Essentials of Deep Learning

Carlos Cotrini

2019

Agenda

- Many machine learning models cannot make “insights” on data.
- Neural networks.
- How neural networks are built.
- Convolutional neural networks for images.
- Recurrent neural networks for text.


POKER
HAND RANKINGS
#1 ROYAL FLUSH
#2 STRAIGHT FLUSH
#3 FOUR OF A KIND
#4 FULL HOUSE
#5 FLUSH
#6 STRAIGHT
#7 THREE OF A KIND
#8 TWO PAIR
#9 ONE PAIR
#10 HIGH CARD

Many ML algorithms cannot make insights

Full house

Royal flush

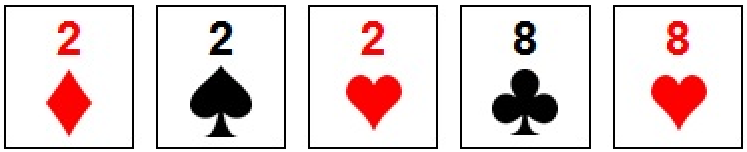
- Logistic model:

49%

Of course, you don’t need ML for this

Rank 1	Suit 1	…	Rank 5	Suit 5	Type
2	♦	…	8	♥	FH
10	♥	…	A	♥	RF

Many ML algorithms cannot make insights



Full house

Royal flush

- Logistic model:

99.5%

Rank 1	Suit 1	…	Rank 5	Suit 5	# A	#2	…	#♠	#♥	Type
2	♦	…	8	♥	0	3		1	2	FH
10	♥	…	A	♥	1	0		0	5	RF

Many ML algorithms cannot make insights

Full house

Royal flush

Rank 1	**Suit 1**	**…**	**Rank 5**	**Suit 5**	**Type**
2	♦	…	8	♥	FH
10	♥	…	A	♥	RF

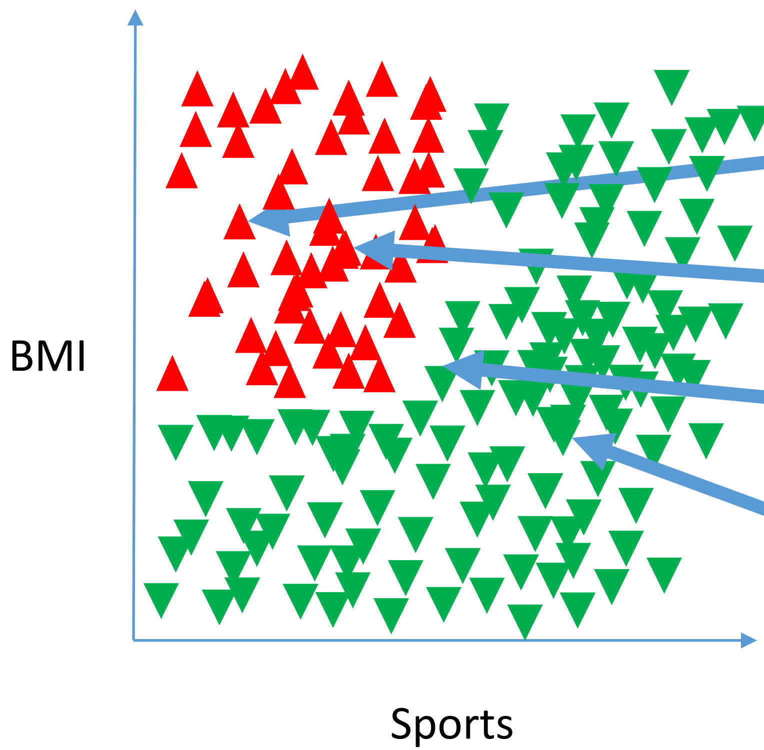
- Neural network:

99%

Agenda

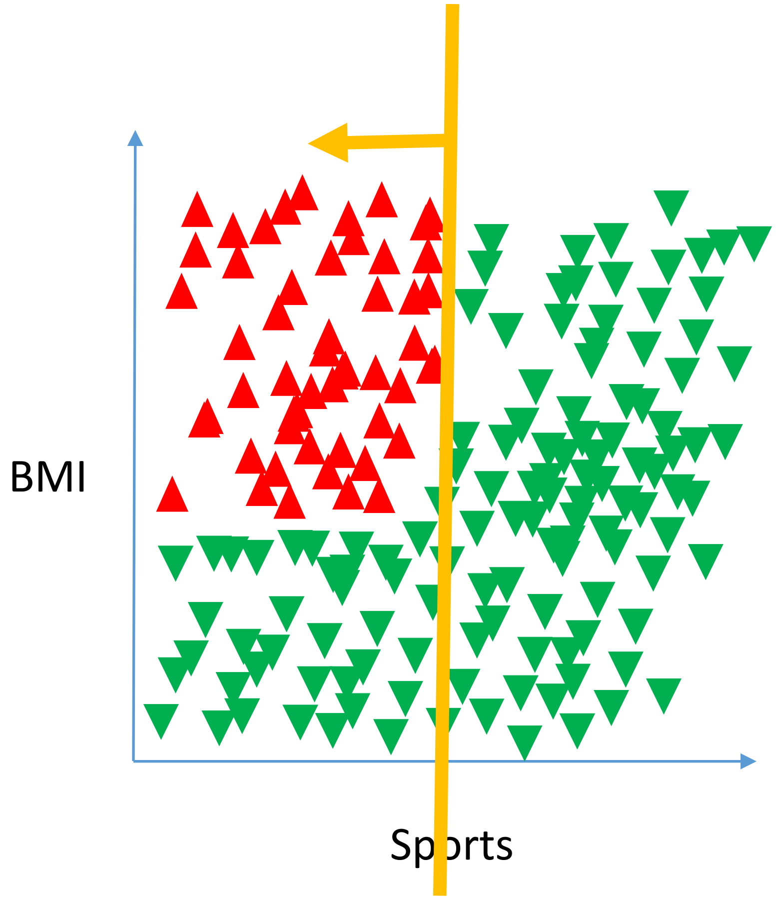
- Many machine learning models cannot make "insights" on data.
- Neural networks.
- How neural networks are built.
- Convolutional neural networks for images.
- Recurrent neural networks for text.

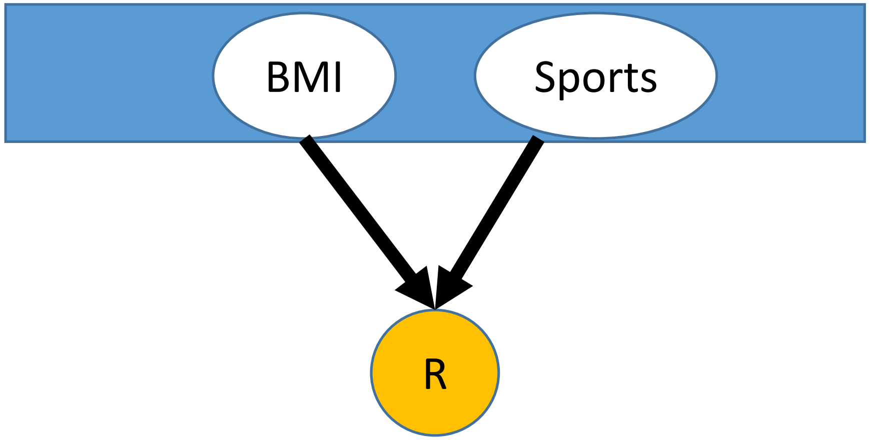
Neural networks are assemblies of logistic models



BMI	Sports	High risk?
36	1	1
34	2	1
23	3	0
22	4	0

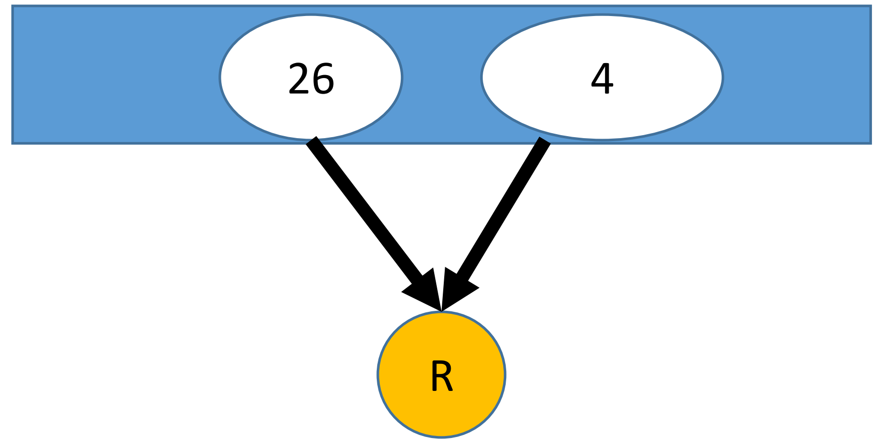
Neural networks are assemblies of logistic models

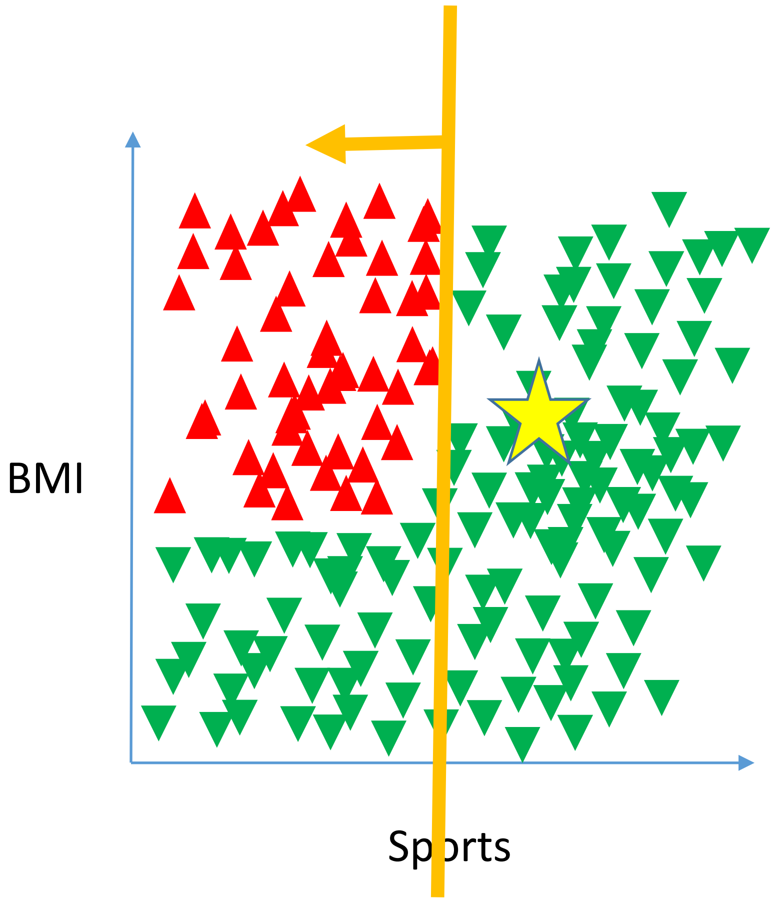




$$R = \sigma(0 \times BMI - 1.5 \times Sports + 3)$$

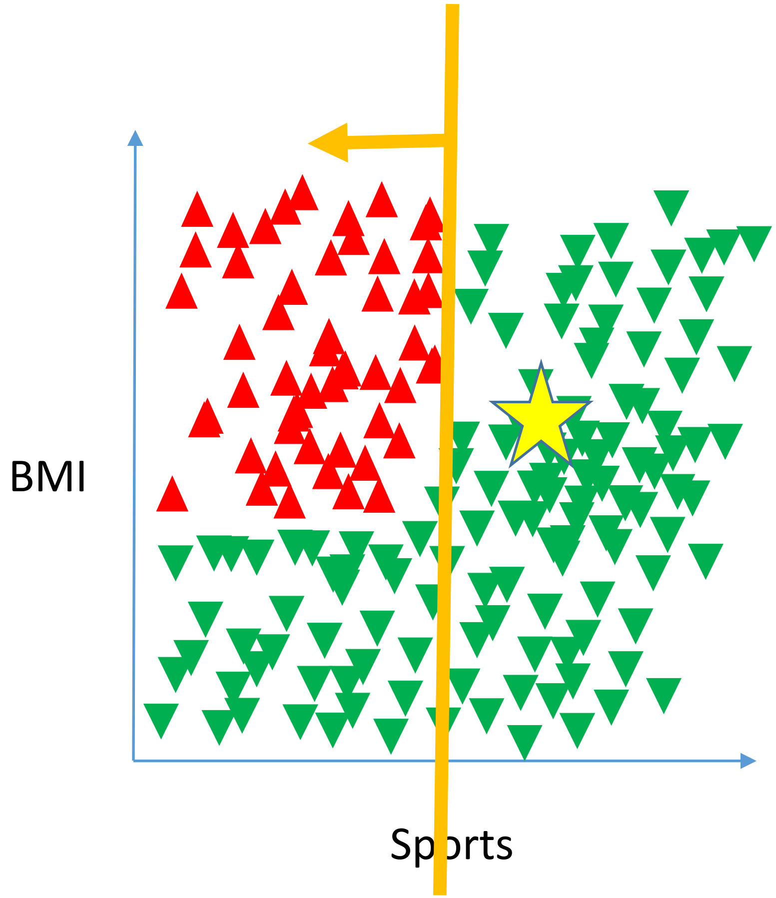
Neural networks are assemblies of logistic models

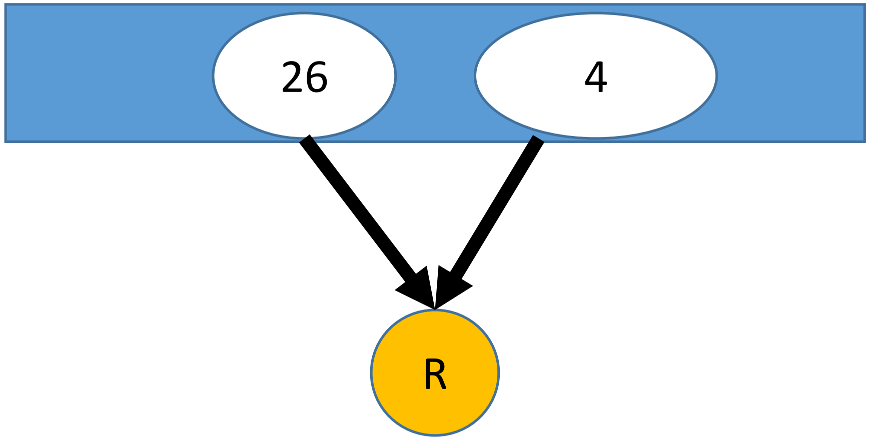




$$\boldsymbol{R} = \sigma(\mathbf{0} \times \mathbf{26} - \mathbf{1.5} \times \mathbf{4} + \mathbf{3})$$

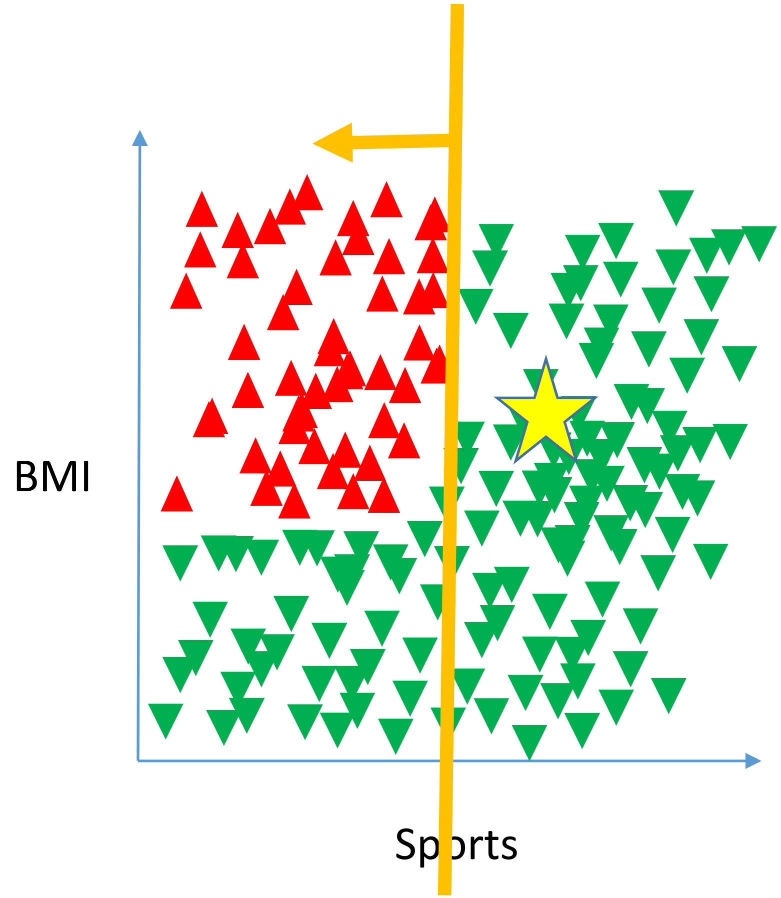
Neural networks are assemblies of logistic models

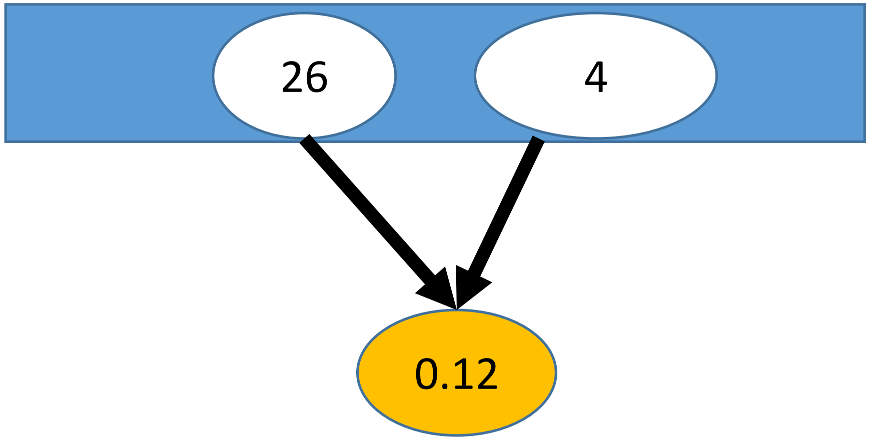




$$\boldsymbol{R} = \sigma(-3)$$

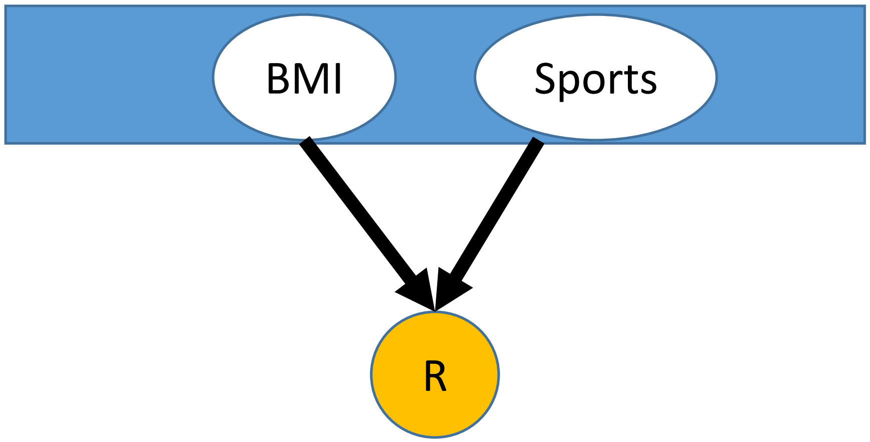
Neural networks are assemblies of logistic models

