Tugas Besar IF3270 Pembelajaran Mesin

Bagian A: Implementasi Forward Propagation untuk Feed Forward Neural Network

Anggota kelompok:

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1. Perancangan struktur file eksternal untuk penyimpanan model

Deklarasi Kelas

- Kelas case. Kelas case akan menerima parameter masukan berupa model, data yang akan diprediksi (input), dan nilai bobot (weights). Di dalam kelas case akan dilakukan operasi untuk mendapatkan matriks bias dan matriks bobot yang nantinya akan diperlukan sebagai perhitungan untuk memprediksi suatu input. Di dalam kelas case juga terdapat method untuk menggambar struktur dari model yang dibuat.
- Kelas model. Kelas model menyimpan jumlah parameter input dan array dari layers yang terdapat di dalam model tersebut
- Kelas layer. Berisi detail dari layer, yakni jumlah neuron dan fungsi aktivasi
- Kelas expect. Menyimpan nilai ekspektasi keluaran dan maksimum sse

In [ ]:
```
import networkx as nx
import matplotlib.pyplot as plt

class Case:
    def __init__(self, model, input, weights):
      self.model = Model(model["input_size"], model["layers"])
      self.input = input
      self.weights = weights

        # mengembalikan informasi array bobot neuron
      def get_arr_neurons_weights(weights):
        arr_neurons = []
        for i in weights:
           arr_neurons.append(i[1:])
        return arr_neurons

      self.neuron_weights = get_arr_neurons_weights(self.weights)

      # mengembalikan informasi array bobot bias
      def get_arr_bias_weights(weights):
        arr_bias = []
        for i in weights:
```

```python
            arr_bias.append(i[0])
        return arr_bias

      self.bias_weights = get_arr_bias_weights(self.weights)

    # menggambar struktur jaringan dengan bobot yang disingkat
    def draw_compact_structure(self):
        # input layer
        print(f'x({self.model.input_size})')
        print(' ↓ ')

        # hidden layer
        for i in range(len(self.model.layers)-1):
            print(f'h{i+1}({self.model.layers[i].number_of_neurons})\t= {self.model
            print(' ↓ ')

        # output layer
        print(f'y({self.model.layers[-1].number_of_neurons})\t= {self.model.layers

    # menggambar struktur jaringan dengan bobot yang lengkap
    def draw_structure(self):
        G = nx.Graph()

        weight_label = {}

        # input layer
        for i in range(self.model.input_size + 1): # neuron+bias
            G.add_node(f'x{i}', pos=(1, i + 1)) # x1, x2, ...

        # hidden layer
        if len(self.model.layers) > 1:
            for i in range(len(self.model.layers) - 1): # layer+bias
                for j in range(self.model.layers[i].number_of_neurons + 1): # neur
                    G.add_node(f'h{i+1}{j}', pos=((i + 2) * 2, j + 1)) # hi0, hi1,

                    if (j > 0): # other than bias
                        if (i == 0):
                            # first hidden layer
                            for k in range(self.model.input_size + 1): # input lay
                                G.add_edge(f'x{k}', f'h{i+1}{j}')
                                weight_label[(f'x{k}', f'h{i+1}{j}')] = self.weigh
                        else:
                            # previous hidden layer neurons
                            for k in range(self.model.layers[i-1].number_of_neuron
                                G.add_edge(f'h{i}{k}', f'h{i+1}{j}')
                                weight_label[(f'h{i}{k}', f'h{i+1}{j}')] = self.we

            # output layer
            for i in range(self.model.layers[-1].number_of_neurons): # neurons in
                G.add_node(f'o{i+1}', pos=((len(self.model.layers) + 1) * 2, i+2))
                for j in range(self.model.layers[-1].number_of_neurons + 1):
                    G.add_edge(f'h{len(self.model.layers)-1}{j}', f'o{i+1}')
                    weight_label[f'h{len(self.model.layers)-1}{j}', f'o{i+1}'] = s

        else: # only input-output layer
            for i in range(self.model.layers[-1].number_of_neurons):
                G.add_node(f'o{i+1}', pos=((len(self.model.layers) + 1) * 2, i+2))
                for j in range(self.model.input_size + 1):
                    G.add_edge(f'x{j}', f'o{i+1}')
                    weight_label[f'x{j}', f'o{i+1}'] = self.weights[-1][j][i]

        pos = nx.get_node_attributes(G, 'pos')
        fig, ax = plt.subplots()
        nx.draw_networkx_nodes(G, pos, ax=ax, node_size=1000)
```

```
        nx.draw_networkx_edges(G, pos, ax=ax)
        labels = {n: n for n in G.nodes()}
        nx.draw_networkx_labels(G, pos, labels, font_color='white', ax=ax)
        nx.draw_networkx_edge_labels(G, pos, weight_label, ax=ax)
        ax.set_xticks([])
        ax.set_yticks([])

        self.print_weight_labels(weight_label)

        plt.show()

    # menampilkan bobot setiap neuron
    def print_weight_labels(self, weight_label):
        print("Daftar bobot:")

        # filter input weights
        x = dict(filter(lambda w: 'x' in w[0][0], weight_label.items()))
        for i in sorted(x.items()):
            print(i[0], '→', i[1])

        # the rest
        h = dict(filter(lambda w: 'h' in w[0][0], weight_label.items()))
        for i in sorted(h.items()):
            print(i[0], '→', i[1])

class Model:
    def __init__(self, input_size, layers):
        self.input_size = input_size

        # membuat array dari layer
        def create_array_layer(layers):
            arr_layers = []
            for i in range(len(layers)):
                arr_layers.append(Layers(layers[i]["number_of_neurons"], layers[i]
            return arr_layers

        self.layers = create_array_layer(layers)
        self.cnt_layers = len(self.layers)

class Layers:
    def __init__ (self, number_of_neurons, activation_function):
        self.number_of_neurons = number_of_neurons
        self.activation_function = activation_function

    # menampilkan informasi layer
    def __str__ (self):
        return f'number of neurons: {self.number_of_neurons}\nactivation_function:

class Expect:
    def __init__ (self, output, max_sse):
        self.output = output
        self.max_sse = max_sse
```

Deklarasi Fungsi Aktivasi

Fungsi di bawah ini merupakan fungsi aktivasi yang akan dijalankan untuk melakukan update value pada neuron

In [ ]:

```
# Helper function
from math import exp

# net -> persamaan linear (ax+b+...)
```

```
def linear(net):
    return net

def relu(net):
    return max(0, net)

def sigmoid(net):
    return float(1/(1 + exp(net * -1)))

def softmax(net_i, arr_net):
    net_sum = 0
    for i in arr_net:
        net_sum += exp(i)

    return float(exp(net_i)/net_sum)
```

