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Neural Network Concepts

7 Types of Neural Network Activation Functions: How to Choose?

Neural network activation functions are a crucial component of deep learning. Activation functions determine the output of a deep learning model, its accuracy, and also the computational efficiency of training a model—which can make or break a large scale neural network. Activation functions also have a major effect on the neural network's ability to converge and the convergence speed, or in some cases, activation functions might prevent neural networks from converging in the first place.

This article is part of MissingLink's Neural Network Guide, which focuses on practical explanations of concepts and processes, skipping the theoretical background. We'll provide you with an overview of the subject, pro tips for choosing activation functions, and explain how to use the MissingLink deep learning platform to speed up your experiments.

In this article you will learn

≡   What is a Neural Network Activation Function?   ↓

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☰ Seven common nonlinear activation functions and how to
   choose an activation function for your model—sigmoid,   ↓

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☰ How neural network activation functions are used in real
   world projects   ↓

What is a Neural Network Activation Function?

Activation functions are mathematical equations that
determine the output of a neural network. The function is
attached to each neuron in the network, and determines
whether it should be activated ("fired") or not, based on
whether each neuron's input is relevant for the model's
prediction. Activation functions also help normalize the output
of each neuron to a range between 1 and 0 or between -1 and
1.

An additional aspect of activation functions is that they must
be computationally efficient because they are calculated
across thousands or even millions of neurons for each data
sample. Modern neural networks use a technique called
backpropagation to train the model, which places an increased
computational strain on the activation function, and its
derivative function.

The need for speed has led to the development of new
functions such as ReLu and Swish (see more about nonlinear
activation functions below).

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Two common neural network activation functions - Sigmoid and Tanh

What are Artificial Neural Networks and Deep Neural Networks?

Artificial Neural Networks (ANN) are comprised of a large number of simple elements, called neurons, each of which makes simple decisions. Together, the neurons can provide accurate answers to some complex problems, such as natural language processing, computer vision, and AI.
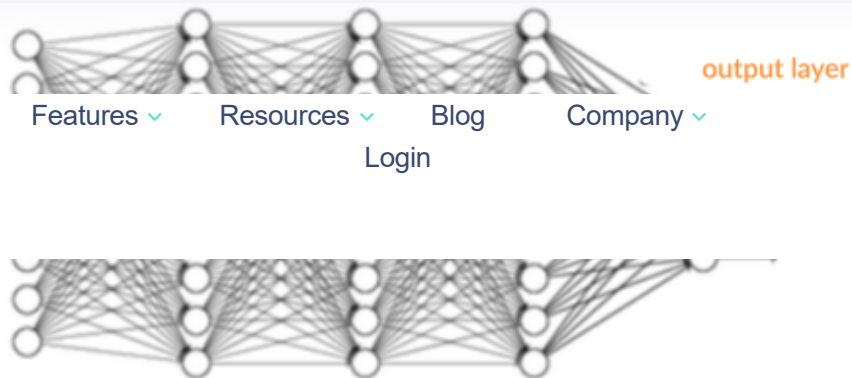
A neural network can be "shallow", meaning it has an input layer of neurons, only one "hidden layer" that processes the inputs, and an output layer that provides the final output of the model. A Deep Neural Network (DNN) commonly has between 2-8 additional layers of neurons. Research from Goodfellow, Bengio and Courville and other experts suggests that neural networks increase in accuracy with the number of hidden layers.

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"Non-deep" feedforward neural network

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output layer

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Deep neural network

Role of the Activation Function in a Neural Network Model

In a neural network, numeric data points, called inputs, are fed into the neurons in the input layer. Each neuron has a weight, and multiplying the input number with the weight gives the output of the neuron, which is transferred to the next layer.

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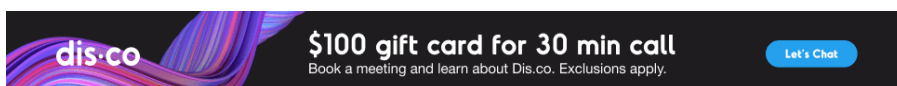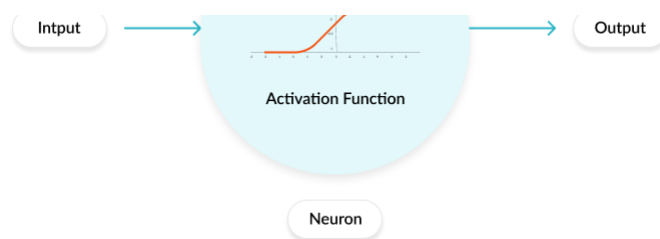
function.

