Part III

In "Nature" 27 January 2016:

"DeepMind's program AlphaGo beat Fan Hui, the European Go champion, five times out of five in tournament conditions..."

"AlphaGo **was not preprogrammed to play Go**: rather, it learned using a general-purpose algorithm that allowed it to interpret the game's patterns."

"…AlphaGo uses a **Monte Carlo** tree search algorithm to find its moves based on knowledge previously "learned" by machine learning, specifically by an **artificial neural network** (a deep learning method) by extensive training, both from human and computer play

Defining a multivariate critical region

For each event, measure, e.g.,

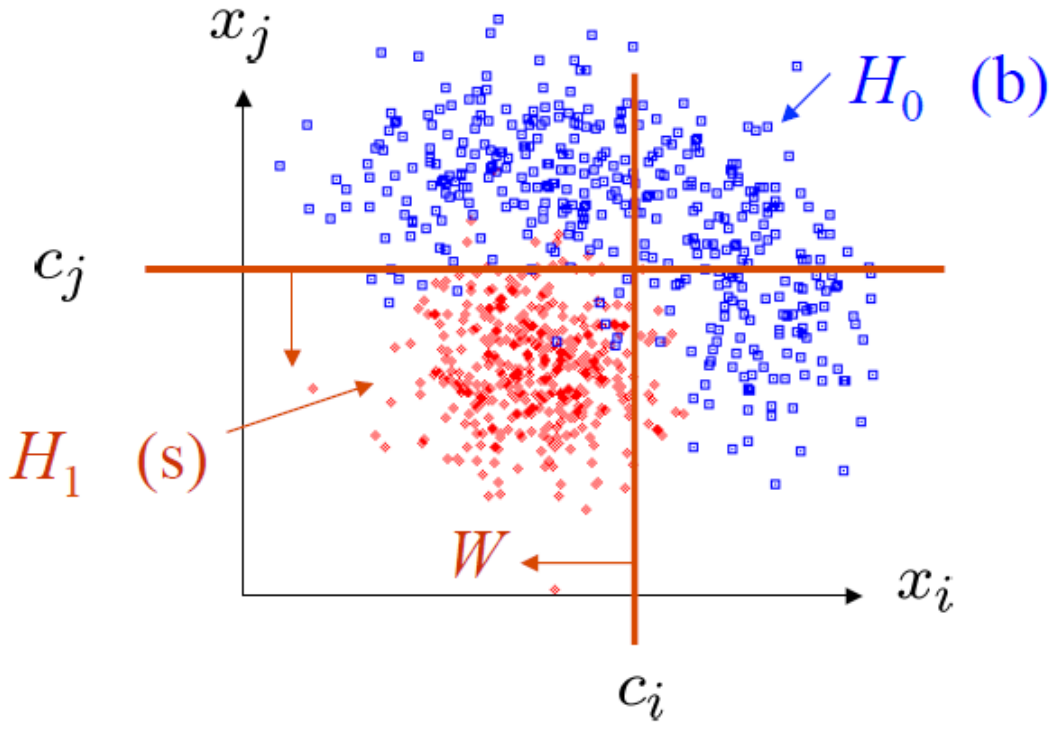
x_1 = missing energy, x_2 = electron p_T, x_3 = ...

Each event is a point in n-dimensional $\boldsymbol{x}$-space; critical region is now defined by a 'decision boundary' in this space.
What is best way to determine the boundary?

Perhaps with 'cuts':