Deklarasi Fungsi Pembanding (Menghitung SSE)

Fungsi di bawah ini dibuat untuk menghitung nilai SSE dari predict output dan expect output

In [ ]:
```
def count_sse(predict_output, expect_output):
    sse = 0.0

    # print predict_output
    print("predict = [", end = "")
    for i in range(len(expect_output)):
        print(predict_output[i], end="")
        if(i < len(expect_output) - 1):
            print(",", end = " ")
    print("]")

    # print expect_output
    print(f"expect = {expect_output}")

    for i in range(len(expect_output)):
        sse += (expect_output[i] - predict_output[i]) ** 2
    return sse
```

2. Implementasi load dari file teks

In [ ]:
```
import json

def load_file(filename):
    f = open(filename)

    data = json.load(f)

    # get model
    model = data["case"]["model"]

    # get input data
    arr_input = data["case"]["input"]

    # get weights data
    arr_weight = data["case"]["weights"]

    expect_output = data["expect"]["output"]
    expect_max_sse = data["expect"]["max_sse"]
```

```python
    # create object case
    case = Case(model, arr_input, arr_weight)
    expect = Expect(expect_output, expect_max_sse)

    f.close()

    return case, expect
```

3. Implementasi forward propagation

Digunakan numpy di dalam perhitungan forward propagation untuk menghitung nilai kali antara weight dengan nilai pada neuron yang kemudian ditambah oleh bias. Perkalian matriks antara nilai pada neuron dan weight ditambah bias akan menghasilkan kombinasi linear. Kombinasi linear tersebut kemudian dimasukkan ke dalam fungsi aktivasi untuk update nilai pada neuron tersebut. Hal tersebut dilakukan berulang hingga diperoleh nilai prediksi pada output layer.

In [ ]:
```python
import numpy as np

def forward_propagation(case):
    print("*************************************")
    # draw compact
    print("Compact structure")
    case.draw_compact_structure()

    print("*************************************")
    print("Structure")
    # draw structure
    case.draw_structure()
    # create array of output
    output = []

    print("*************************************")
    print("Predict")

    # print count input
    print(f'{len(case.input)} Input')
    print("---------------------------------")

    # loop for every input
    for i in range(len(case.input)):
        current_data = [case.input[i]]

        # print input idx
        print(f"input ke-{i+1}")

        # print input layer
        print(f"input layer has {len(case.input[i])} neurons")

        # print neurons
        print(f"input neurons:")
        print('x0 (bias) = 1')
        for j in range(len(case.input[i])):
            print(f'x{j+1} = {case.input[i][j]}')

        print("")

        # print count of Hidden Layer
        print(f"{case.model.cnt_layers - 1} Hidden layer")
```

```
        # Loop for every layer
        for j in range(case.model.cnt_layers):

            kombinasilinear = np.dot(current_data, case.neuron_weights[j]) + case.l
            current_data = kombinasilinear

            current_data_cpy = current_data.copy()

            if( j == case.model.cnt_layers - 1):
                # print output layer
                print("")
                print("Output layer")

            if (j < case.model.cnt_layers - 1):
                # print hidden layer
                print('')
                print(f"Hidden layer ke-{j+1}: {len(current_data[0])} neurons")
            else:
                # print output layer
                print(f"Output layer has {len(current_data[0])} neurons")

            # print bias
            if (j < case.model.cnt_layers - 1):
                print(f"n{j+1}0 (bias) = 1")

            # Loop for every neuron
            for k in range(len(current_data[0])):

                if (case.model.layers[j].activation_function == "linear"):
                    current_data[0][k] = linear(current_data[0][k])
                if (case.model.layers[j].activation_function == "relu"):
                    current_data[0][k] = relu(current_data[0][k])
                if (case.model.layers[j].activation_function == "sigmoid"):
                    current_data[0][k] = sigmoid(current_data[0][k])
                if (case.model.layers[j].activation_function == "softmax"):
                    current_data[0][k] = softmax(
                        current_data_cpy[0][k], current_data_cpy[0])

                if (j < case.model.cnt_layers - 1):
                    # neuron in hidden layer
                    print(f"n{j+1}{k+1} = {current_data[0][k]}")
                else:
                    # neuron in output layer
                    print(f"o{j+1}{k+1} = {current_data[0][k]}")

        output.append(current_data)
        if (i < len(case.input) - 1):
            print("----------------------------------")
        else:
            print("************************************")
    return output
```

a. Menampilkan struktur jaringan

linear.json

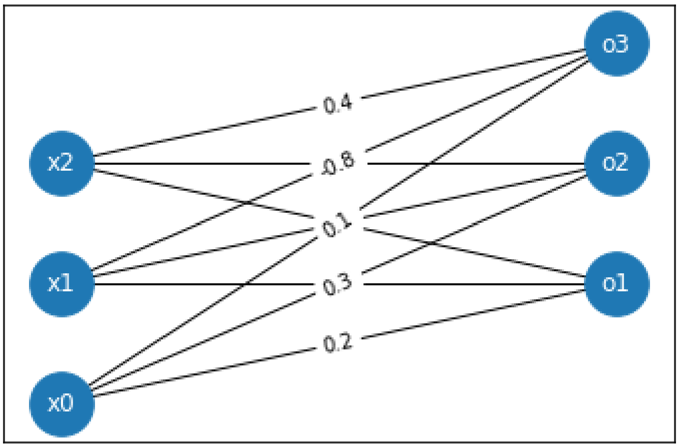
In [ ]:

```
case_linear = load_file("linear.json")[0]
case_linear.draw_compact_structure()
```

```
x(2)
 ↓
y(3)    = linear
```

In [ ]:
```python
case_linear.draw_structure()
```

```
Daftar bobot:
('x0', 'o1') → 0.2
('x0', 'o2') → 0.3
('x0', 'o3') → 0.1
('x1', 'o1') → 0.5
('x1', 'o2') → 0.2
('x1', 'o3') → -0.8
('x2', 'o1') → 0.3
('x2', 'o2') → -0.6
('x2', 'o3') → 0.4
```



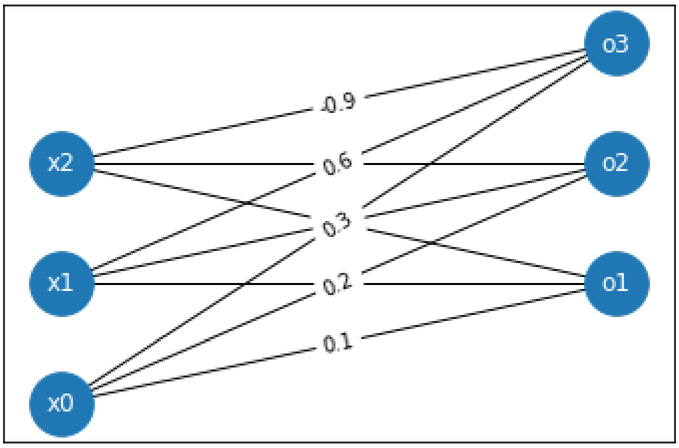
relu.json

In [ ]:
```python
case_relu = load_file("relu.json")[0]
case_relu.draw_compact_structure()
```

```
x(2)
 ↓
y(3)    = relu
```

