# Project

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## 1 Preliminaries

### 1.1 Hyperbolic Functions

Hyperbolic functions are analogs of ordinary trigonometric functions but are defined using the hyperbola rather than the circle. Mathematically, they are defined as:

$$\sinh(x) = \frac{e^x - e^{-x}}{2},$$
$$\cosh(x) = \frac{e^x + e^{-x}}{2},$$
$$\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}.$$

In this paper, we use $\tanh(\theta)$ as an activation function for our neural network.

### 1.2 CORDIC Algorithm

Coordinate Rotation Digital Computer (CORDIC) is an efficient machine for computing trigonometric and hyperbolic functions without multipliers. The recursive equations are given by:

$$x_{n+1} = x_n - m d_n y_n 2^{-\sigma(n)},$$
$$y_{n+1} = y_n + d_n x_n 2^{-\sigma(n)},$$
$$z_{n+1} = z_n - d_n w_{\sigma(n)}.$$

### 1.3 Multi-level Perceptron

A Multi-Level Perceptron (MLP) consists of an input layer, one or more hidden layers, and an output layer. Each neuron applies a nonlinear activation function to a weighted sum of its inputs.

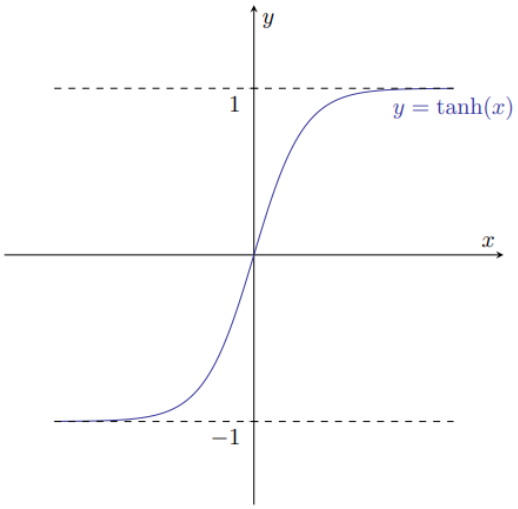


FIGURE 1 – Plot of hyperbolic tangent function $y = \tanh(x)$.

# 2 Implementation

## 2.1 CORDIC Implementation

To compute $\tanh(\theta)$ using CORDIC, we first calculate $\sinh(\theta)$ and $\cosh(\theta)$ and then compute:

$$\tanh(\theta) = \frac{\sinh(\theta)}{\cosh(\theta)}.$$

## 2.2 Resolution

The design uses Q4.16 fixed-point representation for precision.

## 2.3 Preprocessor

A C program generates initial values for LUTs, adhering to the fixed-point representation.

## 2.4 Node

We implement two Nodes:

- 3-input
- 5-input

Each perceptron computes weighted sums and applies activation functions.

### 2.5 Single-layer Implementation

Each layer consists of multiple perceptrons, taking inputs and producing outputs accordingly.

### 2.6 Multi-layer Implementation

Multiple layers are connected sequentially, with outputs from one layer serving as inputs to the next.