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Increasingly, neural networks use non-linear activation functions, which can help the network learn complex data, compute and learn almost any function representing a question, and provide accurate predictions.

The basic process carried out by a neuron in a neural network is:

 * This is just the number 1, making it possible to represent activation functions that do not cross the origin. Biases are also assigned a weight.

3 Types of Activation Functions
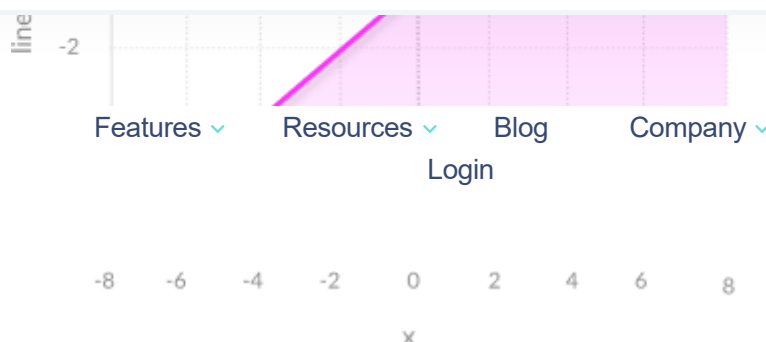
Binary Step Function

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The problem with a step function is that it does not allow multi-value outputs—for example, it cannot support classifying the inputs into one of several categories.

Linear Activation Function

A linear activation function takes the form:

$$A = cx$$

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line   -2

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-8   -6   -4   -2   0   2   4   6   8

x

It takes the inputs, multiplied by the weights for each neuron, and creates an output signal proportional to the input. In one sense, a linear function is better than a step function because it allows multiple outputs, not just yes and no.

However, a linear activation function has two major problems:

1. Not possible to use backpropagation (gradient descent) to train the model—the derivative of the function is a constant, and has no relation to the input, X. So it's not possible to go back and understand which weights in the input neurons can provide a better prediction.

Go in-depth: See our guide on backpropagation

2. All layers of the neural network collapse into one—with linear activation functions, no matter how many layers in the neural network, the last layer will be a linear function of the first layer (because a linear combination of linear functions is still a linear function). So a linear activation function turns the neural network into just one layer.

A neural network with a linear activation function is simply a linear regression model. It has limited power and ability to handle complexity varying parameters of input data.

Non-Linear Activation Functions

Modern neural network models use non-linear activation functions. They allow the model to create complex mappings

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~~functional computation in a neural network, provided that the~~
activation function is non-linear.

1. ~~They allow backpropagation because they have a~~
   derivative function which is related to the inputs.
2. They allow "stacking" of multiple layers of neurons to
   create a deep neural network. Multiple hidden layers of
   neurons are needed to learn complex data sets with high
   levels of accuracy.

7 Common Nonlinear Activation Functions and How to Choose an Activation Function

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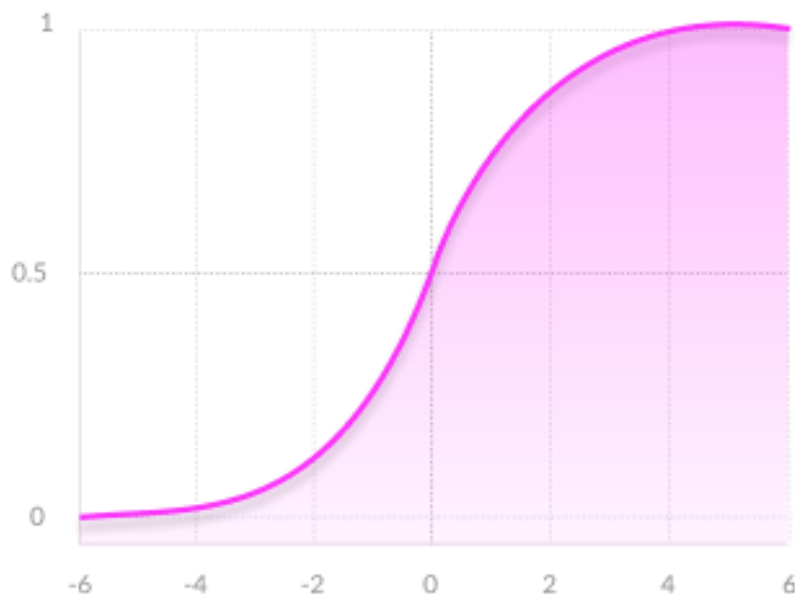
Advantages

