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A neural network is a type of machine learning model. It is inspired by the human brain, which is composed of neurons that form different pathways to process data and learn patterns. To mimic this behaviour, neural networks in coumputers are made of artificial neurons. An artificial neuron is a function which is conceived as a model of biological neuron in a neural network. An artificial neuron is the smallest unit of the Artificial Neural Network (ANN). The artificial neuron is based on how biological neurons work in human brain.

The artificial neurons are placed in layers to form our neural network. The input is passed to the first layer which is called the input layer, after which it moves forwards where are transformations are done on it by each neuron. This process is called the forward propagation. Eventually, the signal reaches the last layer called the output layer. The layers between input layer and output layers are called hidden layers. The number of artificial neurons in the input layer will depend on the size of our input. In our project, we have a sized image, thus we will have 16,384 neurons in our input layer. We are making a recognizer, so number of neurons in output layer is number of classes. Thus our model will have 36 neurons in the output layer.

The design of artificial neurons is inspired by how biological neurons work. More precisely, it uses two types of behaviour from the biological neuron. There is excitatory potential and inhibitory potential for activation. So for every incoming signal, the neuron either increases it with excitatory potential or decreases it with inhibitory potential. This is copied in our artificial neuron as weights. These weights are multiplied with our inputs and can be used to increase or decrease the intensity of the different inputs. The appropriate value for these weights is calculated during training using a process called backpropagation.

The structure of an artificial neuron is shown in Figure [[fig:artificialneuron]]. A single neuron has multiple inputs it can take. This is shown in figure as variables $x_1, x_2, x_3 ... x_n$. Every input to the neuron will have an associated weight. If we suppose the neuron number is j in the layer. We will represent the weights as $w_{1j}, w_{2j}, w_{3j} ... w_{nj}$. Now we need to combine all the inputs. This is done by a transfer function, which is
summation in most models. Therefore, we will combine all the inputs as,

$$ x_1 w_{1j} + x_2 w_{2j} + x_3 w_{3j} + ... + x_n w_{nj} = \sum_{i=1}^{n} x_i w_{ij} $$

Our model is only using a single activation function. It is the ReLU activation function. This function is very useful, specially in our project. This function helps to avoid the problem of vanishing gradients, which occurs in other activation functions. It is also simple to implement and computationally inexpensive. The one limitation of ReLU is that if inputs are consistently negetive, output will always be zero. In our project, we are using images with intensity of each pixel as input, this problem won't occur in our model. The graph of the

ReLU function is shown in Figure [[fig:relu]].

$$ ReLU(x) = \frac{x + |x|}{2} $$
But it is easier to implement in code by using the defition

The process of training in a neural network involves tweaking the weights associated with inputs of the neurons until we get expected results. In training and tweaking the weights, the model will learn the patterns in our input data. Thus, we will split our dataset into training data and testing data. The training data is used in the training process and the testing data is for testing our model. In our model, we have an 80 split for training and 20 for testing. The first step in training the model is choosing the loss function.

The loss function (also called the cost function) is a function which shows how far our current predictions are from the actual answer. This allows us to automate the task of tweaking our weights in a way such that gets us better predictions, since we now only need to worry about minimizing the cost function and not worry about all of the neurons individually. There are multiple loss functions to choose from based on different use cases. A frequently used loss function is the Mean Square Error (MSE), but that function is better suited for regression. The loss function which is suitable for classification task is the Cross-Entropy loss function.

The Cross-Entropy loss function is used from [cite:@lossfunc]. The cross-entropy loss increases as the predicted probability diverges from actual label. This function minimizes the cost when the signal of the predicted label is correct. It also increases the cost for when signals of other labels are high but this effect is weaker than previous. This is shown in Figure [[fig:crossloss]] with the value of loss in y-axis and signal strength of predicted label is in x-axis.

The Cross-Entropy loss is calculated by the following equation. Here, M is the number of classes, y_i is the expected output of label i and p_i is the prediction.
$$ - \sum_{i = 1}^{M} y_{i} \ln (p_{i}) $$

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