$$x_i < c_i$$

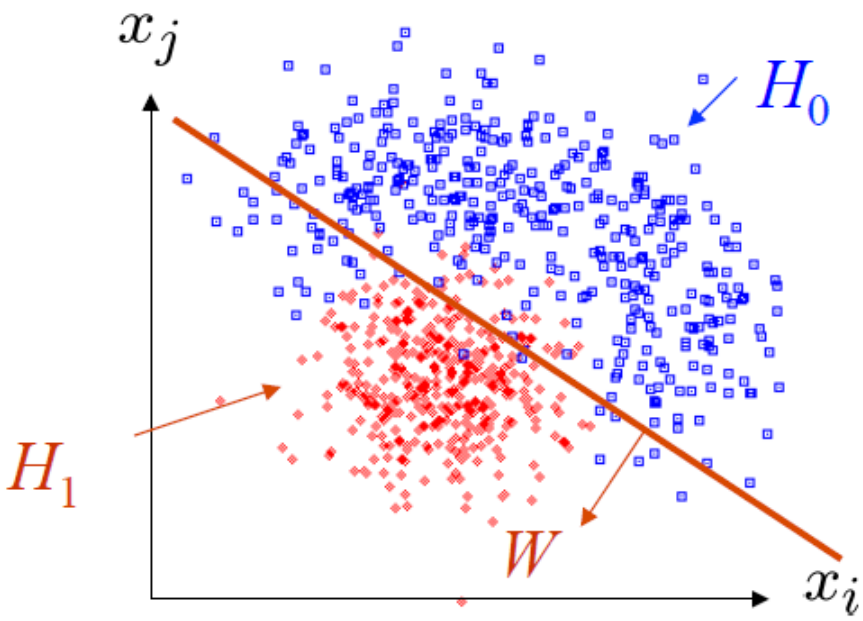
$$x_j < c_j$$



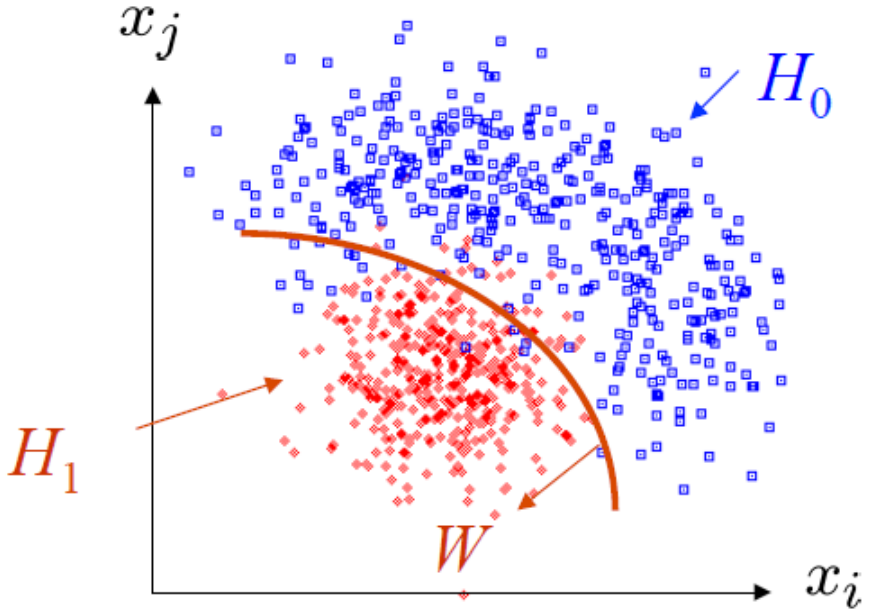
Other multivariate decision boundaries

Or maybe use some other sort of decision boundary:

linear



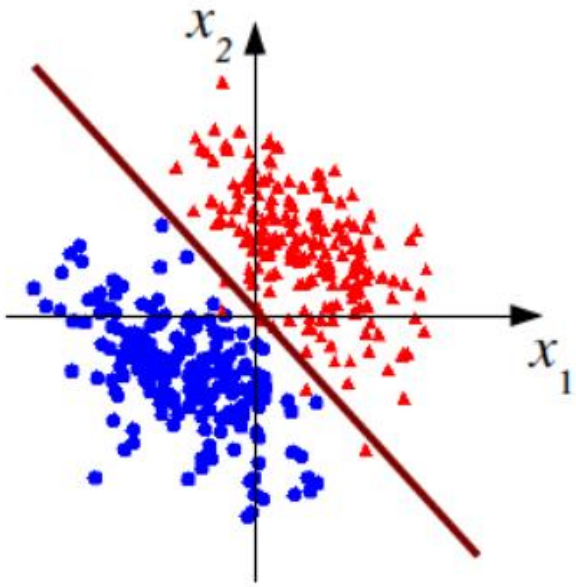
or nonlinear

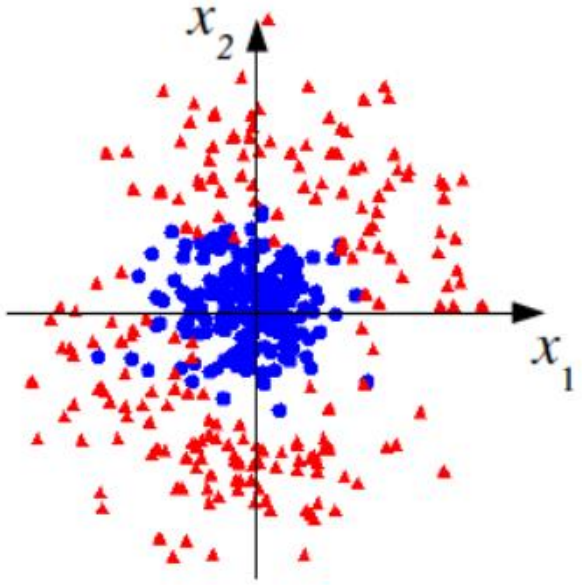


Multivariate methods for finding optimal critical region have become a Big Industry (neural networks, boosted decision trees,...).