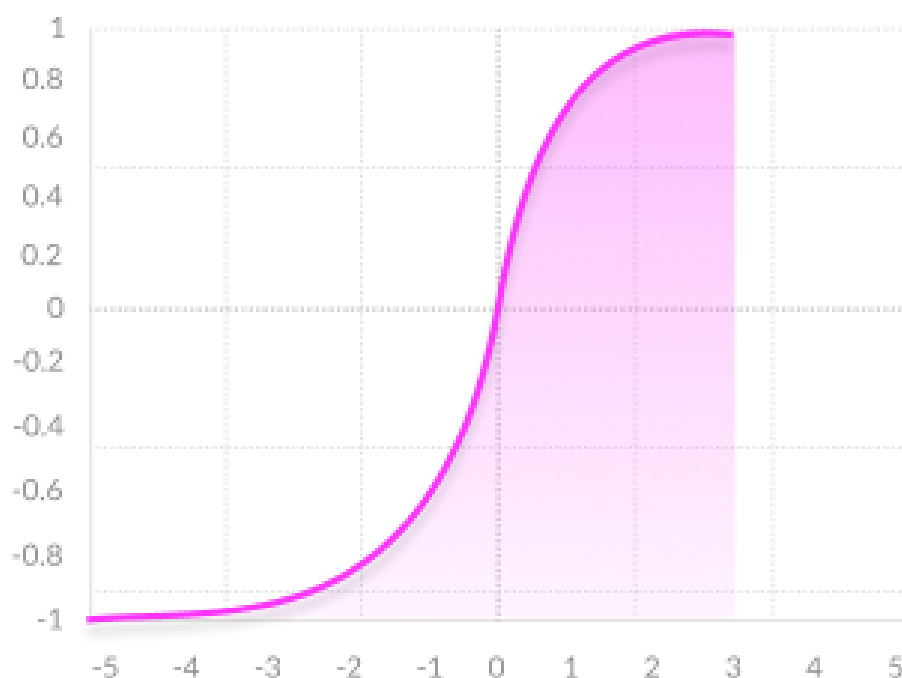Features ˅　　　Resources ˅　　　Blog　　　Company ˅
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- **Clear predictions**—For X above 2 or below -2, tends to bring the Y value (the prediction) to the edge of the curve, very close to 1 or 0. This enables clear predictions.

Disadvantages

- **Vanishing gradient**—for very high or very low values of X, there is almost no change to the prediction, causing a vanishing gradient problem. This can result in the network refusing to learn further, or being too slow to reach an accurate prediction.
- **Outputs not zero centered**.
- **Computationally expensive**

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have strongly negative, neutral, and strongly positive
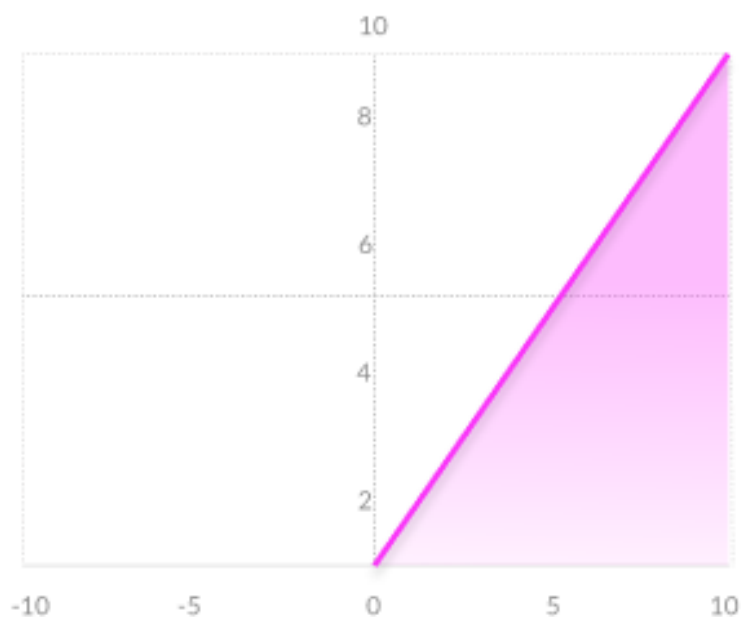values.

