Applications of Brain Activity Data in Predicting Brain Disorders

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Neurons

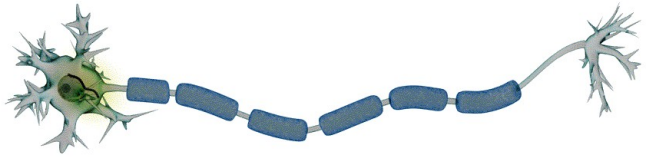
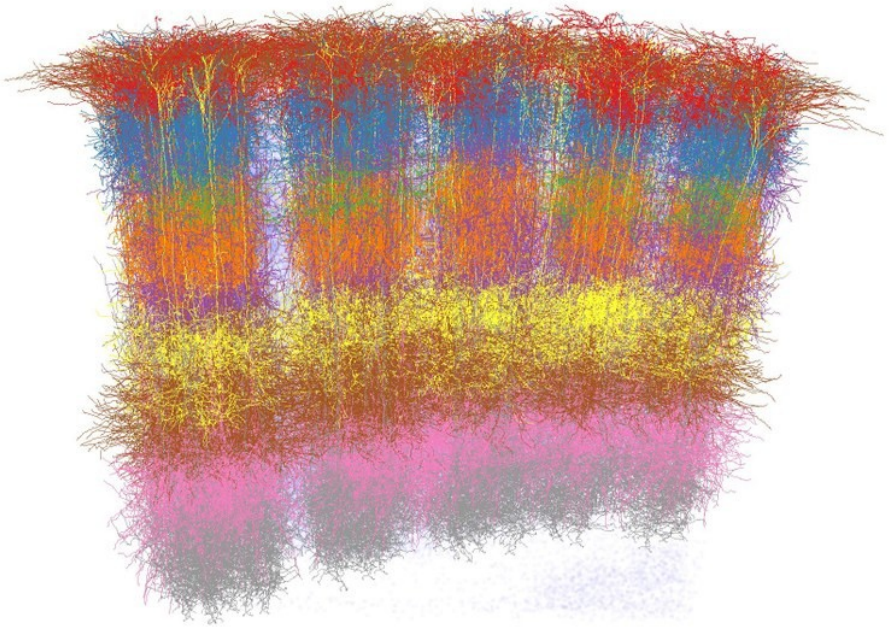


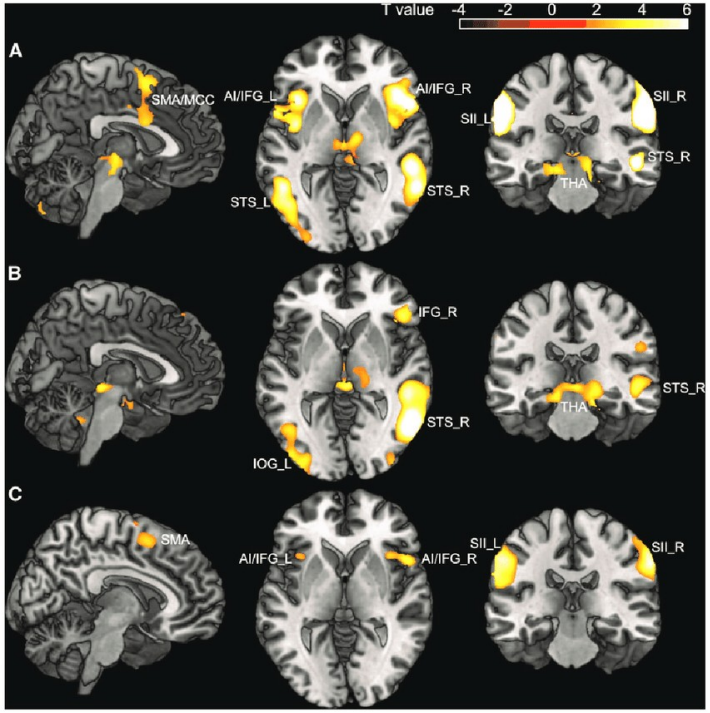
Image from Doctor Jana



Marcel Oberlaender et al.(2014)

Brain Data

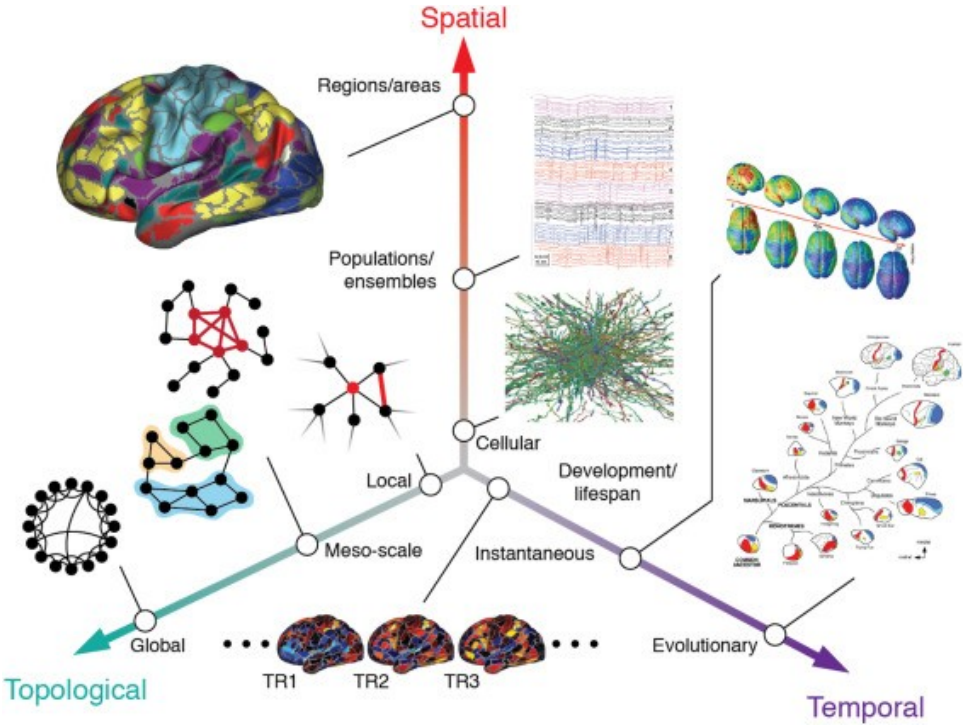
- MRI Based Data
- EEG



fMRI results of whole-brain.
Xiaochun Han et al (2017)

The multi-scale brain

Brain networks are organized across multiple spatiotemporal scales and also can be analyzed at topological (network) scales ranging from individual nodes to the network as a whole.

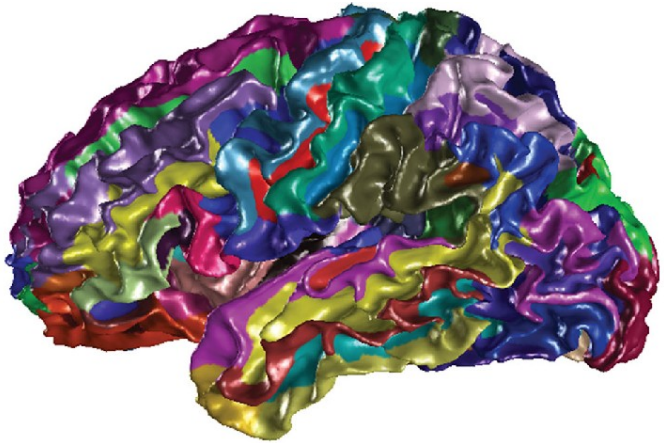


Richard F.Betzel et al. (2016)

Constructing Brain Networks

- Parcellation

  Defining distinct partitions in the brain



Destrieux atlas (Christophe Destrieux et al. 2010)

148 ROIs (Cortical Parcellation)

Constructing Brain Networks

- Connectivity Estimators
  - Functional Connectivity
  - Structural Connectivity

Network Analysis

- Clustering

  It is the property that two vertices of the network that are both adjacent of the same third vertex have an increased probability of also being adjacent of one another.

- Small-world

  Most nodes can be reached from every other node by a small number of hops or steps.

Network Analysis

- Centerality Measures

  To rank graph nodes based on their topological importance.

  Exampls:

  - Degree
  - Betweenness:

    measure of the influence of a vertex over the flow of information between every pair of vertices.
  - etc

Machine Learning For Disease Detection

Machine Learning

Machine learning is a subfield of computer science that is concerned with building algorithms which, to be useful, rely on a collection of examples of some phenomenon.