Linear decision boundaries

A linear decision boundary is only optimal when both classes follow multivariate Gaussians with equal covariances and different means.





For some other cases a linear boundary is almost useless.

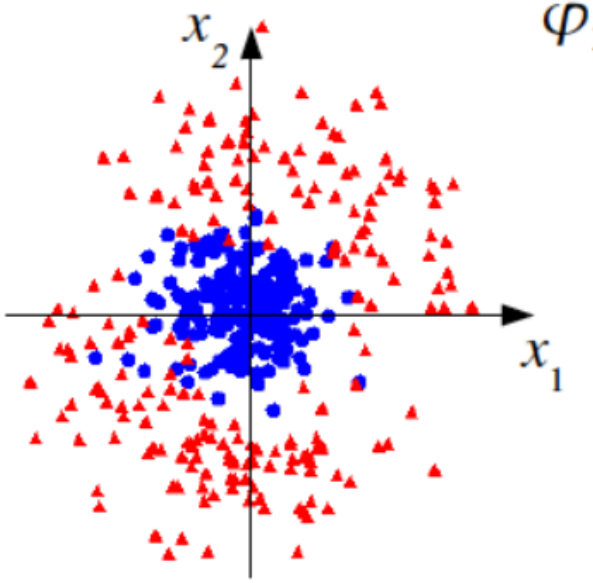
Nonlinear transformation of inputs

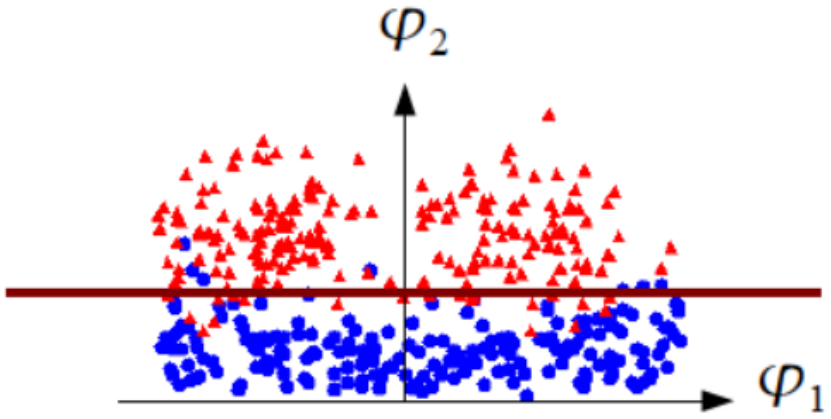
We can try to find a transformation, $x_1, \ldots, x_n \rightarrow \varphi_1(\vec{x}), \ldots, \varphi_m(\vec{x})$ so that the transformed "feature space" variables can be separated better by a linear boundary:

$$\varphi_1 = \tan^{-1}(x_2/x_1)$$

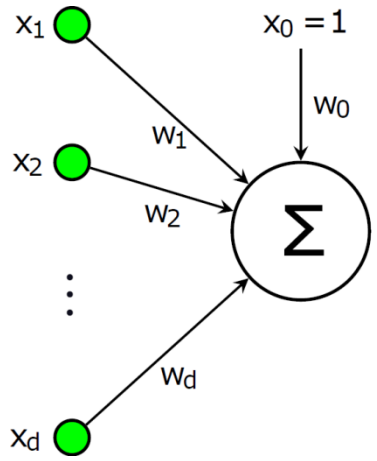
$$\varphi_2 = \sqrt{x_1^2 + x_2^2}$$

Here, guess fixed basis functions (no free parameters)





- **Artificial neural networks (ANN) mimic the behaviour of biological neuronal networks, interconnected group of neurons arranged in layers**



