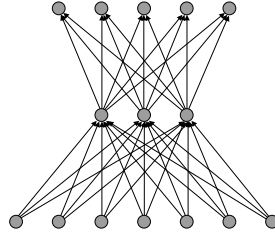# COSMONET: How to build a map from cosmological parameters to the CMB power spectrum using a neural network.

COSMONET's neural network maps are all based on Multi-Layer Perceptrons (MLPs) with 3 layers of neurons.

A 3-Layer Multi-Layer Perceptron Neural Network.

For a set of cosmological input parameters, each neuron in the network takes a particular numerical value called an activation. The activations of the neurons in each layer of the network depend on those of the neurons in the preceding layer, according to a feed-forward calculation detailed below.

The activations of the input neurons depend on the values of the cosmological input parameters and the ones at the output layer are the predicted values of the CMB power spectrum at the values of l commonly output by CAMB, and used as input by COSMOMC.

Calculation Details:

First, the inputs, $\mathbf{x}$, are simply assigned the values of the cosmological parameters for the model under consideration. In the case of the flat ΛCDM model, the inputs are: $h^2\Omega_b$, $h^2\Omega_c$, θ, τ, n_s and A_s. The activations of the nodes in the second, hidden layer, and output layer, are then calculated as:

$$\text{hidden layer:} \quad h_j = \tanh(f_j^{(1)}); \quad f_j^{(1)} = \sum_l w_{jl}^{(1)} x_l + \theta_j^{(1)},$$

$$\text{output layer:} \quad y_i = f_i^{(2)}; \quad f_i^{(2)} = \sum_j w_{ij}^{(2)} h_j + \theta_i^{(2)},$$

where the index l runs over input nodes, j runs over hidden nodes and i runs over output nodes. The output vector $\mathbf{y}$ then has entries which are the CMB spectrum at the commonly used values of l.

The parameters of the network are $w_{jl}^{(1)}$, $\theta_j^{(1)}$, $w_{ij}^{(2)}$ and $\theta_i^{(2)}$. For a network with N_{in} cosmological parameters, N_{hid} neurons in the hidden layer, and N_{out} values of l, there are $N_{in}N_{hid}$ values of $w_{jl}^{(1)}$, N_{hid} values of $\theta_j^{(1)}$, $N_{hid}N_{out}$ values of $w_{ij}^{(2)}$ and N_{out} values of $\theta_i^{(2)}$.

Further Information:

The descriptions and parameters of COSMONET networks for a variety of standard cosmological models are being released, starting with the flat ΛCDM model. COSMONET and an interface to COSMOMC are publicly available at: `www.mrao.cam.ac.uk/software/cosmonet`.