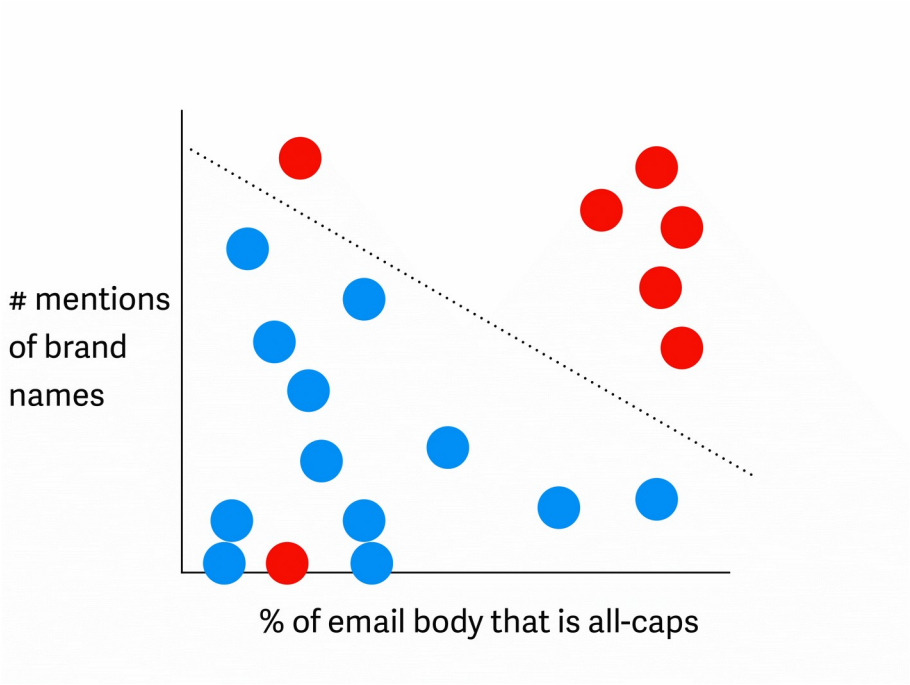
Machine learning can also be defined as the process of solving a practical problem by 1)gathering a dataset, and 2) algorithmically building a statistical model based on that dataset. That statistical model is assumed to be used somehow to solve the practical problem.

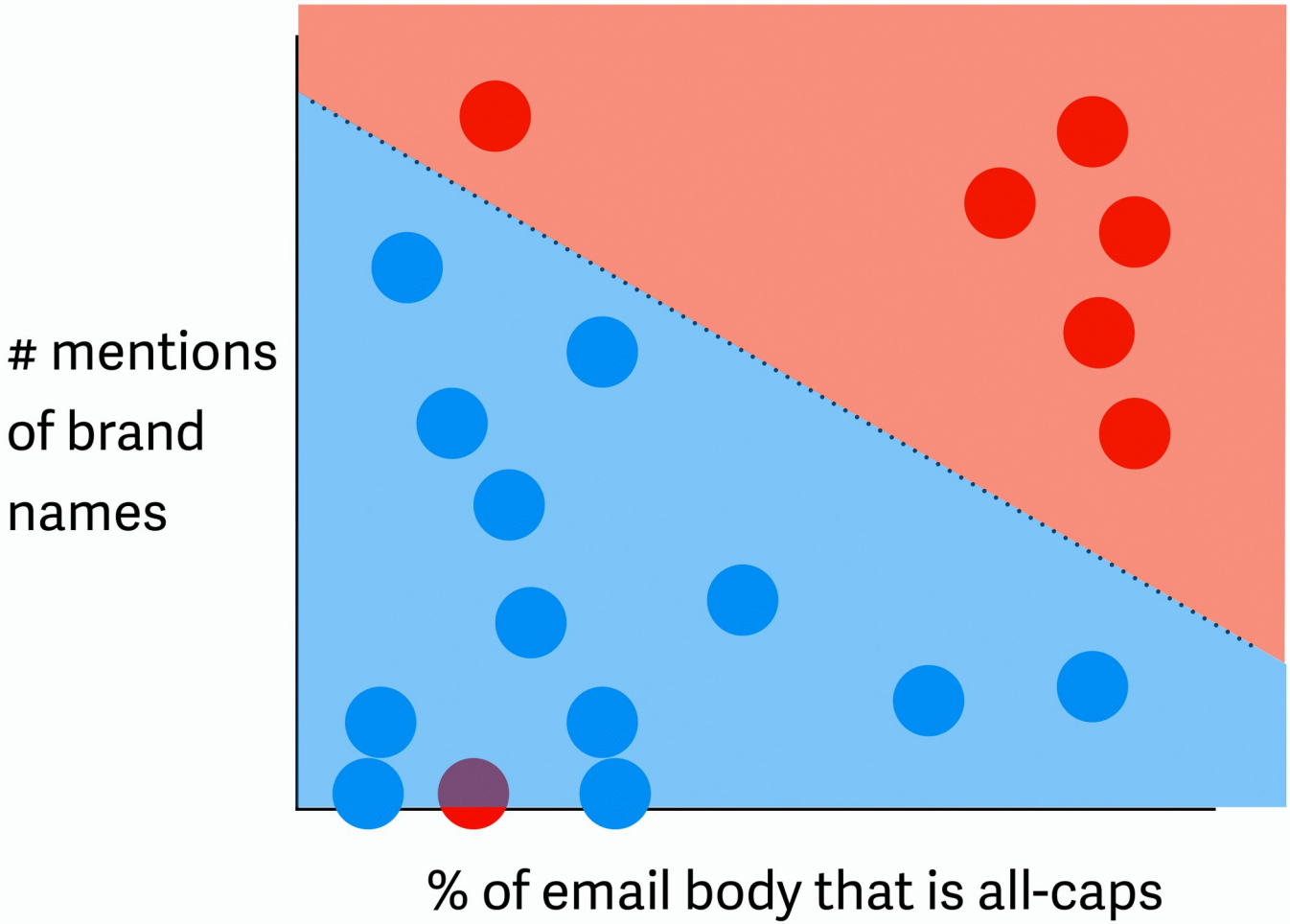
Classification

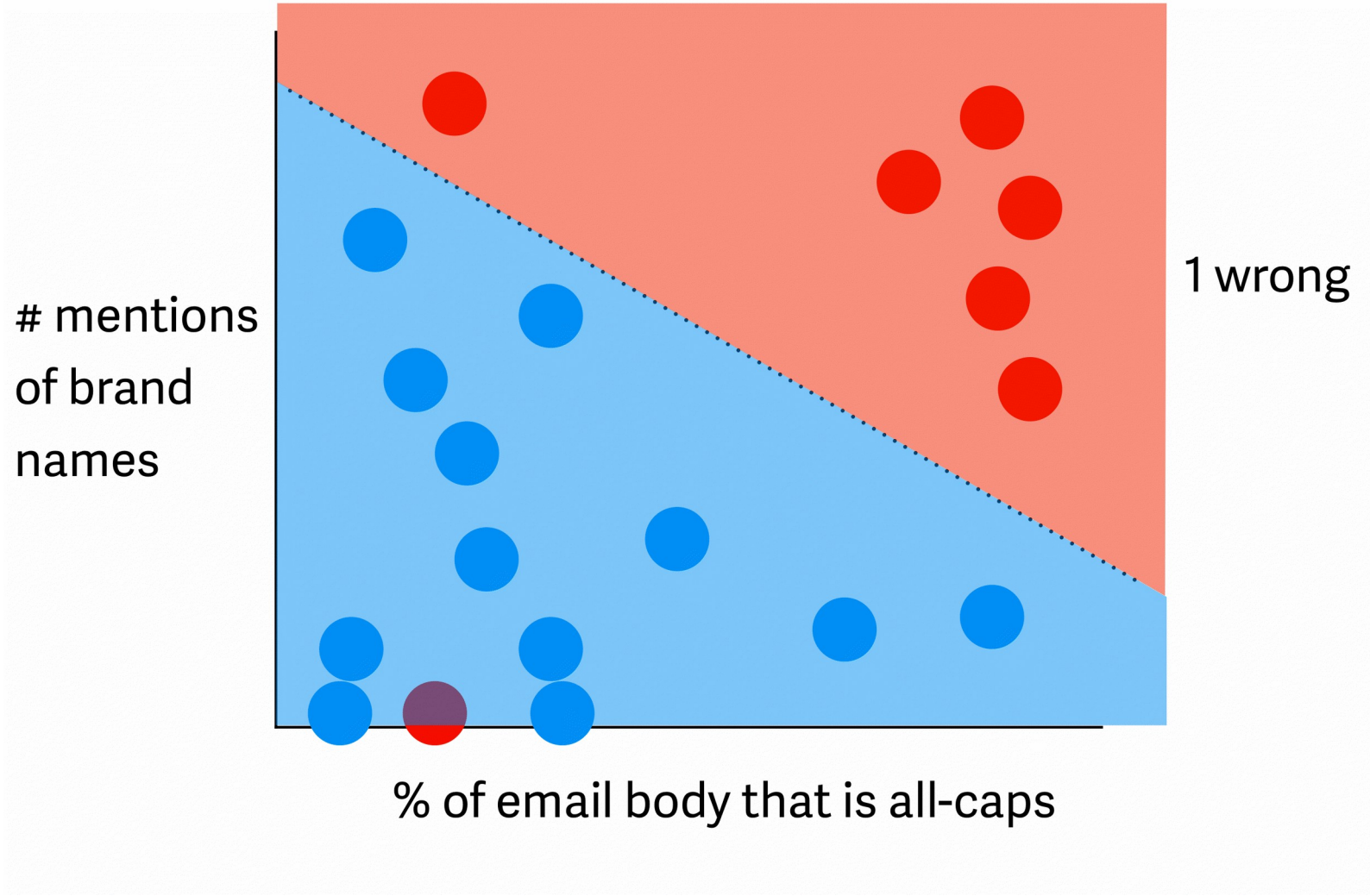
- Supervised learning: You need data labaled with the correct answers to train these algorithms before they work.
- Features: Attribute of the data
- Class, Labales: The groups that we are sorting things into them