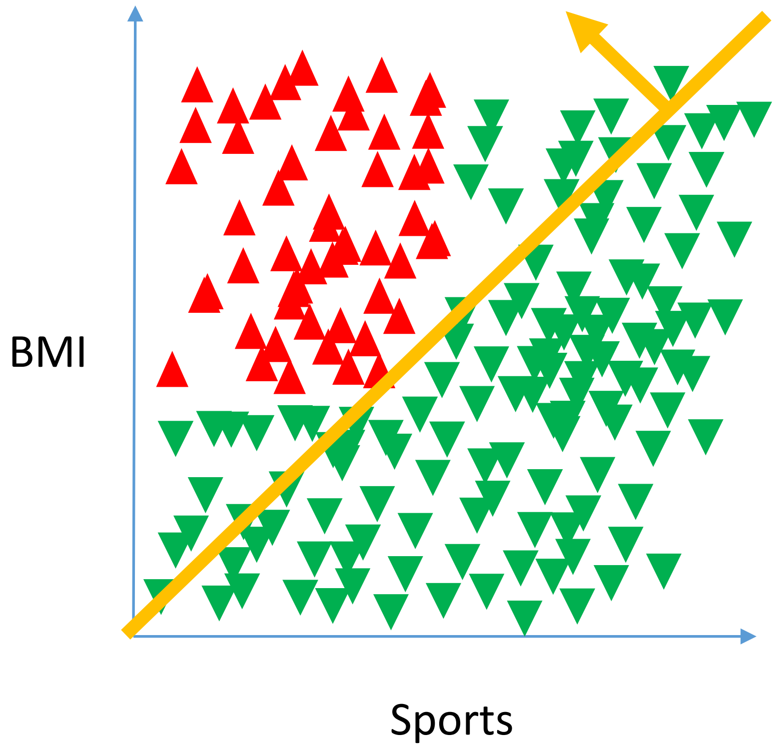




$\boldsymbol{R} = 0.12$

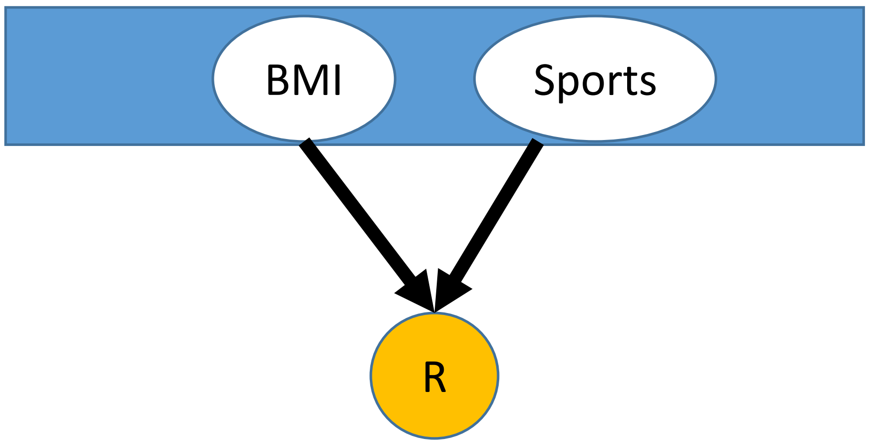
Neural networks are assemblies of logistic models

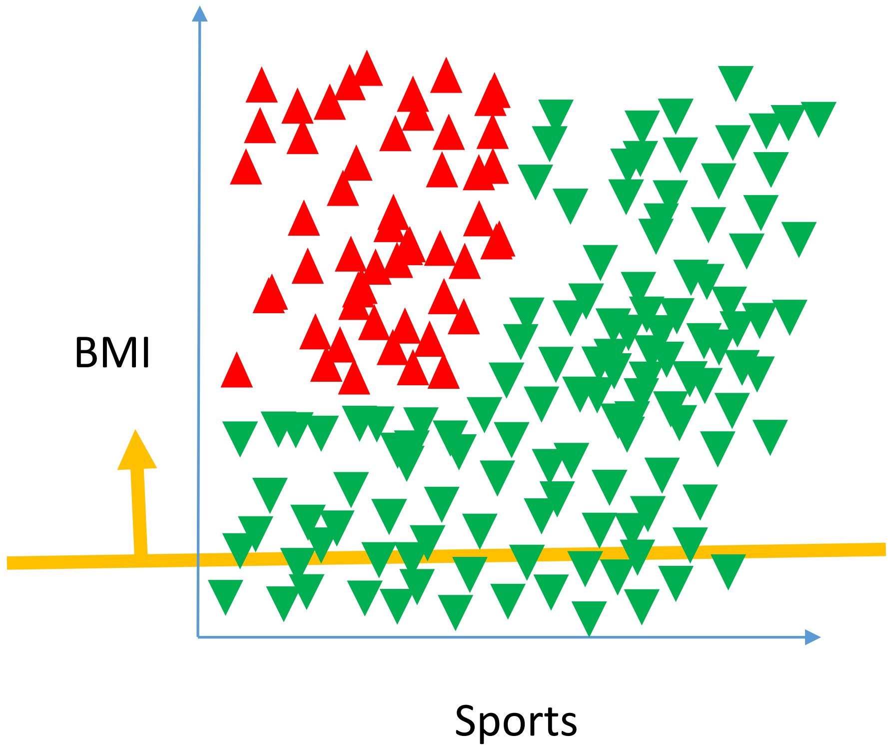




$$R = \sigma(-4 \times BMI + 1 \times Sports + 60)$$

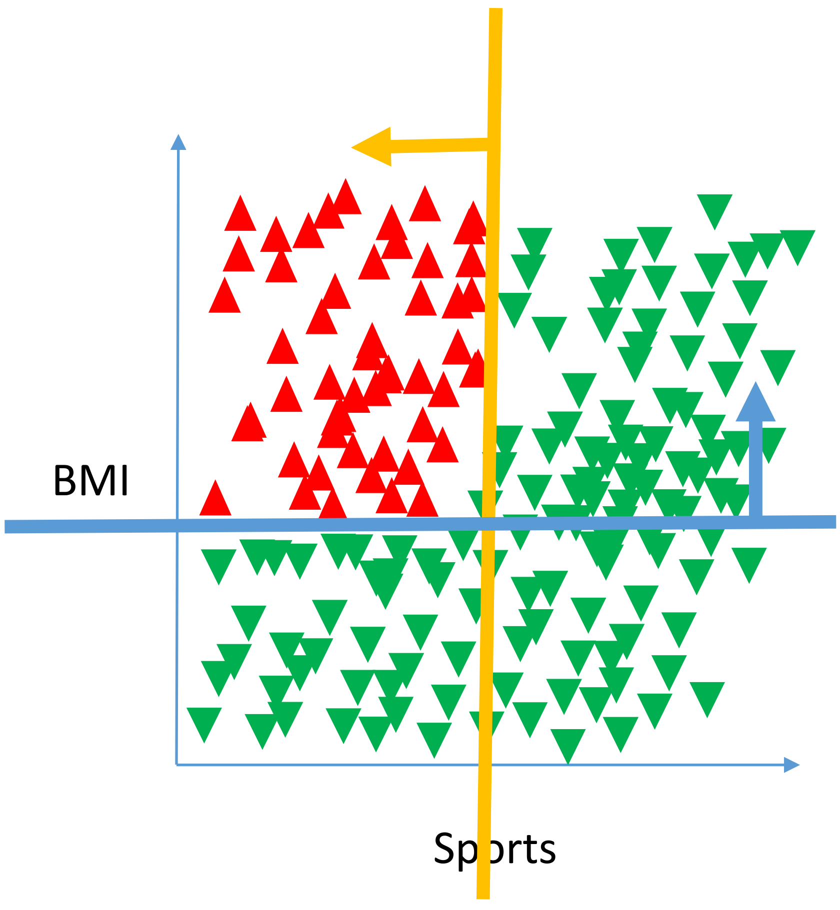
Neural networks are assemblies of logistic models

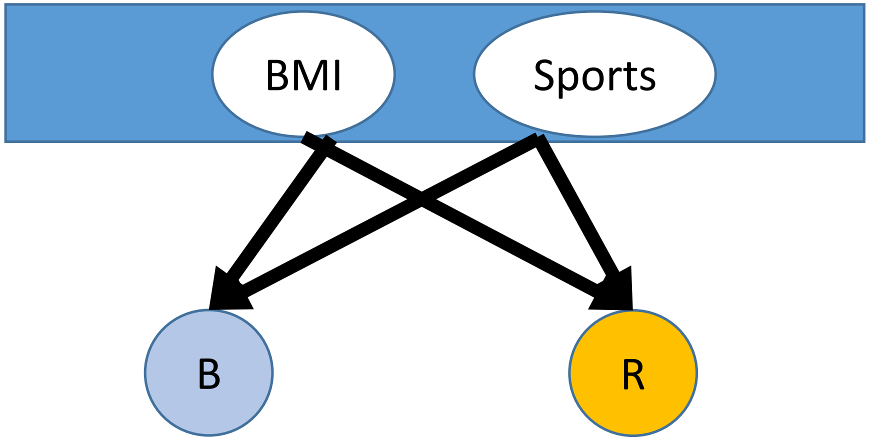




$$R = \sigma(1.2 \times BMI + 0 \times Sports - 21)$$

Neural networks are assemblies of logistic models

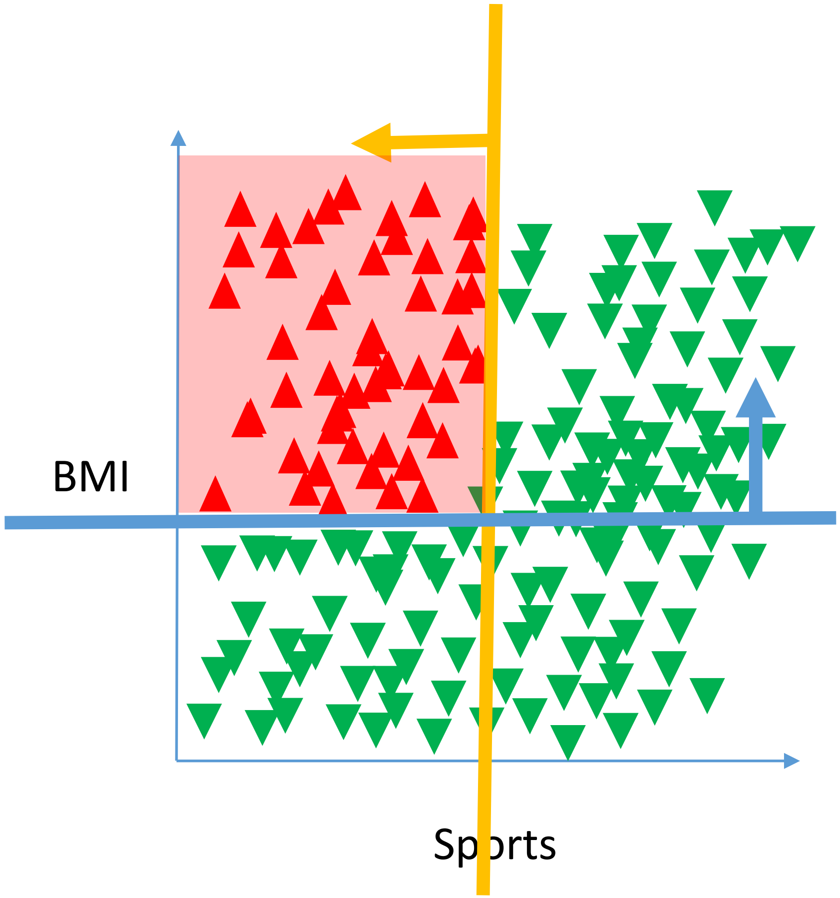


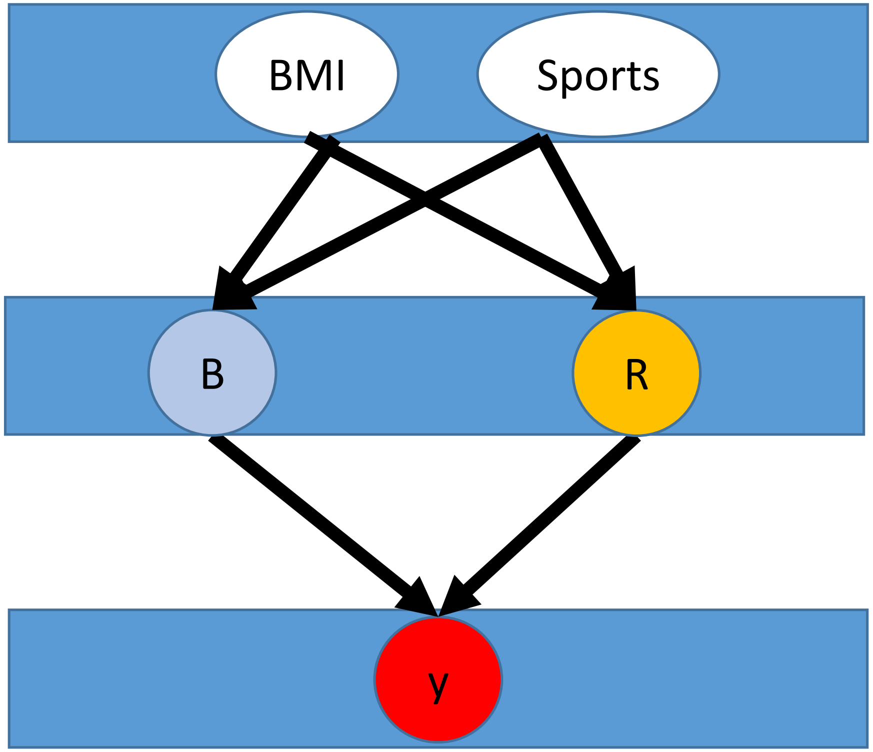


$$R = \sigma(0 \times BMI + 1.5 \times Sports - 3)$$

$$B = \sigma(-2.5 \times BMI + 0 \times Sports - 27)$$

Neural networks are assemblies of logistic models



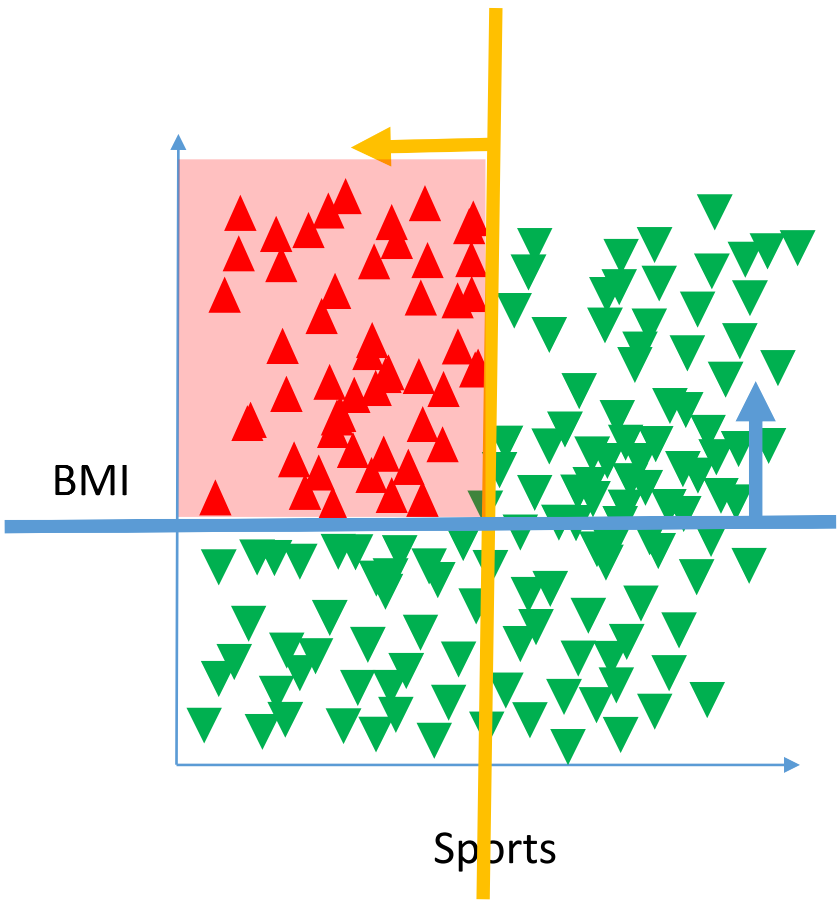


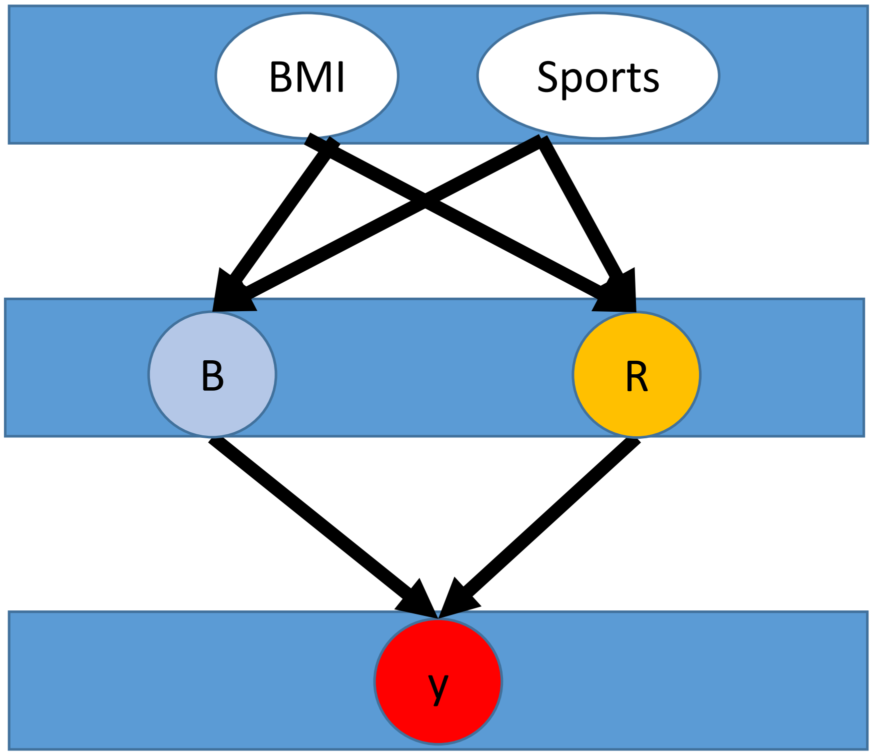
$$R = \sigma(0 \times BMI + 1.5 \times Sports - 3)$$