In [ ]:
```python
case_relu.draw_structure()
```

```
Daftar bobot:
('x0', 'o1') → 0.1
('x0', 'o2') → 0.2
('x0', 'o3') → 0.3
('x1', 'o1') → 0.4
('x1', 'o2') → -0.5
('x1', 'o3') → 0.6
('x2', 'o1') → 0.7
('x2', 'o2') → 0.8
('x2', 'o3') → -0.9
```



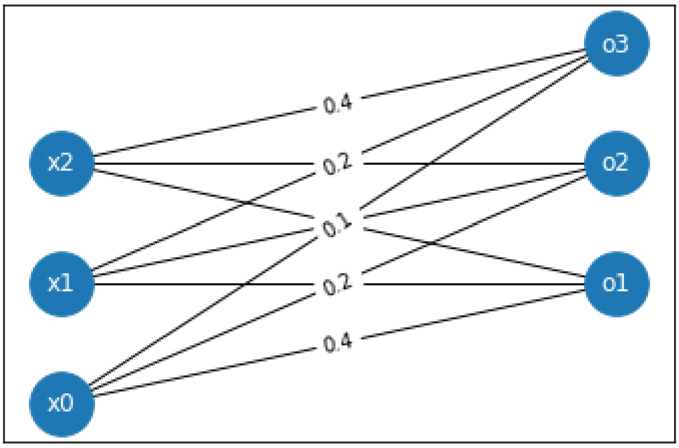
sigmoid.json

In [ ]:
```
case_sigmoid = load_file("sigmoid.json")[0]
case_sigmoid.draw_compact_structure()
```

```
x(2)
 ↓
y(3)    = sigmoid
```

In [ ]:
```
case_sigmoid.draw_structure()
```

```
Daftar bobot:
('x0', 'o1') → 0.4
('x0', 'o2') → 0.2
('x0', 'o3') → 0.1
('x1', 'o1') → 0.2
('x1', 'o2') → 0.4
('x1', 'o3') → 0.2
('x2', 'o1') → 0.1
('x2', 'o2') → 0.2
('x2', 'o3') → 0.4
```



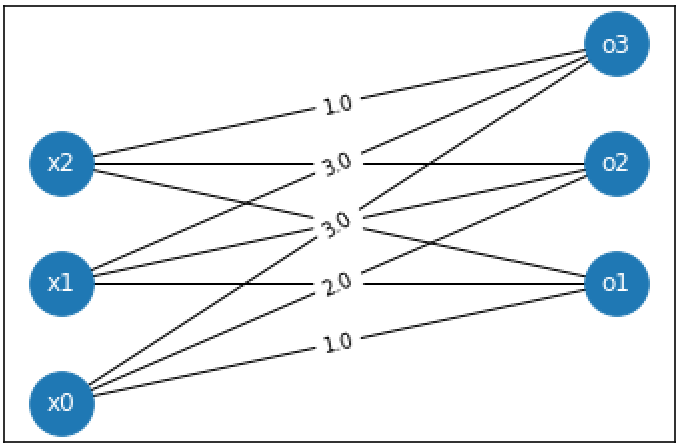
softmax.json

In [ ]:
```
case_softmax = load_file("softmax.json")[0]
case_softmax.draw_compact_structure()
```

```
x(2)
 ↓
y(3)    = softmax
```

In [ ]:
```
case_softmax.draw_structure()
```

```
Daftar bobot:
('x0', 'o1') → 1.0
('x0', 'o2') → 2.0
('x0', 'o3') → 3.0
('x1', 'o1') → 2.0
('x1', 'o2') → 1.0
('x1', 'o3') → 3.0
('x2', 'o1') → 3.0
('x2', 'o2') → 2.0
('x2', 'o3') → 1.0
```



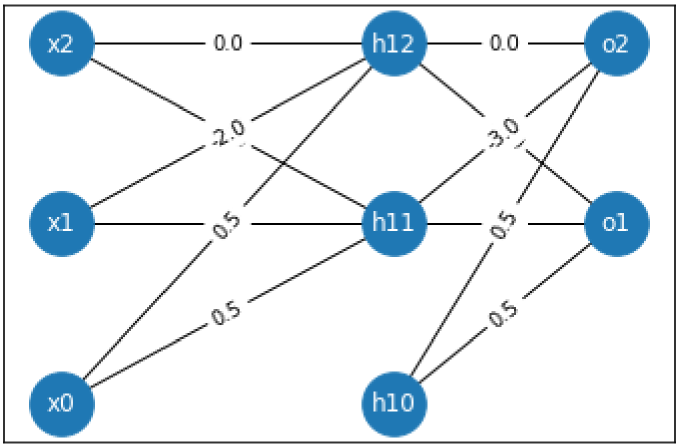
multilayer.json

In [ ]:
```
case_multilayer = load_file("multilayer.json")[0]
case_multilayer.draw_compact_structure()
```

```
x(2)
 ↓
h1(2)    = linear
 ↓
y(2)     = relu
```

In [ ]:
```
case_multilayer.draw_structure()
```

```
Daftar bobot:
('x0', 'h11') → 0.5
('x0', 'h12') → 0.5
('x1', 'h11') → 0.0
('x1', 'h12') → -2.0
('x2', 'h11') → -1.0
('x2', 'h12') → 0.0
('h10', 'o1') → 0.5
('h10', 'o2') → 0.5
('h11', 'o1') → 0.0
('h11', 'o2') → -3.0
('h12', 'o1') → -1.0
('h12', 'o2') → 0.0
```



b. Memprediksi output untuk input 1 instance

In [ ]:
```
case_one_instance_data = {
        "model": {
            "input_size": 3,
            "layers": [
                {
                    "number_of_neurons": 4,
                    "activation_function": "relu"
                },
                {
                    "number_of_neurons": 3,
                    "activation_function": "sigmoid"
                },
                {
                    "number_of_neurons": 2,
                    "activation_function": "softmax"
                },
                {
                    "number_of_neurons": 2,
                    "activation_function": "linear"
                }
            ]
        },
        "input": [
            [
                7.0,
                2.4,
                3.6
            ]
        ],
        "weights": [
            [
                [
                    0.6,
                    0.2,
                    1.8,
                    2.5
                ],
                [
                    2.5,
                    1.2,
                    -0.3,
                    1.4
                ],
                [
                    0.6,
```