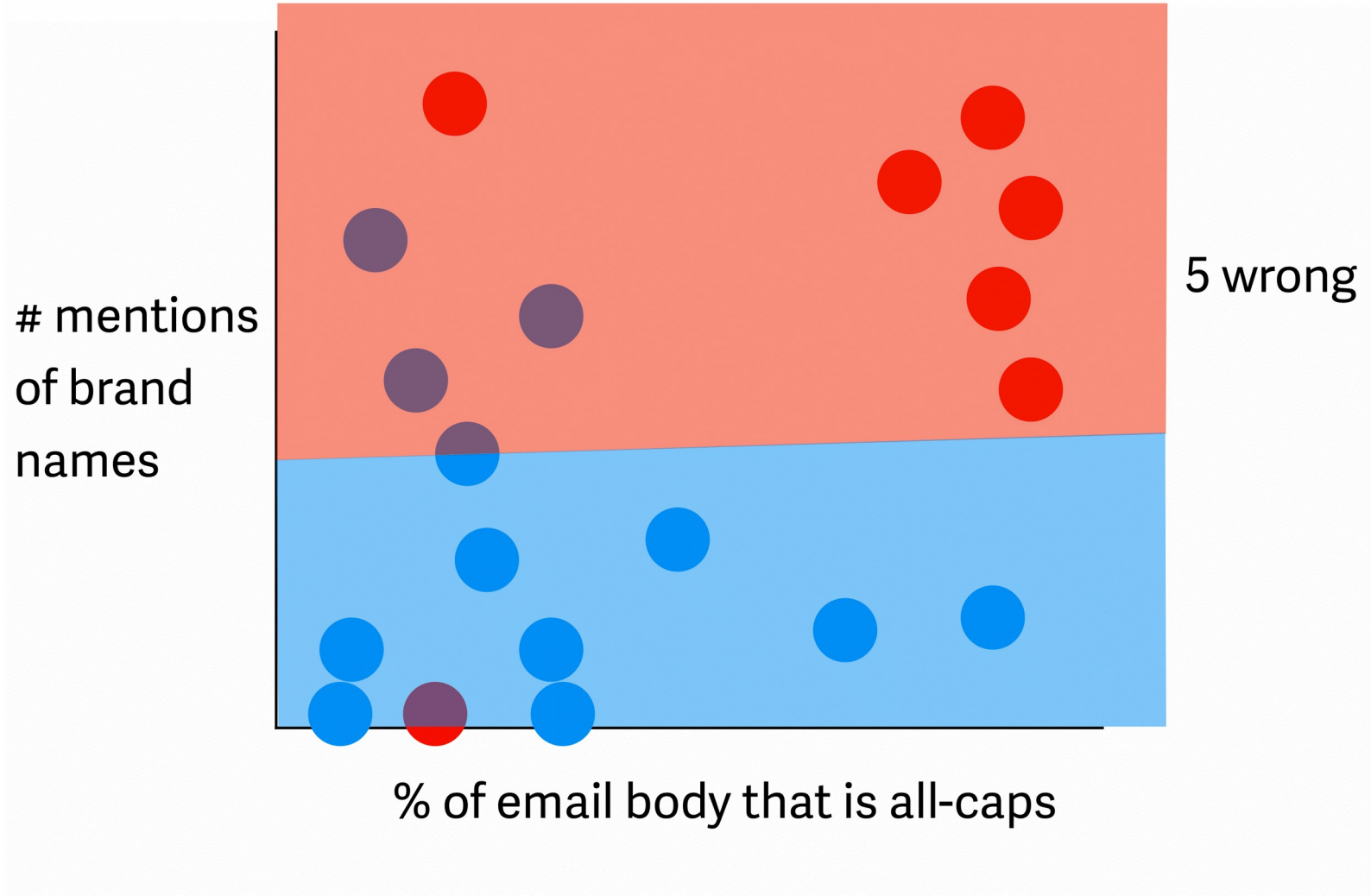
Toy Problem

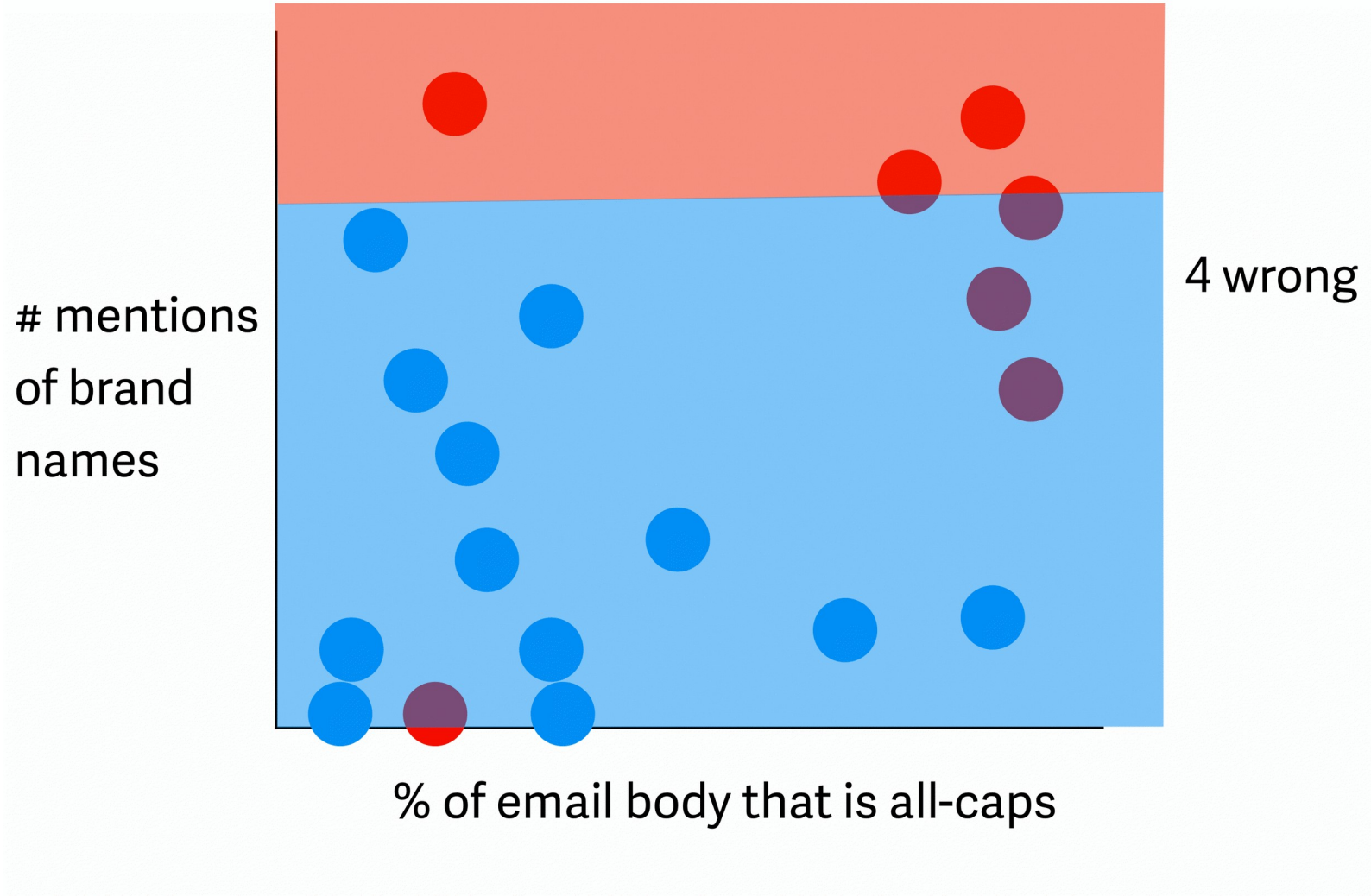
- Spam email detection: Binary Classification: Spam/ Not Spam

