0[:,:,1]

4	7	6	-1	

b0

1

x[:,:,2] * w0[:,:,2]

-17	0	14	-2	

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6	7	

x[:,:,1] * w1[:,:,1]

-13	-11	-21	-17	

b1

0

x[:,:,2] * w1[:,:,2]

-2	-21	-1	3	

Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18	25	21

x[:,:,1] * w0[:,:,1]

4	7	6	-1	12

x[:,:,2] * w0[:,:,2]

-17	0	14	-2	-8

b0

1

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6	7	18

x[:,:,1] * w1[:,:,1]

-13	-11	-21	-17	-9

x[:,:,2] * w1[:,:,2]

-2	-21	-1	3	-17

b1

0

Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18	25	21
-5				

x[:,:,1] * w0[:,:,1]

4	7	6	-1	12
-5				

b0

1

x[:,:,2] * w0[:,:,2]

-17	0	14	-2	-8
-3				

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6	7	18
7				

x[:,:,1] * w1[:,:,1]

-13	-11	-21	-17	-9
-20				

b1

0

x[:,:,2] * w1[:,:,2]

-2	-21	-1	3	-17
3				

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x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18	25	21
12				

x[:,:,1] * w0[:,:,1]

4	7	6	-1	12
4				

x[:,:,2] * w0[:,:,2]

-17	0	14	-2	-8
-17				

b0

1

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6	7	18
7				

x[:,:,1] * w1[:,:,1]

-13	-11	-21	-17	-9
-20				

x[:,:,2] * w1[:,:,2]

-2	-21	-1	3	-17
3				

b1

0

Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18	25	21
-5	28	19	4	24
-5	11	15	17	24
4	16	20	26	14
1	16	5	5	20

x[:,:,1] * w0[:,:,1]

4	7	6	-1	12
-5	3	-4	-9	13
-7	15	-10	-2	-6
-15	8	3	-2	15
-12	2	13	3	19

b0

1

x[:,:,2] * w0[:,:,2]

-17	0	14	-2	-8
-3	-5	32	11	-10
9	-7	22	12	-14
9	2	17	14	-13
4	-1	15	9	-5

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6	7	18
7	20	20	22	17
3	17	2	22	28
-15	26	27	1	35
11	15	22	36	35

x[:,:,1] * w1[:,:,1]

-13	-11	-21	-17	-9
-20	-30	-7	-27	-5
-26	-15	-34	-28	-28
-38	-34	-49	-31	-21
-15	-17	-6	-19	-1

b1

0

x[:,:,2] * w1[:,:,2]

-2	-21	-1	3	-17
3	-33	-25	-7	-18
-3	-5	-28	-4	-16
-7	-12	-5	-15	-10
-4	-1	-11	0	-6

Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18	25	21
-5	28	19	4	24
-5	11	15	17	24
4	16	20	26	14
1	16	5	5	20

x[:,:,1] * w0[:,:,1]

4	7	6	-1	12
-5	3	-4	-9	13
-7	15	-10	-2	-6
-15	8	3	-2	15
-12	2	13	3	19

b0

1

x[:,:,2] * w0[:,:,2]

-17	0	14	-2	-8
-3	-5	32	11	-10
9	-7	22	12	-14
9	2	17	14	-13
4	-1	15	9	-5

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6	7	18
7	20	20	22	17
3	17	2	22	28
-15	26	27	1	35
11	15	22	36	35

x[:,:,1] * w1[:,:,1]

-13	-11	-21	-17	-9
-20	-30	-7	-27	-5
-26	-15	-34	-28	-28
-38	-34	-49	-31	-21
-15	-17	-6	-19	-1

b1

0

x[:,:,2] * w1[:,:,2]

-2	-21	-1	3	-17
3	-33	-25	-7	-18
-3	-5	-28	-4	-16
-7	-12	-5	-15	-10
-4	-1	-11	0	-6

Camada convolucional

https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	*0*	*0*	*0*	*0*	*0*	*0*
0	6	3	4	6	2	*0*
0	7	4	4	6	1	*0*
0	2	6	2	2	7	*0*
0	4	3	7	7	2	*0*
0	5	4	1	7	3	*0*
0	*0*	*0*	*0*	*0*	*0*	*0*

x[:,:,1] 5×5 + pad 1

0	*0*	*0*	*0*	*0*	*0*	*0*
0	5	5	1	7	3	*0*
0	4	0	3	1	5	*0*
0	4	3	0	0	2	*0*
0	2	6	1	7	3	*0*
0	3	7	6	5	5	*0*
0	*0*	*0*	*0*	*0*	*0*	*0*

x[:,:,2] 5×5 + pad 1

0	*0*	*0*	*0*	*0*	*0*	*0*
0	6	5	2	3	6	*0*
0	3	7	0	2	4	*0*
0	2	6	4	0	6	*0*
0	1	3	0	3	5	*0*
0	1	1	0	1	4	*0*
0	*0*	*0*	*0*	*0*	*0*	*0*

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18	25	21
-5	28	19	4	24
-5	11	15	17	24
4	16	20	26	14
1	16	5	5	20

x[:,:,1] * w0[:,:,1]

4	7	6	-1	12
-5	3	-4	-9	13
-7	15	-10	-2	-6
-15	8	3	-2	15
-12	2	13	3	19

x[:,:,2] * w0[:,:,2]

-17	0	14	-2	-8
-3	-5	32	11	-10
9	-7	22	12	-14
9	2	17	14	-13
4	-1	15	9	-5

b0

1

$\sum$

v[:,:,0]

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6	7	18
7	20	20	22	17
3	17	2	22	28
-15	26	27	1	35
11	15	22	36	35

x[:,:,1] * w1[:,:,1]

-13	-11	-21	-17	-9
-20	-30	-7	-27	-5
-26	-15	-34	-28	-28
-38	-34	-49	-31	-21
-15	-17	-6	-19	-1

x[:,:,2] * w1[:,:,2]

-2	-21	-1	3	-17
3	-33	-25	-7	-18
-3	-5	-28	-4	-16
-7	-12	-5	-15	-10
-4	-1	-11	0	-6

b1

0

$\sum$

v[:,:,1]

Camada convolucional

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https://cs231n.github.io/convolutional-networks/

x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18	25	21
-5	28	19	4	24
-5	11	15	17	24
4	16	20	26	14
1	16	5	5	20

x[:,:,1] * w0[:,:,1]

4	7	6	-1	12
-5	3	-4	-9	13
-7	15	-10	-2	-6
-15	8	3	-2	15
-12	2	13	3	19

x[:,:,2] * w0[:,:,2]

-17	0	14	-2	-8
-3	-5	32	11	-10
9	-7	22	12	-14
9	2	17	14	-13
4	-1	15	9	-5

b0

1

$\sum$

v[:,:,0]

0	34	39	23	35
-12	27	48	7	28
-2	20	28	48	5
-1	27	41	39	17
-6	15	34	18	35

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6	7	18
7	20	20	22	17
3	17	2	22	28
-15	26	27	1	35
11	15	22	36	35

x[:,:,1] * w1[:,:,1]

-13	-11	-21	-17	-9
-20	-30	-7	-27	-5
-26	-15	-34	-28	-28
-38	-34	-49	-31	-21
-15	-17	-6	-19	-1

x[:,:,2] * w1[:,:,2]

-2	-21	-1	3	-17
3	-33	-25	-7	-18
-3	-5	-28	-4	-16
-7	-12	-5	-15	-10
-4	-1	-11	0	-6

b1

0

$\sum$

v[:,:,1]

-24	-18	-16	-7	-8
-10	-43	-12	-12	-6
-26	-3	-60	-10	-16
-60	-20	-27	-45	4
-8	-3	5	17	28

Camada convolucional

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x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18	25	21
-5	28	19	4	24
-5	11	15	17	24
4	16	20	26	14
1	16	5	5	20

x[:,:,1] * w0[:,:,1]

4	7	6	-1	12
-5	3	-4	-9	13
-7	15	-10	-2	-6
-15	8	3	-2	15
-12	2	13	3	19

x[:,:,2] * w0[:,:,2]

-17	0	14	-2	-8
-3	-5	32	11	-10
9	-7	22	12	-14
9	2	17	14	-13
4	-1	15	9	-5

b0

1

∑

v[:,:,0]

0	34	39	23	35
-12	27	48	7	28
-2	20	28	48	5
-1	27	41	39	17
-6	15	34	18	35

f

ReLu

y[:,:,0]

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6	7	18
7	20	20	22	17
3	17	2	22	28
-15	26	27	1	35
11	15	22	36	35

x[:,:,1] * w1[:,:,1]

-13	-11	-21	-17	-9
-20	-30	-7	-27	-5
-26	-15	-34	-28	-28
-38	-34	-49	-31	-21
-15	-17	-6	-19	-1

x[:,:,2] * w1[:,:,2]