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- Like the Sigmoid function

ReLU (Rectified Linear Unit)

Advantages

- **Computationally efficient**—allows the network to
  converge very quickly
- **Non-linear**—although it looks like a linear function, ReLU
  has a derivative function and allows for backpropagation

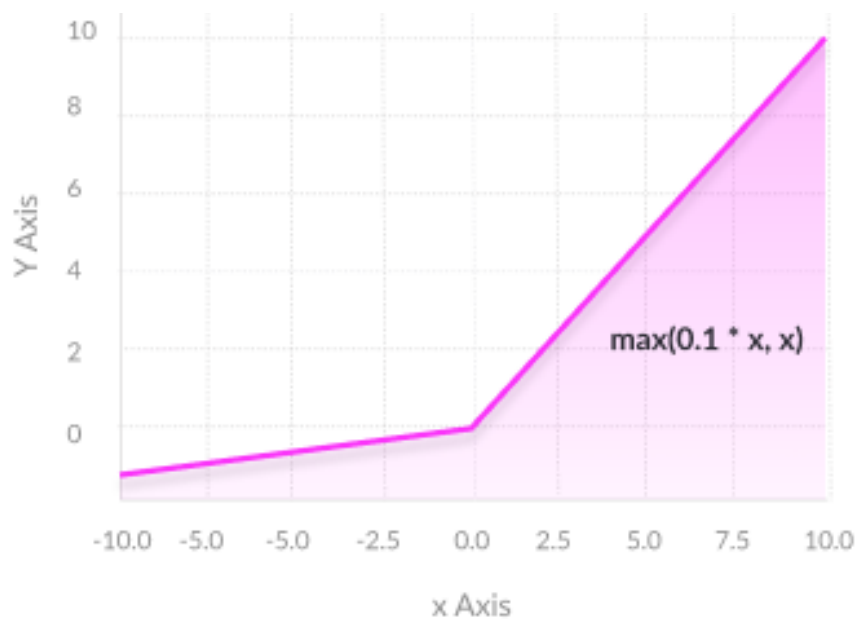**missinglink**.ai   ☰

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Leaky ReLU

Advantages

- **Prevents dying ReLU problem**—this variation of ReLU has a small positive slope in the negative area, so it does enable backpropagation, even for negative input values
- Otherwise like ReLU

Disadvantages

- **Results not consistent**—leaky ReLU does not provide consistent predictions for negative input values.

$$f(x)=max(a\partial,\partial)$$

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Parametric ReLU

Advantages

- **Allows the negative slope to be learned**—unlike leaky ReLU, this function provides the slope of the negative part of the function as an argument. It is, therefore, possible to perform backpropagation and learn the most appropriate value of α.
- Otherwise like ReLU

Disadvantages

- **May perform differently** for different problems.

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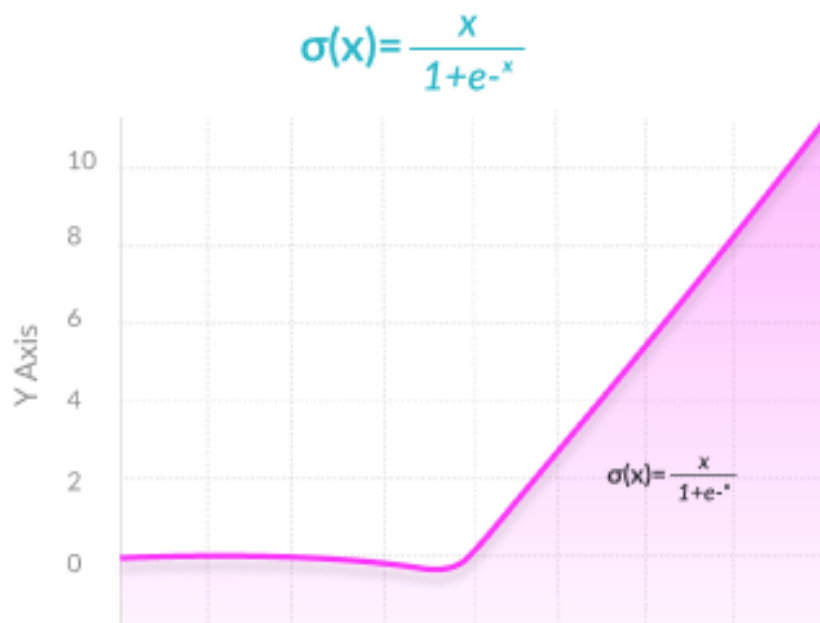Features ⌄   Resources ⌄   Blog   Company ⌄
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Advantages