$$B = \sigma(-2.5 \times BMI + 0 \times Sports - 27)$$

$$y = \sigma(1 \times R + 1 \times B)$$

Neural networks are assemblies of logistic models

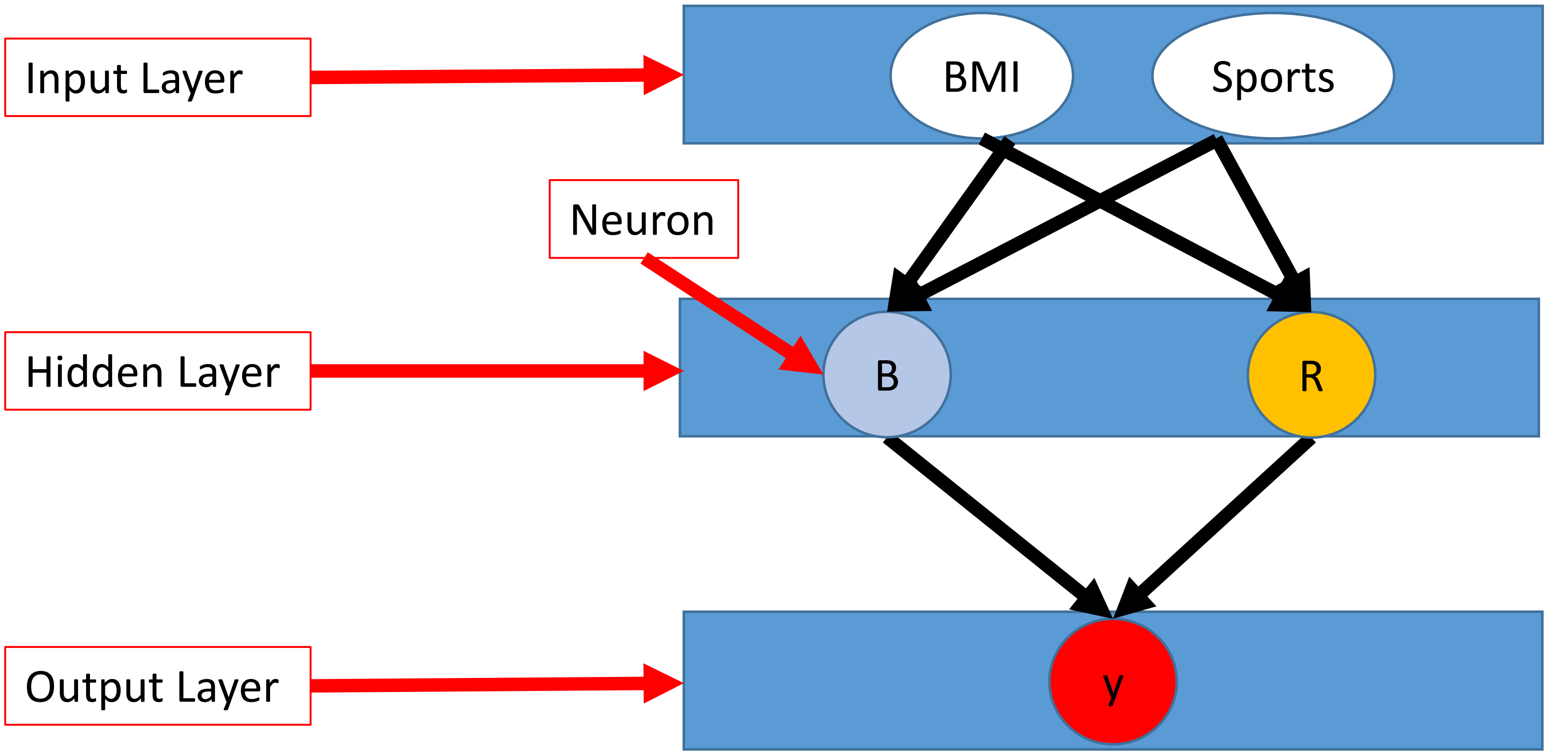




$$R = \sigma(? \times BMI + ? \times Sports + ?)$$

$$B = \sigma(? \times BMI + ? \times Sports + ?)$$

$$y = \sigma(? \times R + ? \times B)$$

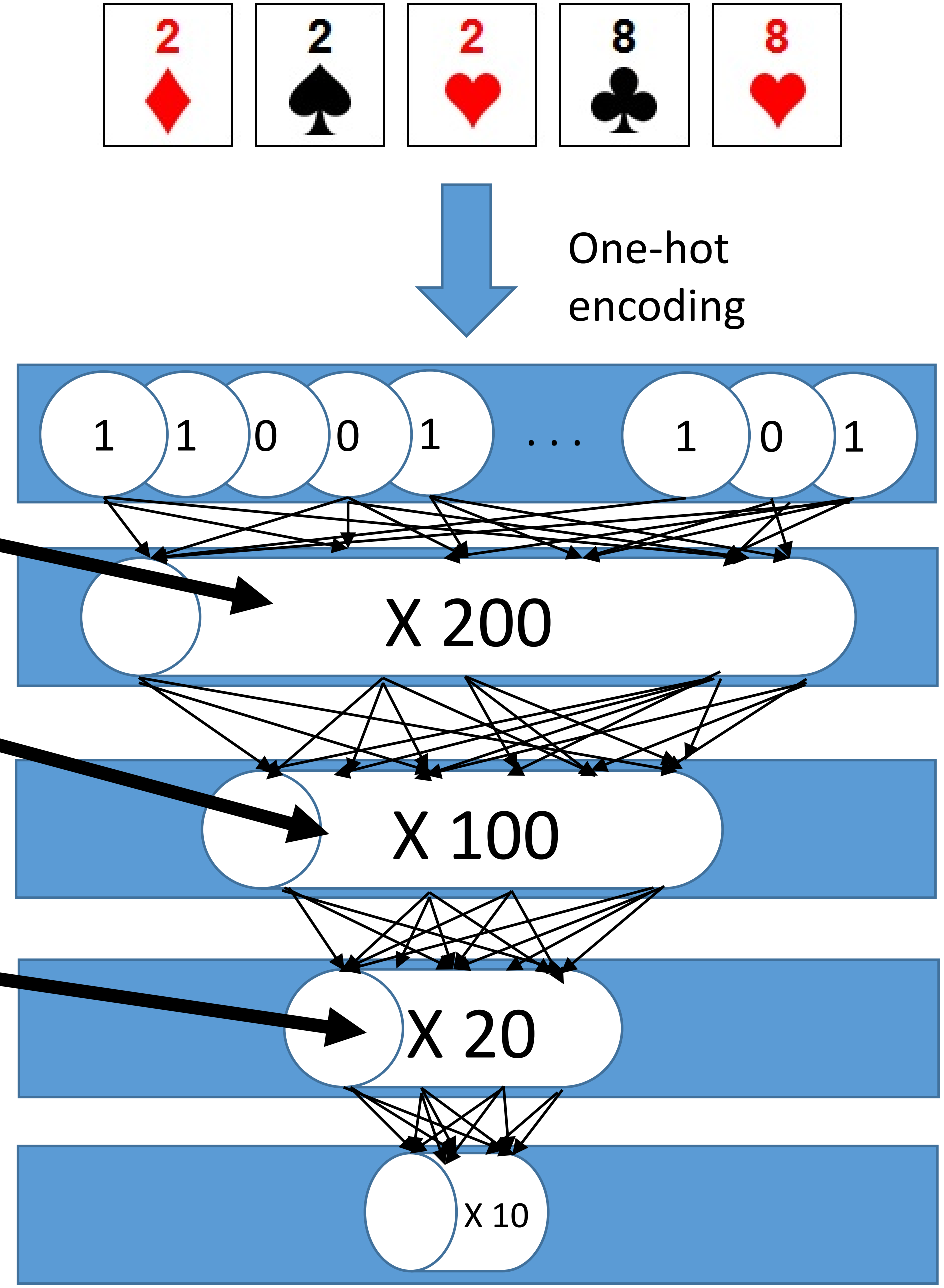


$$\boldsymbol{R} = \sigma(? \times BMI + ? \times Sports - ?)$$

$$\boldsymbol{B} = \sigma(? \times BMI + ? \times Sports - ?)$$

$$\boldsymbol{y} = \sigma(? \times R + ? \times B)$$

Predicting poker hands



Are there more than 2 aces in the hand?

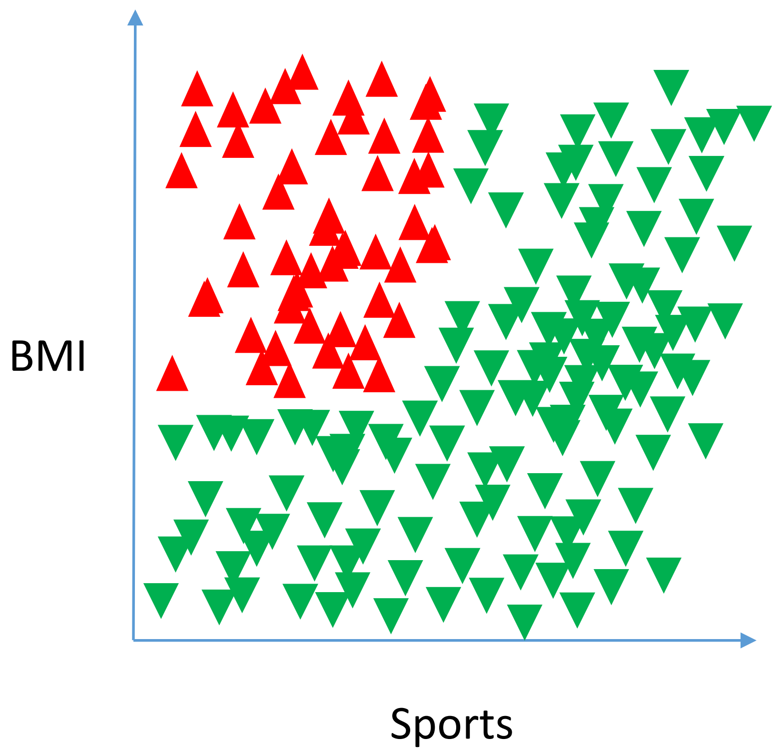
Are all cards of the same suit?

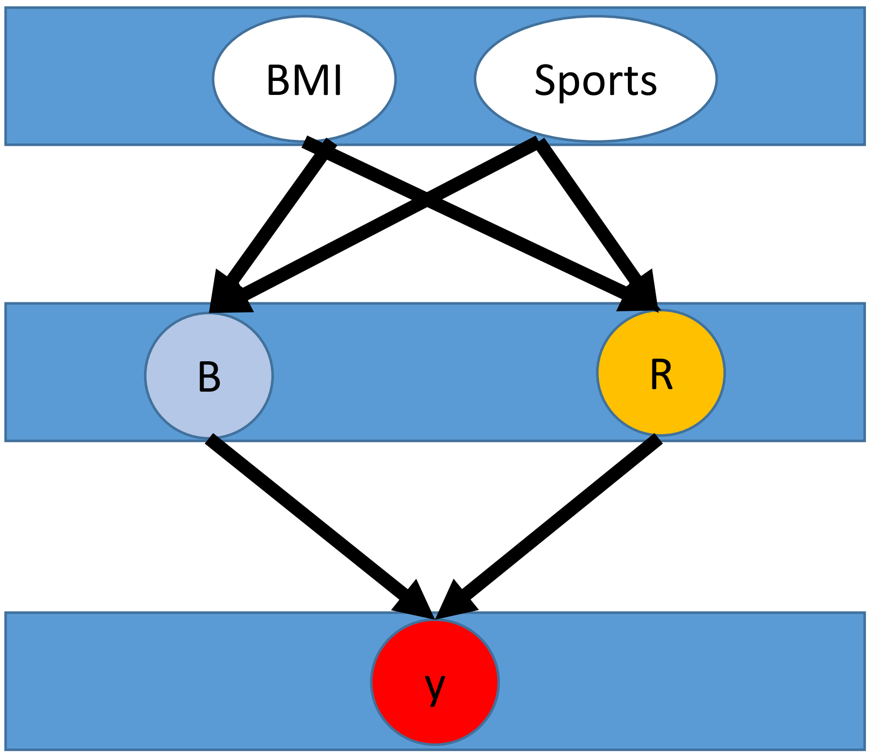
Is it a straight?

Agenda

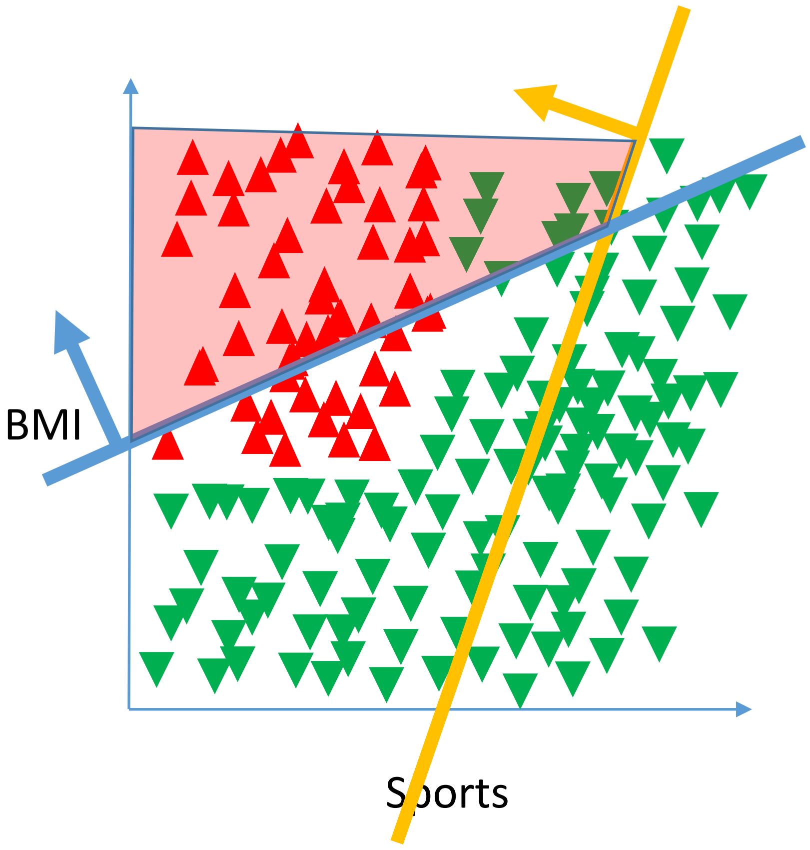
- Many machine learning models cannot make "insights" on data.
- Neural networks.
- How neural networks are built.
- Convolutional neural networks for images.
- Recurrent neural networks for text.

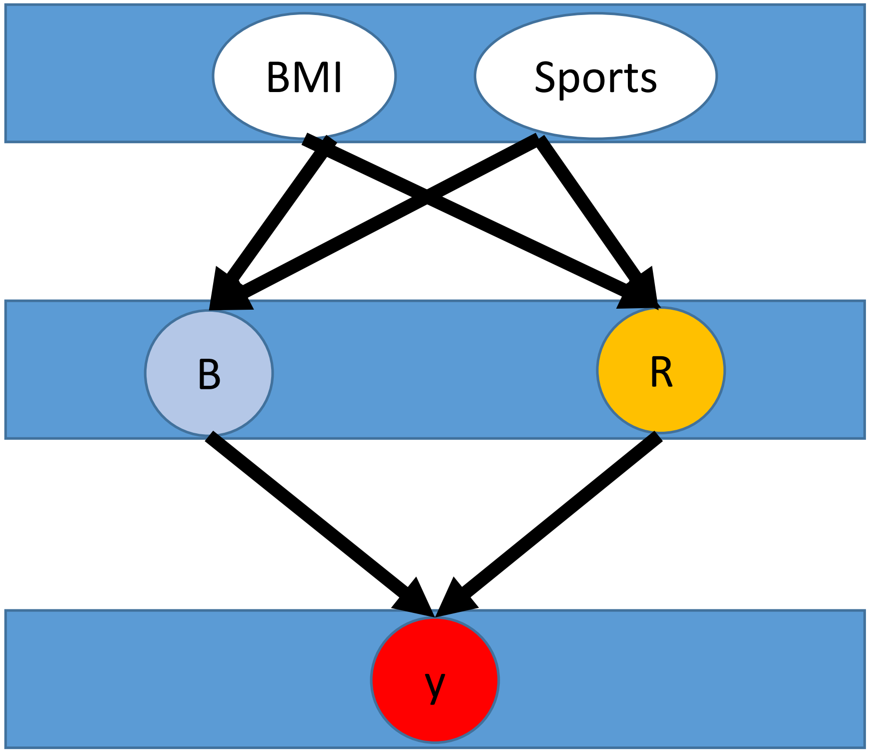
Gradient descent:
How neural networks are built