-2	-21	-1	3	-17
3	-33	-25	-7	-18
-3	-5	-28	-4	-16
-7	-12	-5	-15	-10
-4	-1	-11	0	-6

b1

0

∑

v[:,:,1]

-24	-18	-16	-7	-8
-10	-43	-12	-12	-6
-26	-3	-60	-10	-16
-60	-20	-27	-45	4
-8	-3	5	17	28

f

ReLu

y[:,:,1]

Camada convolucional

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x[:,:,0] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	3	4	6	2	0
0	7	4	4	6	1	0
0	2	6	2	2	7	0
0	4	3	7	7	2	0
0	5	4	1	7	3	0
0	0	0	0	0	0	0

x[:,:,1] 5×5 + pad 1

0	0	0	0	0	0	0
0	5	5	1	7	3	0
0	4	0	3	1	5	0
0	4	3	0	0	2	0
0	2	6	1	7	3	0
0	3	7	6	5	5	0
0	0	0	0	0	0	0

x[:,:,2] 5×5 + pad 1

0	0	0	0	0	0	0
0	6	5	2	3	6	0
0	3	7	0	2	4	0
0	2	6	4	0	6	0
0	1	3	0	3	5	0
0	1	1	0	1	4	0
0	0	0	0	0	0	0

w0[:,:,0]

-1	1	1
1	1	2
0	-2	1

w0[:,:,1]

-1	1	-1
-1	1	2
-1	-1	1

w0[:,:,2]

-1	-1	1
1	-2	2
2	-1	2

x[:,:,0] * w0[:,:,0]

12	26	18	25	21
-5	28	19	4	24
-5	11	15	17	24
4	16	20	26	14
1	16	5	5	20

x[:,:,1] * w0[:,:,1]

4	7	6	-1	12
-5	3	-4	-9	13
-7	15	-10	-2	-6
-15	8	3	-2	15
-12	2	13	3	19

x[:,:,2] * w0[:,:,2]

-17	0	14	-2	-8
-3	-5	32	11	-10
9	-7	22	12	-14
9	2	17	14	-13
4	-1	15	9	-5

b0

1

$\sum$

v[:,:,0]

0	34	39	23	35
-12	27	48	7	28
-2	20	28	48	5
-1	27	41	39	17
-6	15	34	18	35

f

ReLu

y[:,:,0]

0	34	39	23	35
0	27	48	7	28
0	20	28	48	5
0	27	41	39	17
0	15	34	18	35

w1[:,:,0]

-1	-2	1
1	1	2
-2	2	2

w1[:,:,1]

-2	-2	-2
-2	1	0
0	-2	0

w1[:,:,2]

0	-2	0
2	-1	-1
-2	1	-2

x[:,:,0] * w1[:,:,0]

-9	14	6	7	18
7	20	20	22	17
3	17	2	22	28
-15	26	27	1	35
11	15	22	36	35

x[:,:,1] * w1[:,:,1]

-13	-11	-21	-17	-9
-20	-30	-7	-27	-5
-26	-15	-34	-28	-28
-38	-34	-49	-31	-21
-15	-17	-6	-19	-1

x[:,:,2] * w1[:,:,2]

-2	-21	-1	3	-17
3	-33	-25	-7	-18
-3	-5	-28	-4	-16
-7	-12	-5	-15	-10
-4	-1	-11	0	-6

b1

0

$\sum$

v[:,:,1]

-24	-18	-16	-7	-8
-10	-43	-12	-12	-6
-26	-3	-60	-10	-16
-60	-20	-27	-45	4
-8	-3	5	17	28

f

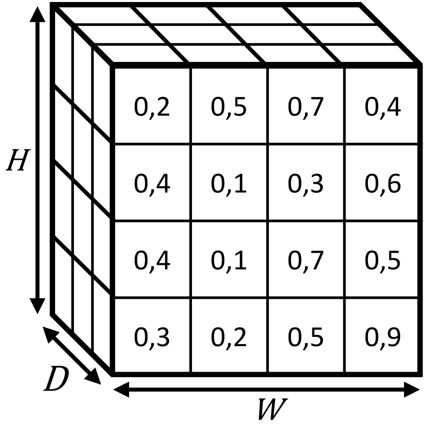
ReLu

y[:,:,1]

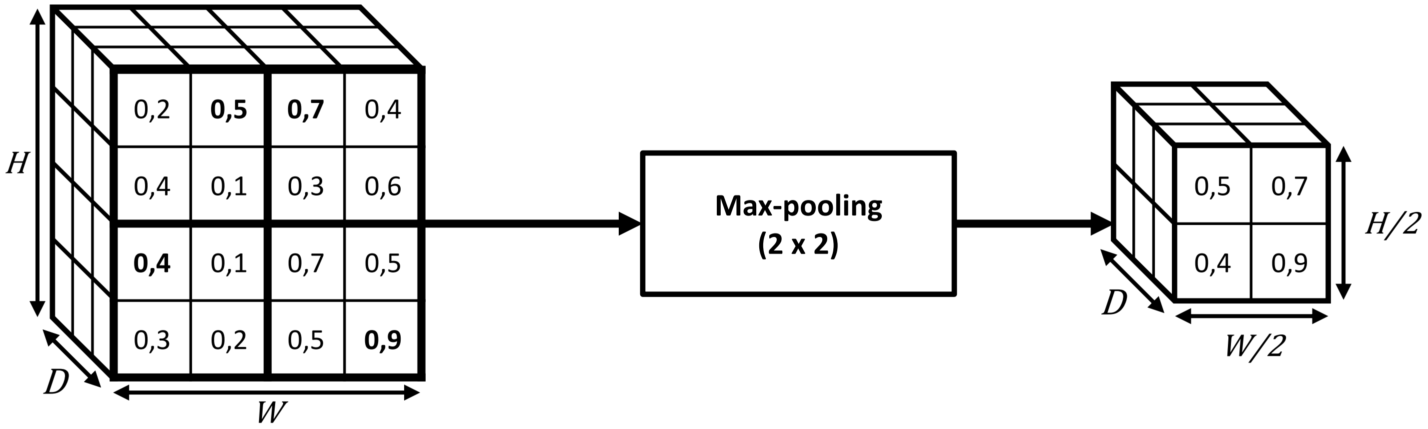
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	4
0	0	5	17	28