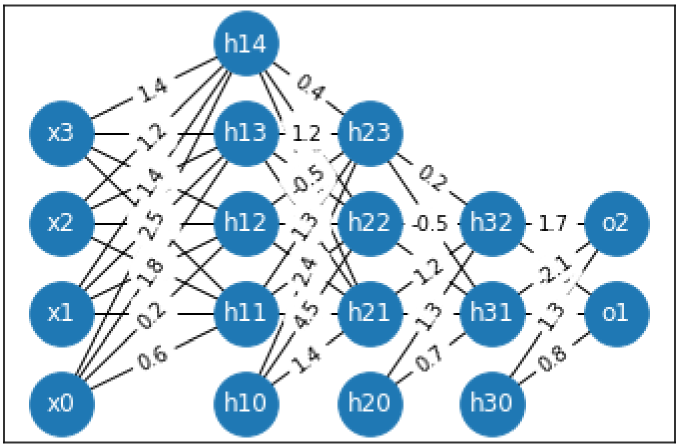
```
                        -0.3,
                        0.7,
                        1.2
                    ],
                    [
                        2.2,
                        -1.3,
                        0.6,
                        1.4
                    ]
                ],
                [
                    [
                        1.4,
                        4.5,
                        2.4
                    ],
                    [
                        2.6,
                        1.2,
                        1.3
                    ],
                    [
                        1.1,
                        1.4,
                        -0.5
                    ],
                    [
                        0.1,
                        -0.4,
                        1.2
                    ],
                    [
                        2.4,
                        -1.6,
                        0.4
                    ]
                ],
                [
                    [
                        0.7,
                        1.3
                    ],
                    [
                        0.5,
                        1.2
                    ],
                                    [
                        1.3,
                        -0.5
                    ],
                    [
                        2.2,
                        0.2
                    ]
                ],
                [
                    [
                        0.8,
                        1.3
                    ],
                    [
                        2.2,
                        -2.1
```

```
                ],
                [
                    -0.8,
                    1.7
                ]
            ]
        ]
    }
```

In [ ]:
```
# get model
model_one_instance = case_one_instance_data["model"]

# get input data
arr_input_one_instance = case_one_instance_data["input"]

# get weights data
arr_weight_one_instance = case_one_instance_data["weights"]

# create object case
case_one_instance = Case(model_one_instance, arr_input_one_instance, arr_weight_on
```

In [ ]:
```
output_one_instance = forward_propagation(case_one_instance)
```

```
***********************************
Compact structure
x(3)
 ↓
h1(4)   = relu
 ↓
h2(3)   = sigmoid
 ↓
h3(2)   = softmax
 ↓
y(2)    = linear
***********************************
Structure
Daftar bobot:
('x0', 'h11') → 0.6
('x0', 'h12') → 0.2
('x0', 'h13') → 1.8
('x0', 'h14') → 2.5
('x1', 'h11') → 2.5
('x1', 'h12') → 1.2
('x1', 'h13') → -0.3
('x1', 'h14') → 1.4
('x2', 'h11') → 0.6
('x2', 'h12') → -0.3
('x2', 'h13') → 0.7
('x2', 'h14') → 1.2
('x3', 'h11') → 2.2
('x3', 'h12') → -1.3
('x3', 'h13') → 0.6
('x3', 'h14') → 1.4
('h10', 'h21') → 1.4
('h10', 'h22') → 4.5
('h10', 'h23') → 2.4
('h11', 'h21') → 2.6
('h11', 'h22') → 1.2
('h11', 'h23') → 1.3
('h12', 'h21') → 1.1
('h12', 'h22') → 1.4
('h12', 'h23') → -0.5
('h13', 'h21') → 0.1
('h13', 'h22') → -0.4
('h13', 'h23') → 1.2
('h14', 'h21') → 2.4
('h14', 'h22') → -1.6
('h14', 'h23') → 0.4
('h20', 'h31') → 0.7
('h20', 'h32') → 1.3
('h21', 'h31') → 0.5
('h21', 'h32') → 1.2
('h22', 'h31') → 1.3
('h22', 'h32') → -0.5
('h23', 'h31') → 2.2
('h23', 'h32') → 0.2
('h30', 'o1') → 0.8
('h30', 'o2') → 1.3
('h31', 'o1') → 2.2
('h31', 'o2') → -2.1
('h32', 'o1') → -0.8
('h32', 'o2') → 1.7
```




```
***********************************
Predict
1 Input
---------------------------------
input ke-1
input layer has 3 neurons
input neurons:
x0 (bias) = 1
x1 = 7.0
x2 = 2.4
x3 = 3.6

3 Hidden layer

Hidden layer ke-1: 4 neurons
n10 (bias) = 1
n11 = 27.460000000000004
n12 = 3.1999999999999993
n13 = 3.54
n14 = 20.22

Hidden layer ke-2: 3 neurons
n20 (bias) = 1
n21 = 1.0
n22 = 0.9997153598140323
n23 = 1.0

Hidden layer ke-3: 2 neurons
n30 (bias) = 1
n31 = 0.9241058943697005
n32 = 0.07589410563029957

Output layer
Output layer has 2 neurons
o41 = 2.772317683109102
o42 = -0.5116023986048619
***********************************
```

Hasil Perhitungan Manual Case One Instance

Matrix Input

$$x_1 = \begin{bmatrix} 7.0 & 2.4 & 3.6 \end{bmatrix}$$

Matrix Bias

$$b_1 = \begin{bmatrix} 0.6 & 0.2 & 1.8 & 2.5 \end{bmatrix}$$

$$b_2 = \begin{bmatrix} 1.4 & 4.5 & 2.4 \end{bmatrix}$$

$$b_3 = \begin{bmatrix} 0.7 & 1.3 \end{bmatrix}$$

$$b_4 = \begin{bmatrix} 0.8 & 1.3 \end{bmatrix}$$

Matrix Weight

$$w_1 = \begin{bmatrix} 2.5 & 1.2 & -0.3 & 1.4 \\ 0.6 & -0.3 & 0.7 & 1.2 \\ 2.2 & -1.3 & 0.6 & 1.4 \end{bmatrix}$$

$$w_2 = \begin{bmatrix} 2.6 & 1.2 & 1.3 \\ 1.1 & 1.4 & -0.5 \\ 0.1 & -0.4 & 1.2 \\ 2.4 & -1.6 & 0.4 \end{bmatrix}$$