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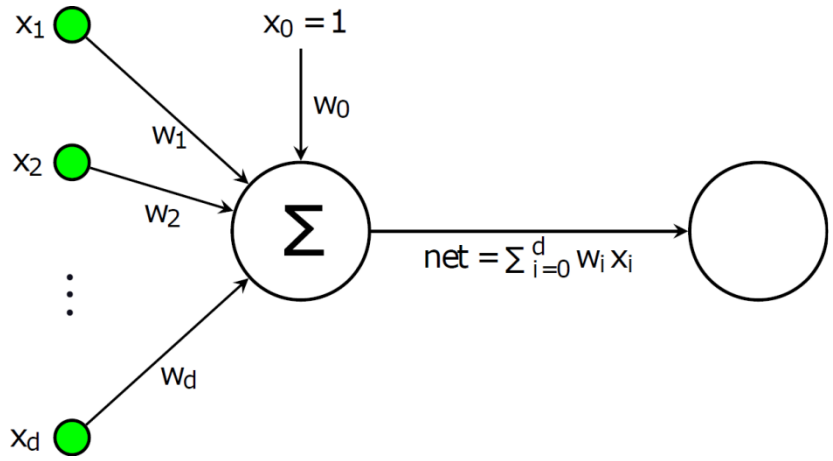