CAMADA DE POOLING

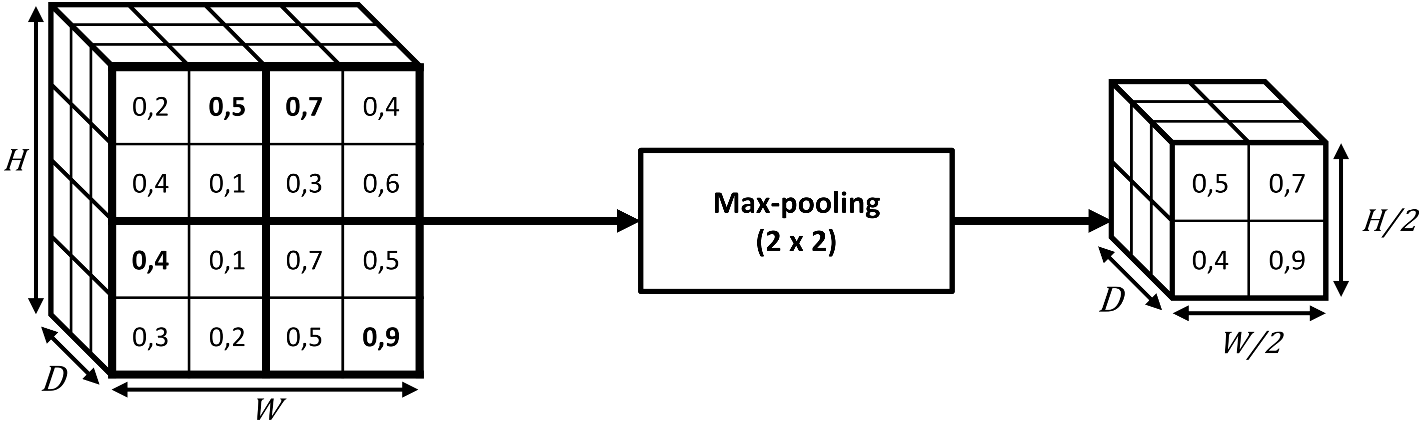
Camada de pooling

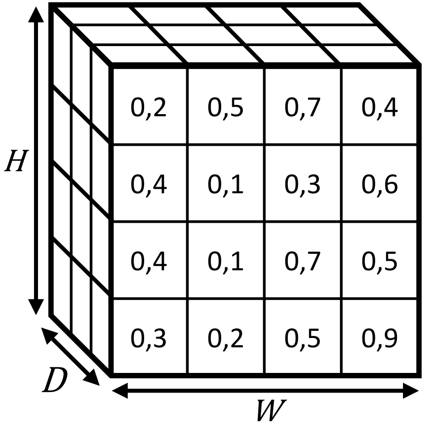


Camada de pooling

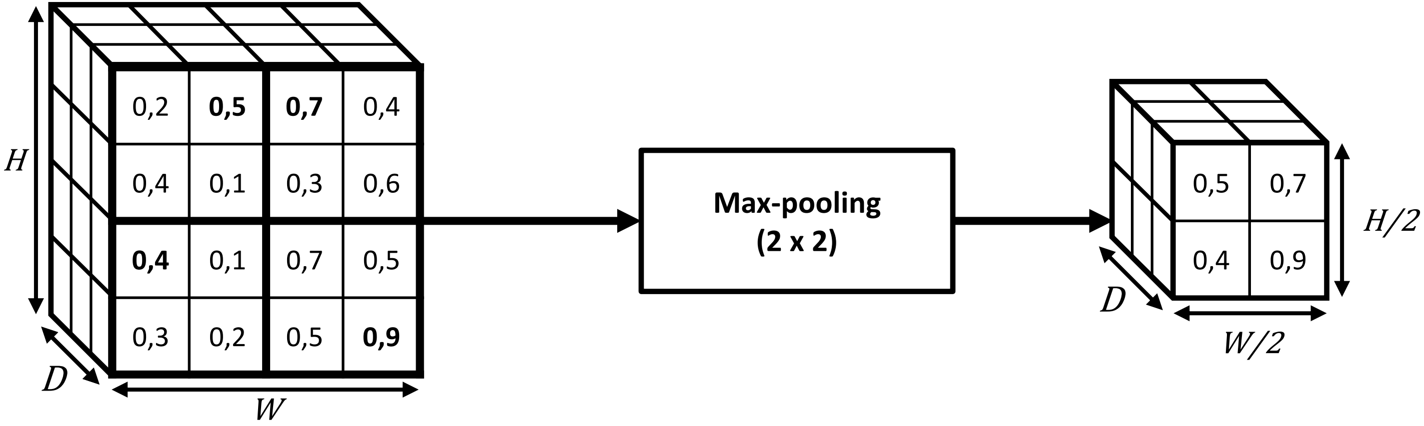


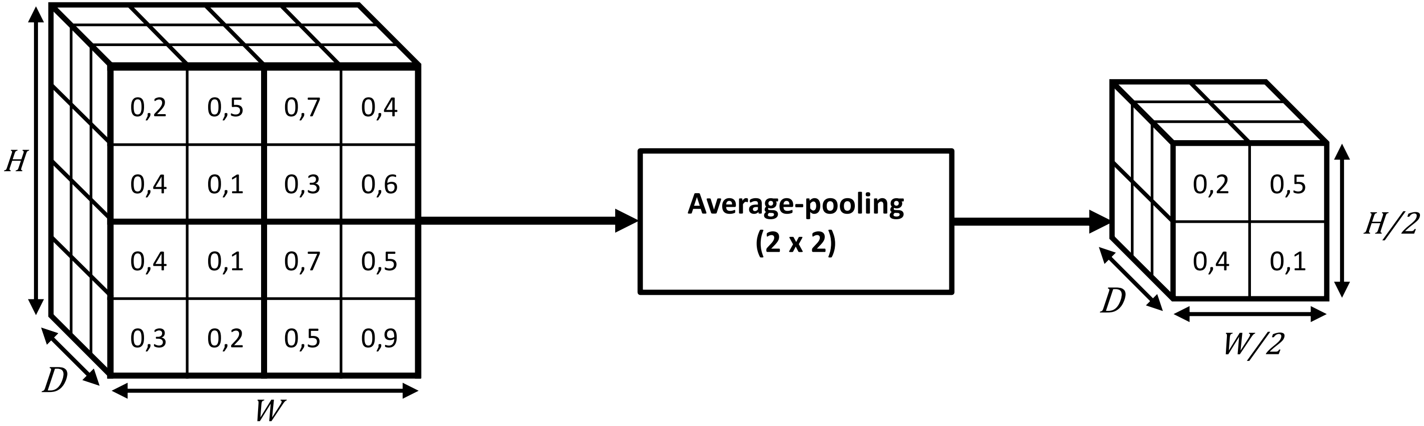
Camada de pooling





Camada de pooling

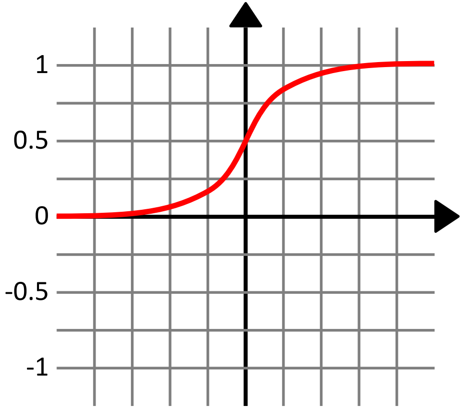




FUNÇÃO DE ATIVAÇÃO

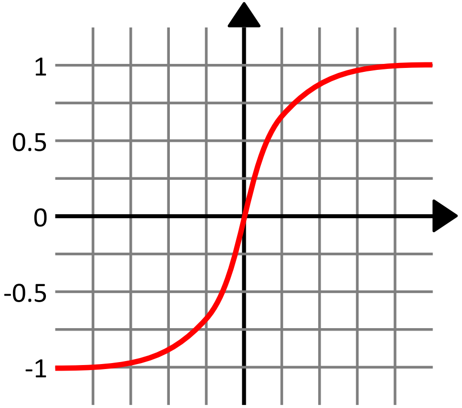
Função de ativação

Logística



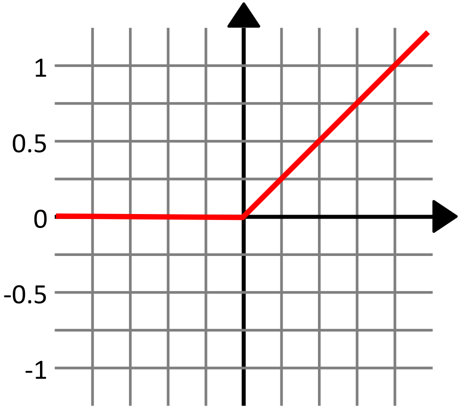
$$y = \frac{1}{1 + e^{-v}}$$

Tangente hiperbólica



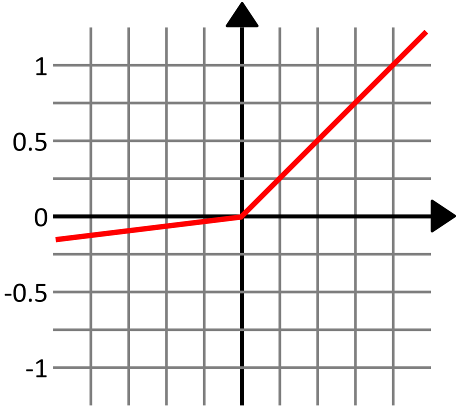
$$y = tanh(v) = \frac{sen(v)}{\cos(v)}$$