$$w_3 = \begin{bmatrix} 0.5 & 1.2 \\ 1.3 & -0.5 \\ 2.2 & 0.2 \end{bmatrix}$$

$$w_4 = \begin{bmatrix} 2.2 & -2.1 \\ -0.8 & 1.7 \end{bmatrix}$$

Matrix h1

$$h_1 = ReLU(x_1 * w_1 + b_1) = max(0, x_1 * w_1 + b)$$

$$h_1 = \begin{bmatrix} 27.46 & 3.2 & 3.54 & 20.22 \end{bmatrix}$$

Matrix h2

$$h_2 = \sigma(h_1 * w_2 + b_2)$$

$$h_2 = \begin{bmatrix} 1 & 0.998 & 1 \end{bmatrix}$$

Matrix h3

$$h_3 = softmax(h_2 * w_3 + b_3)$$

$$h_3 = \begin{bmatrix} 0.924 & 0.076 \end{bmatrix}$$

Matrix output

$$o_1 = h_3 * w_4 + b_4$$

$$o_1 = \begin{bmatrix} 2.772 & -0.551 \end{bmatrix}$$

c. Memprediksi output untuk input sejumlah instance

In [ ]:
```
case_multi_instances_data = {
        "model": {
            "input_size": 2,
            "layers": [
                {
                    "number_of_neurons": 2,
                    "activation_function": "linear"
                },
                {
```

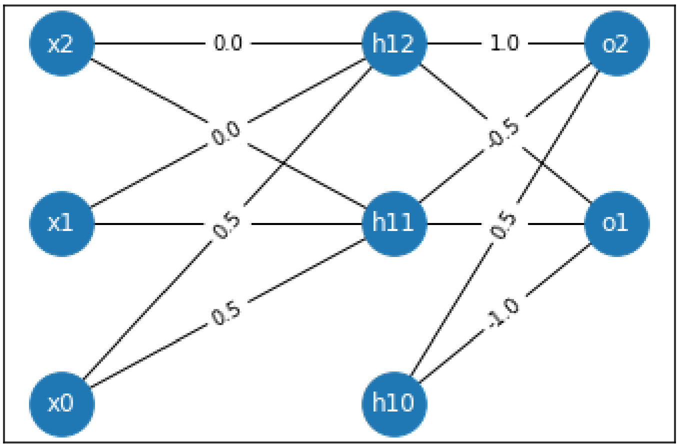
```
                    "number_of_neurons": 2,
                    "activation_function": "sigmoid"
                }
            ]
        },
        "input": [
            [
                1.0,
                2.0
            ],
            [
                1.0,
                0.0
            ],
            [
                0.0,
                2.0
            ]
        ],
        "weights": [
            [
                [
                    0.5,
                    0.5
                ],
                [
                    0.5,
                    0.0
                ],
                [
                    0.0,
                    0.0
                ]
            ],
            [
                [
                    -1.0,
                    0.5
                ],
                [
                    0.5,
                    -0.5
                ],
                [
                    0.0,
                    1.0
                ]
            ]
        ]
    }
```

In [ ]:

```
# get model
model_multi_instances = case_multi_instances_data["model"]

# get input data
arr_input_multi_instances = case_multi_instances_data["input"]

# get weights data
arr_weight_multi_instances = case_multi_instances_data["weights"]

# create object case
case_multi_instances = Case(model_multi_instances, arr_input_multi_instances, arr_
```

In [ ]:
```
output_multi_instances = forward_propagation(case_multi_instances)
```

```
************************************
Compact structure
x(2)
 ↓
h1(2)   = linear
 ↓
y(2)    = sigmoid
************************************
Structure
Daftar bobot:
('x0', 'h11') → 0.5
('x0', 'h12') → 0.5
('x1', 'h11') → 0.5
('x1', 'h12') → 0.0
('x2', 'h11') → 0.0
('x2', 'h12') → 0.0
('h10', 'o1') → -1.0
('h10', 'o2') → 0.5
('h11', 'o1') → 0.5
('h11', 'o2') → -0.5
('h12', 'o1') → 0.0
('h12', 'o2') → 1.0
```



```
***********************************
Predict
3 Input
----------------------------------
input ke-1
input layer has 2 neurons
input neurons:
x0 (bias) = 1
x1 = 1.0
x2 = 2.0

1 Hidden layer

Hidden layer ke-1: 2 neurons
n10 (bias) = 1
n11 = 1.0
n12 = 0.5

Output layer
Output layer has 2 neurons
o21 = 0.3775406687981454
o22 = 0.6224593312018546
----------------------------------
input ke-2
input layer has 2 neurons
input neurons:
x0 (bias) = 1
x1 = 1.0
x2 = 0.0

1 Hidden layer

Hidden layer ke-1: 2 neurons
n10 (bias) = 1
n11 = 1.0
n12 = 0.5

Output layer
Output layer has 2 neurons
o21 = 0.3775406687981454
o22 = 0.6224593312018546
----------------------------------
input ke-3
input layer has 2 neurons
input neurons:
x0 (bias) = 1
x1 = 0.0
x2 = 2.0

1 Hidden layer

Hidden layer ke-1: 2 neurons
n10 (bias) = 1
n11 = 0.5
n12 = 0.5

Output layer
Output layer has 2 neurons
o21 = 0.320821300824607
o22 = 0.679178699175393
***********************************
```

Hasil Perhitungan Manual Case Multi Instances

Input Ke-	Input x0	Input x1	Input x2	Fungsi Aktivasi	h11	h12	Fungsi Aktivasi	o21	o22
1	1.0	1.0	2.0	Linear	(0.5 + 0.5 x1) = 1	(0.5)	Sigmoid	σ(-1 + 0.5h11) = 1/(1+e^0.5) = 0.3775406687981454	σ(0.5 - 0.5h11 + h12) = 1/(1+e^-0.5) = 0.622459331201854
2	1.0	1.0	0.0	Linear	(0.5 + 0.5 x1) = 1	(0.5)	Sigmoid	σ(-1 + 0.5h11) = 1/(1+e^0.5) = 0.3775406687981454	σ(0.5 - 0.5h11 + h12) = 1/(1+e^-0.5) = 0.622459331201854
3	1.0	0.0	2.0	Linear	(0.5 + 0.5 x1) = 0.5	(0.5)	Sigmoid	σ(-1 + 0.5h11) = 1/(1+e^0.75) = 0.320821300824607	σ(0.5 - 0.5h11 + h12) = 1/(1+e^-0.75) = 0.679178699175393