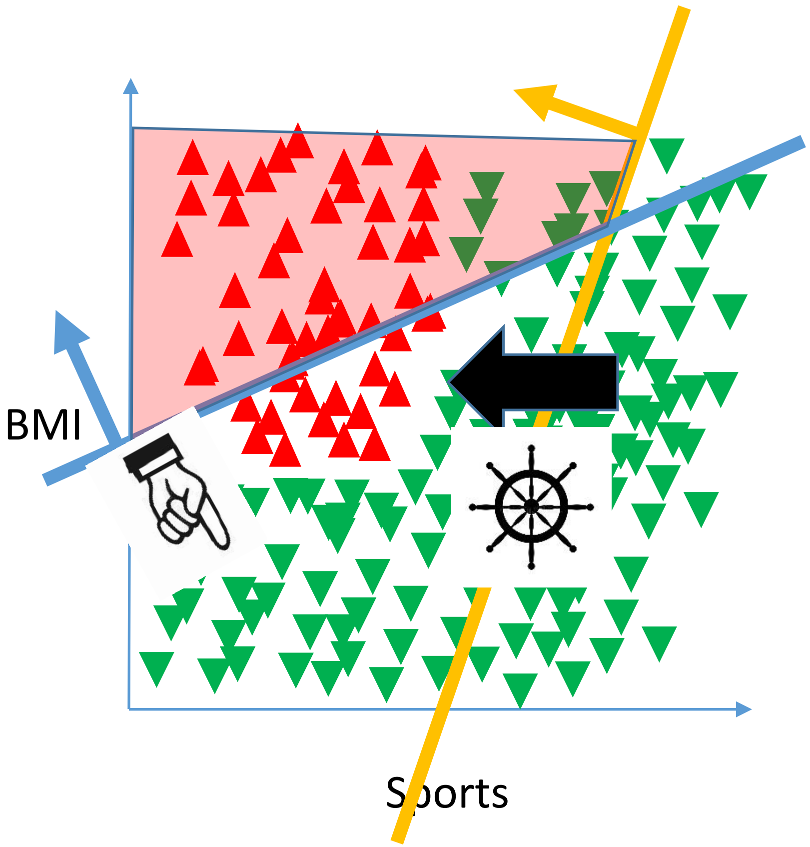


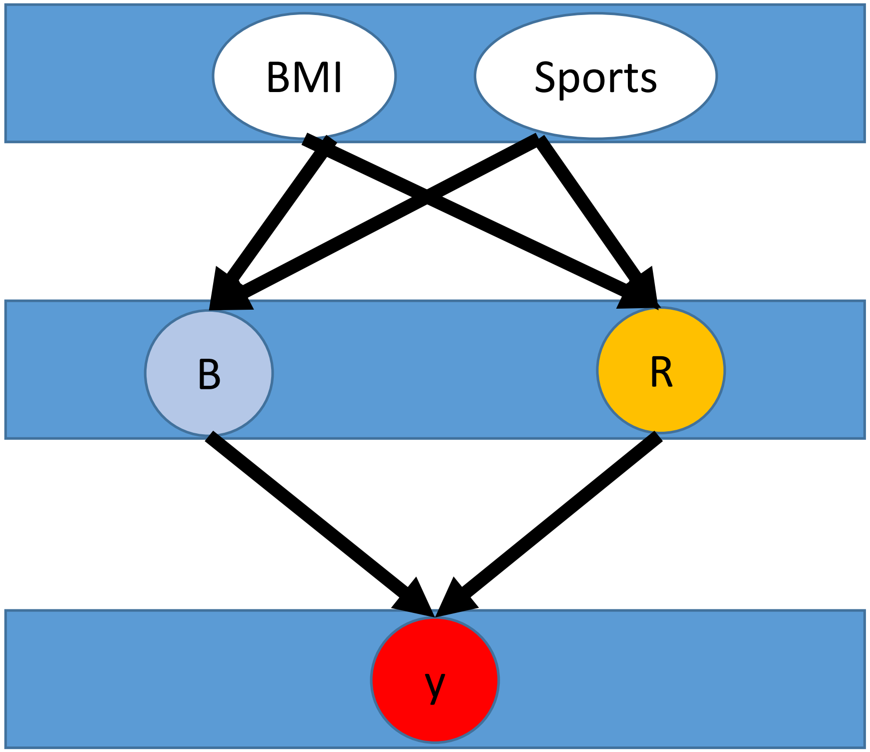
1) Make a guess for the lines



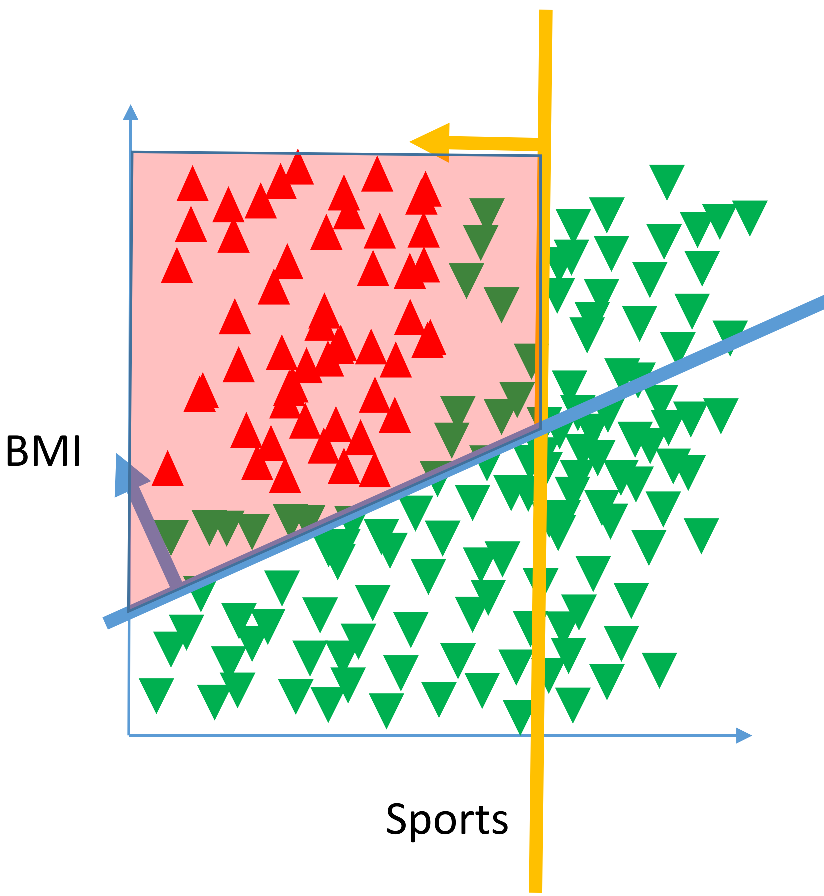


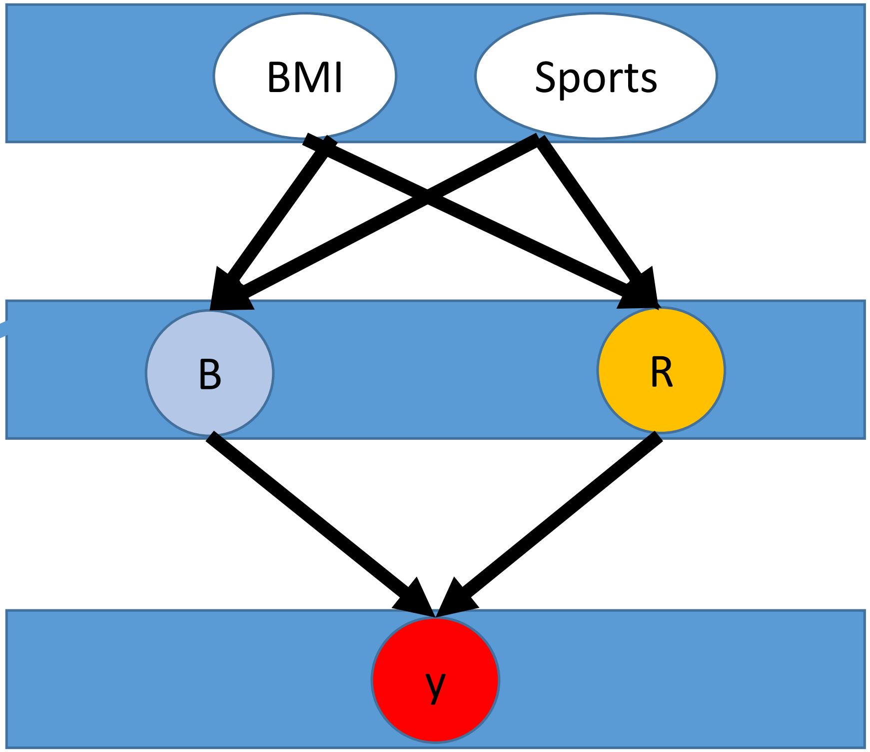
2) Compute gradients for all lines



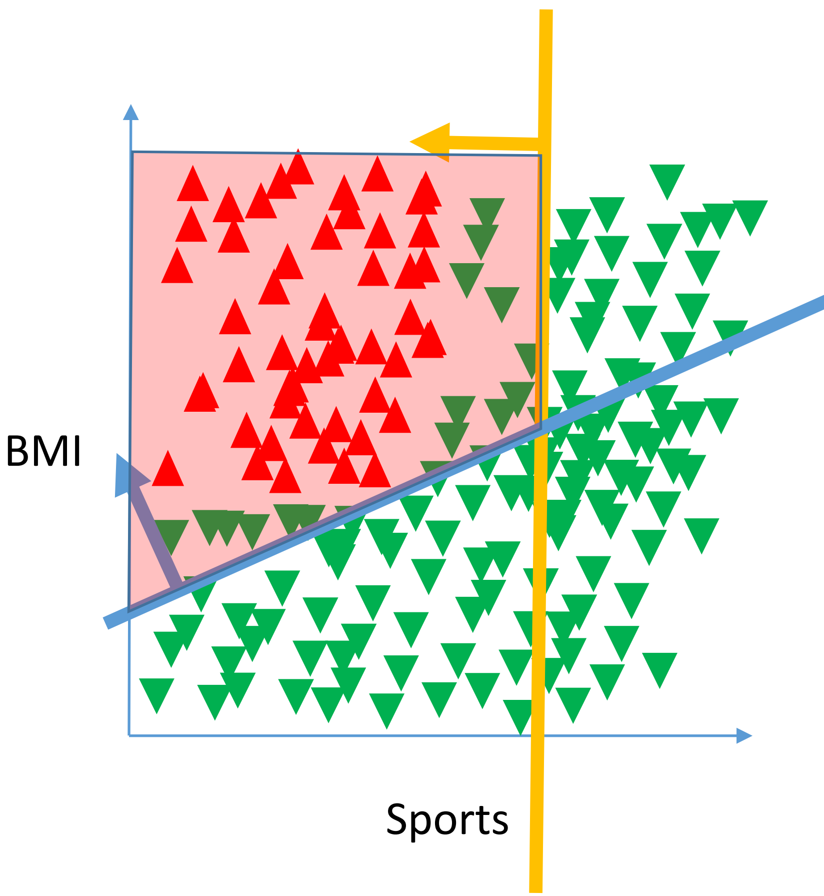


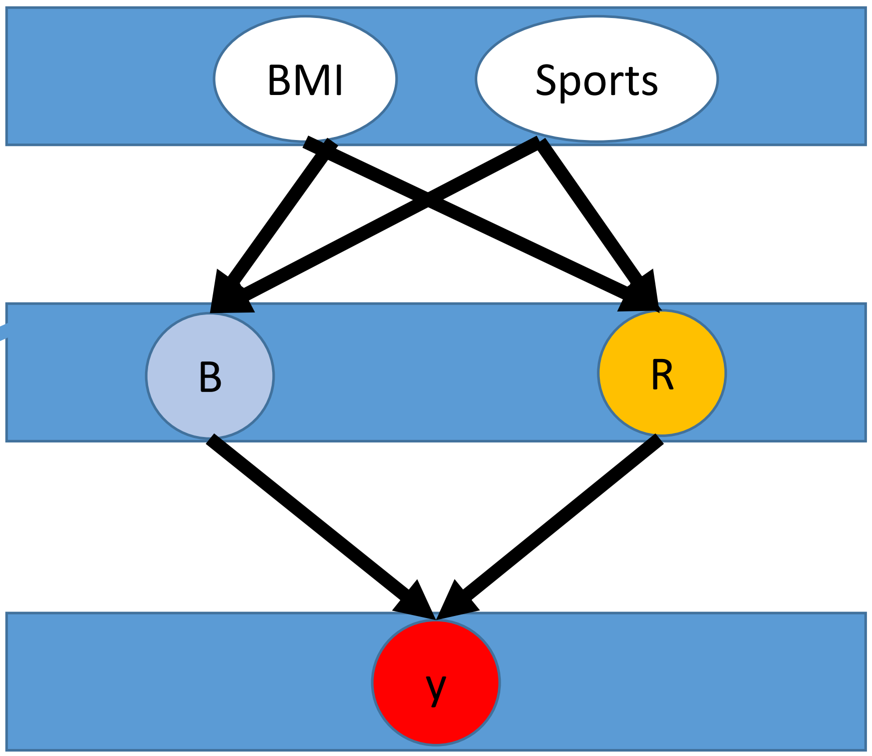
3) Slightly move lines as indicated by the gradients



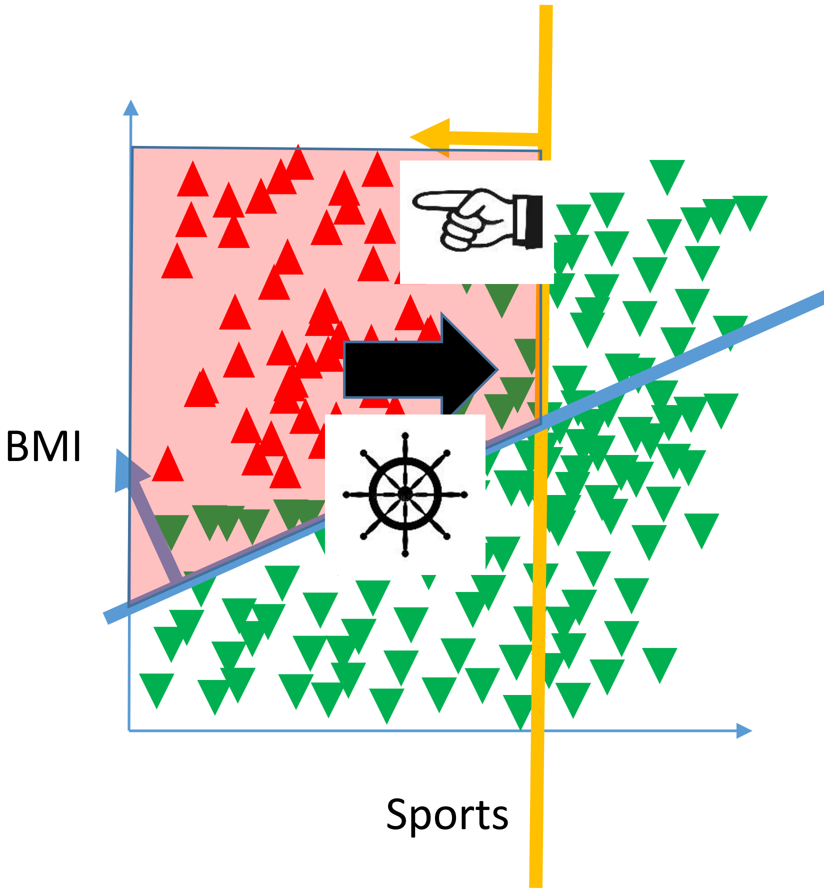


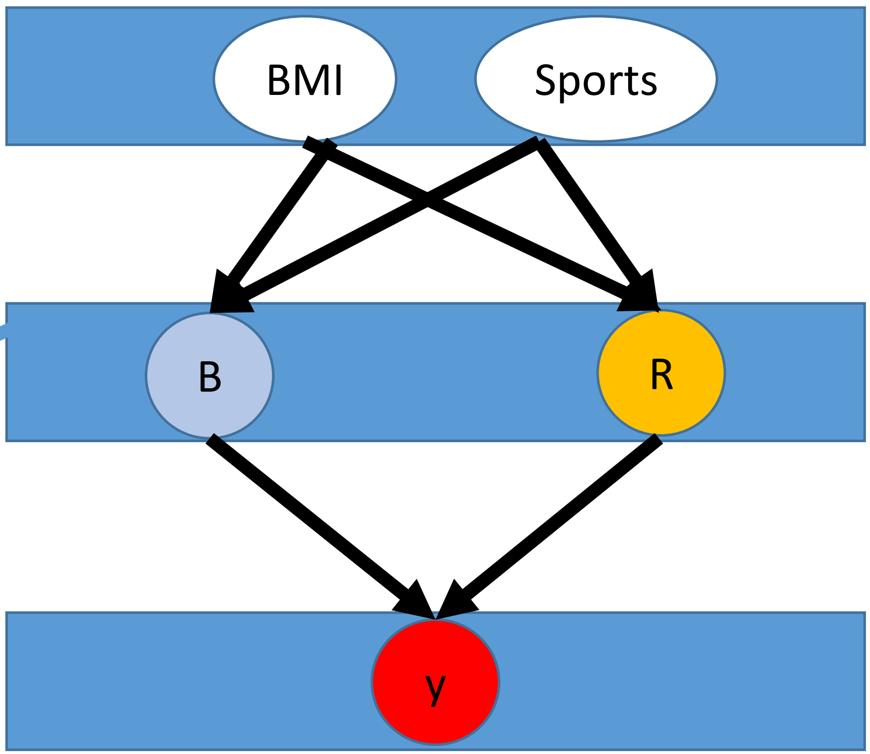
4) Go to step 2



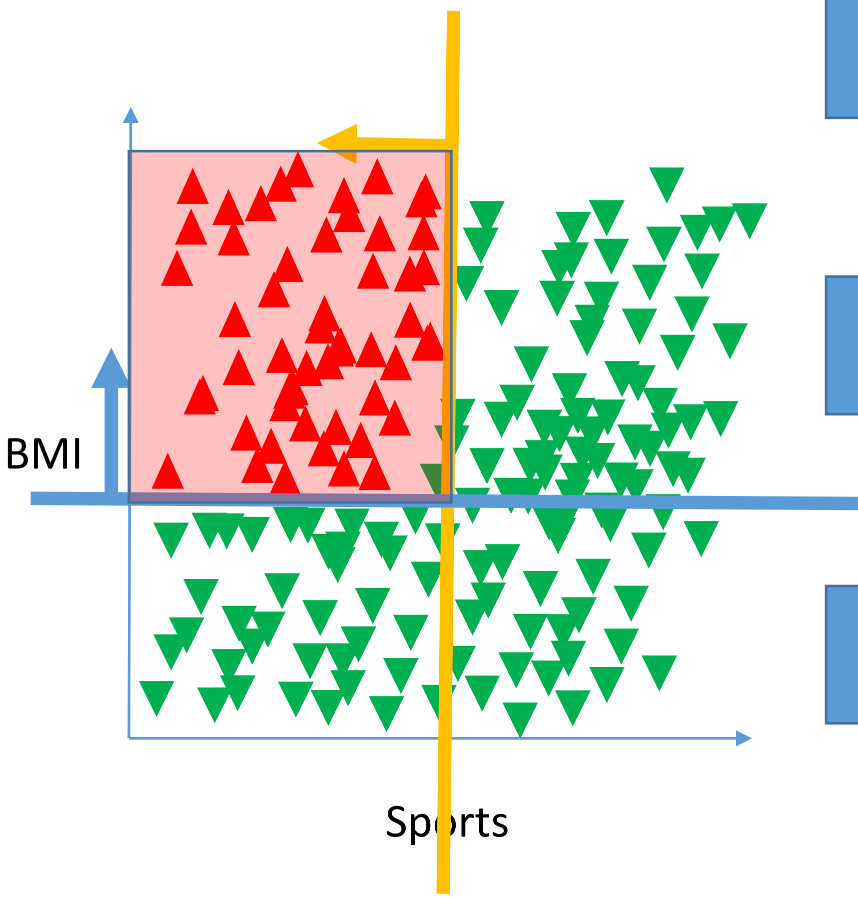


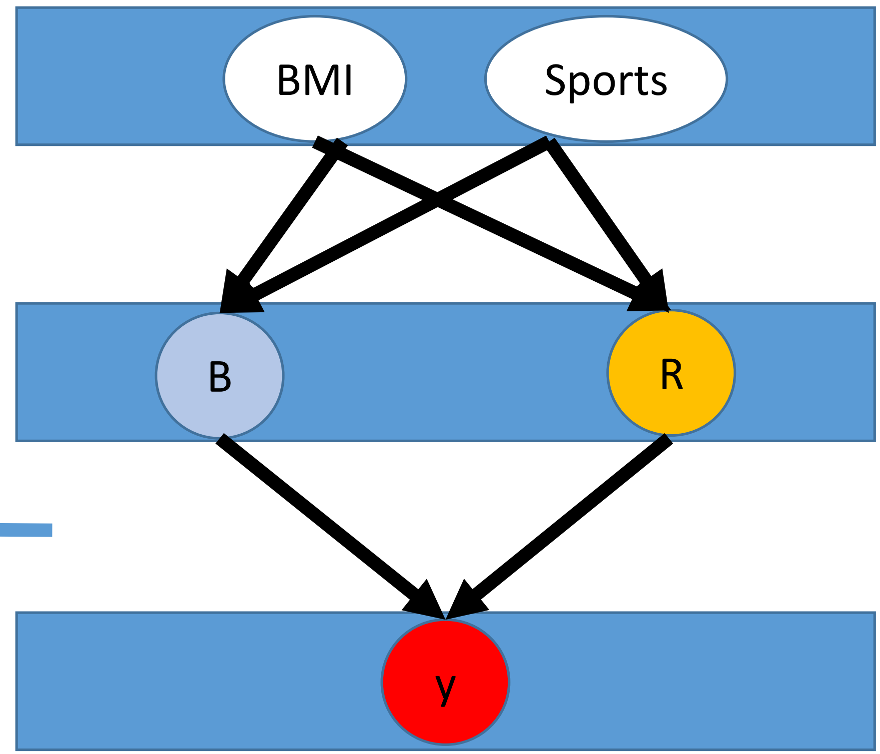
2) Compute gradients for all lines





3) Slightly move lines as indicated by the gradients





Algorithm for training a neural network

1. Make a guess for the lines.
2. Compute gradients.
3. Slightly move lines.
4. Go to (2).

Algorithm for training a neural network

1. Make a guess for the lines.
2. For i = 1 … NumEpochs
   a) Compute gradients.
   b) Slightly move lines.

Each iteration in step (2) is called an **epoch.**

You must indicate (ahem! guess) the number of epochs before calling this algorithm.