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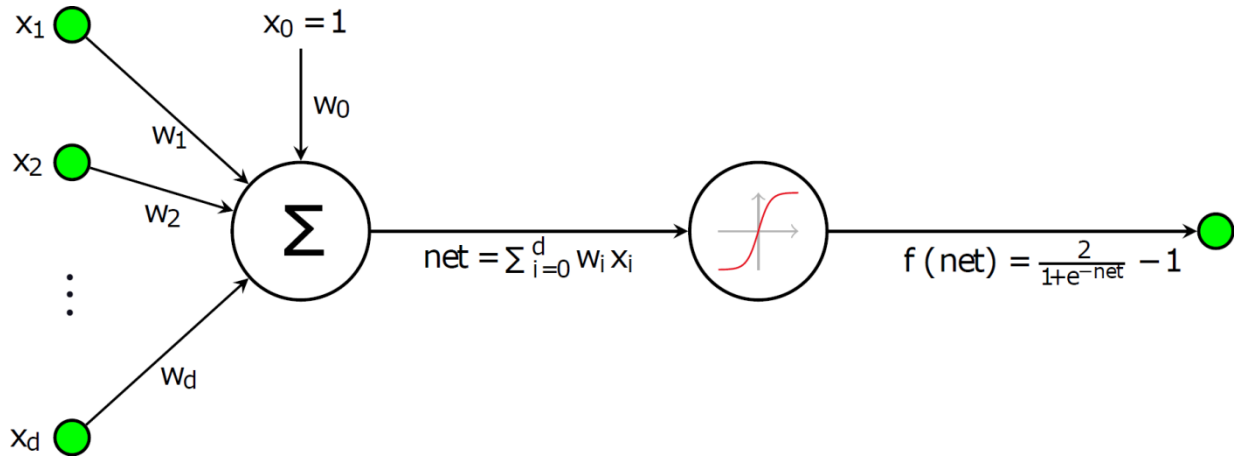
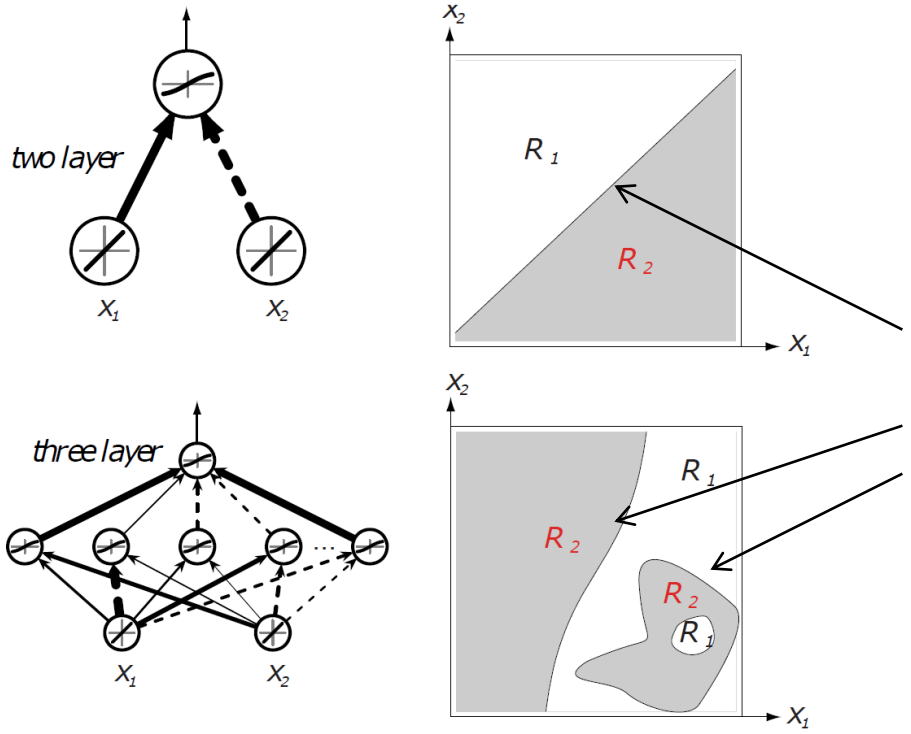
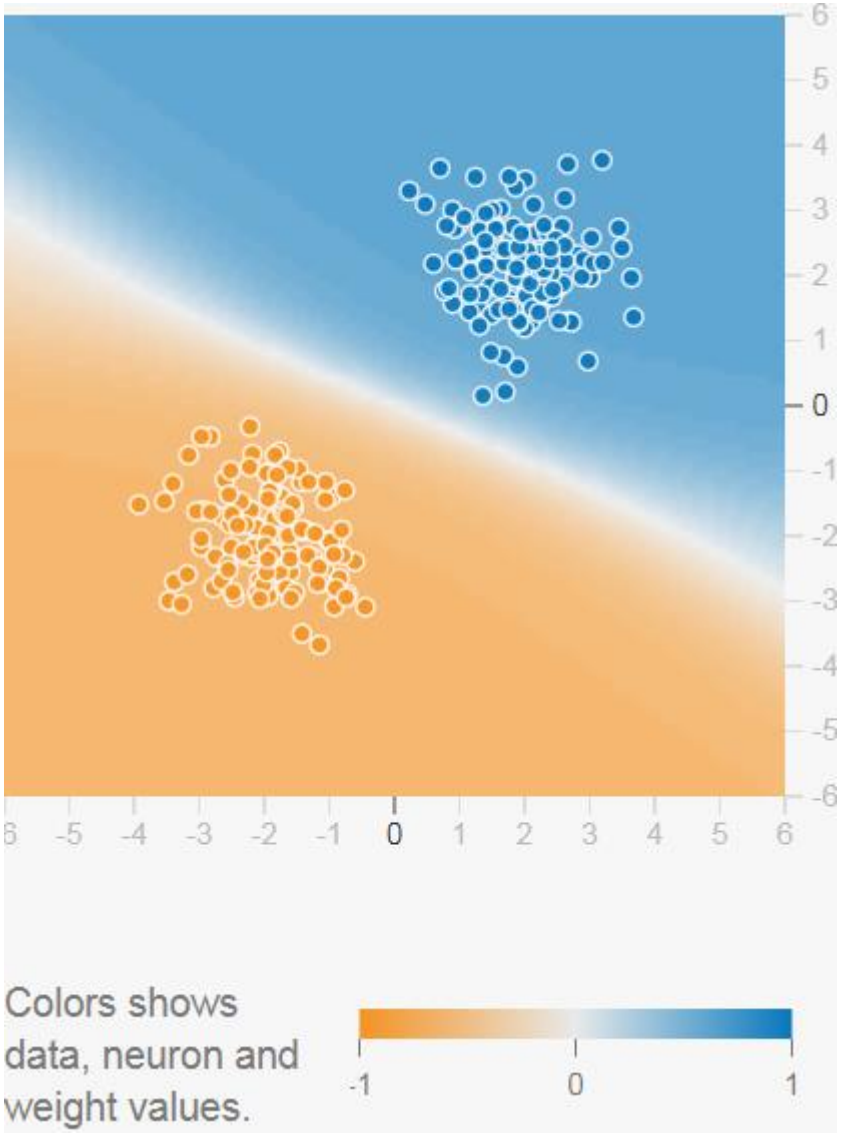


- (≥) Three-layer network implements arbitrary decision boundaries and model possible analytical dependencies between inputs



Decision boundary of the classifier



Orange shows negative values

Bue shows positive values

The data points (represented by small circles) are initially colored orange or blue, which correspond to positive one and negative one.

Play here:

www.playground.tensorflow.org