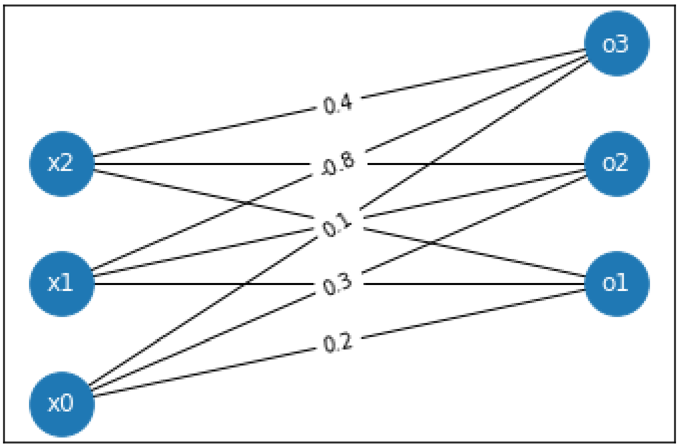
4. Pengujian kebenaran fungsional

a. Memprediksi kasus dengan test case linear.json

In [ ]:

```
case_linear = load_file("linear.json")[0]
output_linear = forward_propagation(case_linear)

expect_linear = load_file("linear.json")[1]

print("Menghitung Nilai SSE")

for i in range(len(case_linear.input)):
    print('----------------------------------')
    print(f"input ke-{i+1}")
    sse = count_sse(output_linear[i][0], expect_linear.output[i])
    print(f"SSE untuk input ke-{i+1} =", sse, end = "")
    if (sse < expect_linear.max_sse):
        print(" => Result: True")
    else:
        print(" => Result: False")
```

```
************************************
Compact structure
x(2)
 ↓
y(3)     = linear
************************************
Structure
Daftar bobot:
('x0', 'o1') → 0.2
('x0', 'o2') → 0.3
('x0', 'o3') → 0.1
('x1', 'o1') → 0.5
('x1', 'o2') → 0.2
('x1', 'o3') → -0.8
('x2', 'o1') → 0.3
('x2', 'o2') → -0.6
('x2', 'o3') → 0.4
```



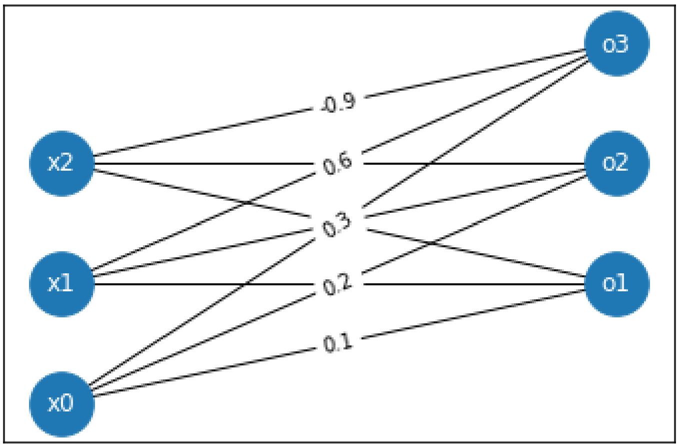

```
************************************
Predict
1 Input
----------------------------------
input ke-1
input layer has 2 neurons
input neurons:
x0 (bias) = 1
x1 = 3.0
x2 = 1.0

0 Hidden layer

Output layer
Output layer has 3 neurons
o11 = 2.0
o12 = 0.30000000000000001
o13 = -1.9000000000000004
************************************
Menghitung Nilai SSE
----------------------------------
input ke-1
predict = [2.0, 0.30000000000000001, -1.9000000000000004]
expect = [2.0, 0.3, -1.9]
SSE untuk input ke-1 = 2.0954117794933126e-31 => Result: True
```

b. Memprediksi kasus dengan test case relu.json

In [ ]:

```
case_relu = load_file("relu.json")[0]
output_relu = forward_propagation(case_relu)

expect_relu = load_file("relu.json")[1]
print("Menghitung Nilai SSE")

for i in range(len(case_relu.input)):
    print('----------------------------------')
    print(f"input ke-{i+1}")
    sse = count_sse(output_relu[i][0], expect_relu.output[i])
    print(f"SSE untuk input ke-{i+1} =", sse, end = "")
    if (sse < expect_relu.max_sse):
        print(" => Result: True")
    else:
        print(" => Result: False")
```

```
***********************************
Compact structure
x(2)
 ↓
y(3)    = relu
***********************************
Structure
Daftar bobot:
('x0', 'o1') → 0.1
('x0', 'o2') → 0.2
('x0', 'o3') → 0.3
('x1', 'o1') → 0.4
('x1', 'o2') → -0.5
('x1', 'o3') → 0.6
('x2', 'o1') → 0.7
('x2', 'o2') → 0.8
('x2', 'o3') → -0.9
```



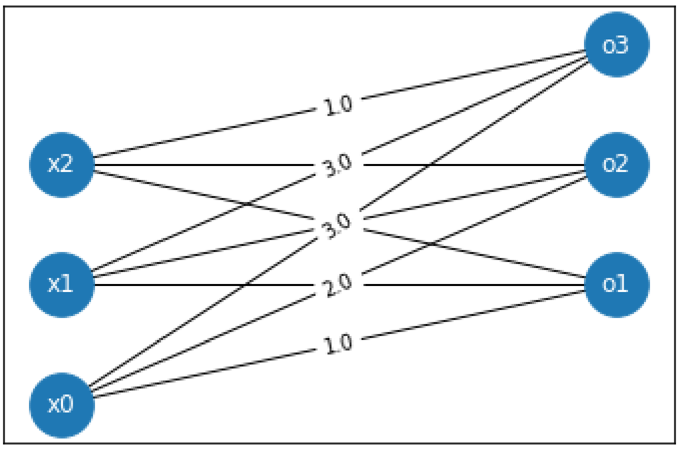

```
***********************************
Predict
1 Input
----------------------------------
input ke-1
input layer has 2 neurons
input neurons:
x0 (bias) = 1
x1 = -1.0
x2 = 0.5

0 Hidden layer

Output layer
Output layer has 3 neurons
o11 = 0.04999999999999996
o12 = 1.1
o13 = 0.0
***********************************
Menghitung Nilai SSE
----------------------------------
input ke-1
predict = [0.04999999999999996, 1.1, 0.0]
expect = [0.05, 1.1, 0.0]
SSE untuk input ke-1 = 1.7333369499485123e-33 => Result: True
```

c. Memprediksi kasus dengan test case softmax.json

In [ ]:
```
case_softmax = load_file("softmax.json")[0]
output_softmax = forward_propagation(case_softmax)
```

```
expect_softmax = load_file("softmax.json")[1]

print("Menghitung Nilai SSE")

for i in range(len(case_softmax.input)):
    print('----------------------------------')
    print(f"input ke-{i+1}")
    sse = count_sse(output_softmax[i][0], expect_softmax.output[i])
    print(f"SSE untuk input ke-{i+1} =", sse, end = "")
    if (sse < expect_softmax.max_sse):
        print(" => Result: True")
    else:
        print(" => Result: False")
```

```
************************************
Compact structure
x(2)
 ↓
y(3)    = softmax
************************************
Structure
Daftar bobot:
('x0', 'o1') → 1.0
('x0', 'o2') → 2.0
('x0', 'o3') → 3.0
('x1', 'o1') → 2.0
('x1', 'o2') → 1.0
('x1', 'o3') → 3.0
('x2', 'o1') → 3.0
('x2', 'o2') → 2.0
('x2', 'o3') → 1.0
```