Flower classification

Iris setosa

Iris tectorum

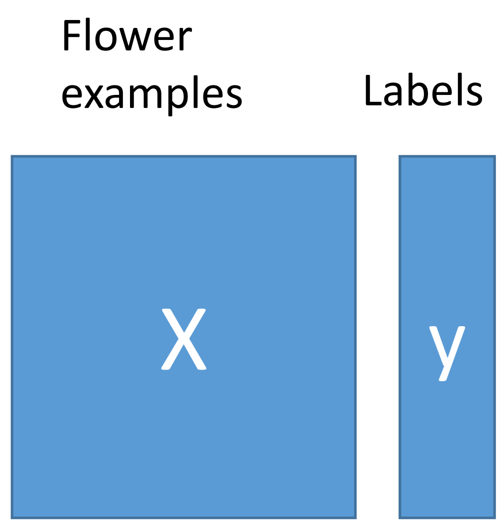
Iris latifolia

Data representation

Sepal length	Sepal width	Petal length	Petal width	Is setosa?
5.1	3.5	1.4	0.2	1
2.1	1.2	3.3	3.2	0
3.1	1.6	2.2	4.1	1
2.2	4.1	1.3	1.4	1

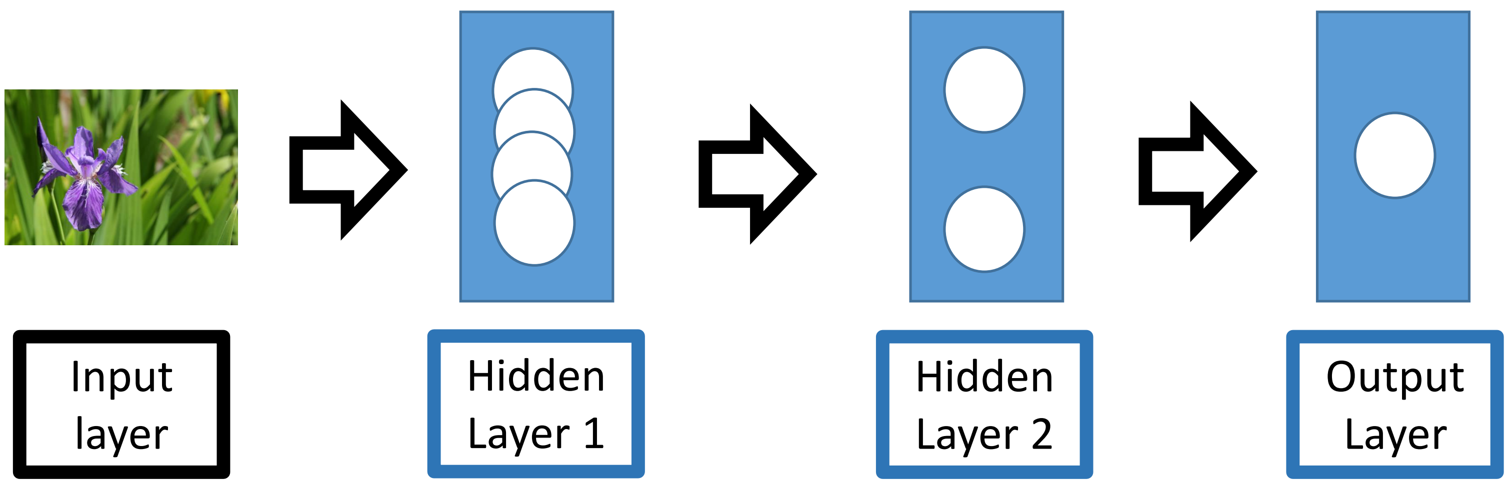
Data representation

- X[i, j]: Value of column j for flower i.
- y[i]: 1 if flower i is an iris setosa and 0 otherwise.



Script organization

1. **Input parsing:** Read X and y.
2. **Network architecture:** Define neural network layers.

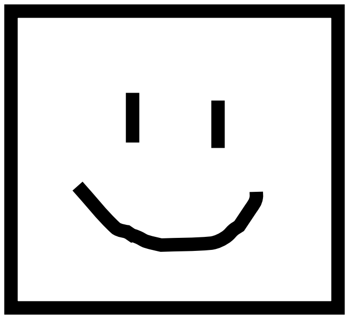


3. **Compilation and training:** Compile and train neural network.

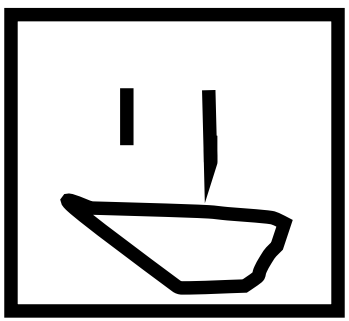
Agenda

- Many machine learning models cannot make "insights" on data.
- Neural networks.
- How neural networks are built.
- Convolutional neural networks for images.
- Recurrent neural networks for text.