ReLu



$$y = max(0, v)$$

PReLu

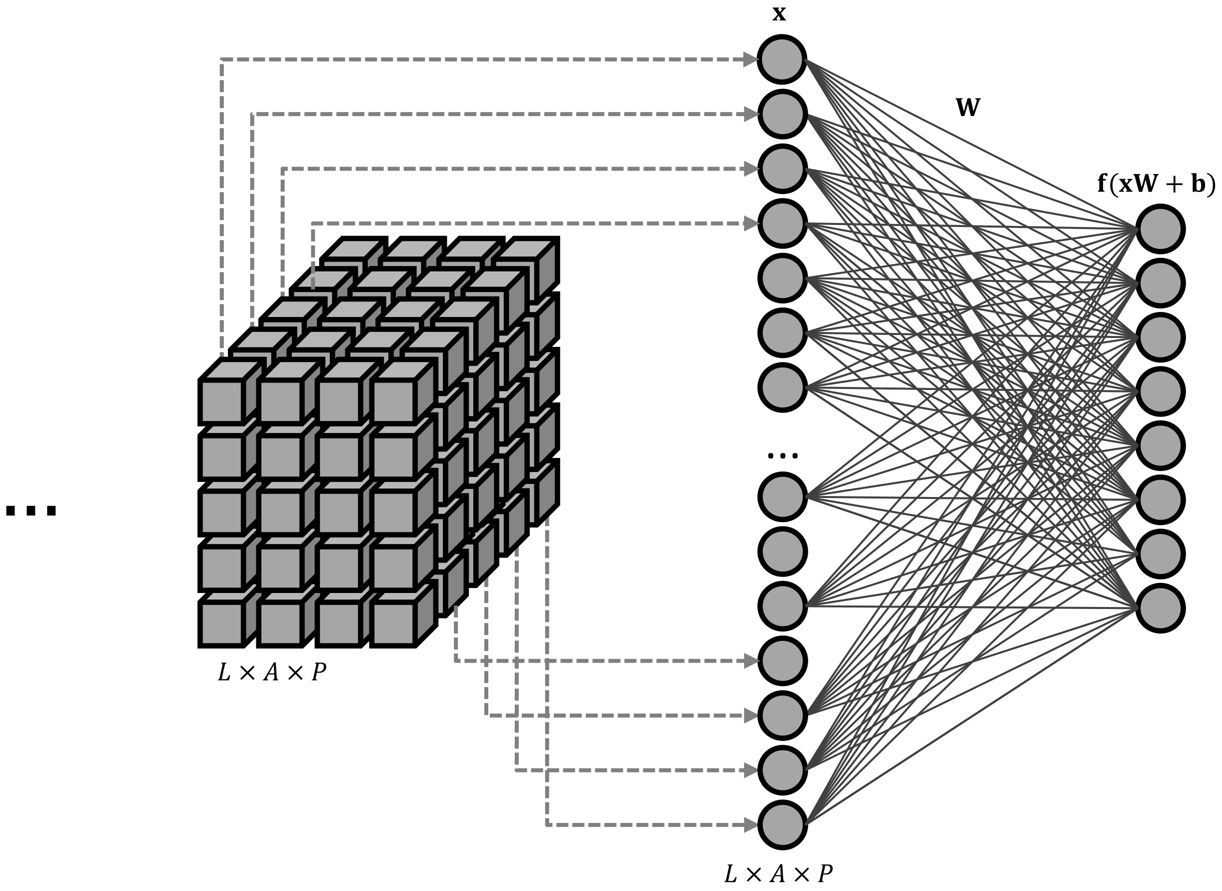


$$y = max(av, v)$$

- Se *a*=0,01 → Leak ReLu

CAMADA COMPLETAMENTE CONECTADA

Camada completamente conectada



CAMADA DE SAÍDA - SOFTMAX

Camada de saída – softmax

- Função softmax para M classes:
  - $softmax(x_i) = \frac{e^{x_i}}{\sum_{j=0}^{M-1} e^{x_j}}$

- **Exemplo:**
  - $\mathbf{x} = [-0{,}8 \quad 2{,}0 \quad 6.0 \quad -2{,}7 \quad 0{,}8]$
    - $\sum_{j=0}^{M-1} x_j = 5{,}3$
    - *Soma != de 1,0. Não pode ser interpretado como probabilidades.*
  - $\sum_{j=0}^{M-1} e^{x_j} = 0{,}4493 + 7{,}3891 + 403{,}4288 + 0{,}0672 + 2{,}2255 = 413{,}5599$
  - $softmax(x_i) = [0.0011 \quad 0{,}0179 \quad 0{,}9755 \quad 0{,}0002 \quad 0{,}0054]$
    - $\sum_{j=0}^{M-1} softmax(x_i) = 1{,}0$
    - *Representa a probabilidade da amostra pertencer a cada classe.*

FUNÇÃO DE PERDA (LOSS)

Função de perda (loss)

- Entropia cruzada para mais de 2 classes (M>2):
  - $L(\boldsymbol{y}, \widehat{\boldsymbol{y}}) = -\sum_{j=0}^{M-1} \boldsymbol{y}_j \cdot \log(\widehat{\boldsymbol{y}}_j)$

- Entropia cruzada para 2 classes (M=2):
  - $L(\boldsymbol{y}, \widehat{\boldsymbol{y}}) = -(\boldsymbol{y} \cdot \log(\widehat{\boldsymbol{y}}) + (1 - \boldsymbol{y}) \log(1 - \widehat{\boldsymbol{y}}))$

Entropia cruzada para M>2

- 5 classes, classificação **correta**, com 72% de probabilidade:
  - $\boldsymbol{y} = [0 \quad 0 \quad 0 \quad 1 \quad 0]$
  - $\hat{\boldsymbol{y}} = [0{,}20 \quad 0{,}0 \quad 0{,}05, \quad 0{,}72 \quad 0{,}03]$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}2 + 0 \times \log 0{,}0 + 0 \times \log 0{,}5 + 1 \times \log 0{,}72 + 0 \times \log 0{,}03)$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(\log 0{,}72) = 0{,}14267$

Entropia cruzada para M>2

- 5 classes, classificação **correta**, com 72% de probabilidade:
  - $\boldsymbol{y} = [0 \quad 0 \quad 0 \quad 1 \quad 0]$
  - $\hat{\boldsymbol{y}} = [0{,}20 \quad 0{,}0 \quad 0{,}05, \quad 0{,}72 \quad 0{,}03]$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}2 + 0 \times \log 0{,}0 + 0 \times \log 0{,}5 + 1 \times \log 0{,}72 + 0 \times \log 0{,}03)$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(\log 0{,}72) = 0{,}14267$
- 5 classes, classificação **correta**, com 52% de probabilidade:
  - $\boldsymbol{y} = [0 \quad 0 \quad 0 \quad 1 \quad 0]$
  - $\hat{\boldsymbol{y}} = [0{,}30 \quad 0{,}0 \quad 0{,}05, \quad 0{,}52 \quad 0{,}13]$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}3 + 0 \times \log 0{,}0 + 0 \times \log 0{,}5 + 1 \times \log 0{,}52 + 0 \times \log 0{,}13)$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(\log 0{,}52) = 0{,}284$

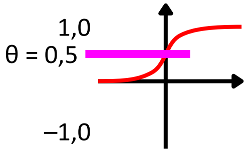
Entropia cruzada para M>2

- 5 classes, classificação **correta**, com 72% de probabilidade:
  - $\boldsymbol{y} = [0 \quad 0 \quad 0 \quad 1 \quad 0]$
  - $\widehat{\boldsymbol{y}} = [0{,}20 \quad 0{,}0 \quad 0{,}05, \quad 0{,}72 \quad 0{,}03]$
  - $L(\boldsymbol{y}, \widehat{\boldsymbol{y}}) = -(0 \times \log 0{,}2 + 0 \times \log 0{,}0 + 0 \times \log 0{,}5 + 1 \times \log 0{,}72 + 0 \times \log 0{,}03)$
  - $L(\boldsymbol{y}, \widehat{\boldsymbol{y}}) = -(\log 0{,}72) = 0{,}14267$
- 5 classes, classificação **correta**, com 52% de probabilidade:
  - $\boldsymbol{y} = [0 \quad 0 \quad 0 \quad 1 \quad 0]$
  - $\widehat{\boldsymbol{y}} = [0{,}30 \quad 0{,}0 \quad 0{,}05, \quad 0{,}52 \quad 0{,}13]$
  - $L(\boldsymbol{y}, \widehat{\boldsymbol{y}}) = -(0 \times \log 0{,}3 + 0 \times \log 0{,}0 + 0 \times \log 0{,}5 + 1 \times \log 0{,}52 + 0 \times \log 0{,}13)$
  - $L(\boldsymbol{y}, \widehat{\boldsymbol{y}}) = -(\log 0{,}52) = 0{,}284$
- 5 classes, classificação **incorreta**:
  - $\boldsymbol{y} = [0 \quad 0 \quad 0 \quad 1 \quad 0]$
  - $\widehat{\boldsymbol{y}} = [0{,}60 \quad 0{,}0 \quad 0{,}07, \quad 0{,}30 \quad 0{,}03]$
  - $L(\boldsymbol{y}, \widehat{\boldsymbol{y}}) = -(0 \times \log 0{,}6 + 0 \times \log 0{,}0 + 0 \times \log 0{,}07 + 1 \times \log 0{,}3 + 0 \times \log 0{,}03)$
  - $L(\boldsymbol{y}, \widehat{\boldsymbol{y}}) = -(\log 0{,}3) = 0{,}5229$

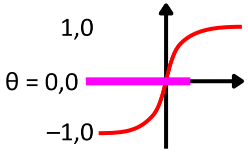
Entropia cruzada para M=2

Universidade Federal de Viçosa

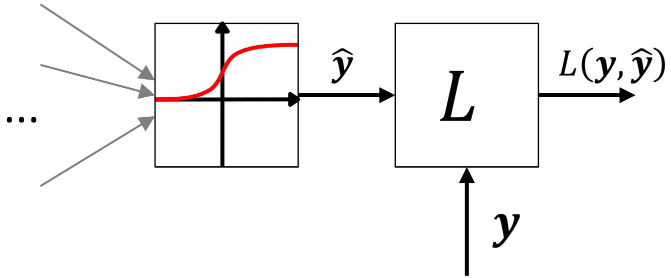
- 2 classes, classificação correta:
  - $\boldsymbol{y} = [0]$
  - $\hat{\boldsymbol{y}} = [0{,}20]$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}2 + (1 - 0) \times \log(1 - 0{,}2))$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}2 + (1) \times \log(0{,}8)) = -(\log(0{,}8)) = 0{,}09691$