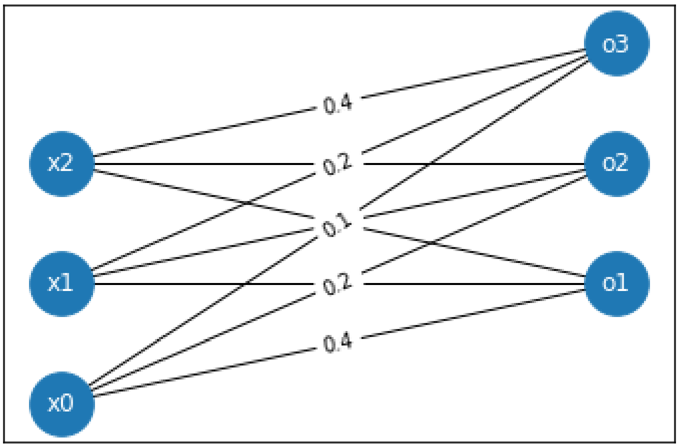
```
************************************
Predict
1 Input
----------------------------------
input ke-1
input layer has 2 neurons
input neurons:
x0 (bias) = 1
x1 = 1.0
x2 = 2.0

0 Hidden layer

Output layer
Output layer has 3 neurons
o11 = 0.6652409557748219
o12 = 0.09003057317038045
o13 = 0.24472847105479764
************************************
Menghitung Nilai SSE
----------------------------------
input ke-1
predict = [0.6652409557748219, 0.09003057317038045, 0.24472847105479764]
expect = [0.665241, 0.090031, 0.244728]
SSE untuk input ke-1 = 4.0603201288236806e-13 => Result: True
```

d. Memprediksi kasus dengan test case sigmoid.json

In [ ]:

```python
case_sigmoid= load_file("sigmoid.json")[0]
output_sigmoid = forward_propagation(case_sigmoid)

expect_sigmoid = load_file("sigmoid.json")[1]

print("Menghitung Nilai SSE")

for i in range(len(case_sigmoid.input)):
    print('----------------------------------')
    print(f"input ke-{i+1}")
    sse = count_sse(output_sigmoid[i][0], expect_sigmoid.output[i])
    print(f"SSE untuk input ke-{i+1} =", sse, end = "")
    if (sse < expect_sigmoid.max_sse):
        print(" => Result: True")
    else:
        print(" => Result: False")
```

```
************************************
Compact structure
x(2)
 ↓
y(3)    = sigmoid
************************************
Structure
Daftar bobot:
('x0', 'o1') → 0.4
('x0', 'o2') → 0.2
('x0', 'o3') → 0.1
('x1', 'o1') → 0.2
('x1', 'o2') → 0.4
('x1', 'o3') → 0.2
('x2', 'o1') → 0.1
('x2', 'o2') → 0.2
('x2', 'o3') → 0.4
```



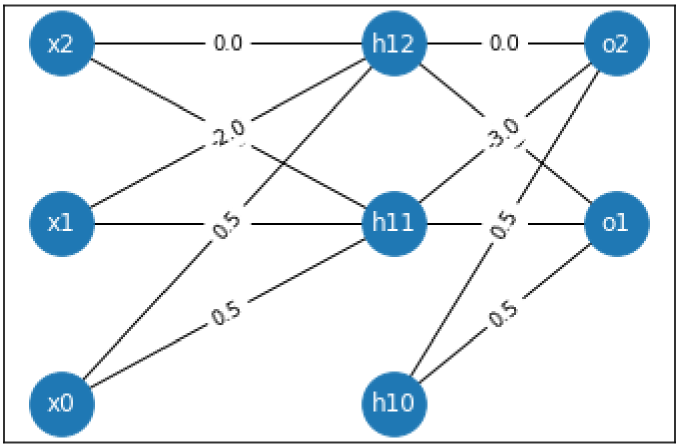

```
************************************
Predict
1 Input
----------------------------------
input ke-1
input layer has 2 neurons
input neurons:
x0 (bias) = 1
x1 = 0.2
x2 = 0.4

0 Hidden layer

Output layer
Output layer has 3 neurons
o11 = 0.617747874769249
o12 = 0.5890404340586651
o13 = 0.574442516811659
************************************
Menghitung Nilai SSE
----------------------------------
input ke-1
predict = [0.617747874769249, 0.5890404340586651, 0.574442516811659]
expect = [0.617747, 0.58904, 0.574442]
SSE untuk input ke-1 = 1.2207224545374987e-12 => Result: True
```

e. Memprediksi kasus dengan test case multilayer.json

In [ ]:

```
case_multilayer = load_file("multilayer.json")[0]
output_multilayer = forward_propagation(case_multilayer)

expect_multilayer = load_file("multilayer.json")[1]

print("Menghitung Nilai SSE")

for i in range(len(case_multilayer.input)):
    print('----------------------------------')
    print(f"input ke-{i+1}")
    sse = count_sse(output_multilayer[i][0], expect_multilayer.output[i])
    print(f"SSE untuk input ke-{i+1} =", sse, end = "")
    if (sse < expect_multilayer.max_sse):
        print(" => Result: True")
    else:
        print(" => Result: False")
```

```
************************************
Compact structure
x(2)
 ↓
h1(2)    = linear
 ↓
y(2)     = relu
************************************
Structure
Daftar bobot:
('x0', 'h11') → 0.5
('x0', 'h12') → 0.5
('x1', 'h11') → 0.0
('x1', 'h12') → -2.0
('x2', 'h11') → -1.0
('x2', 'h12') → 0.0
('h10', 'o1') → 0.5
('h10', 'o2') → 0.5
('h11', 'o1') → 0.0
('h11', 'o2') → -3.0
('h12', 'o1') → -1.0
('h12', 'o2') → 0.0
```



```
************************************
Predict
3 Input
----------------------------------
input ke-1
input layer has 2 neurons
input neurons:
x0 (bias) = 1
x1 = 1.0
x2 = 0.0

1 Hidden layer

Hidden layer ke-1: 2 neurons
n10 (bias) = 1
n11 = 0.5
n12 = -1.5

Output layer
Output layer has 2 neurons
o21 = 2.0
o22 = 0.0
----------------------------------
input ke-2
input layer has 2 neurons
input neurons:
x0 (bias) = 1
x1 = 0.0
x2 = 1.0

1 Hidden layer

Hidden layer ke-1: 2 neurons
n10 (bias) = 1
n11 = -0.5
n12 = 0.5

Output layer
Output layer has 2 neurons
o21 = 0.0
o22 = 2.0
----------------------------------
input ke-3
input layer has 2 neurons
input neurons:
x0 (bias) = 1
x1 = 0.0
x2 = 0.0

1 Hidden layer

Hidden layer ke-1: 2 neurons
n10 (bias) = 1
n11 = 0.5
n12 = 0.5

Output layer
Output layer has 2 neurons
o21 = 0.0
o22 = 0.0
************************************
Menghitung Nilai SSE
----------------------------------
input ke-1
```

```
predict = [2.0, 0.0]
expect = [2.0, 0.0]
SSE untuk input ke-1 = 0.0 => Result: True
----------------------------------
input ke-2
predict = [0.0, 2.0]
expect = [0.0, 2.0]
SSE untuk input ke-2 = 0.0 => Result: True
----------------------------------
input ke-3
predict = [0.0, 0.0]
expect = [0.0, 0.0]
SSE untuk input ke-3 = 0.0 => Result: True
```