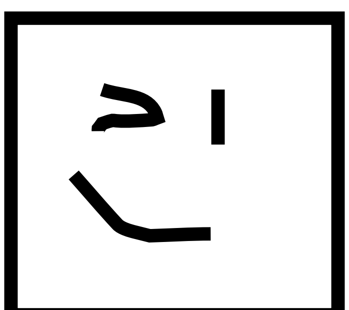
Image recognition



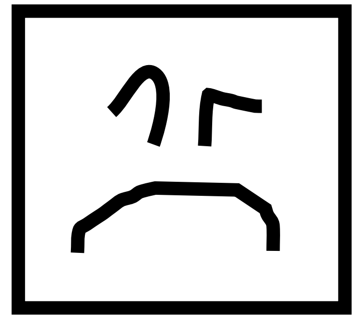
Happy



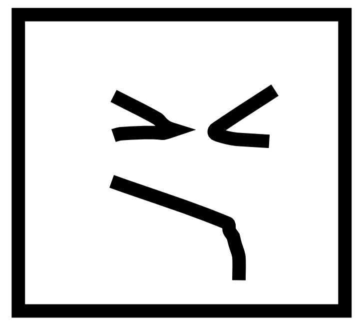
Happy



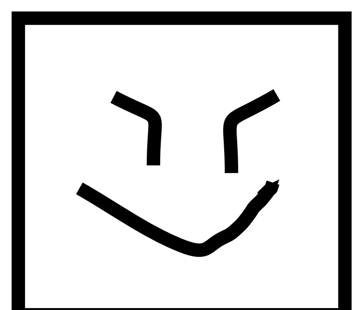
Happy



Not happy

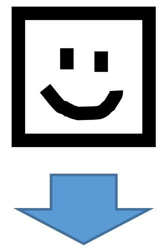


Not happy



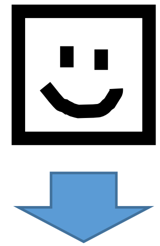
Not happy

Image recognition

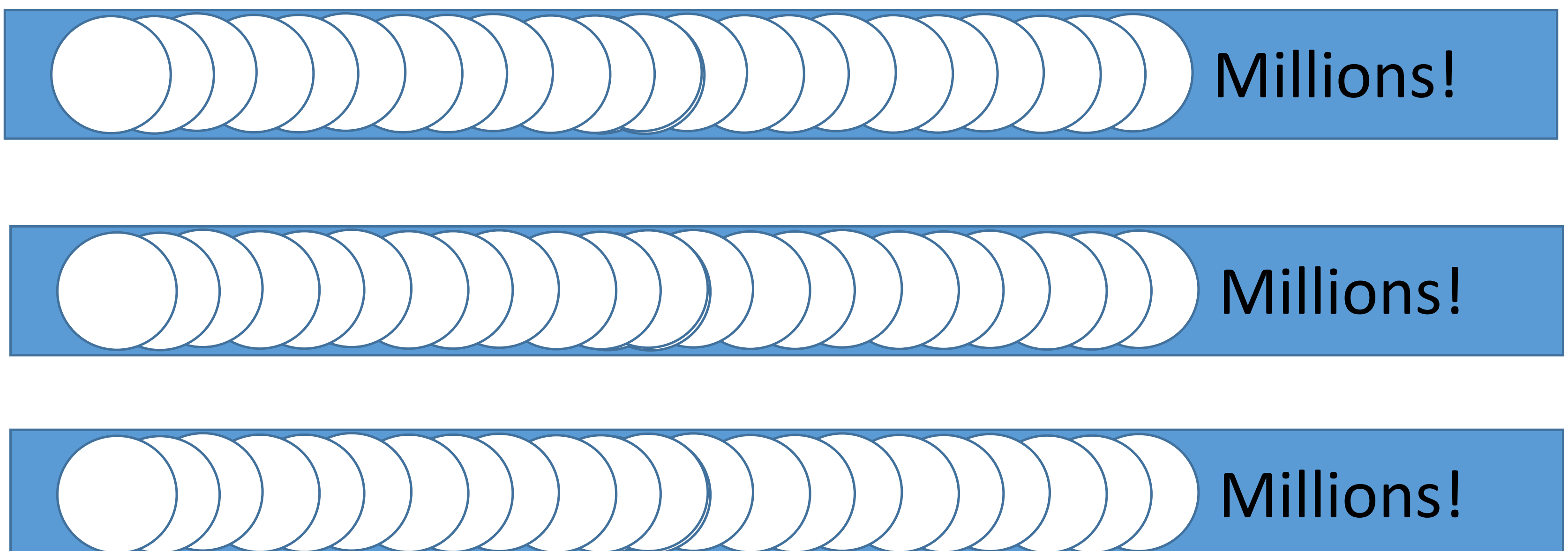


0	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**1**	**…**	**1**

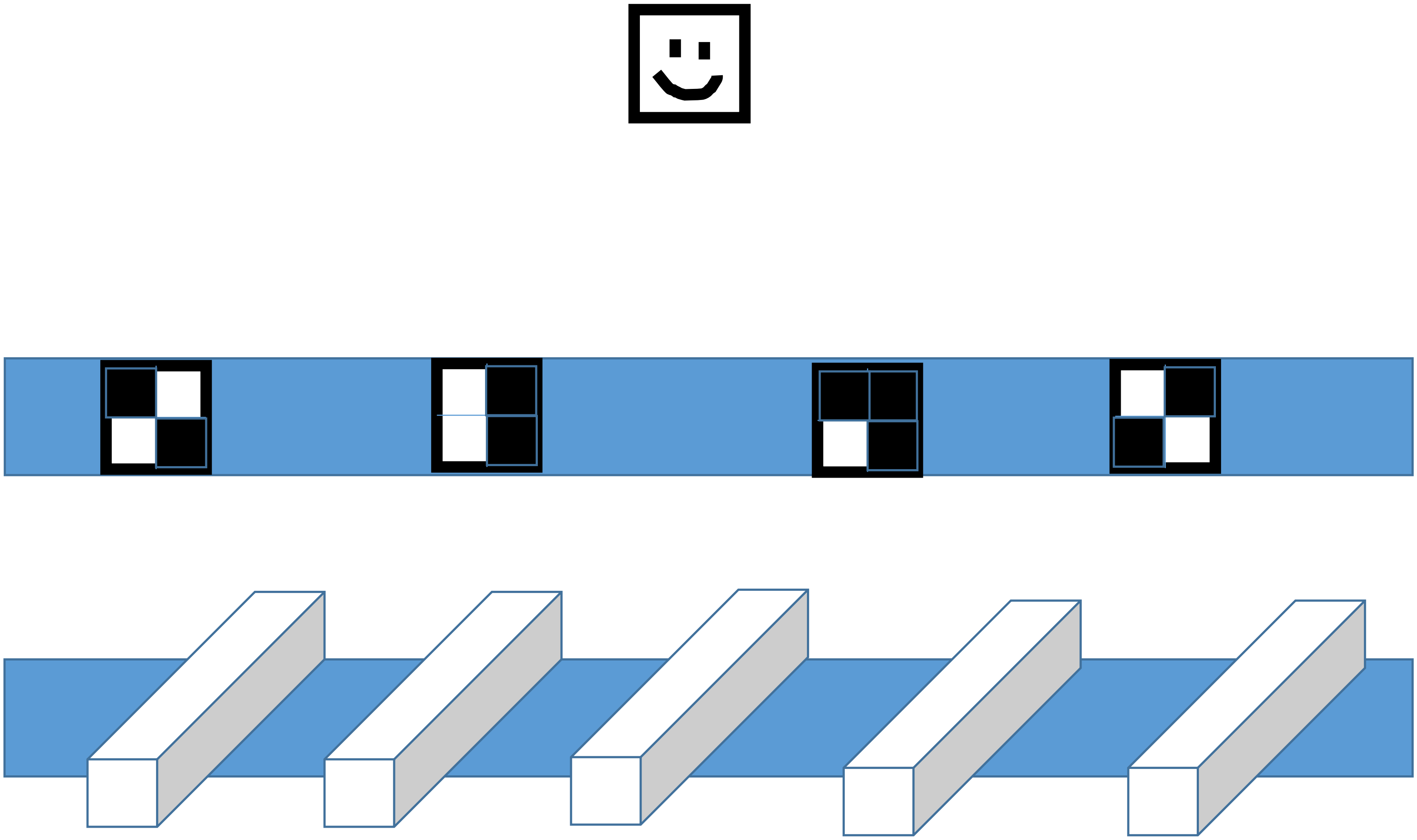
Image recognition



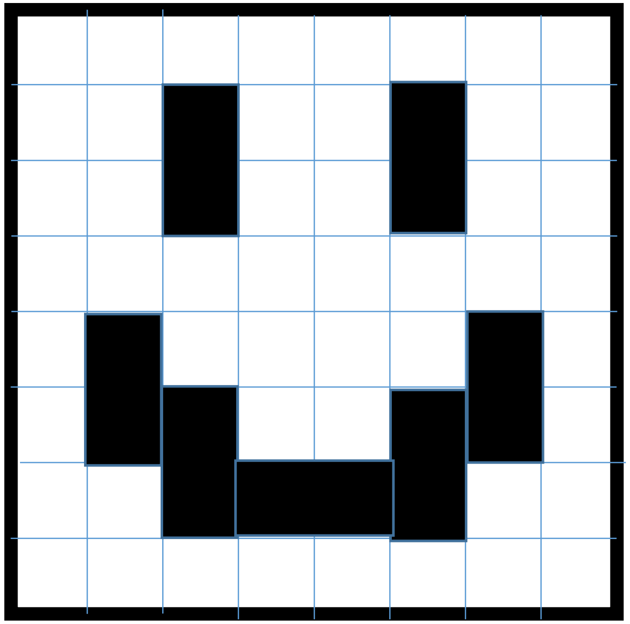
0	1	0	0	1	0	0	1	1	0	1	0	1	0	0	1	1	…	1

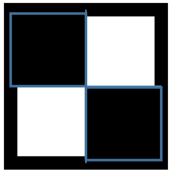


Convolutional neural networks

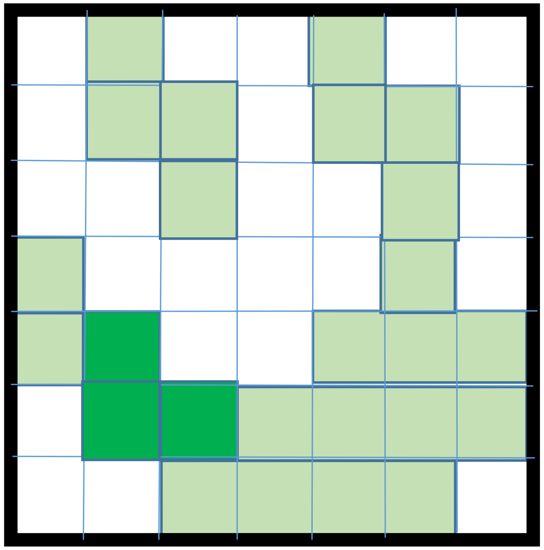


Convolutional neural networks

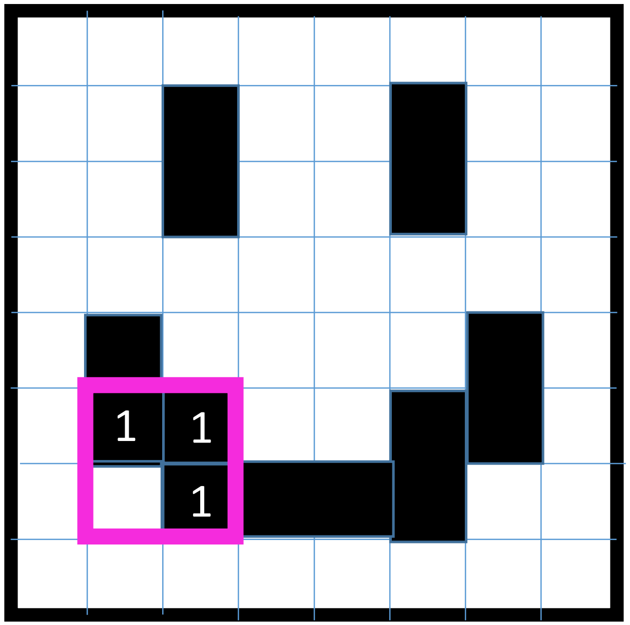


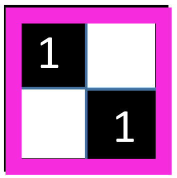


filter

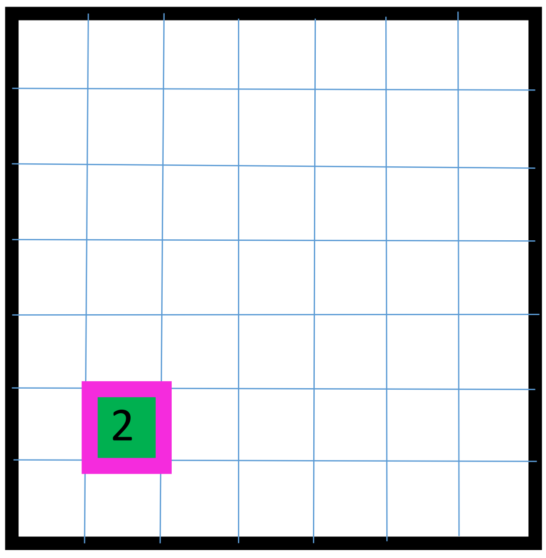


Convolutional neural networks

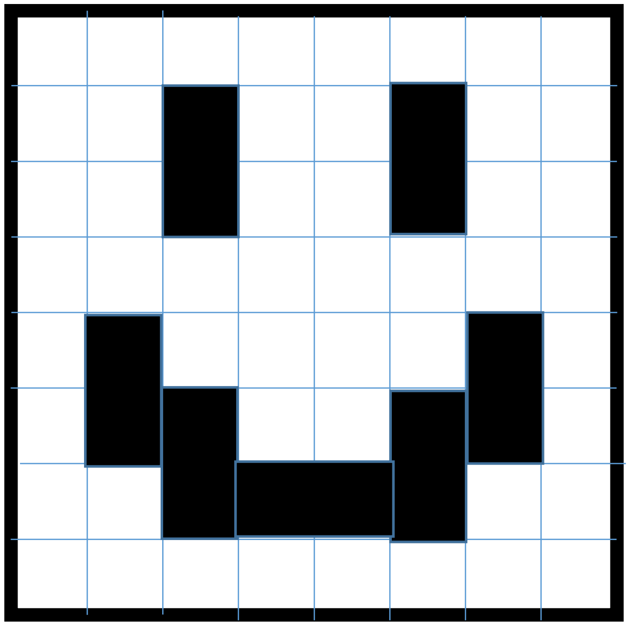


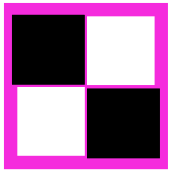


filter

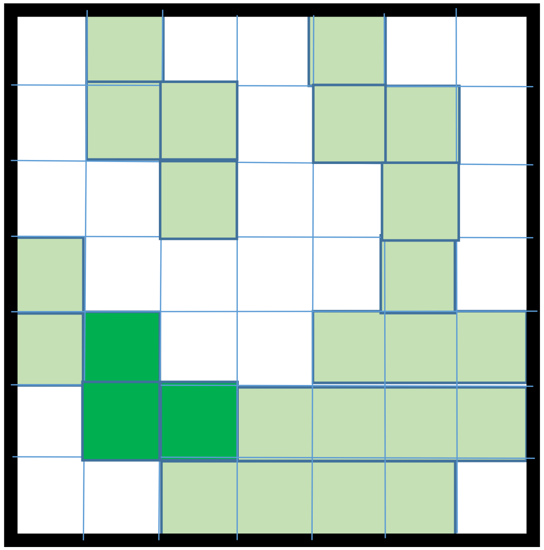


Convolutional neural networks

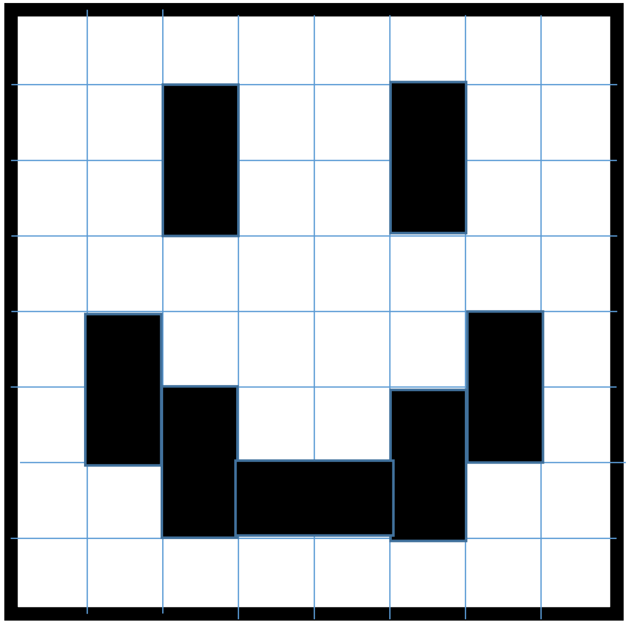


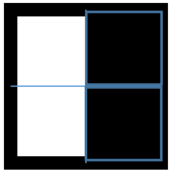


filter

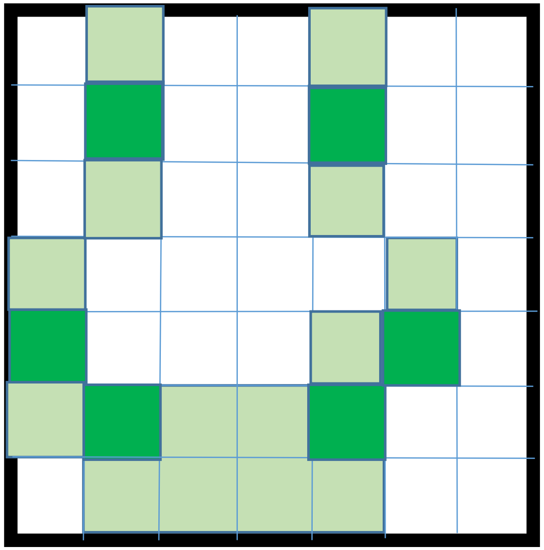


Convolutional neural networks

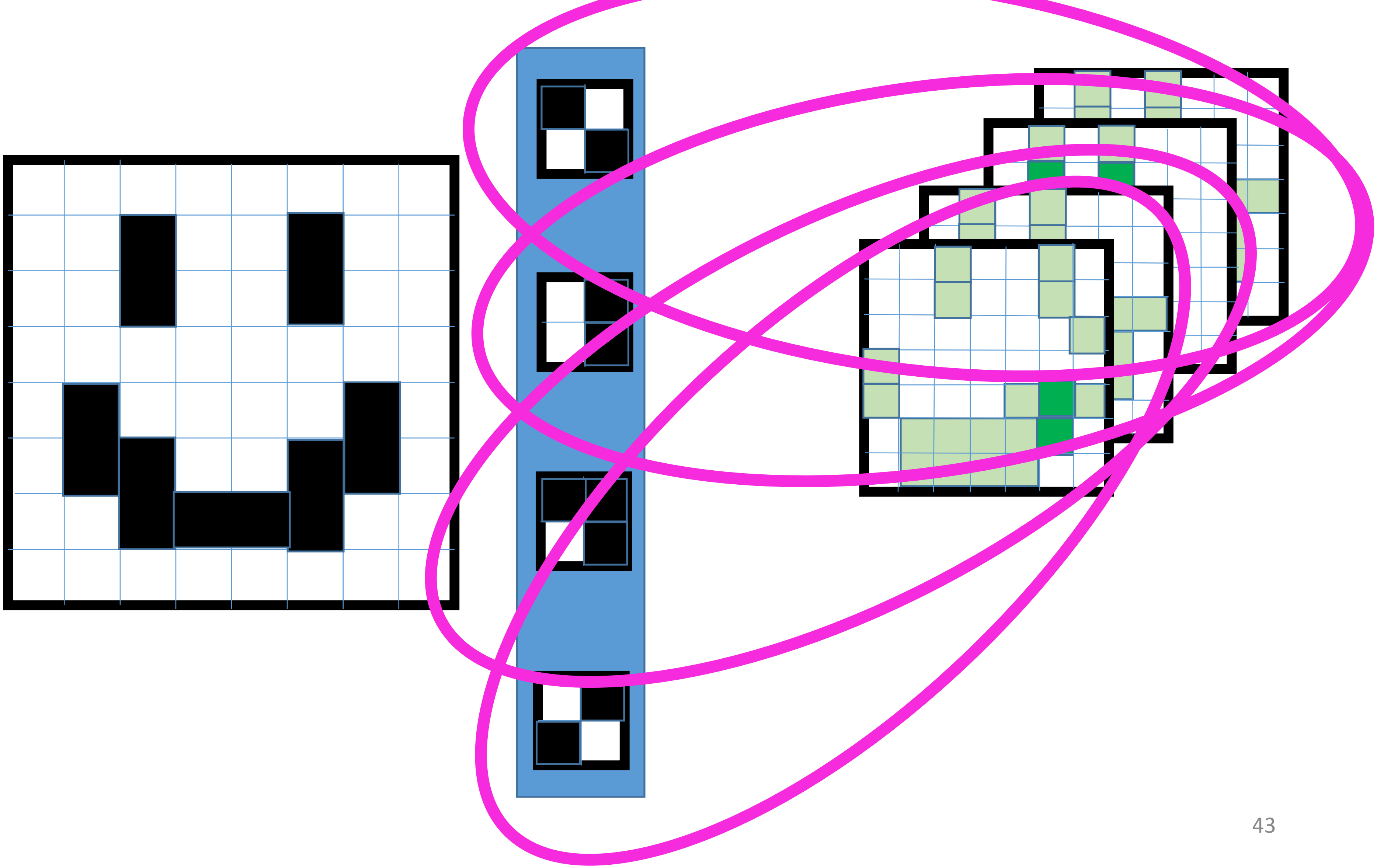




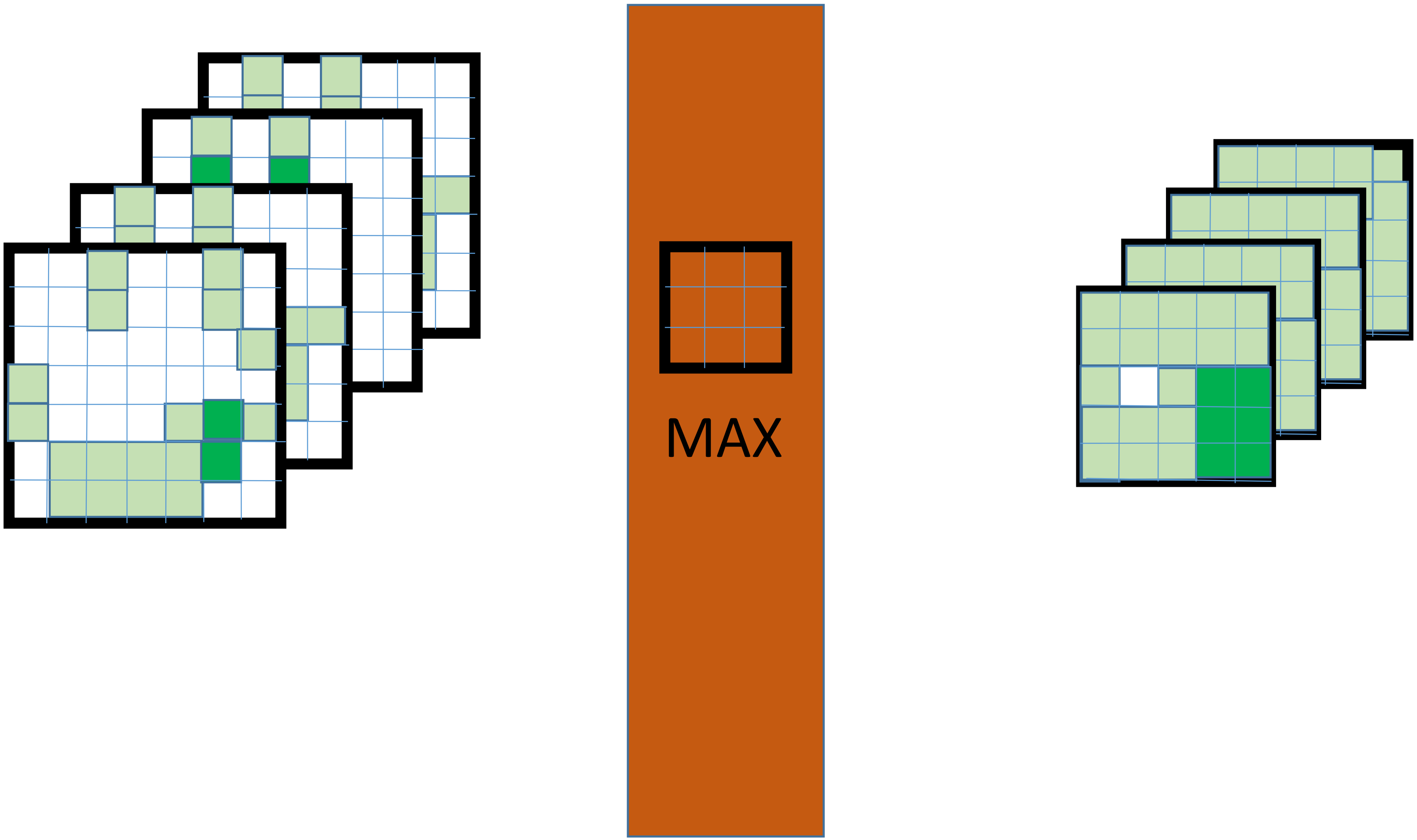
filter



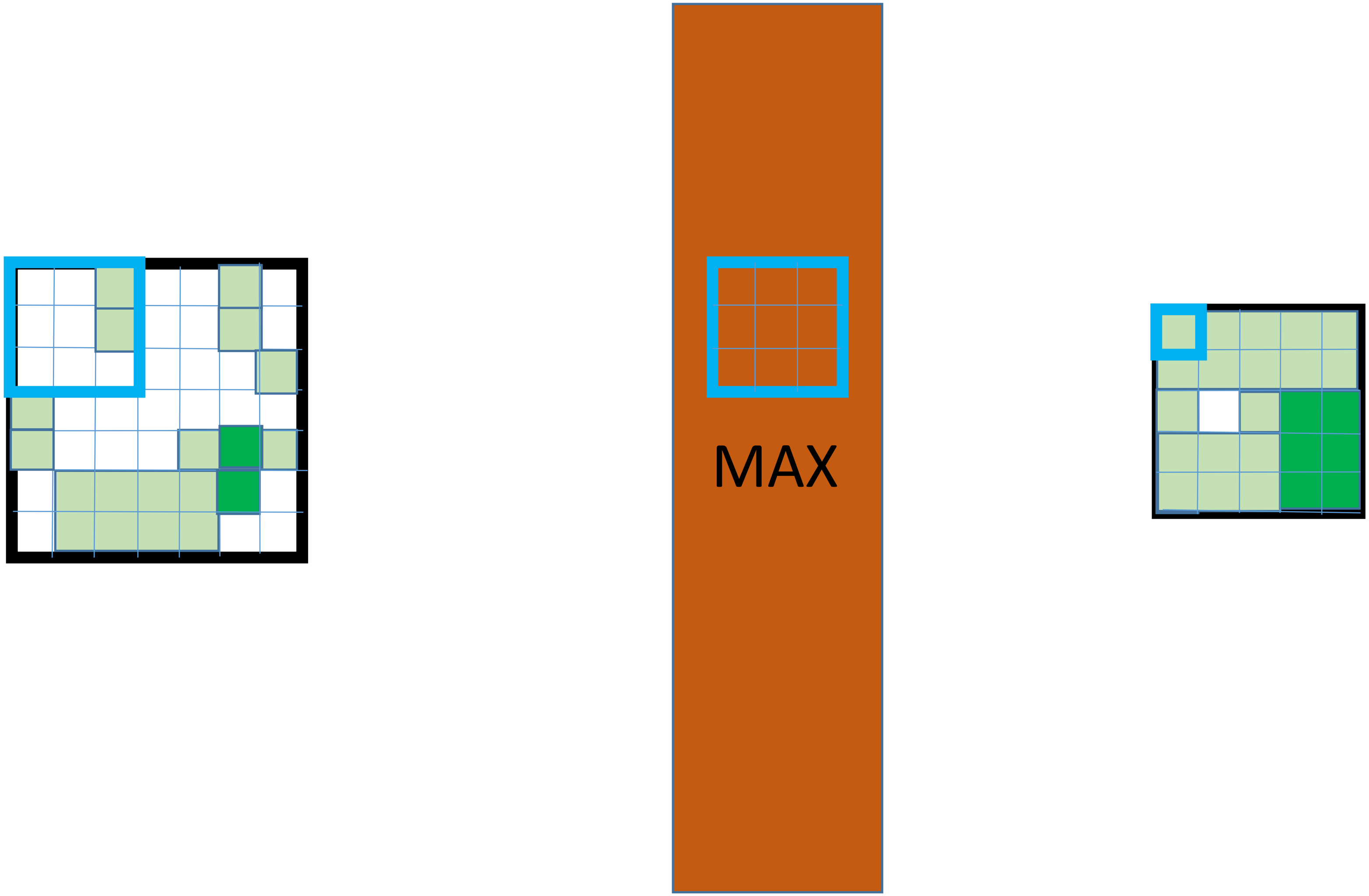
Convolutional neural networks



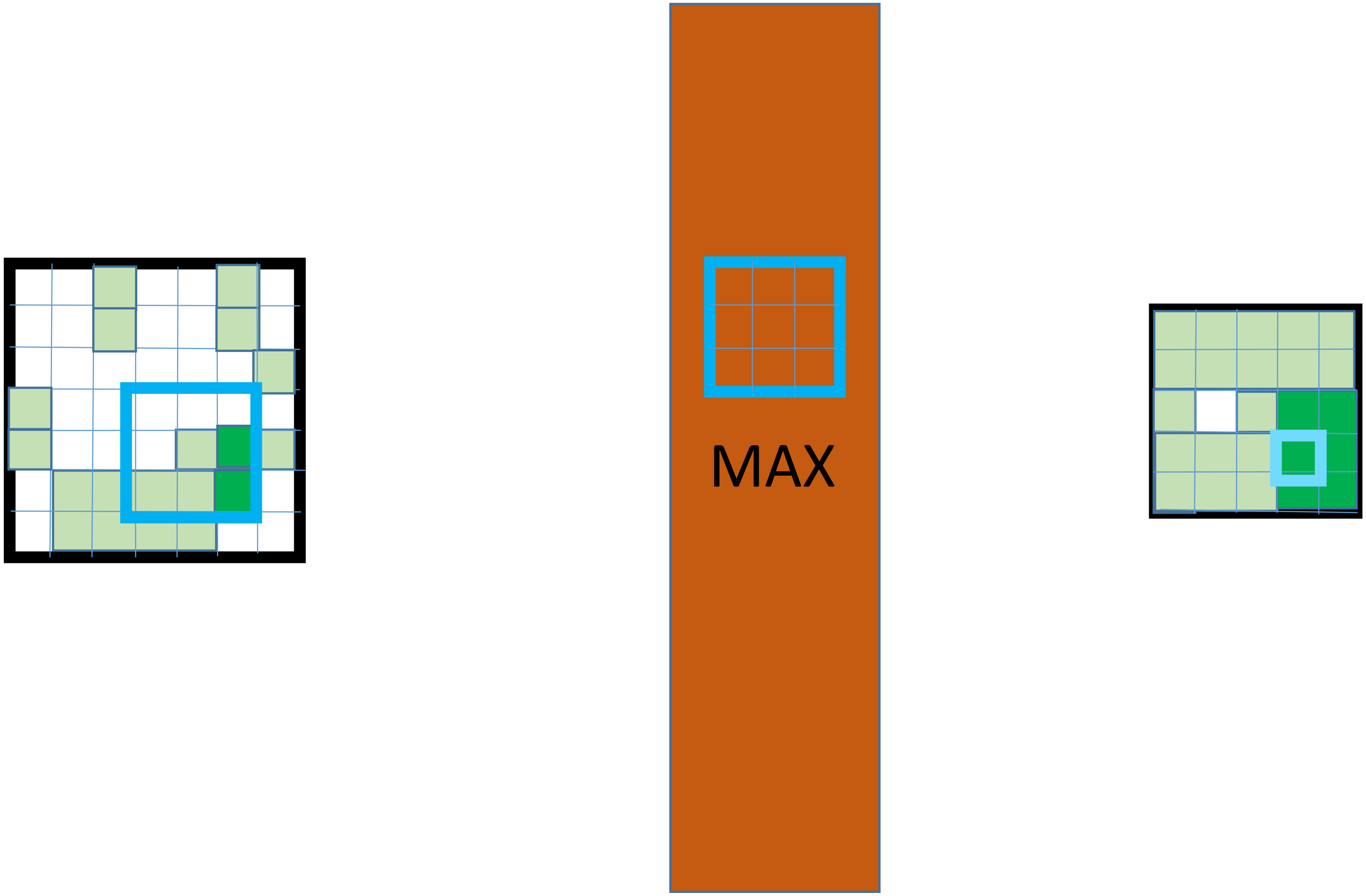
