# CpE 520: HW#7

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# Question 1

## Part (a): Neural Network without Hidden Layer

In this part of the question, we are going to train and examine a neural network with no hidden layer (i.e Perceptron). The structure of this network is repeated in figure 1.

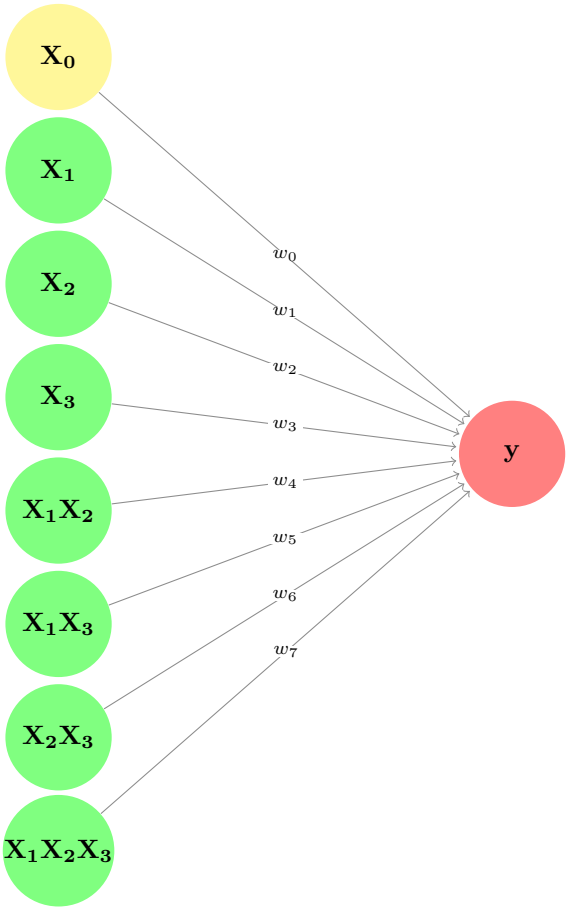


Figure 1: Neural network for binary Parity-3

The whole *Matlab* code for training and examining this neural network is printed in the section below:

```
clc
clear variables
close all

% every sample of input lies on a column vector of X
X = zeros(7, 8);
```

```
x1 = [0 1];
x2 = [0 1];
x3 = [0 1];

% Input sample generation
for i = 1:size(x1, 2)
        for j = 1:size(x2, 2)
                for k = 1:size(x3, 2)
                        X(:, k+2*(j-1)+4*(i-1)) = [x1(i), x2(j), x3(k)
                            ,...
                        x1(i)*x2(j), x1(i)*x3(k),...
                        x2(j)*x3(k), x1(i)*x2(j)*x3(k)];
                end
        end
end

t = [0 1 1 0 1 0 0 1];

% the initialization which converges
rng(3);
net = patternnet([]);
net.divideFcn = 'dividetrain';
net.performFcn = 'mse';
net.trainParam.showCommandLine = 1;
net.trainParam.show = 1;

[net, tr, y, e] = train(net, X, t);

weights_in = net.IW;
weights_hidden = net.LW;
biases  = net.b;
view(net);
```

The resulting *Matlab*-generated block diagram of the neural network is shown in figure 2.

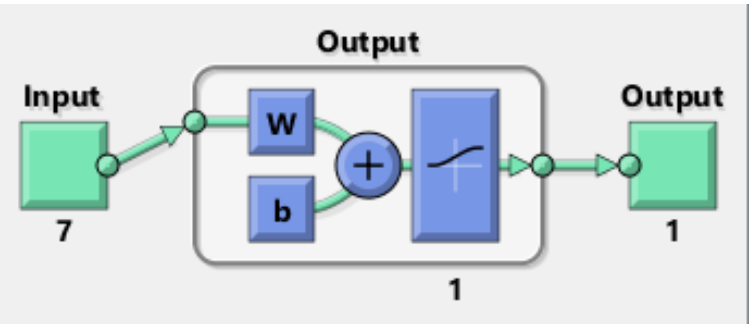


Figure 2: *Matlab*-generated block diagram

Learning curve which shows the decreasing value of mean square error versus the number of epochs is plotted in figure 3. It shows that after 74 epochs the network is trained successfully.