- **Able to handle multiple classes** only one class in other activation functions—normalizes the outputs for each class between 0 and 1, and divides by their sum, giving the probability of the input value being in a specific class.
- **Useful for output neurons**—typically Softmax is used only for the output layer, for neural networks that need to classify inputs into multiple categories.

Swish

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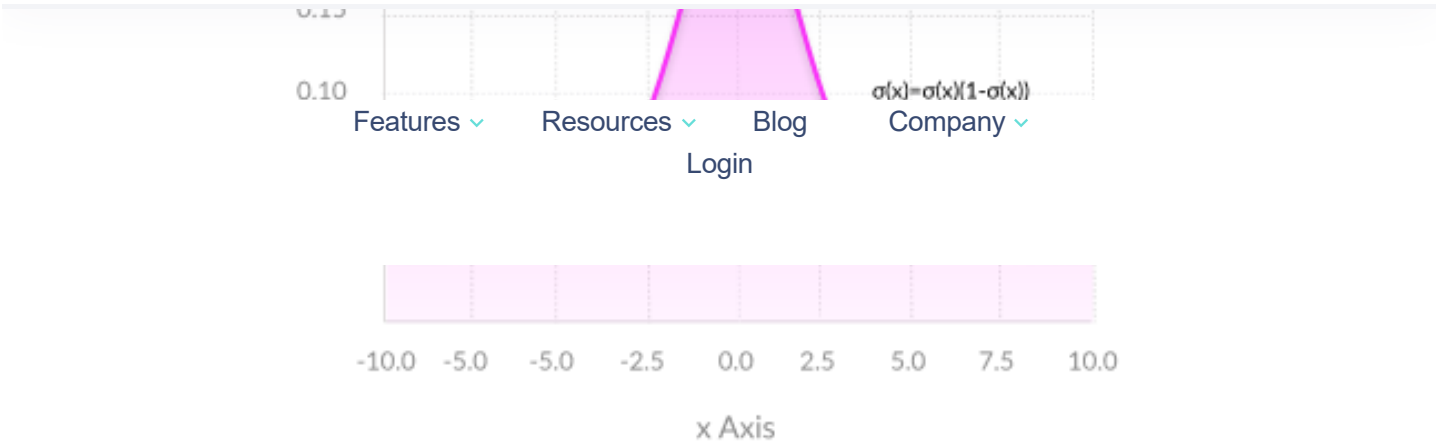## Derivatives or Gradients of Activation Functions

The derivative—also known as a gradient—of an activation function is extremely important for training the neural network.

Neural networks are trained using a process called backpropagation—this is an algorithm which traces back from the output of the model, through the different neurons which were involved in generating that output, back to the original weight applied to each neuron. Backpropagation suggests an optimal weight for each neuron which results in the most accurate prediction.

Go in-depth: See our guide on backpropagation

Below are the derivatives for the most common activation functions.