Logística

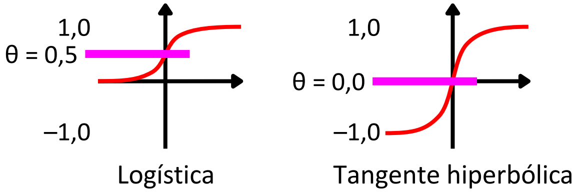


Tangente hiperbólica

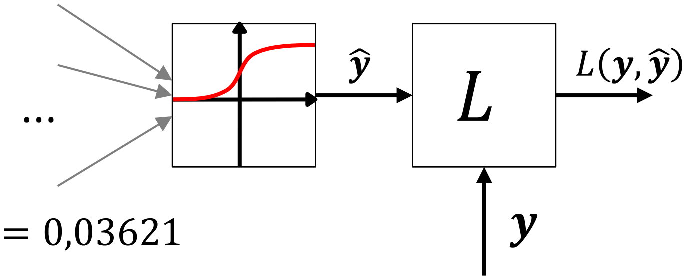


Entropia cruzada para M=2

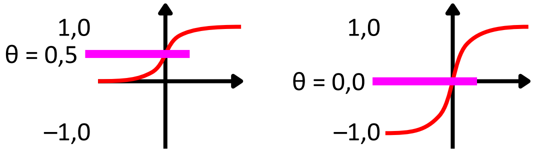
- 2 classes, classificação correta:
  - $\boldsymbol{y} = [0]$
  - $\hat{\boldsymbol{y}} = [0{,}20]$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}2 + (1-0) \times \log(1-0{,}2))$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}2 + (1) \times \log(0{,}8)) = -(\log(0{,}8)) = 0{,}09691$



- 2 classes, classificação correta:
  - $\boldsymbol{y} = [1]$
  - $\hat{\boldsymbol{y}} = [0{,}92]$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(1 \times \log 0{,}92 + (1-1) \times \log(1-0{,}92))$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(1 \times \log 0{,}92 + (0) \times \log(0{,}08)) = -(\log(0{,}92)) = 0{,}03621$

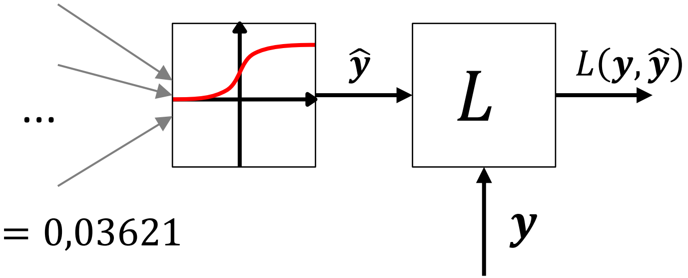


- 2 classes, classificação correta:
  - $\boldsymbol{y} = [0]$
  - $\hat{\boldsymbol{y}} = [0{,}20]$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}2 + (1-0) \times \log(1 - 0{,}2))$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}2 + (1) \times \log(0{,}8)) = -(\log(0{,}8)) = 0{,}09691$



Logística   Tangente hiperbólica

- 2 classes, classificação correta:
  - $\boldsymbol{y} = [1]$
  - $\hat{\boldsymbol{y}} = [0{,}92]$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(1 \times \log 0{,}92 + (1-1) \times \log(1 - 0{,}92))$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(1 \times \log 0{,}92 + (0) \times \log(0{,}08)) = -(\log(0{,}92)) = 0{,}03621$

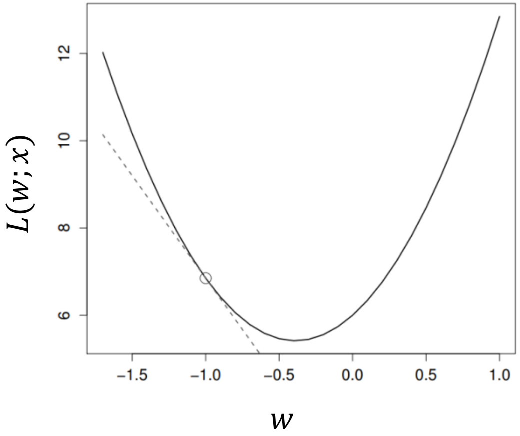


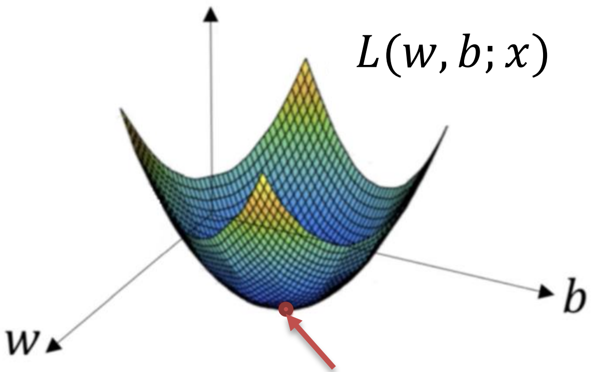
- 2 classes, classificação incorreta:
  - $\boldsymbol{y} = [0]$
  - $\hat{\boldsymbol{y}} = [0{,}65]$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}65 + (1-0) \times \log(1 - 0{,}65))$
  - $L(\boldsymbol{y}, \hat{\boldsymbol{y}}) = -(0 \times \log 0{,}65 + (1) \times \log(0{,}35)) = -(\log(0{,}35)) = 0{,}45593$

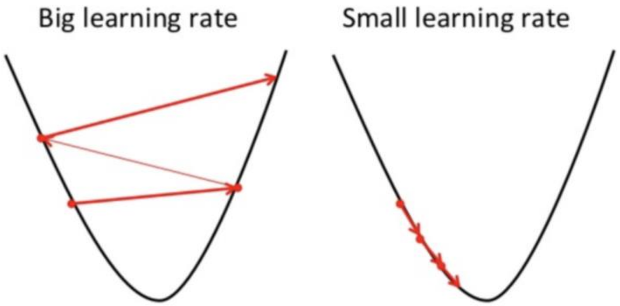
OTIMIZADORES

Otimizadores

- Gradiente descendente (GD - *Gradient descent)*:
  - $W_{t+1} = W_t - \eta \sum_{j=1}^{N} \nabla L(W; x_j)$
  - N é o tamanho do conjunto de treinamento





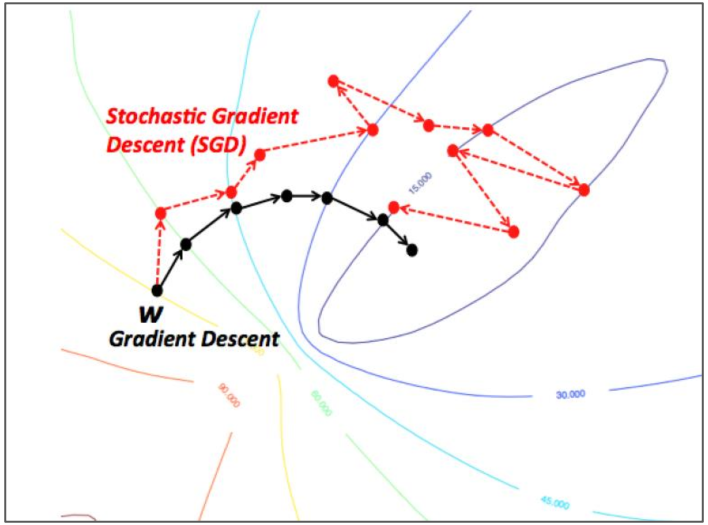


Moacir Ponti. *http://conteudo.icmc.usp.br/pessoas/moacir/p17sibgrapi-tutorial/*

Donges. *Gradient Descent in Machine Learning: A Basic Introduction*. https://builtin.com/data-science/gradient-descent

Otimizadores

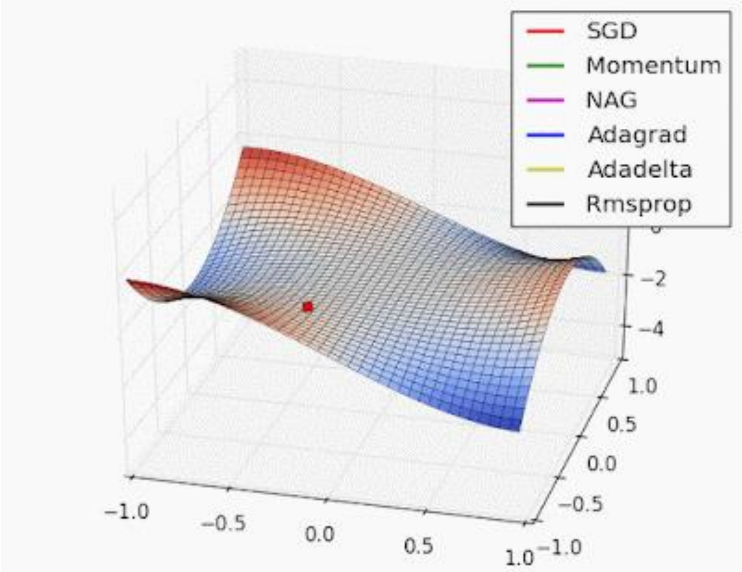
- Gradiente descendente estocástico (SGD – *Stochastic gradient descent*):
  - $W_{t+1} = W_t - \eta \sum_{j=1}^{B} \nabla L(W; x_j^B)$
  - B é o tamanho do mini-lote (*mini-batch*)



https://wikidocs.net/3413

Otimizadores

- SGD com momentum:
  - $W_{t+1} = W_t - \eta \sum_{j=1}^{B} \nabla L(W; x_j^B)$
    - B é o tamanho do mini-lote (*mini-batch*)
  - $W_{t+1} = W_t + \alpha(W_t - W_{t-1}) + (1-\alpha)[-\eta \sum_{j=1}^{B} \nabla L(W; x_j^B)]$