Convolutional neural networks



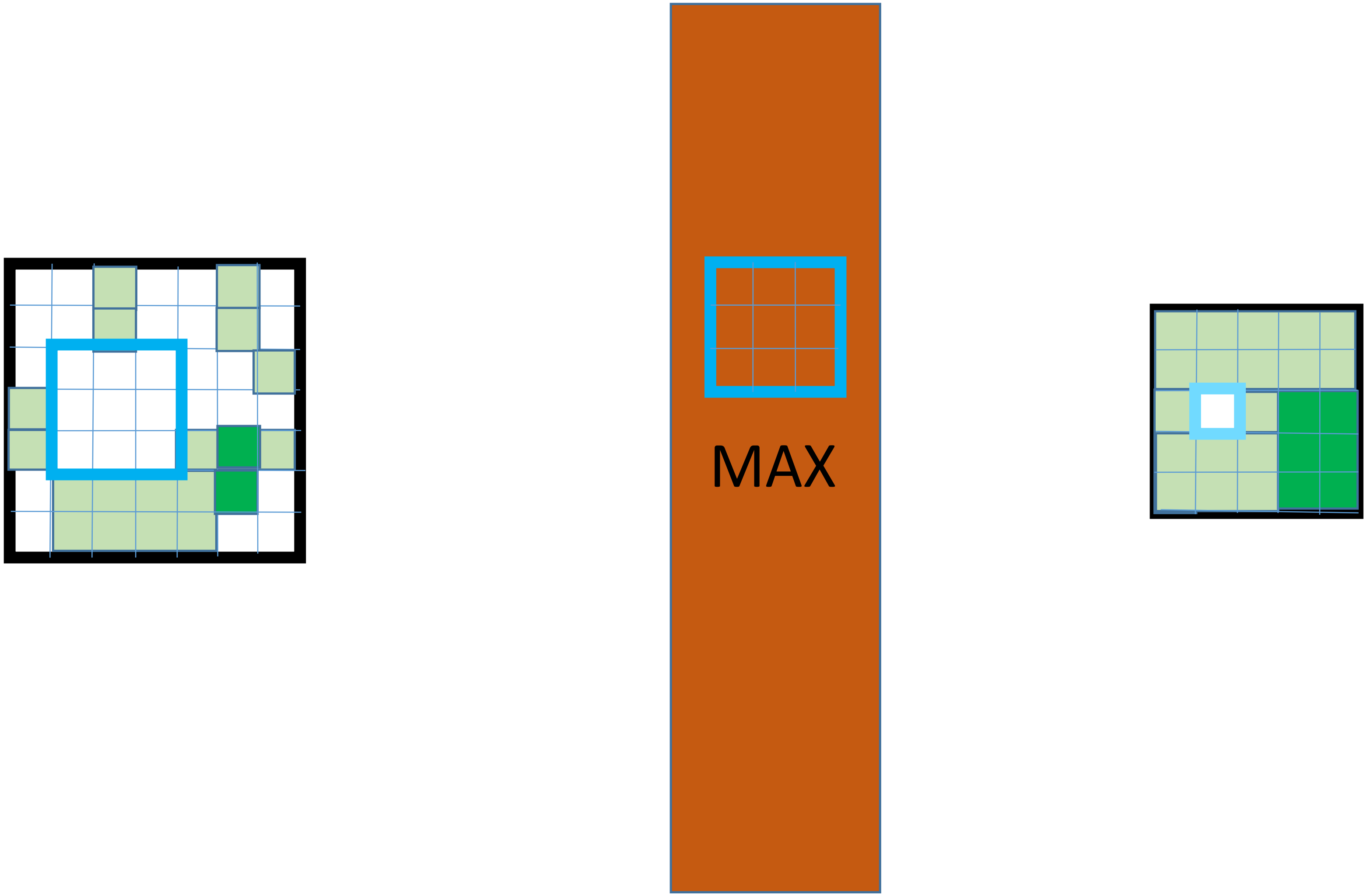
Convolutional neural networks



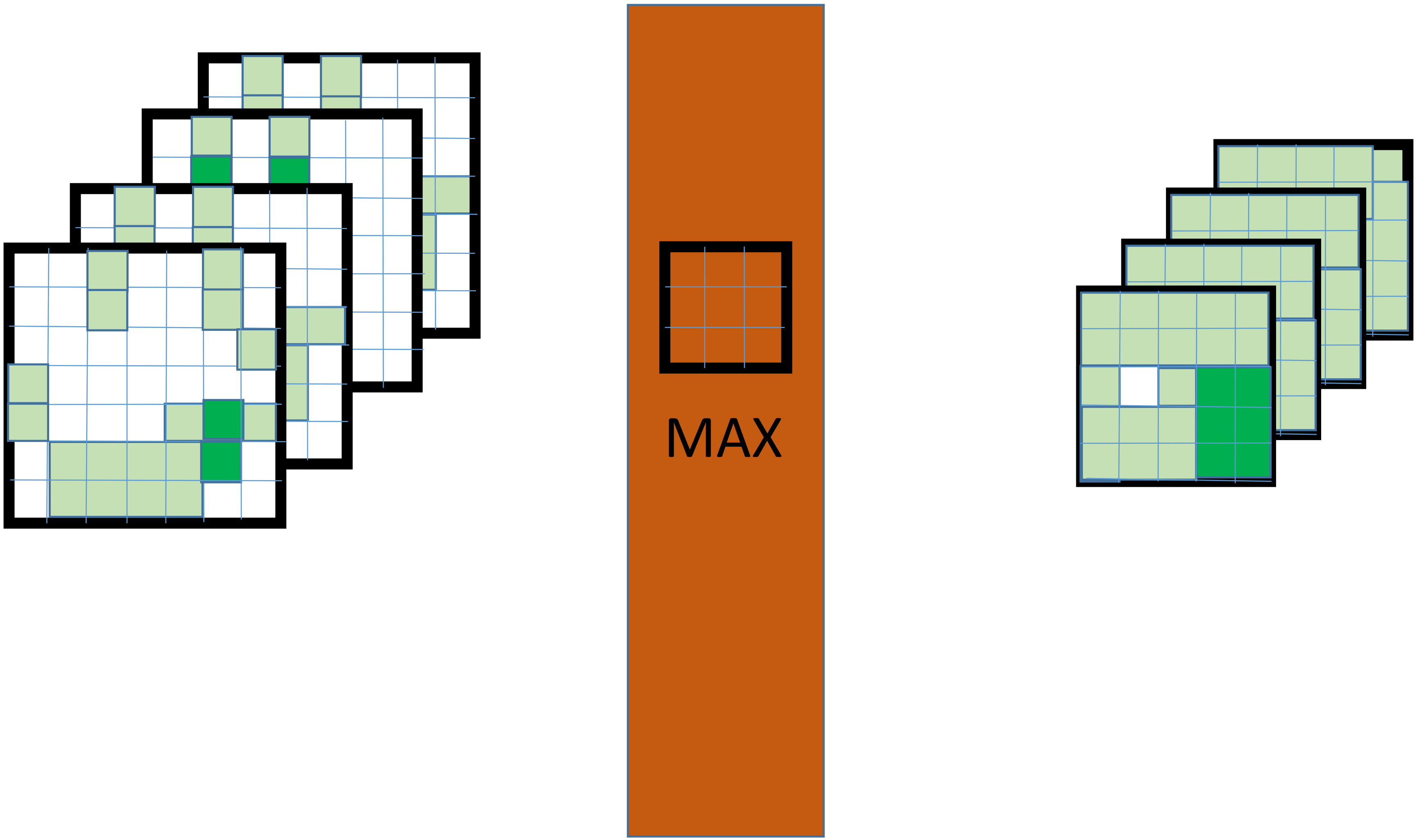
Convolutional neural networks



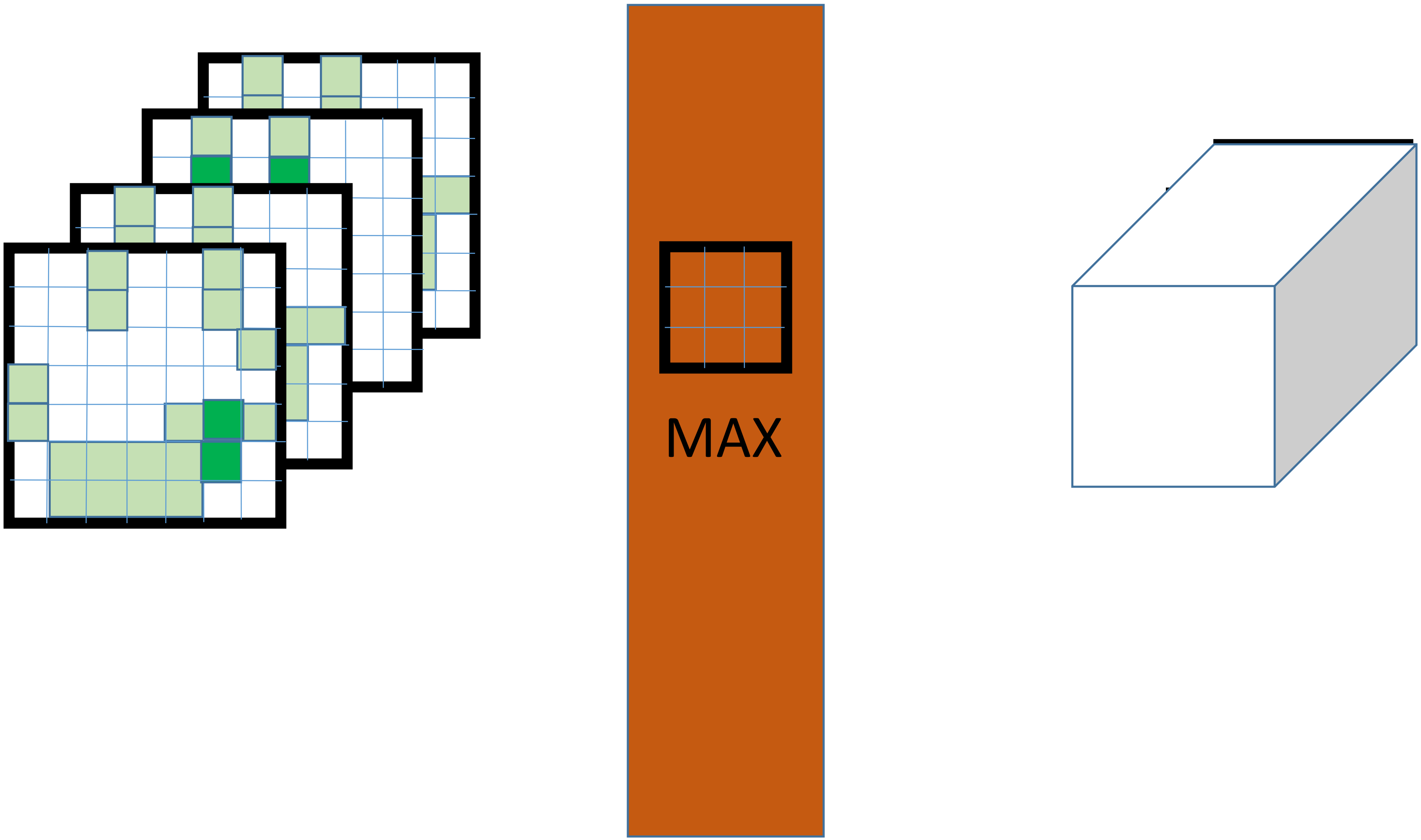
Convolutional neural networks



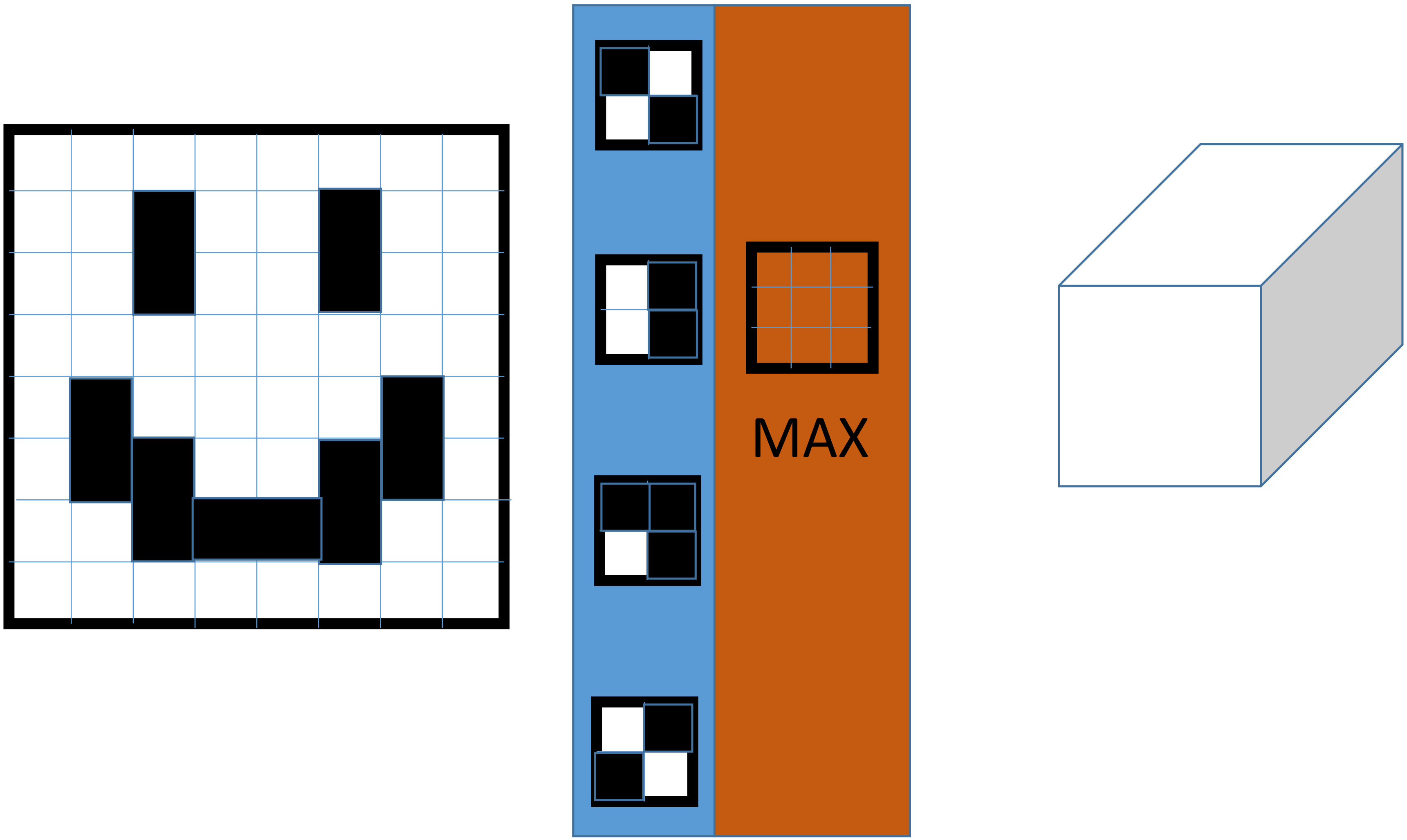
Convolutional neural networks



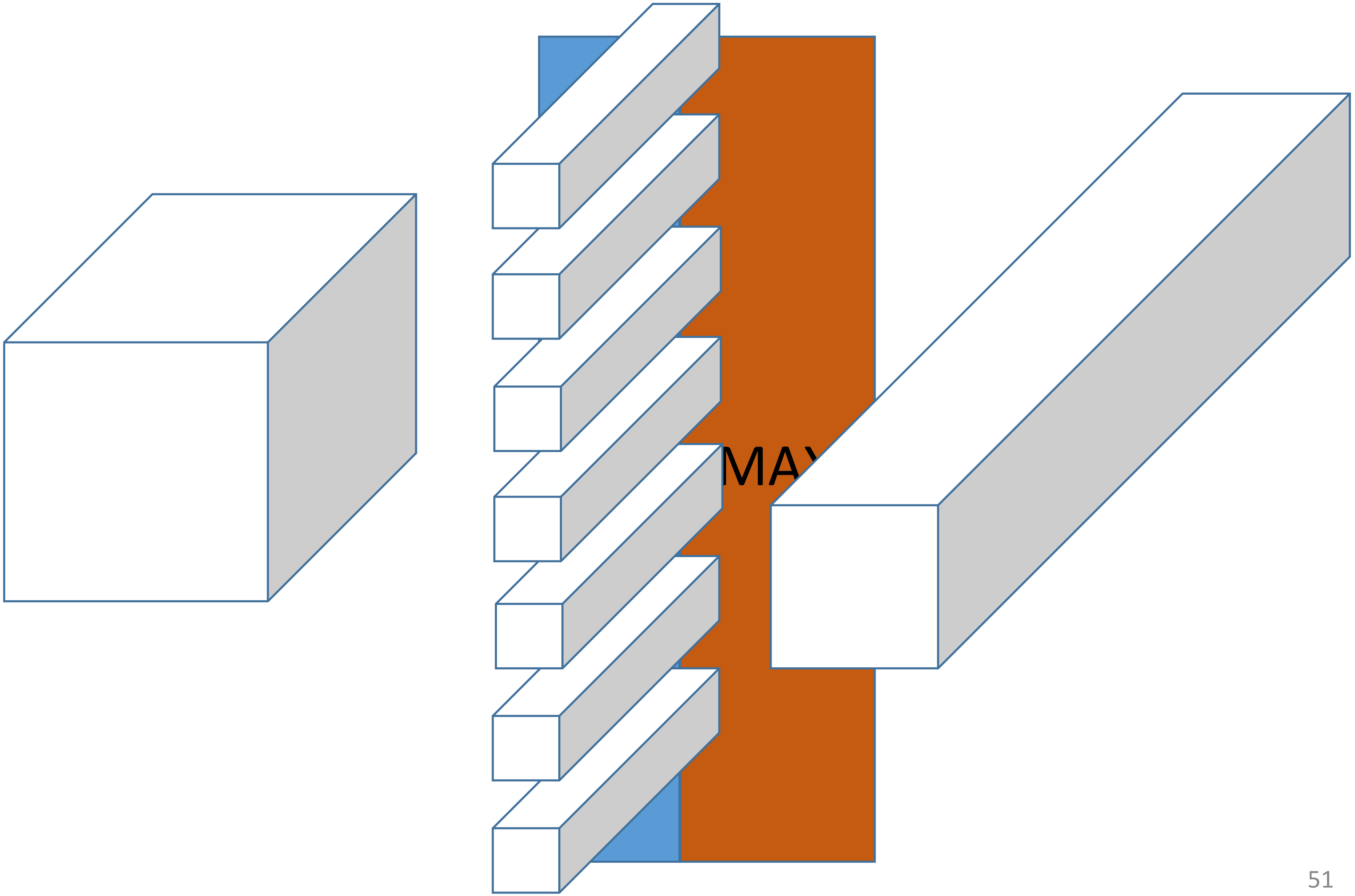
Convolutional neural networks



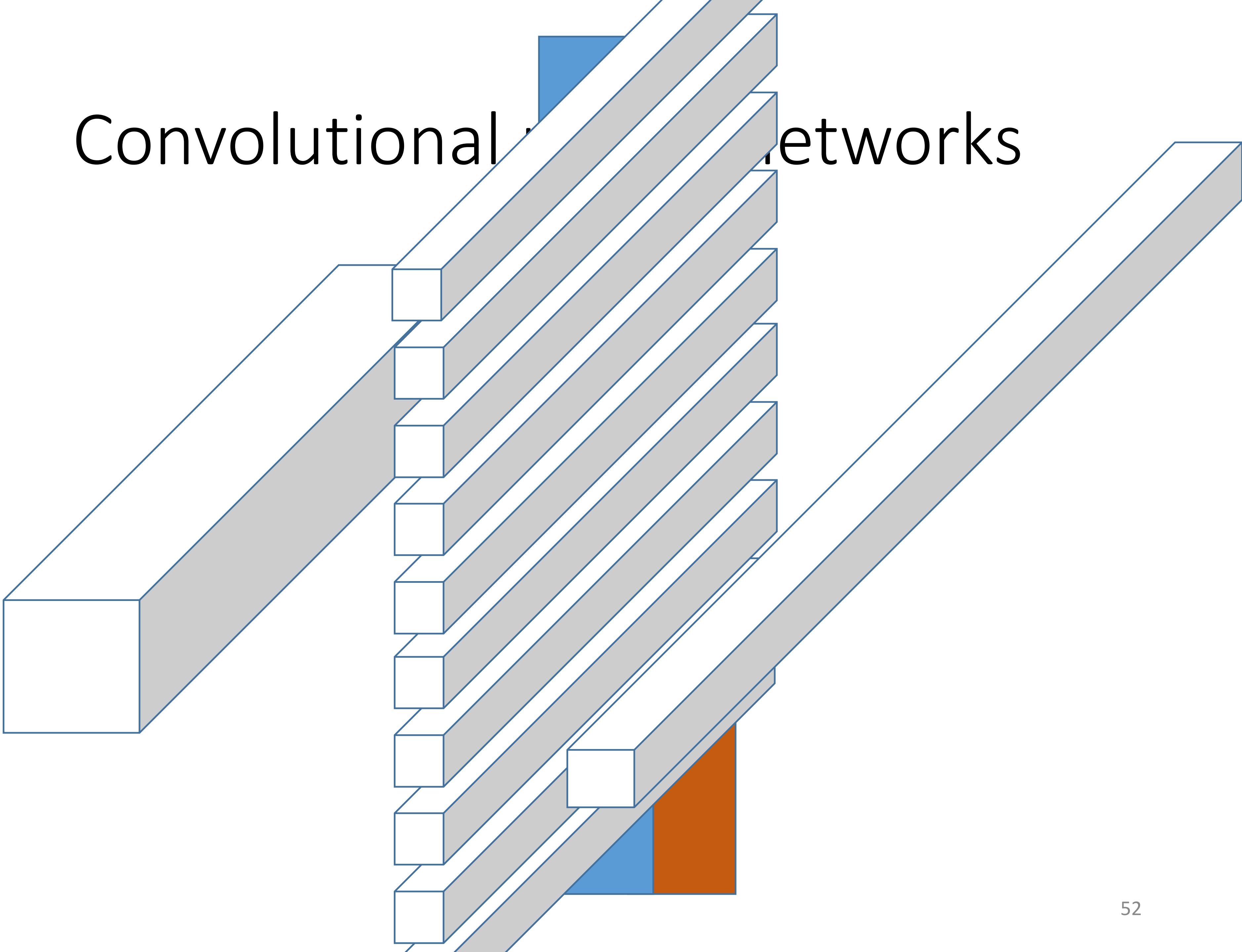
Convolutional neural networks



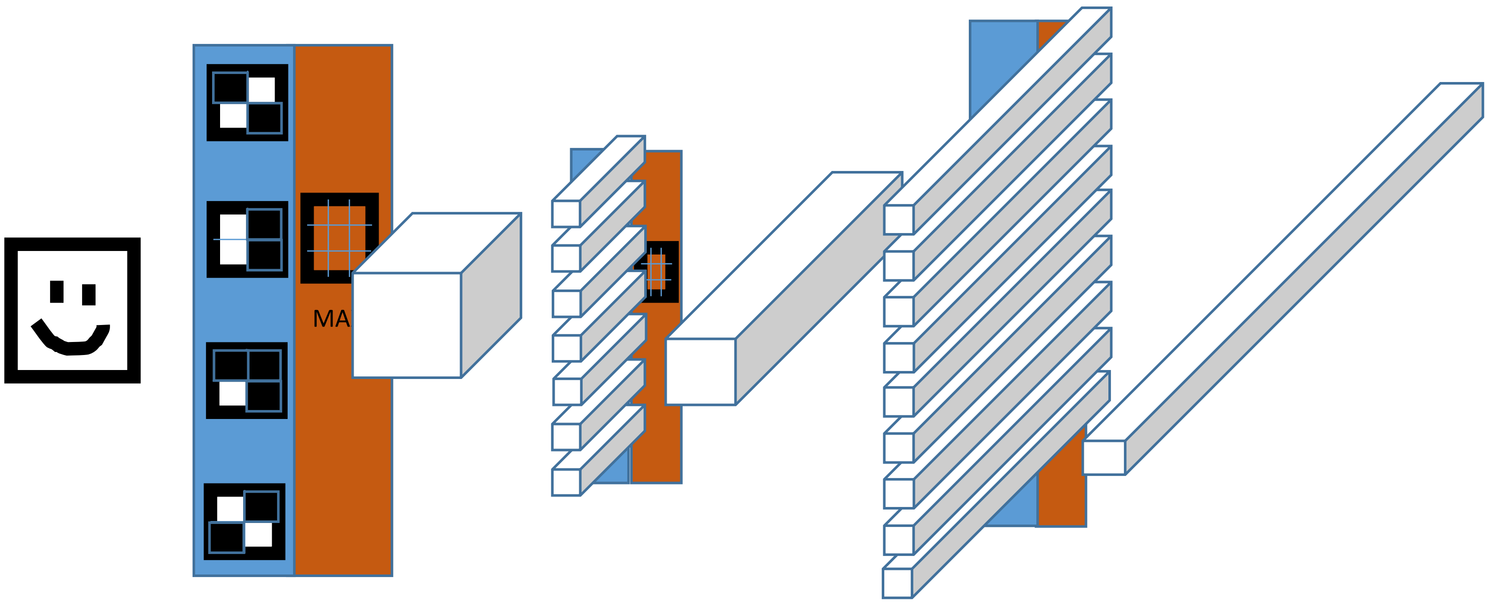
Convolutional neural networks

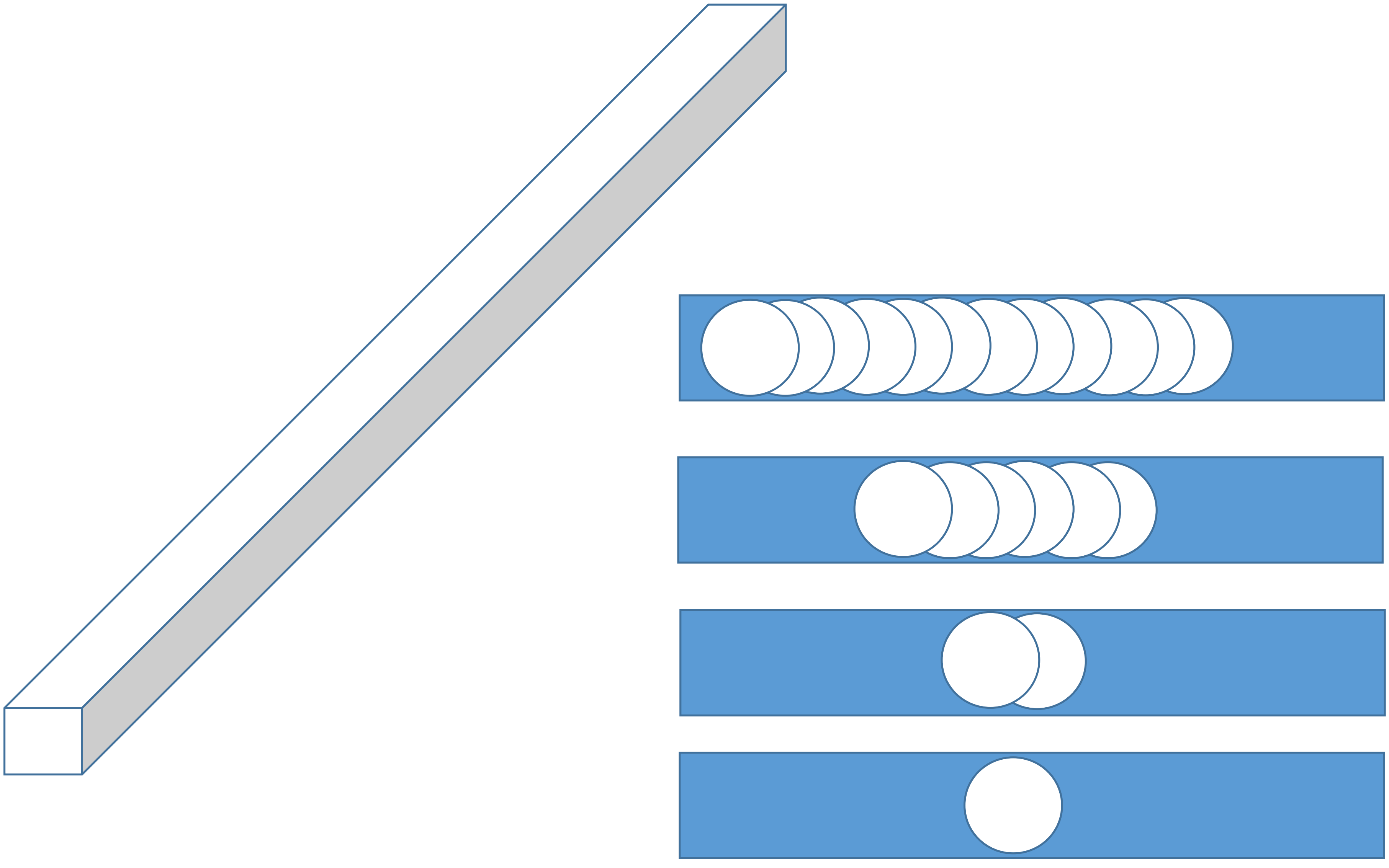


Convolutional etworks

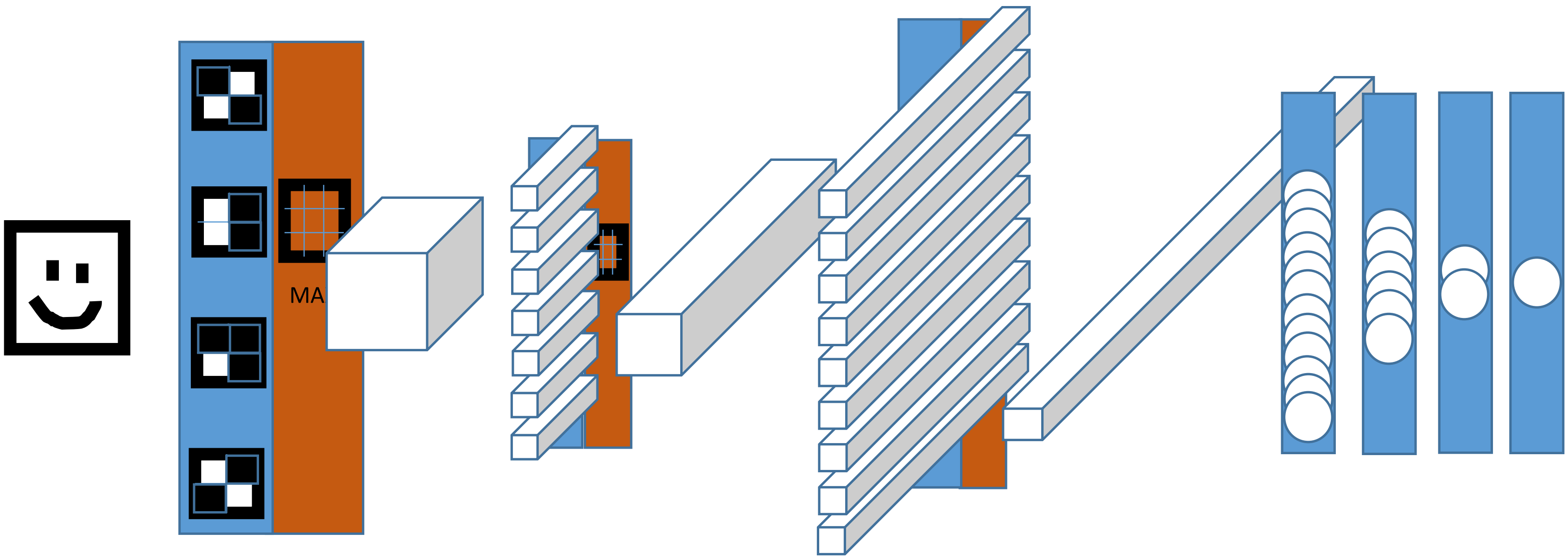


Convolutional neural networks





Convolutional neural networks



Author guessing

Text

- O Romeo, Romeo, wherefore art thou Romeo? Deny thy father and refuse thy name; Or if thou wilt not, be but sworn my love.
- It is better to be feared, than to be loved, if you cannot have both.
- When I was young I thought that money was the most important thing in life; now that I am old I know that it is.

Author

- Shakespeare
- Machiavelli
- Oscar Wilde

Why not…

- Standard neural networks? Text has variable size and with very long texts, we would need very complex neural networks.
- Convolutional neural networks? A filter may miss important information! See Oscar Wilde's quote.

Recurrent neural networks

Review	Positive review?
“Nice film”	1
“OK film”	1
“Bad movie”	0
“Terrible!”	0