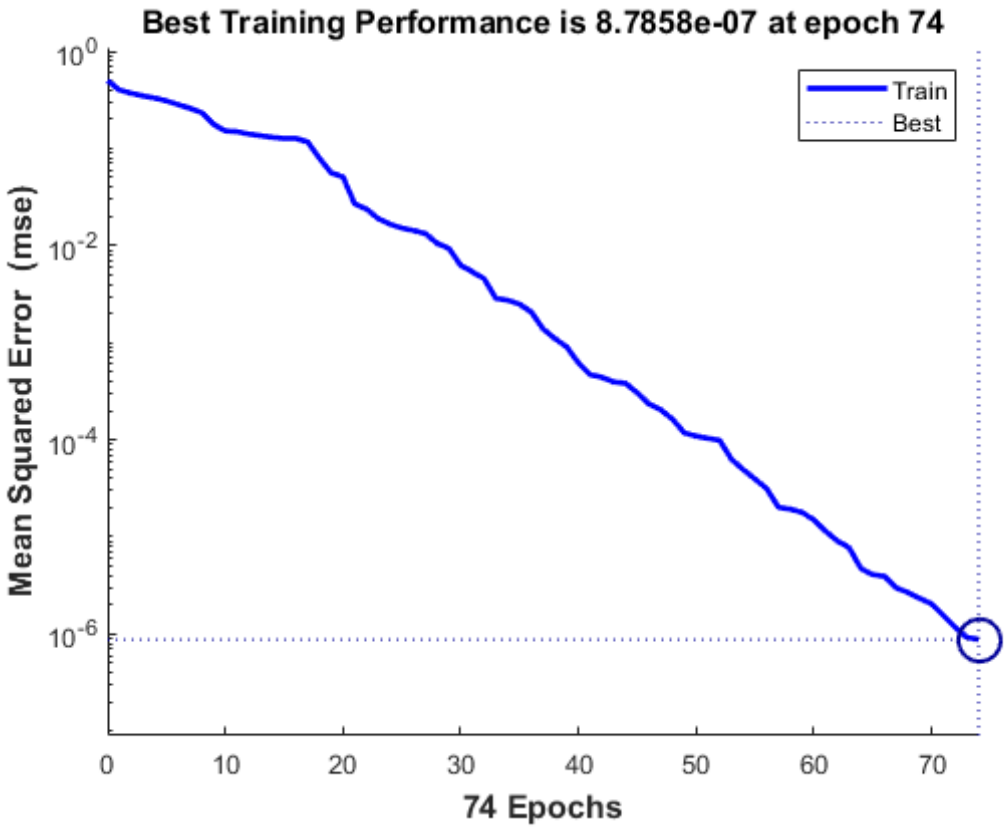


Figure 3: MSE versus epoch number

Calculated weights of the whole network are reported in table 1.

Table 1: Weights of the neural network

| $w_0$ | $w_1$ | $w_2$ | $w_3$ | $w_4$ | $w_5$ | $w_6$ | $w_7$ |
|---|---|---|---|---|---|---|---|
| 0.94 | 6.78 | 6.71 | 6.78 | −13.75 | −13.74 | −13.73 | 28.54 |

Question 1 cont'd on next page...

## Part (b): Neural Network with Hidden Layer

Unlike the neural network of previous part, the structure of network in this part includes a fully connected hidden layer as it is shown in figure 4.