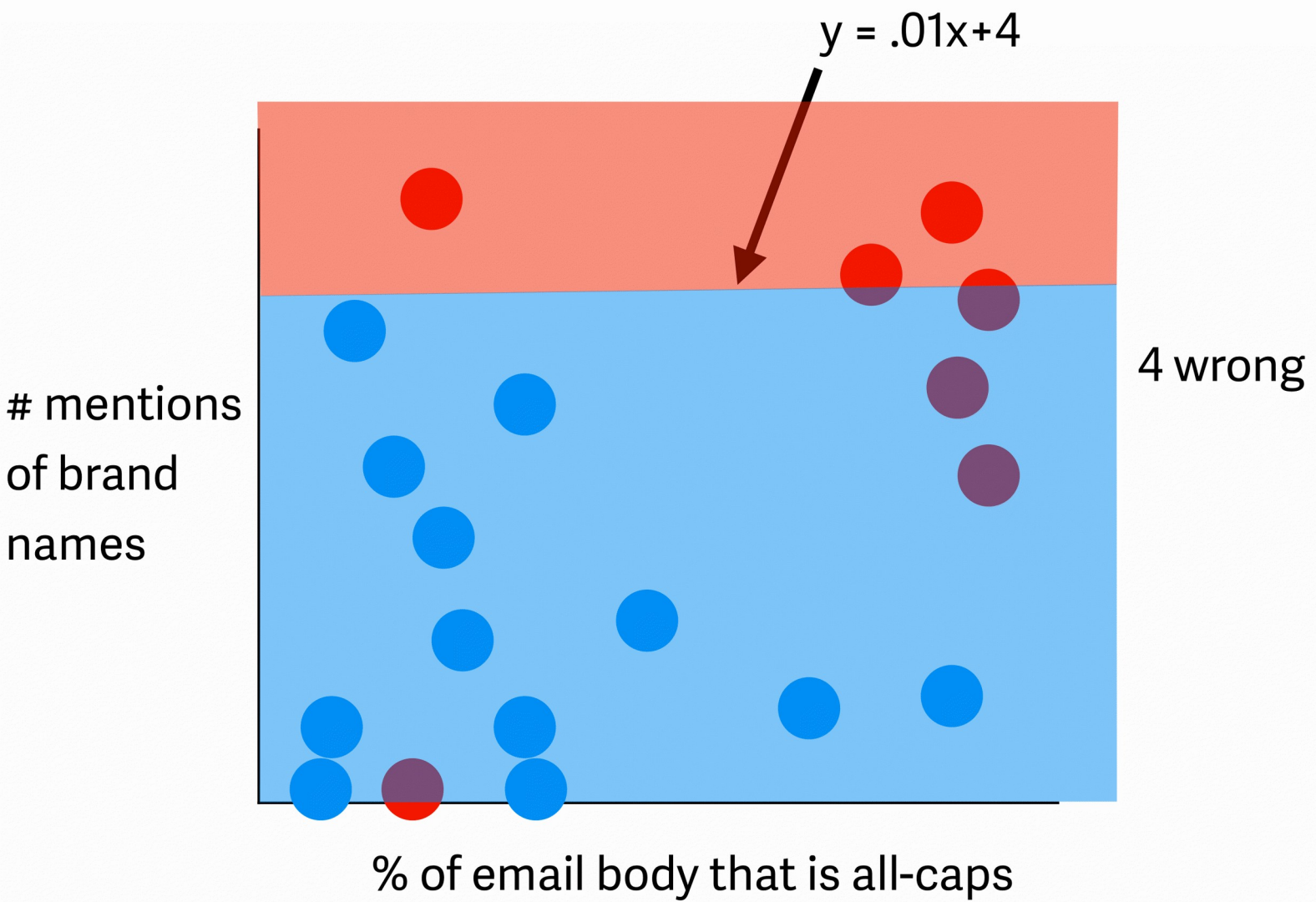



mentions of brand names
% of email body that is all-caps


mentions of brand names
1 wrong
% of email body that is all-caps

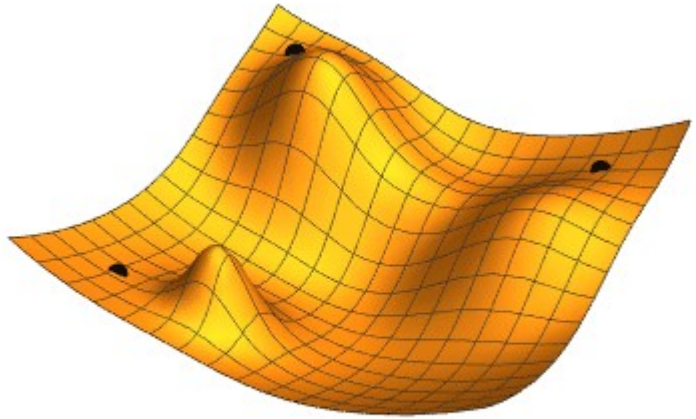

mentions of brand names
5 wrong
% of email body that is all-caps

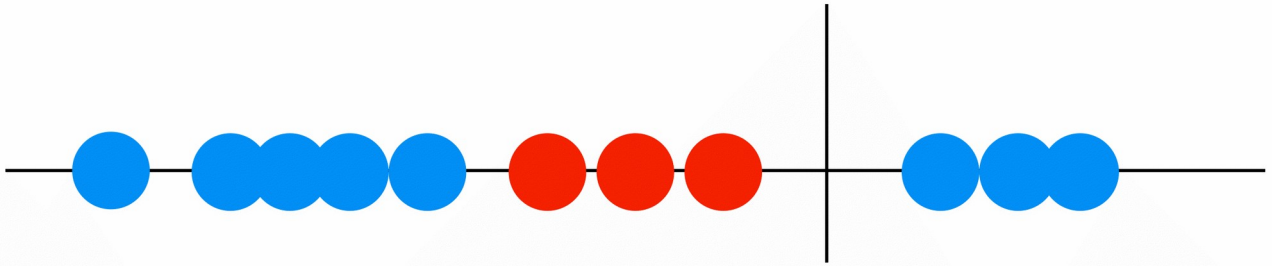

mentions of brand names
4 wrong
% of email body that is all-caps

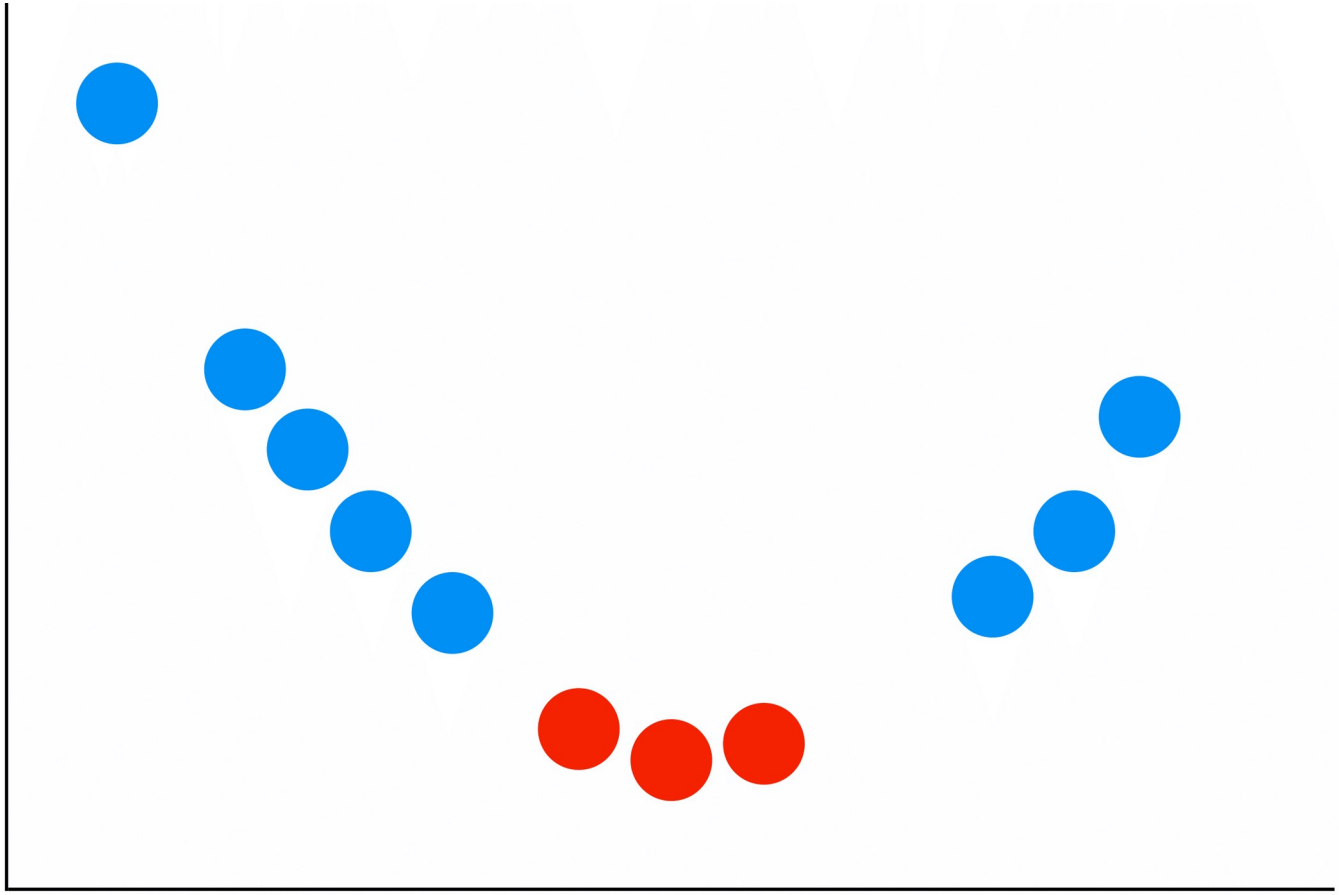

y = .01x+4
# mentions of brand names
4 wrong
% of email body that is all-caps