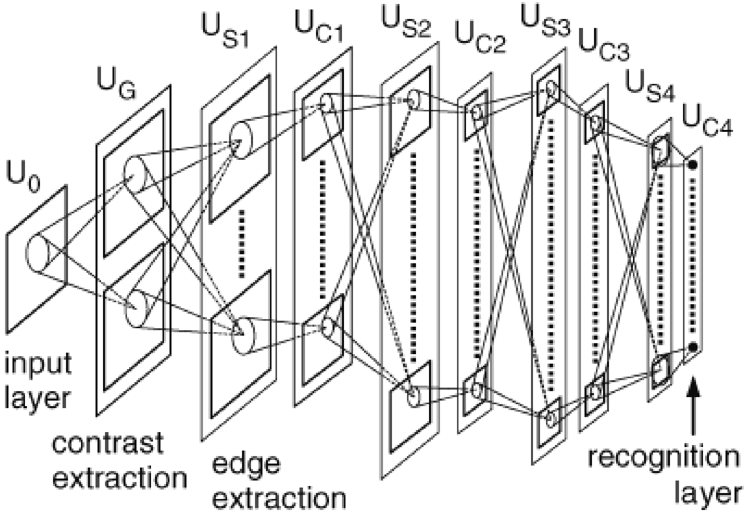
http://www.denizyuret.com/2015/03/alec-radfords-animations-for.html

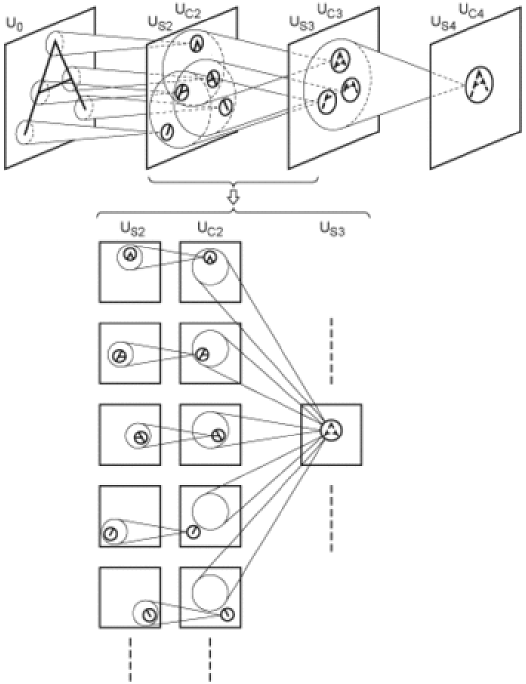
Otimizadores

- Outros otimizadores:
  - AdaGrad - *Adaptive Gradient*
  - AdaDelta - *Adaptive learning rate*
  - RMSProp - *Root Mean Squared Propagation*
  - Adam - *Adaptive moment estimation*
  - ...

ARQUITETURAS

- Neocognitron (1979)

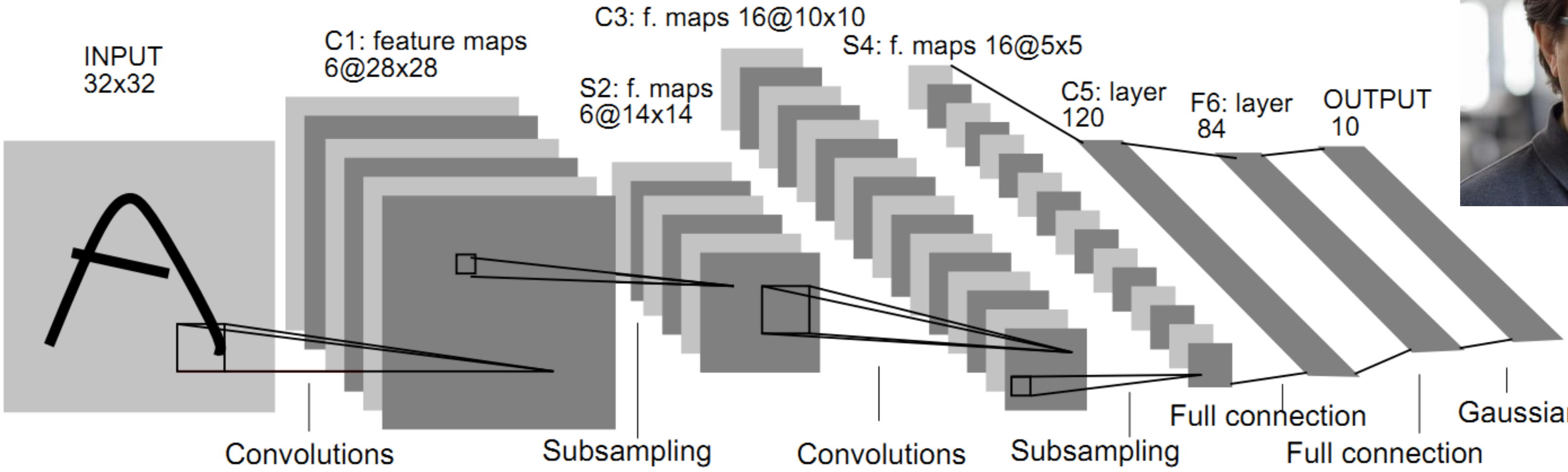




Kunihiko Fukushima

Fukushima, K. (1980). "Neocognitron: A self-organizing neural network model for a mechanism of pattern recognition unaffected by shift in position". Biological Cybernetics. 36 (4): 193–202.

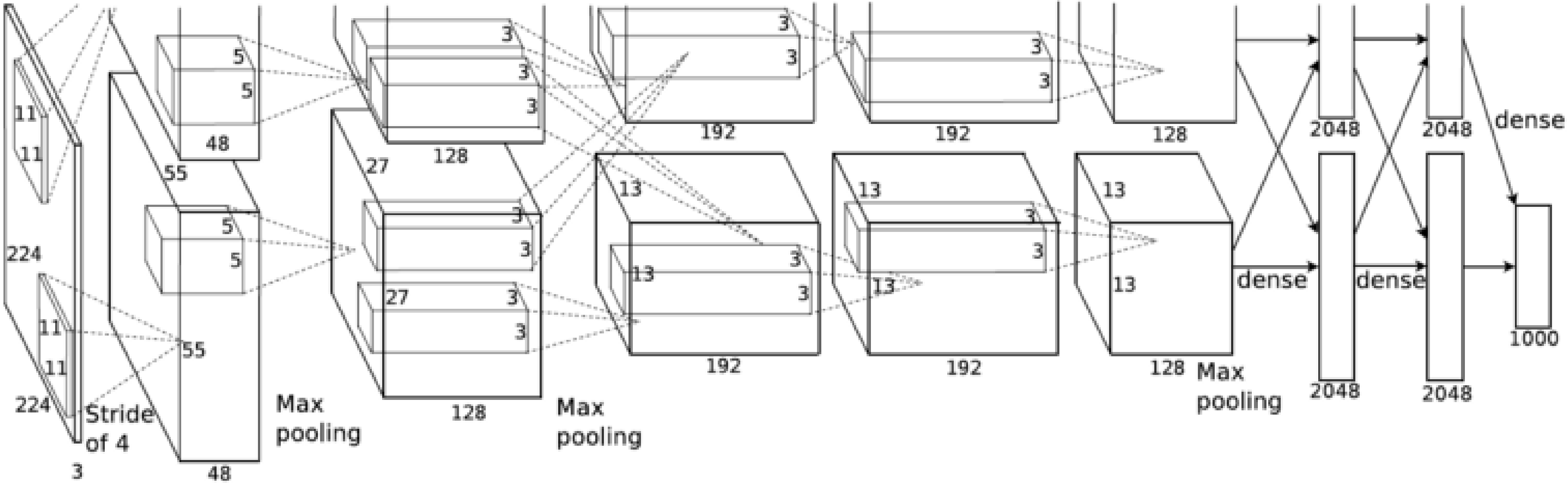
- LeNet-5 (1998)



Yann LeCun

Lecun, Y. et al. (1998). "Gradient-based learning applied to document recognition". Proceedings of the IEEE. 86 (11): 2278–2324.

