# 4. Neural Network Units

## Neural Network Units


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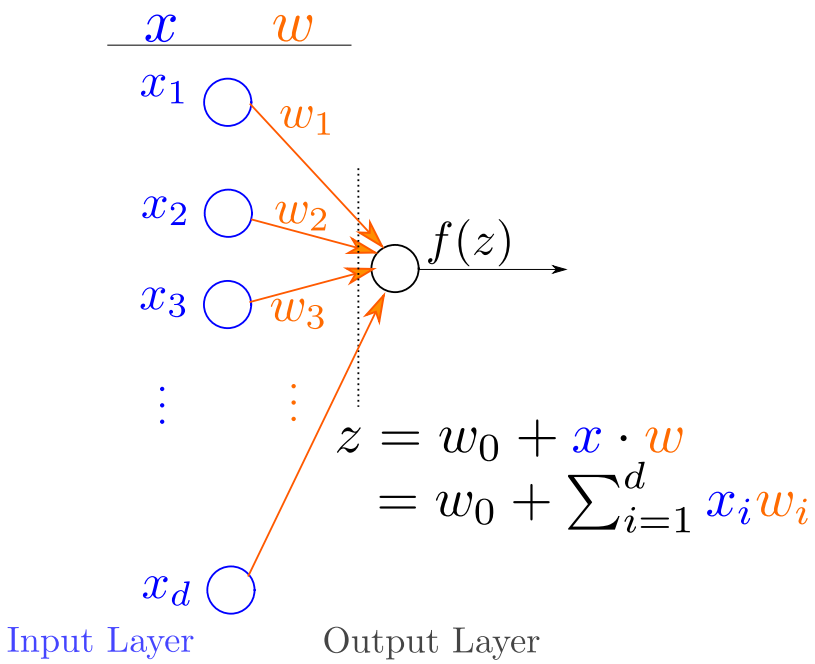
A **neural network unit** is a primitive neural network that consists of only the “input layer", and an output layer with only one output. It is represented pictorially as follows:




A neural network unit computes a non-linear weighted combination of its input:

$$\hat{y} \quad = \quad f(z) \quad \text{where } z = w_0 + \sum_{i=1}^{d} x_i w_i$$

where $w_i$ are numbers called **weights** , $z$ is a number and is the weighted sum of the inputs $x_i$, and $f$ is generally a non-linear function called the **activation function** .

The above equation in vector form is:

$$\hat{y} \quad = \quad f(z) \quad \text{where } z = w_0 + x \cdot w,$$

where $x = [x_1, \ldots, x_d]$ and $w = [w_1, \ldots, w_d]^T$.

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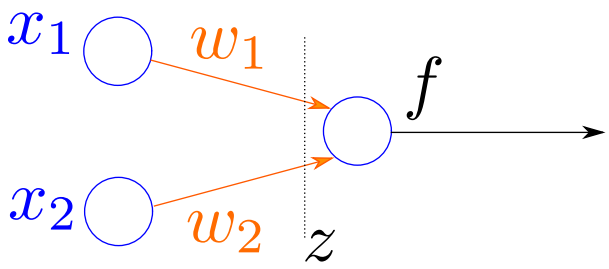
## Numerical Example - Neural Network Unit

2/2 points (graded)

In this problem, you will compute the output $\hat{y} = f(z)$ in the following neural network unit with 2 inputs $x_1$ and $x_2$.




Let

$$\begin{aligned} x &= [1, 0] \\ w_0 &= -3 \\ w &= \begin{bmatrix} 1 \\ -1 \end{bmatrix} \end{aligned}$$

First, compute $z$.

$z =$ -2 ✔ **Answer:** -2

The **rectified linear function (ReLU)** is defined as:

$$f(z) = \max\{0, z\}.$$

Using the ReLU function as the activiation function $f(z)$, compute $\hat{y}$:

$\hat{y} =$ 0 ✔ **Answer:** 0

**Solution:**

$$\begin{aligned} x &= [1, 0] \\ w_0 &= [-3] \end{aligned}$$

$$
\begin{aligned}
w &= \begin{bmatrix} 1 \\ -1 \end{bmatrix} \\
x \cdot w &= [1, 0] . \begin{bmatrix} 1 \\ -1 \end{bmatrix} \\
x \cdot w &= 1 \\
x \cdot w + w_0 &= 1 - 3 \\
x \cdot w + w_0 &= -2 \\
\mathrm{ReLU}\left(x \cdot w + w_0\right) &= \mathrm{ReLU}\left(-2\right) \\
\mathrm{ReLU}\left(x \cdot w + w_0\right) &= max\left(0, -2\right) \\
\mathrm{ReLU}\left(x \cdot w + w_0\right) &= 0
\end{aligned}
$$

Submit You have used 1 of 2 attempts

Answers are displayed within the problem

## Hyperbolic Tangent Activation Function

2.0/2.0 points (graded)

In this problem, we will recall and refamiliarize ourselves with hyperbolic tangent function, which is commonly used as an activation function in a neural network.

Recall the **hyperbolic tangent function** is defined as

$$\tanh\left(z\right) = \frac{e^z - e^{-z}}{e^z + e^{-z}} = 1 - \frac{2}{e^{2z} + 1}.$$

What is the domain of $\tanh\left(z\right)$, i.e. for what values of $z$ is $\tanh\left(z\right)$ defined?

- ○ The set of two numbers $\{-1, 1\}$
- ○ the interval $(-1, 1)$
- ◉ All real numbers ✔

Find $\tanh(0)$. (Enter `e` for $e$.)

$\tanh(0) =$ 0 ✔ **Answer:** 0

Is $\tanh$ odd, even, or neither?

- ◉ odd ✔
- ○ even
- ○ neither

What is the range of $\tanh$? Answer by giving the tightest lower bound, and a tightest upper bound of the set of all possible values of $\tanh(z)$.

Lower bound: -1 ✔ **Answer:** -1

Upper bound: 1 ✔ **Answer:** 1

**Solution:**

Observe that $\tanh$ is an odd function since $\tanh(-z) = -\tanh(z)$. Hence $\tanh(0) = 0$. Since $\tanh$ is a strictly increasing function:

$$\frac{d\tanh(z)}{dz} = \frac{d}{dz}\left(1 - \frac{2}{e^{2z}+1}\right) = \frac{4e^{2z}}{(e^{2z}+1)^2} > 0,$$

the greatest lower bound (or infimum), and the lower upper bound (or supremum) are given by the limits

$$\lim_{z\to-\infty} \tanh(z) = 1 - \frac{2}{(\lim_{z\to-\infty} e^{2z}) + 1} = -1$$
$$\lim_{z\to+\infty} \tanh(z) = 1 - 0 = 1$$

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missing w_d
in the presented pictorially representation, I think there is missing an orange w_d in the pictu... 1

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