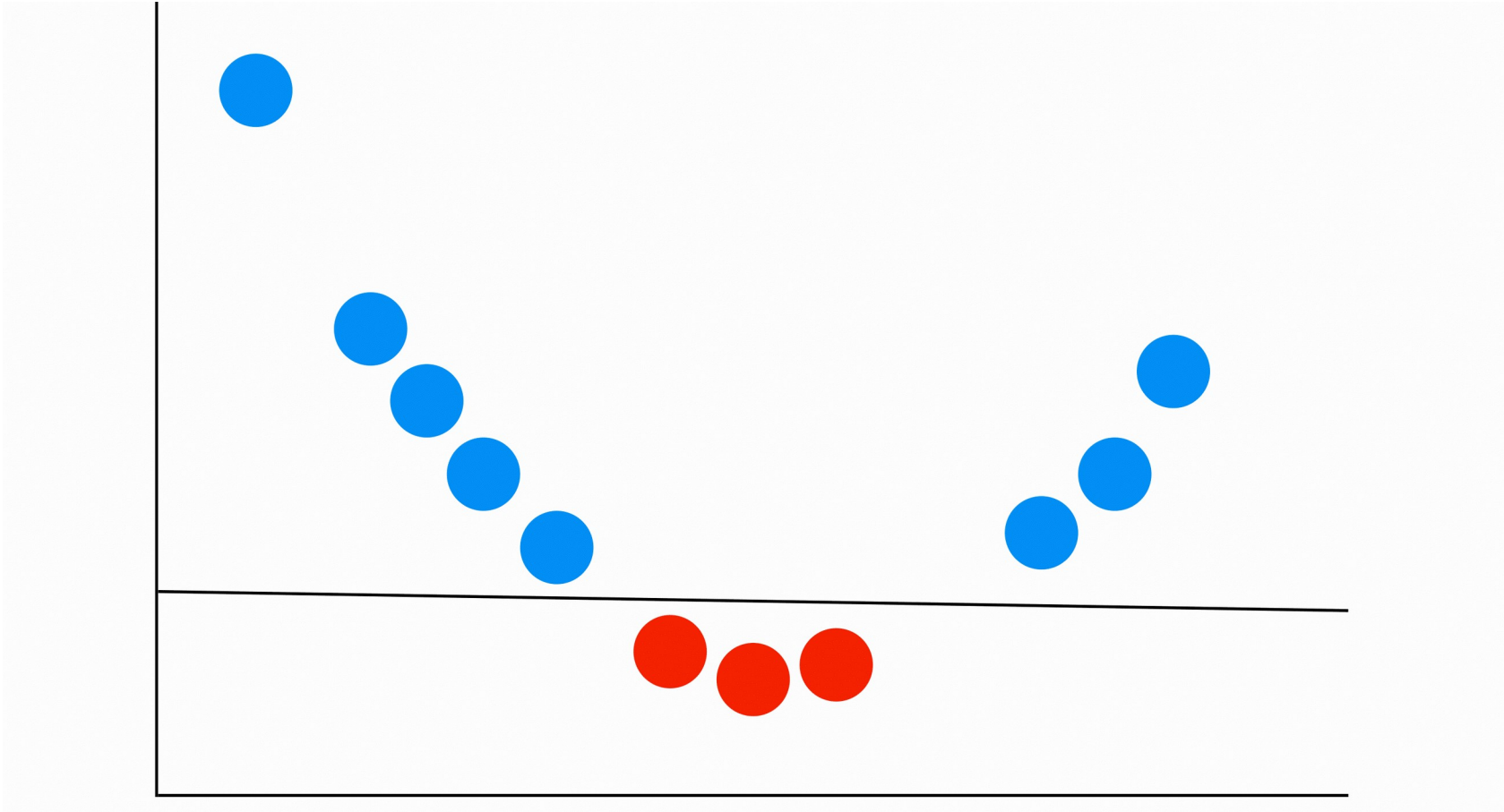
Minimizing the error Function

Finding optimum values for model parameters







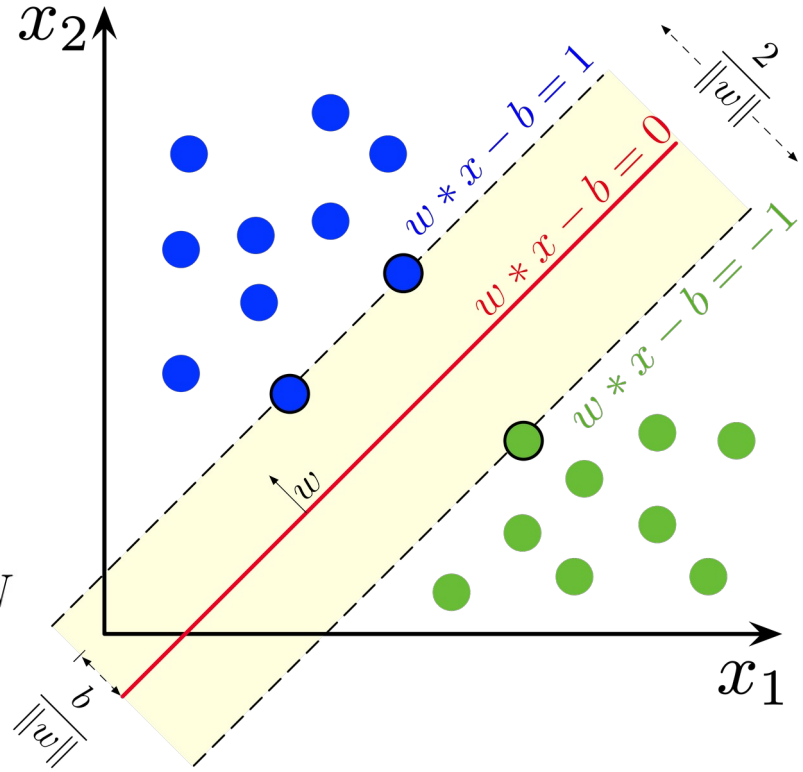


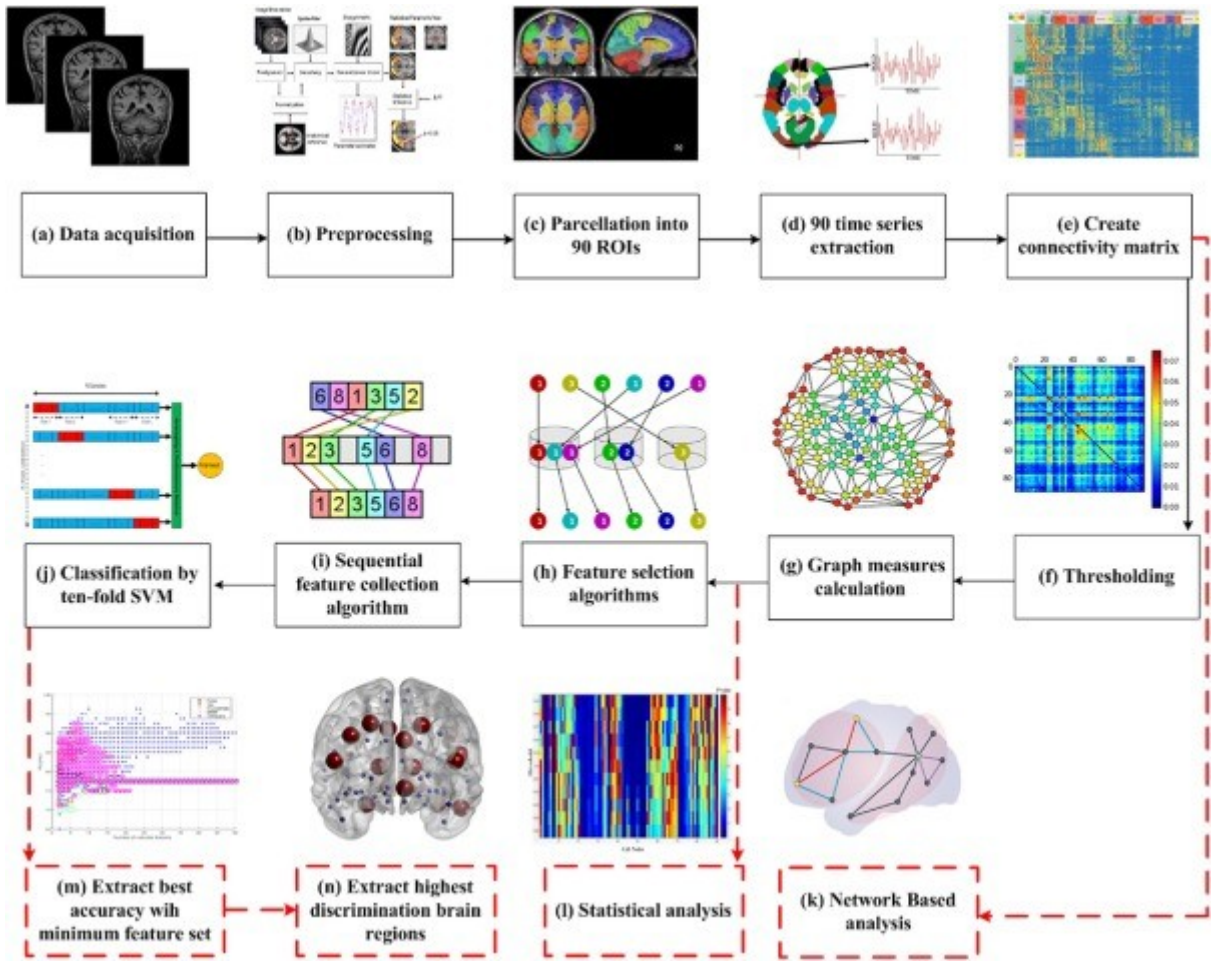
Support Vector Machine (SVM)

- $\mathbf{w}\mathbf{x}_i - b \geq 1$ if $y_i = +1$, and
- $\mathbf{w}\mathbf{x}_i - b \leq -1$ if $y_i = -1$

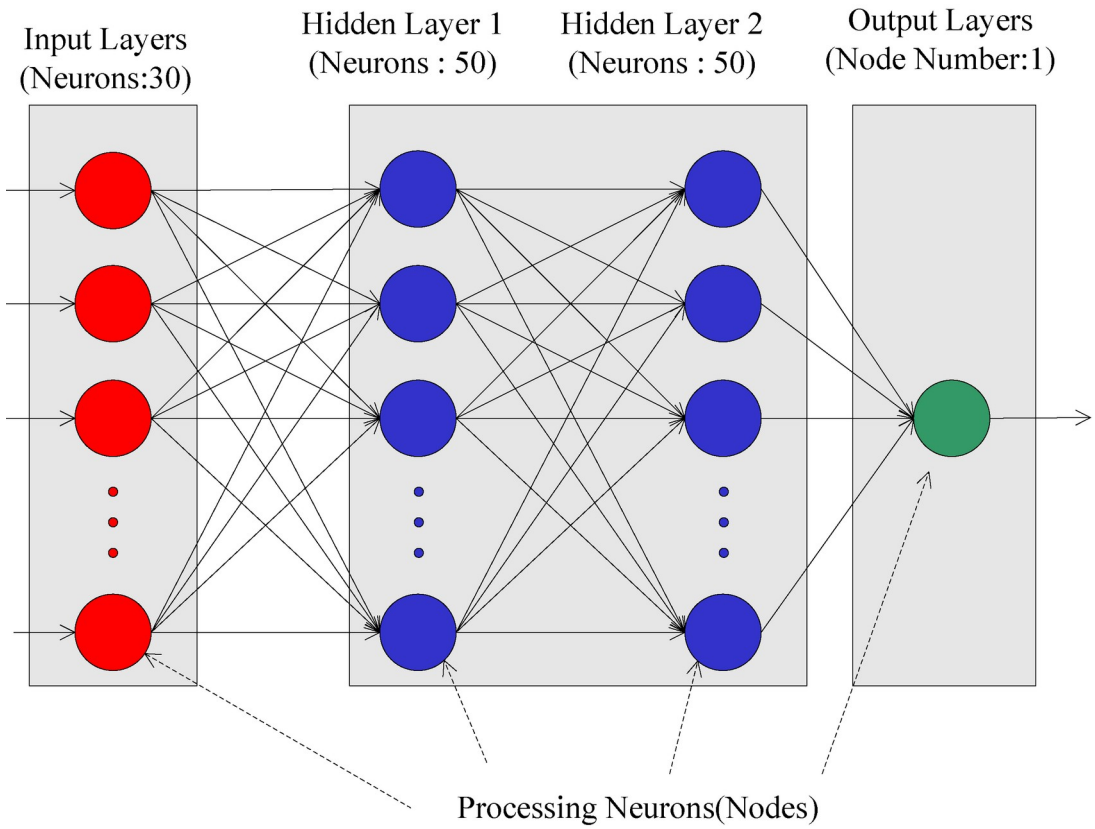
$\frac{2}{\|\mathbf{w}\|}$:The distance between hyperplanes

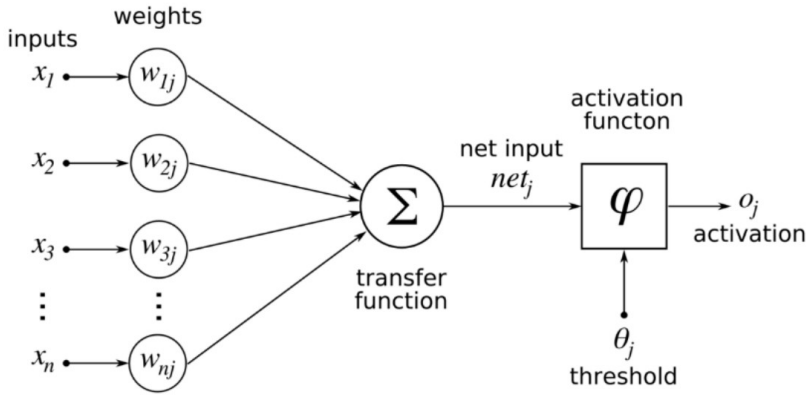
Minimize $\|\mathbf{w}\|$ *subject to* $y_i(\mathbf{w}\mathbf{x}_i - b) \geq 1$ *for* $i = 1, \ldots, N$




(a) Data acquisition
(b) Preprocessing
(c) Parcellation into 90 ROIs
(d) 90 time series extraction
(e) Create connectivity matrix
(f) Thresholding
(g) Graph measures calculation
(h) Feature selction algorithms
(i) Sequential feature collection algorithm
(j) Classification by ten-fold SVM
(k) Network Based analysis
(l) Statistical analysis
(m) Extract best accuracy wih minimum feature set
(n) Extract highest discrimination brain regions