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$\sigma(x)=\sigma(x)(1-\sigma(x))$

-10.0   -5.0   -5.0   -2.5   0.0   2.5   5.0   7.5   10.0

x Axis

Sigmoid

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TanH

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0.15

0.10

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-10.0   -5.0   -5.0   -2.5   0.0   2.5   5.0   7.5   10.0

x Axis
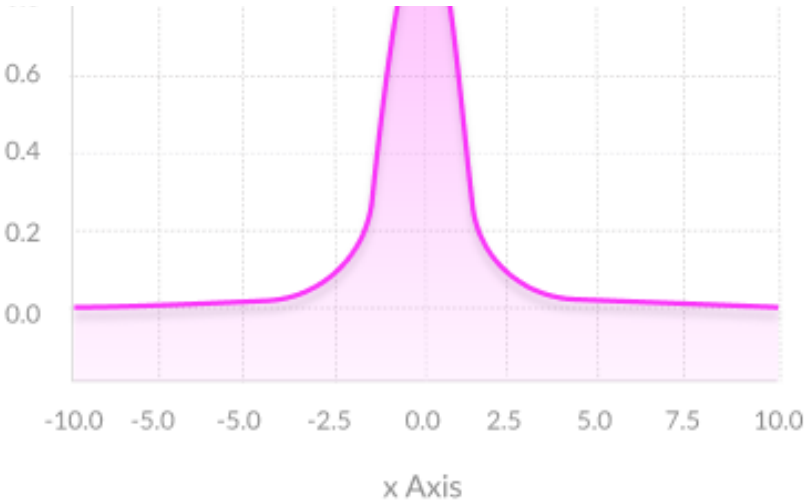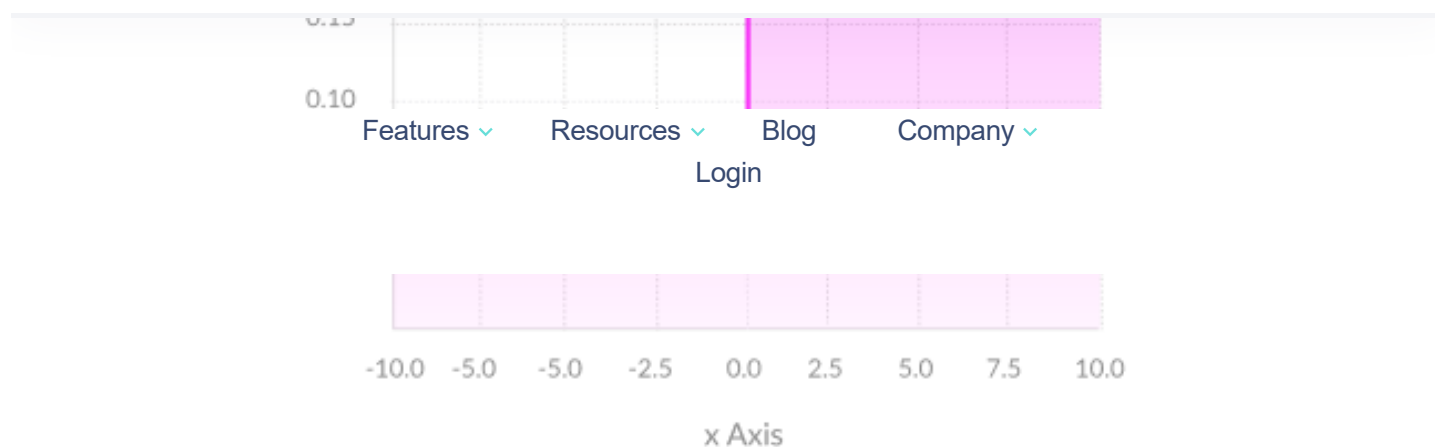
ReLU

[Recent research](#) by Franco Manessi and Alessandro Rozza attempted to find ways to automatically learn which is the optimal activation function for a certain neural network and to even automatically combine activation functions to achieve the

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Neural Network Activation Functions in the Real World

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you to achieve much better results.

In a real-world neural network project, you will switch between activation functions using the deep learning framework of your choice.

For example, here is how to use the ReLU activation function via the Keras library (see all supported activations):

```
keras.activations.relu(x, alpha=0.0,
max_value=None)
```

While selecting and switching activation functions in deep learning frameworks is easy, you will find that managing multiple experiments and trying different activation functions on large test data sets can be challenging.

It can be difficult to:

Track experiment progress source code, metrics and hyperparameters across different experiments trying different activation functions for a model, or variations of the same model.