Bag-of-words vectorization

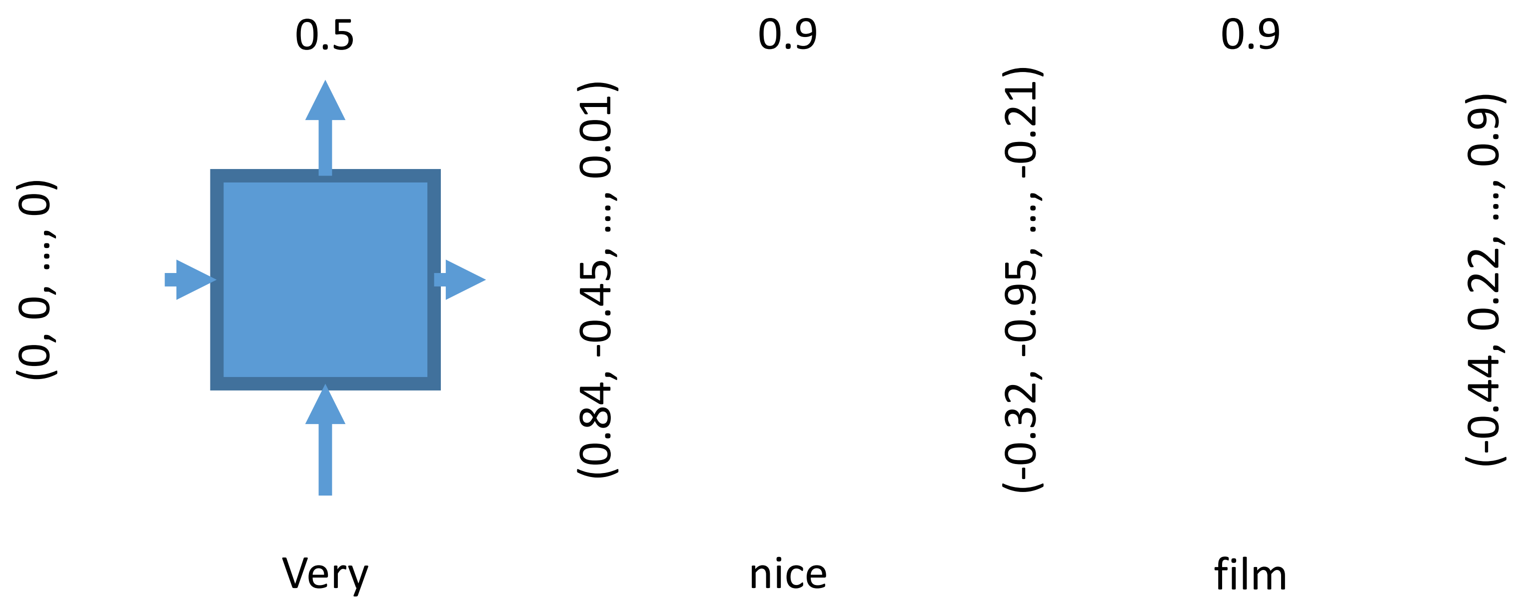
Review	Positive review?
“Nice film”	1
“OK film”	1
“Bad movie”	0
“Terrible!”	0

bad	film	movie	nice	ok	terrible	Positive?
0	1	0	1	0	0	1
0	1	0	0	1	0	1
1	0	1	0	0	0	0
0	0	0	0	0	1	0

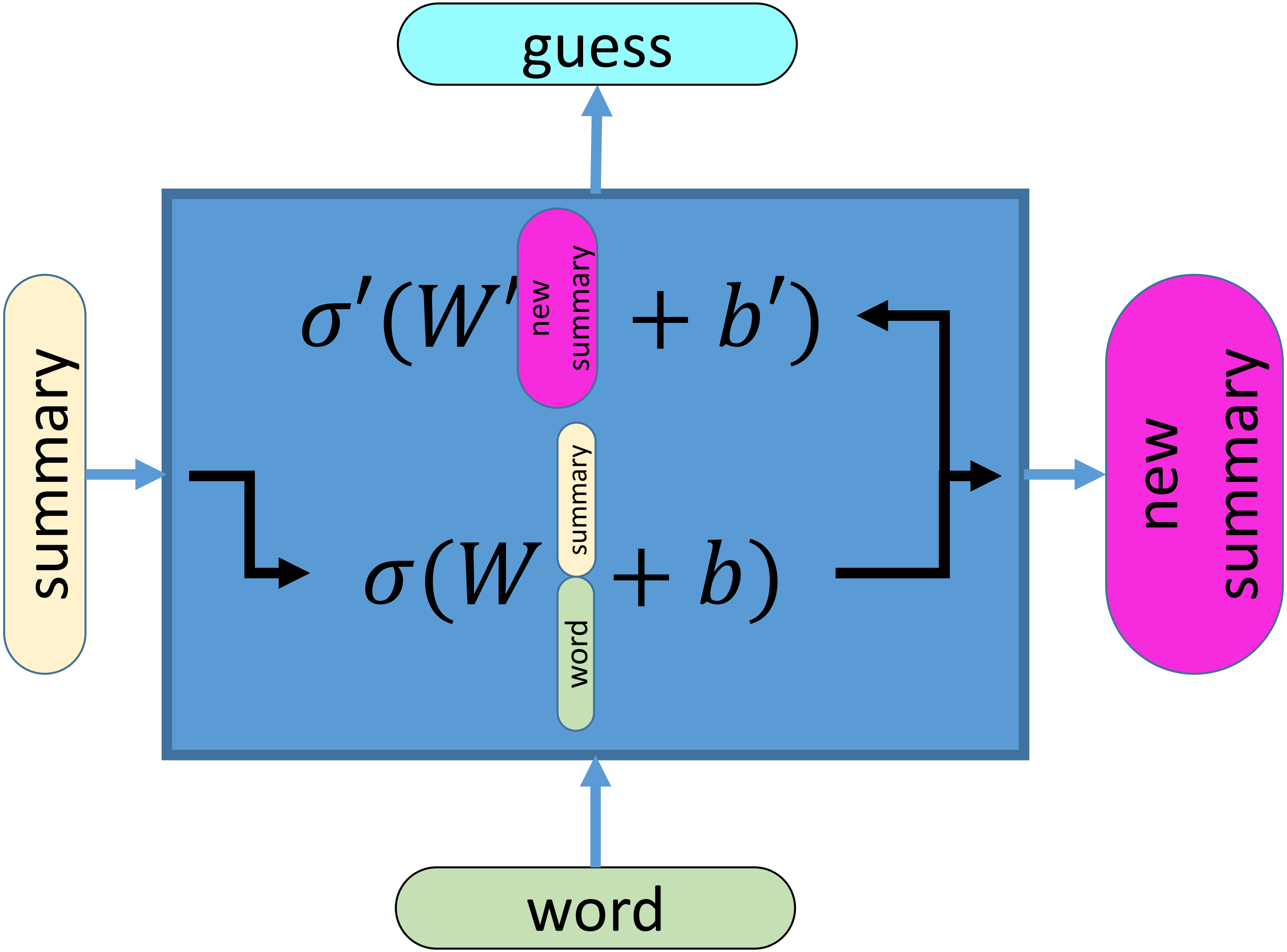
Analogously, words are vectors

	bad	film	movie	nice	ok	terrible
bad	1	0	0	0	0	0
film	0	1	0	0	0	0
movie	0	0	1	0	0	0
nice	0	0	0	1	0	0

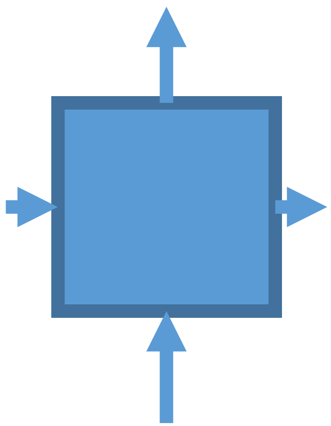
Recurrent neural networks



* Recall that words can be represented as vectors


guess
summary
new summary
$\sigma'(W'$ new summary $+ b')$
$\sigma(W$ summary word $+ b)$
new summary
word

Recurrent neural networks



* Recall that words can be represented as vectors

Author guessing

Text

- O Romeo, Romeo, wherefore art thou Romeo? Deny thy father and refuse thy name; Or if thou wilt not, be but sworn my love.
- Mr. and Mrs. Dursley, of number four Privet Drive, were proud to say that they were perfectly normal, thank you very much.
- It is better to be feared, than to be loved, if you cannot have both.
- When I was young I thought that money was the most important thing in life; now that I am old I know that it is.

Author

- Shakespeare
- J.K. Rowling (Harry Potter)
- Machiavelli
- Oscar Wilde

What we learned

- Many machine learning models cannot make "insights" on data.
- What are neural networks?
- What are convolutional neural networks?
- What are recurrent neural networks?