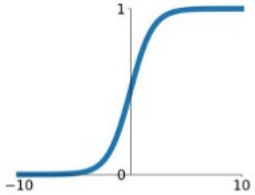
Neural Networks





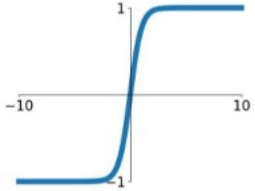
Sigmoid

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



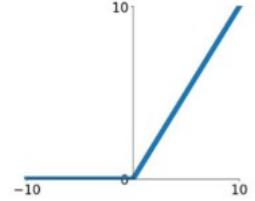
tanh

$$\tanh(x)$$



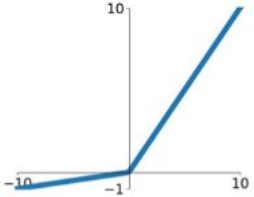
ReLU

$$\max(0, x)$$



Leaky ReLU

$$\max(0.1x, x)$$

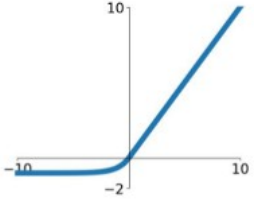


Maxout

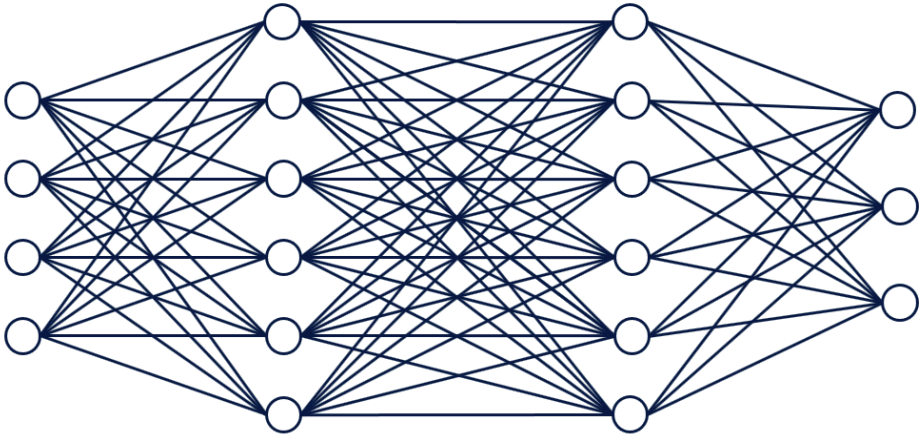
$$\max(w_1^T x + b_1, w_2^T x + b_2)$$

ELU

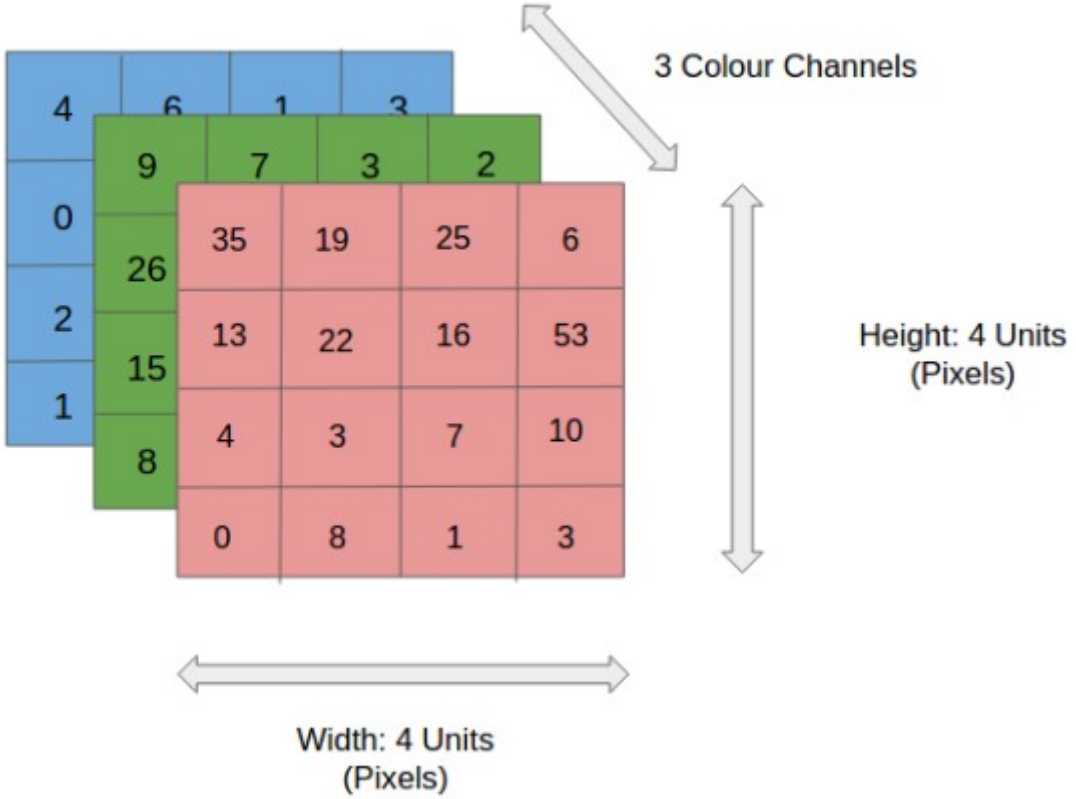
$$\begin{cases} x & x \geq 0 \\ \alpha(e^x - 1) & x < 0 \end{cases}$$



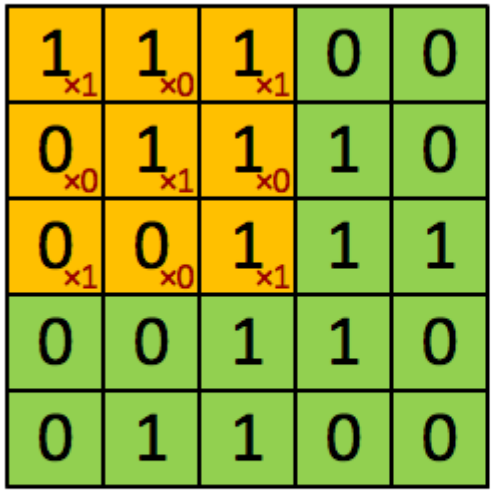
Forward and Backward Propagation

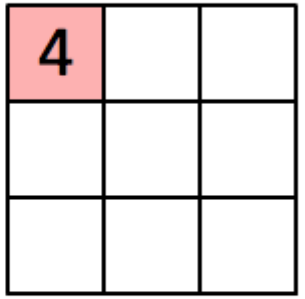


$$Cross\ Entropy = -[ylog(p) + (1-y)\log(1-p)]$$


3 Colour Channels
4
6
1
3
9
7
3
2
0
35
19
25
6
26
2
13
22
16
53
15
1
4
3
7
10
8
0
8
1
3
Height: 4 Units
(Pixels)
Width: 4 Units
(Pixels)