5. Perhitungan Manual untuk Kasus Uji Asisten

a. linear.json

Matrix Input

$$x_1 = \begin{bmatrix} 3.0 & 1.0 \end{bmatrix}$$

Matrix Bias

$$b_1 = \begin{bmatrix} 0.2 & 0.3 & 0.1 \end{bmatrix}$$

Matrix Weight

$$w_1 = \begin{bmatrix} 0.5 & 0.2 & -0.8 \\ 0.3 & -0.6 & 0.4 \end{bmatrix}$$

Matrix output

$$o_1 = x_1 * w_1 + b_1$$

$$o_1 = \begin{bmatrix} 2.0 & 0.3 & -1.9 \end{bmatrix}$$

b. sigmoid.json

Matrix Input

$$x_1 = \begin{bmatrix} 0.2 & 0.4 \end{bmatrix}$$

Matrix Bias

$$b_1 = \begin{bmatrix} 0.4 & 0.2 & 0.1 \end{bmatrix}$$

Matrix Weight

$$w_1 = \begin{bmatrix} 0.2 & 0.4 & 0.2 \\ 0.1 & 0.2 & 0.4 \end{bmatrix}$$

Matrix output

$$o_1 = \sigma(x_1 * w_1 + b_1)$$

$$o_1 = \begin{bmatrix} 0.618 & 0.589 & 0.574 \end{bmatrix}$$

c. softmax.json

Matrix Input

$$x_1 = \begin{bmatrix} 1.0 & 2.0 \end{bmatrix}$$

Matrix Bias

$$b_1 = \begin{bmatrix} 1.0 & 2.0 & 3.0 \end{bmatrix}$$

Matrix Weight

$$w_1 = \begin{bmatrix} 2.0 & 1.0 & 3.0 \\ 3.0 & 2.0 & 1.0 \end{bmatrix}$$

Matrix o1

$$o_1 = softmax(x_1 * w_1 + b_1)$$

$$o_1 = \begin{bmatrix} 0.665 & 0.090 & 0.225 \end{bmatrix}$$

d. relu.json

Matrix Input

$$x_1 = \begin{bmatrix} -1.0 & 0.5 \end{bmatrix}$$

Matrix Bias

$$b_1 = \begin{bmatrix} 0.1 & 0.2 & 0.3 \end{bmatrix}$$

Matrix Weight

$$w_1 = \begin{bmatrix} 0.4 & -0.5 & 0.6 \\ 0.7 & 0.8 & -0.9 \end{bmatrix}$$

Matrix o1

$$o_1 = ReLU(x_1 * w_1 + b_1) = max(0, x_1 * w_1 + b)$$

$$o_1 = \begin{bmatrix} 0.05 & 1.1 & 0.0 \end{bmatrix}$$

g. multilayer.json

Matrix Input

$$x_1 = \begin{bmatrix} 1.0 & 0.0 \end{bmatrix}$$

$$x_2 = \begin{bmatrix} 0.0 & 1.0 \end{bmatrix}$$

$$x_3 = \begin{bmatrix} 0.0 & 0.0 \end{bmatrix}$$

Matrix Bias

$$b_1 = \begin{bmatrix} 0.5 & 0.5 \end{bmatrix}$$

$$b_2 = \begin{bmatrix} 0.5 & 0.5 \end{bmatrix}$$

Matrix Weight

$$w_1 = \begin{bmatrix} 0.0 & -2.0 \\ -1.0 & 0.0 \end{bmatrix}$$

$$w_2 = \begin{bmatrix} 0.0 & -3.0 \\ -1.0 & 0.0 \end{bmatrix}$$

Input x1 </br> Matrix h1

$$h_1 = x_1 * w_1 + b_1$$

$$h_1 = \begin{bmatrix} 0.5 & -1.5 \end{bmatrix}$$

Matrix o1

$$o_1 = ReLU(h_1 * w_2 + b_2) = max(0, h_1 * w_2 + b_2)$$

$$o_1 = \begin{bmatrix} 2.0 & 0.0 \end{bmatrix}$$

Input x2 </br> Matrix h1

$$h_1 = x_2 * w_1 + b_1$$

$$h_1 = \begin{bmatrix} -0.5 & 0.5 \end{bmatrix}$$

Matrix o2

$$o_2 = ReLU(h_1 * w_2 + b_2) = max(0, h_1 * w_2 + b_2)$$

$$o_2 = \begin{bmatrix} 0.0 & 2.0 \end{bmatrix}$$

Input x3 </br> Matrix h1

$$h_1 = x_3 * w_1 + b_1$$

$$h_1 = \begin{bmatrix} 0.5 & 0.5 \end{bmatrix}$$

Matrix o3

$$o_3 = ReLU(h_1 * w_2 + b_2) = max(0, h_1 * w_2 + b_2)$$

$$o_3 = \begin{bmatrix} 0.0 & 0.0 \end{bmatrix}$$

Pembagian tugas

1. Christine Hutabarat (13520005) - Implementasi fungsi FFNN
2. Hana Fathiyah (13520047) - Pengujian dan perhitungan manual untuk kasus 1 instance, pengujian dan perhitungan manual untuk kasus uji dari asisten
3. Yohana Golkaria Nainggolan (13520053) - Pengujian dan perhitungan manual untuk kasus multi-instance
4. Alifia Rahmah (13520122) - Menggambar struktur model