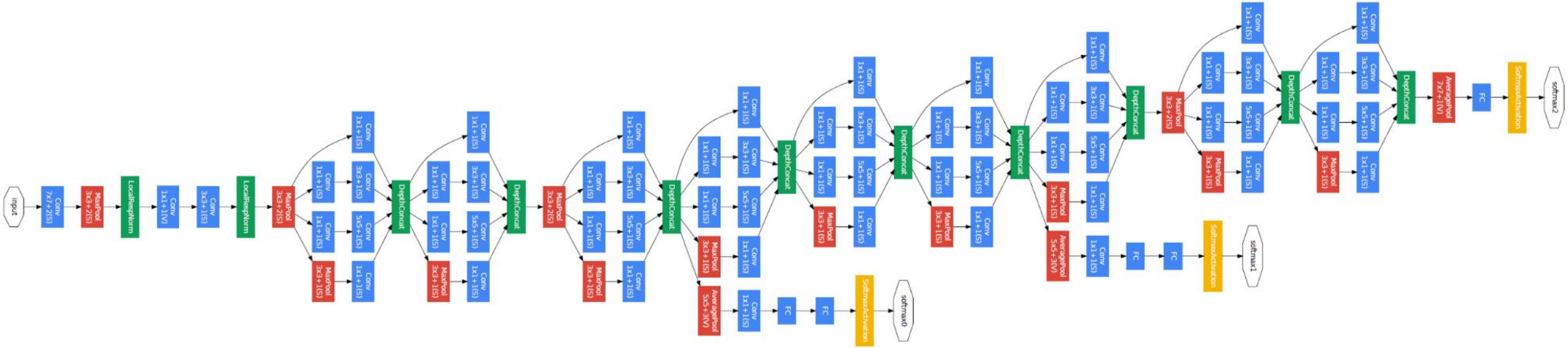
- AlexNet (2012)



Krizhevsky, Sutskever e Hinton. **ImageNet Classification with Deep Convolutional Neural Networks**. NeuripIPS 2012

Arquiteturas

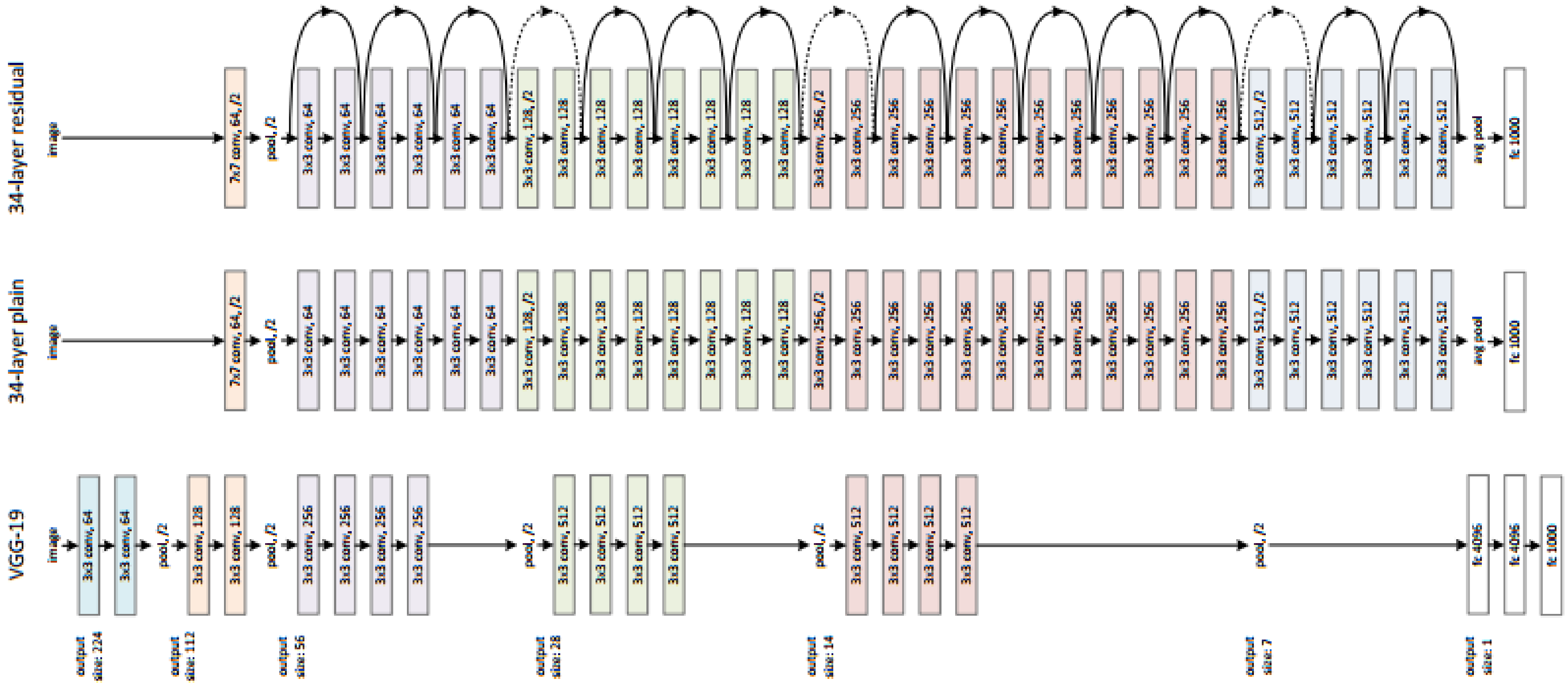
- Inception (GoogLeNet) (2015)



Szegedy, Christian (2015). "Going deeper with convolutions". CVPR2015.

Arquiteturas

- VGG (2014) e ResNet (2015)



Simonyan e Zisserman. Very Deep Convolutional Networks for Large-Scale Image Recognition. 2014

He et al. Deep Residual Learning for Image Recognition. 2015.

- DenseNet (2017)

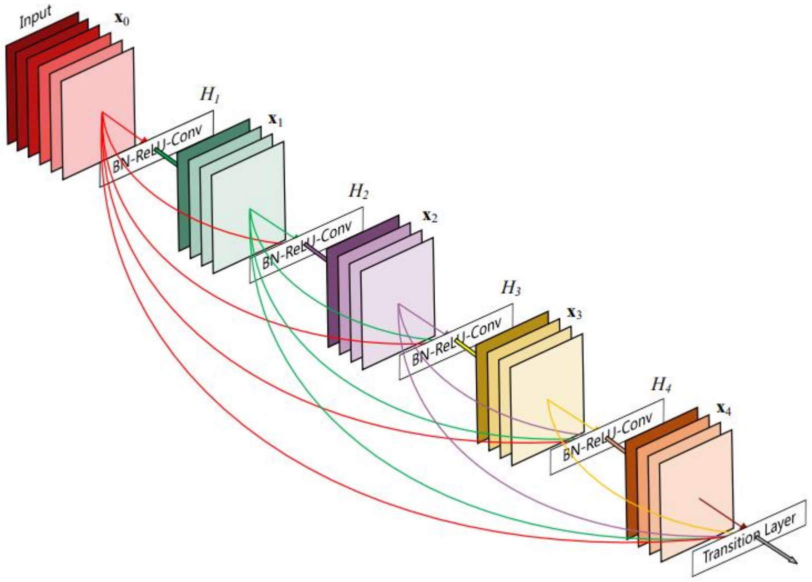


Figure 1: A 5-layer dense block with a growth rate of $k = 4$. Each layer takes all preceding feature-maps as input.