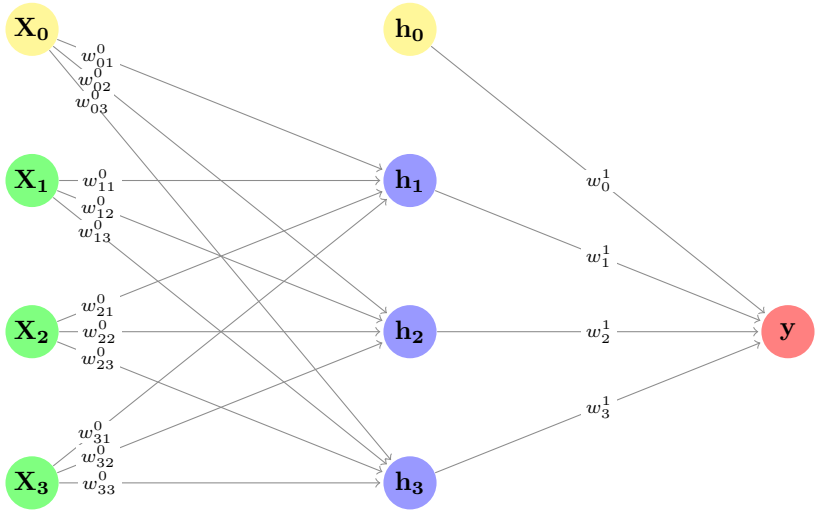


Figure 4: Neural network for binary Parity-3

The whole *Matlab* code for training and examining this neural network is printed in the section below:

```
clc
clear variables
close all

% every sample of input lies on a column vector of X
X = zeros(3, 8);
x1 = [0 1];
x2 = [0 1];
x3 = [0 1];

% Input sample generation
for i = 1:size(x1, 2)
        for j = 1:size(x2, 2)
                for k = 1:size(x3, 2)
                        X(:, k+2*(j-1)+4*(i-1)) = [x1(i), x2(j), x3(k)
                            ];
                end
        end
end

%target outputs
```

```
t = [0 1 1 0 1 0 0 1];

% the initialization which converges
rng(10);
net = patternnet(3);
net.divideFcn = 'dividetrain';
net.performFcn = 'mse';
net.trainParam.showCommandLine = 1;
net.trainParam.show = 1;

[net, tr, y, e] = train(net, X, t);

weights_in = net.IW;
weights_hidden = net.LW;
biases  = net.b;
view(net);
```

The resulting *Matlab*-generated block diagram of the neural network is shown in figure 5.

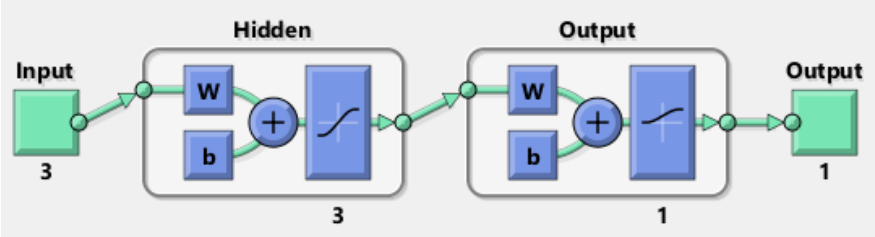


Figure 5: *Matlab*-generated block diagram

Learning curve which shows the decreasing value of mean square error versus the number of epochs is plotted in figure 6. It shows that after 94 epochs the network is trained successfully.

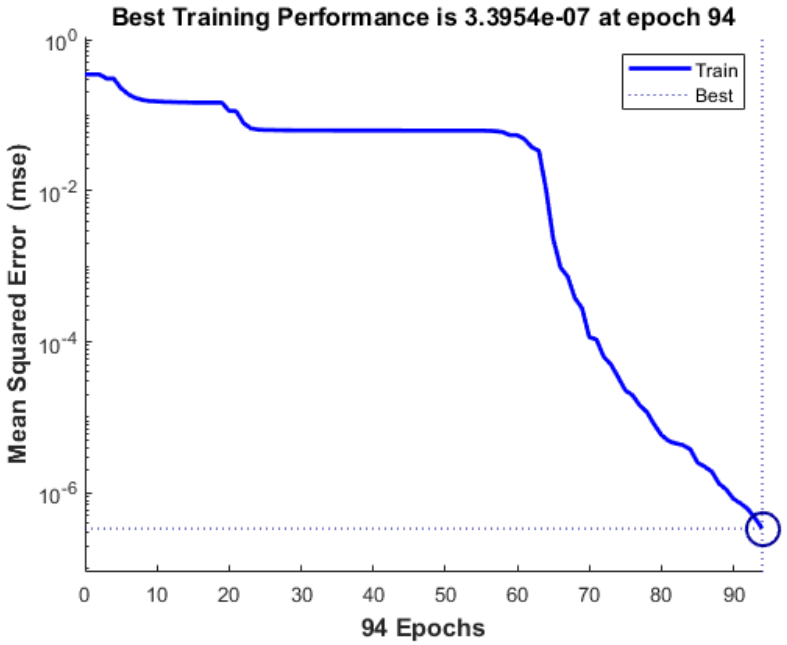


Figure 6: MSE versus epoch number

Calculated weights of the whole network are reported in tables 2 and 3.

Table 2: Weights of the 1st layer of neural network

| $w_{01}^0$ | $w_{02}^0$ | $w_{03}^0$ | $w_{11}^0$ | $w_{12}^0$ | $w_{13}^0$ | $w_{21}^0$ | $w_{22}^0$ | $w_{23}^0$ | $w_{31}^0$ | $w_{32}^0$ | $w_{33}^0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| −0.19 | −0.80 | 3.49 | −4.17 | −3.92 | −2.97 | −6.48 | −6.45 | 3.22 | −0.02 | −0.01 | 4.41 |

Table 3: Weights of the 2nd layer of neural network

| $w_0^1$ | $w_1^1$ | $w_2^1$ | $w_2^1$ |
|---|---|---|---|
| −1.35 | 7.53 | −7.52 | 8.618 |