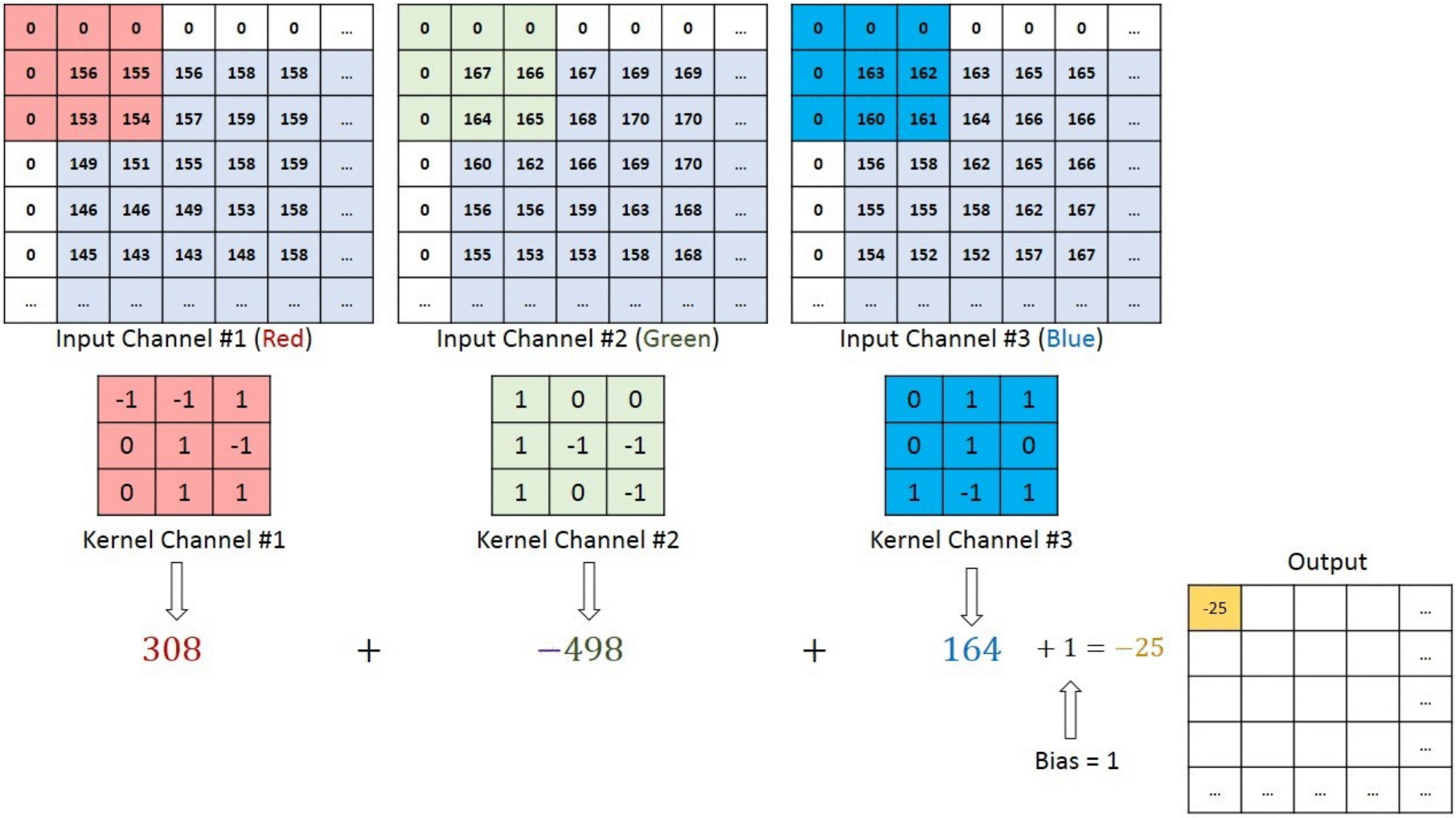
```
Kernel/Filter,
K =
1  0  1
0  1  0
1  0  1
```



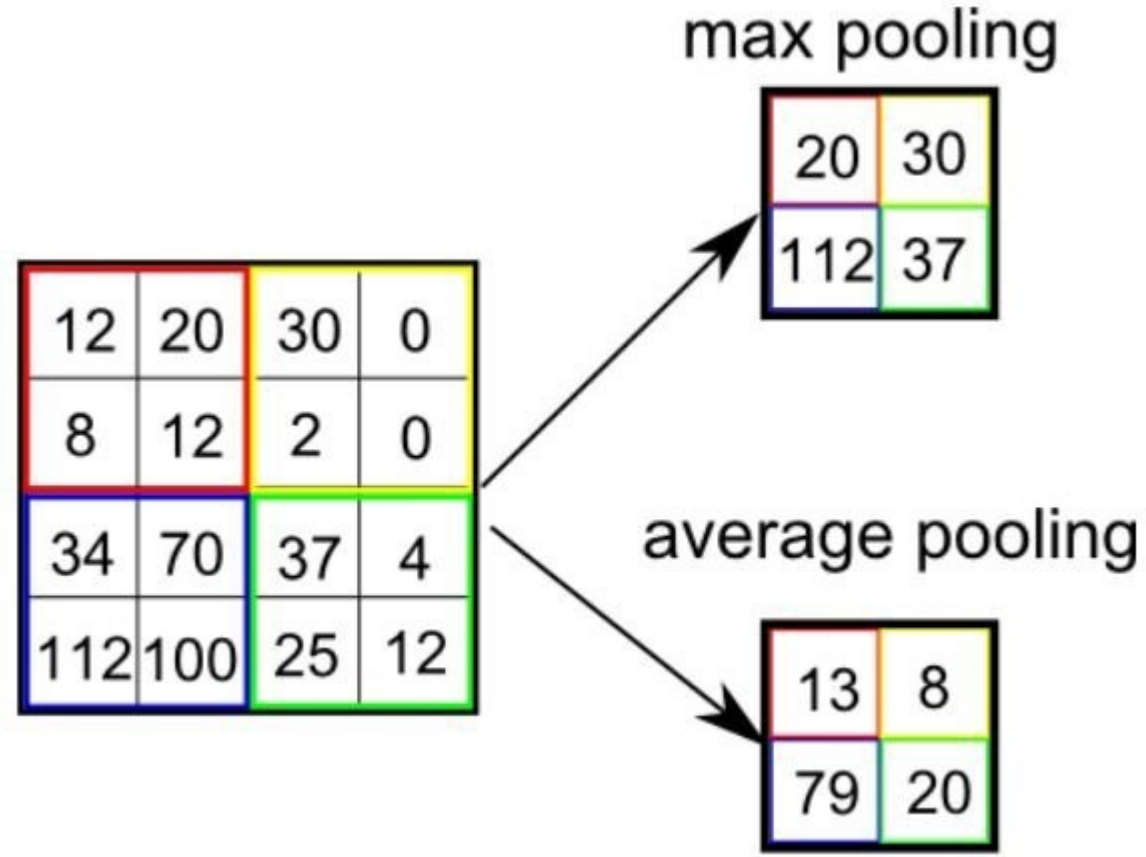


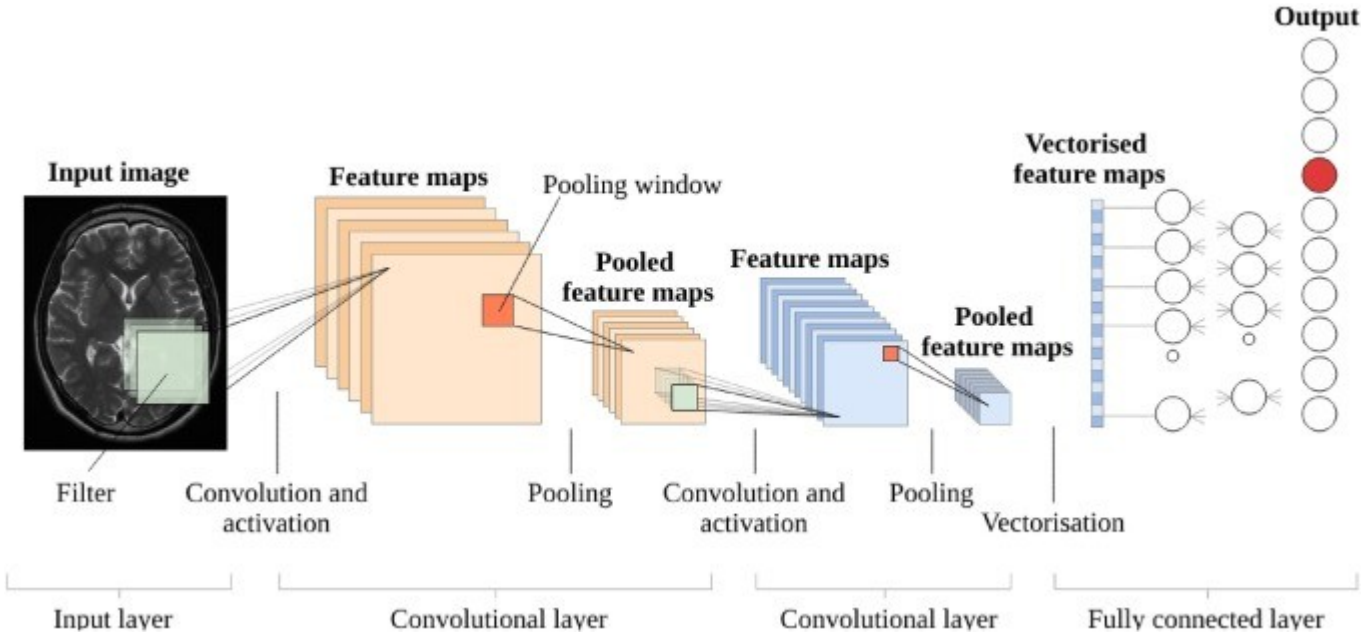
Convolutional neural network

(i) Convolutional layers
(ii) Activation layers
(iii) Pooling


Input Channel #1 (Red)
Input Channel #2 (Green)
Input Channel #3 (Blue)
Kernel Channel #1
Kernel Channel #2
Kernel Channel #3
308
+
−498
+
164
+ 1 = −25
Bias = 1
Output

Max pooling


max pooling
20 30
112 37
12 20 30 0
8 12 2 0
34 70 37 4
112 100 25 12
average pooling
13 8
79 20



Alexander Selvikvåg Lundervold. (2018)