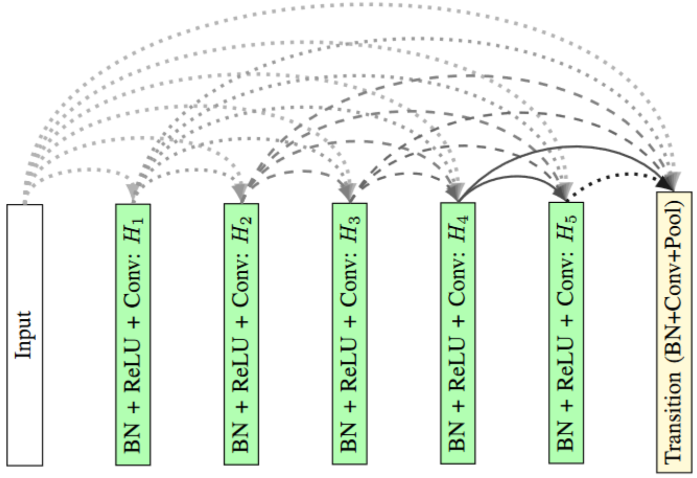


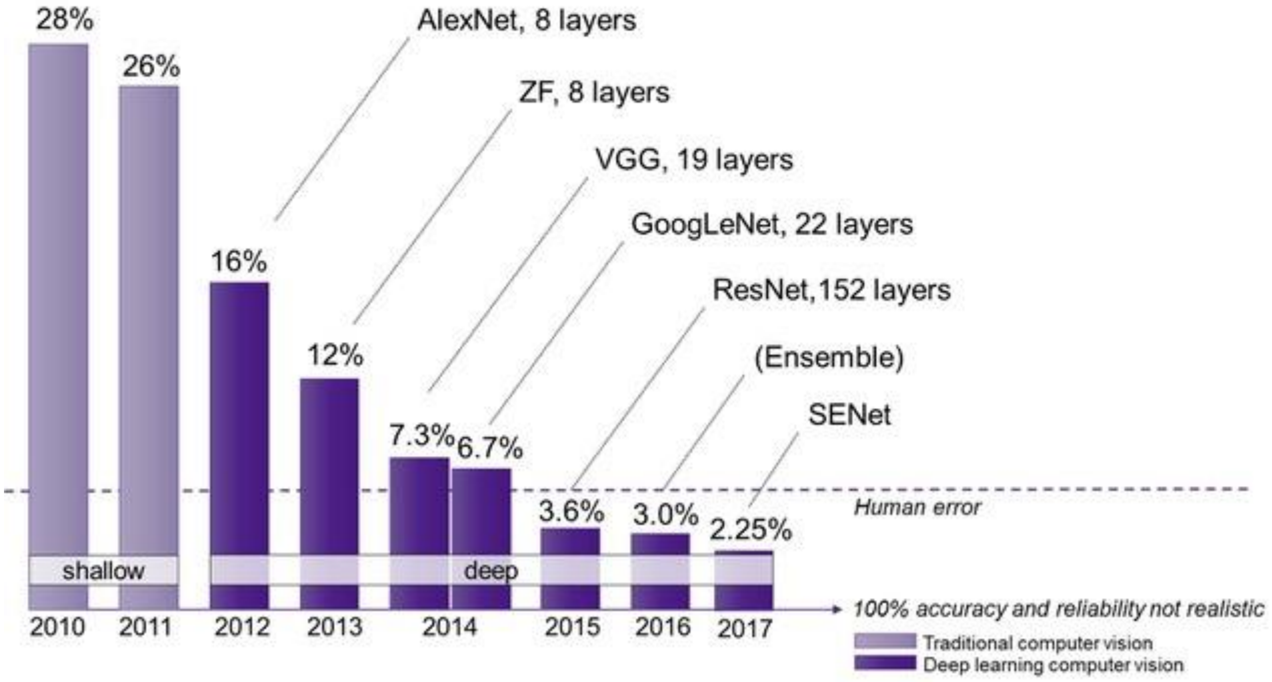
Figure 10. Illustration of a DenseBlock with 5 functions H_l and a Transition Layer.

Huang et al. Densely Connected Convolutional Networks. CVPR 2017.

Ponti et al. Everything You Wanted to Know about Deep Learning for Computer Vision but Were Afraid to Ask. Sibgrapi 2017.

Arquiteturas

- ImageNet Large Scale Visual Recognition Challenge
  - https://image-net.org/challenges/LSVRC/



https://semiengineering.com/new-vision-technologies-for-real-world-applications/

BIBLIOTECAS E DESENVOLVIMENTO

Bibliotecas e desenvolvimento

- O treinamento de CNNs possui alto custo computacional.
  - Recomenda-se que sejam treinados usando GPUs.
  - O Google Colab fornece acesso à GPUs (com algumas restrições).

Bibliotecas e desenvolvimento

- Principais bibliotecas para Deep Learning e Redes Neurais Convolucionais
  - PyTorch
    - https://pytorch.org/
  - Tensorflow
    - https://www.tensorflow.org/

Bibliotecas e desenvolvimento

- **Anaconda Distribution:**
  - Distribuição Python com suporte às principais bibliotecas
  - https://www.anaconda.com/products/distribution
- **Google Colab:**
  - Ambiente de execução em nuvem com GPUs.
  - https://colab.research.google.com

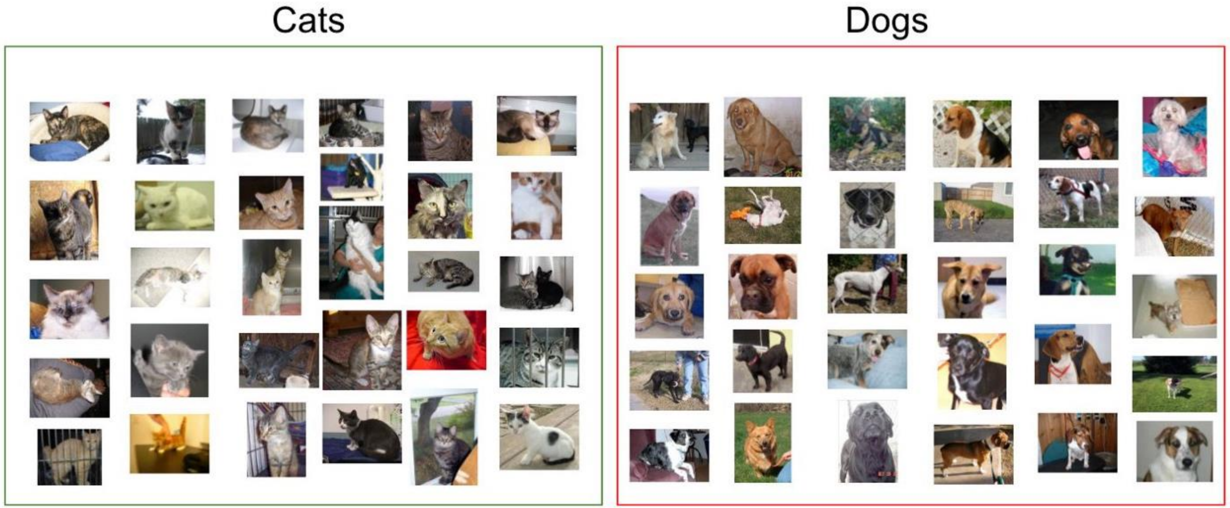
CONJUNTOS DE IMAGENS

Conjuntos de imagens

- MNIST
  - http://yann.lecun.com/exdb/mnist/
  - 60,000 training images
  - 10,000 testing images
  - 28 x 28 pixels
  - Níveis de cinza

Conjuntos de imagens

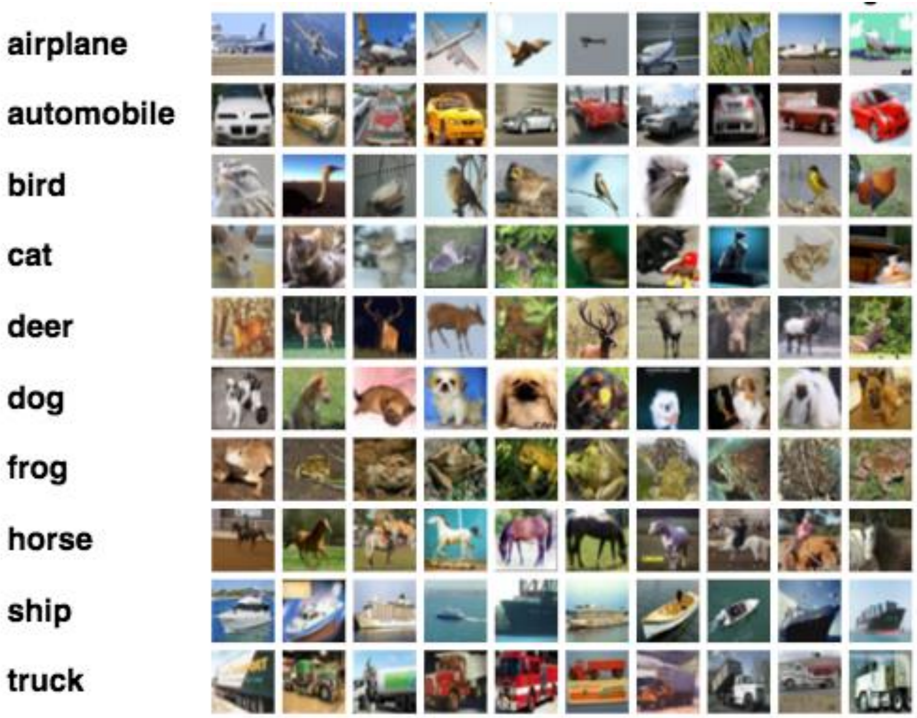
- **Cats vs. Dogs:**
  - https://www.kaggle.com/c/dogs-vs-cats
  - 25,000 images de treinamento
  - 12,500 imagens de teste
  - 2 classes
  - Diversos tamanhos
  - RGB



Sample of cats & dogs images from Kaggle Dataset

Conjuntos de imagens

- **CIFAR10:**
  - https://www.cs.toronto.edu/~kriz/cifar.html
  - 50,000 training images
  - 10,000 testing images
  - 10 classes
  - 32 x 32 pixels
  - RGB



Conjuntos de imagens

- **ImageNet:**
  - https://www.image-net.org/
  - ~1,000,000 imagens
  - 1,000 classes
  - RGB

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