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multiple large scale experiments will usually require you to run
on several machines; you'll need to provision and maintain

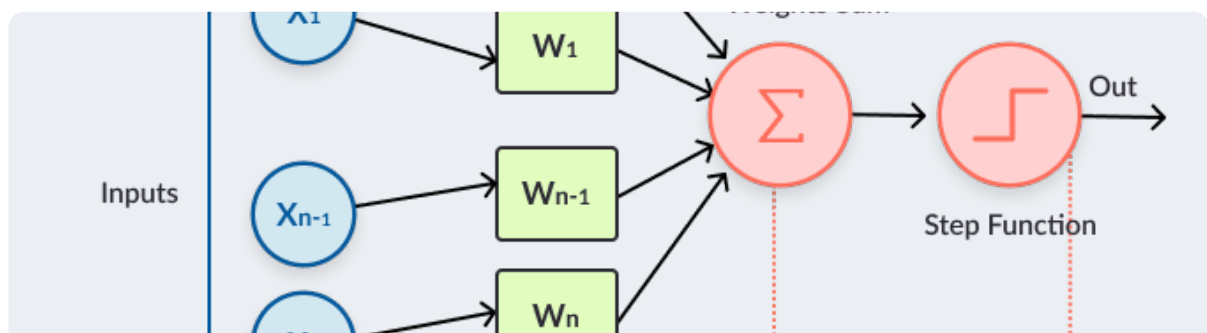Features ⌄   Resources ⌄   Blog   Company ⌄
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Manage training data to achieve good results, you'll need to
experiment with different sets of test data across multiple
model variations on different machines. Moving the training
data each time you need to run an experiment is difficult,
especially if you are processing heavy inputs like images or
video.

MissingLink can help you manage all this, as you experiment
to find the best activation function for your model. Learn more
to see how easy it is to run deep learning experiments at
scale.

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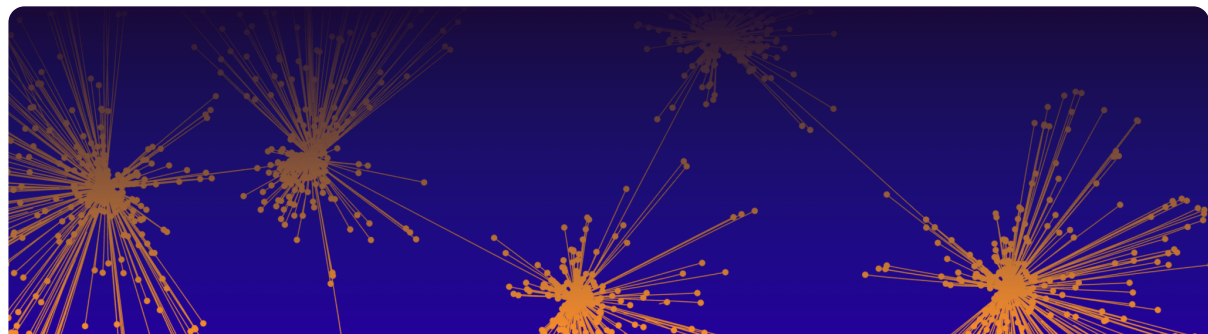
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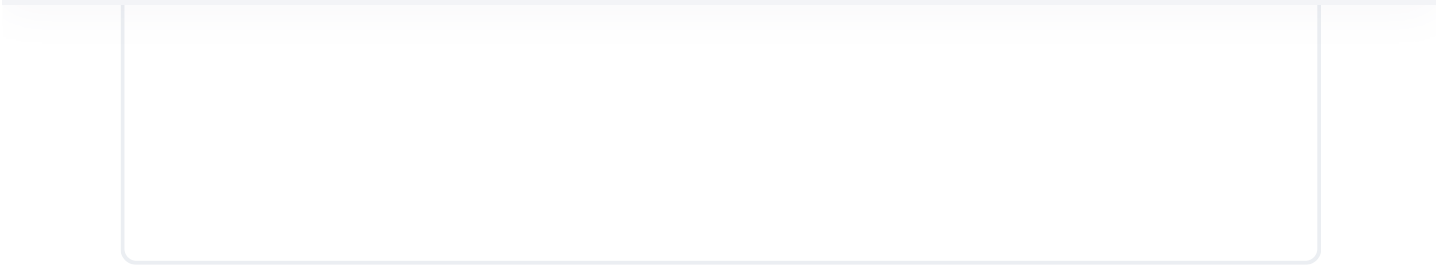
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