

CSCI964 Computational Intelligence: Lab #1

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Task 1

1) Single-layer Neural Network is an Artificial Neural Network (ANN) with an input layer and a output layer.

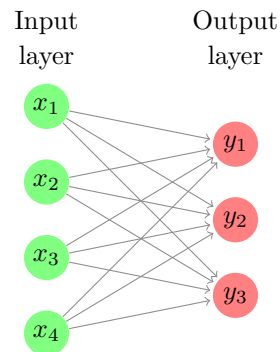


Figure 1: Single-layer Neural Network

2) Multi-layer Neural Network contains more than one layer of artificial neurons with several hidden layer.

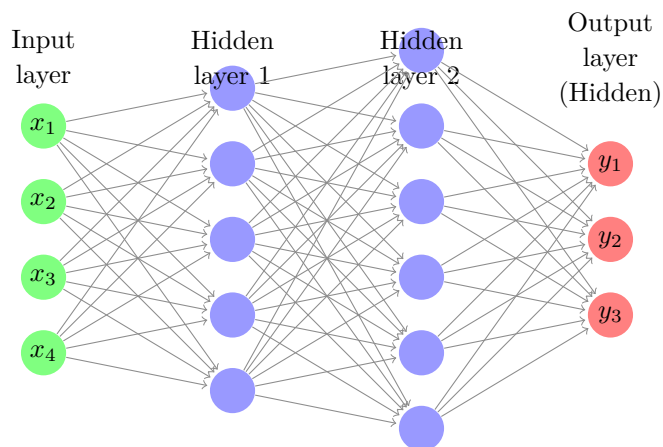


Figure 2: Multi-layer Neural Network

3) Shallow Neural Network contains less than 2 hidden layers. It fit functions with a lot parameters.

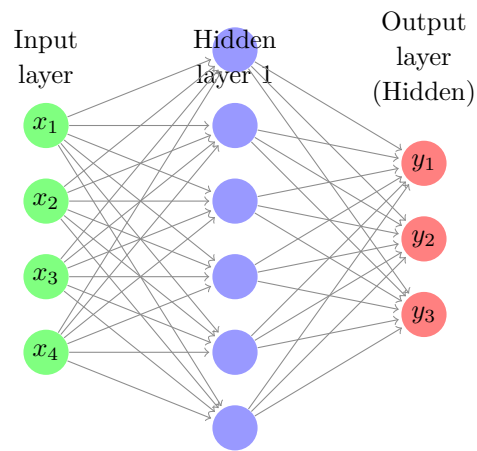


Figure 3: Shallow Neural Network

4) Deep Neural Network contains more than one hidden layers. It can fit functions better with less parameters than a shallow network.

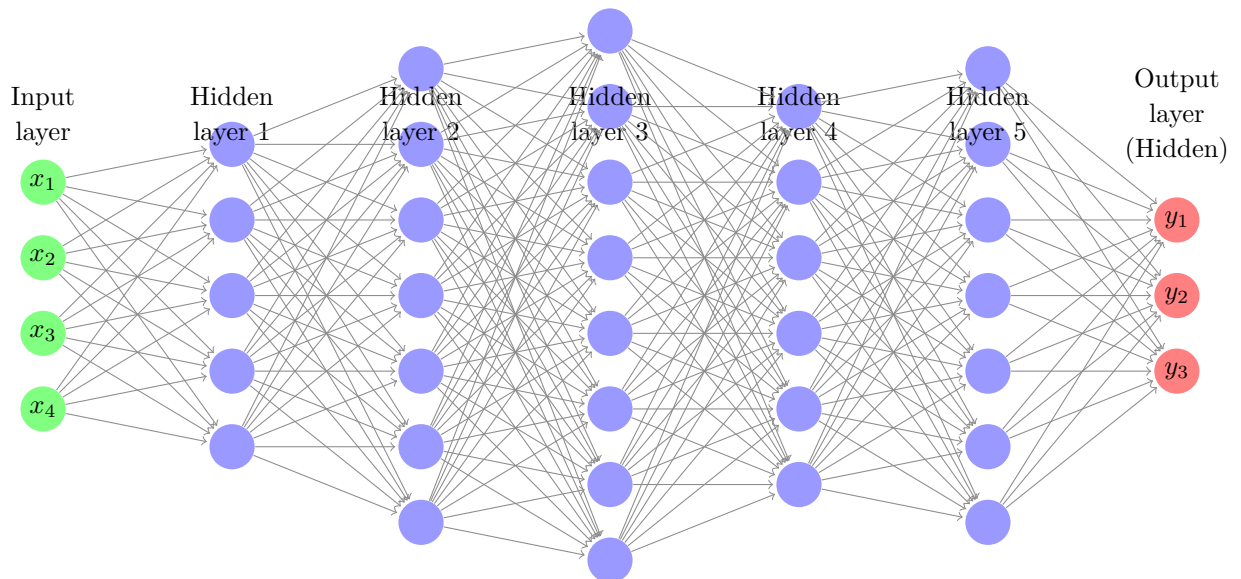


Figure 4: Deep Neural Network

Task 2

The implementation of matrix operation:

```
//matrix.h
class Matrix {
public:
    // constructors
    Matrix();
    Matrix(int m, int n, std::vector<std::vector<double>> matrix);
    Matrix(int m, int n); // zero matrix
    Matrix(std::vector<std::vector<double>> matrix); // zero matrix
    // applies a function over the entire matrix
    template<typename F> void apply(F f) {
        for (int i = 0; i < m; ++i) {
            for (int j = 0; j < n; ++j) {
                matrix[i][j] = f(matrix[i][j]);
            }
        }
    }
}

// matrix operations
Matrix operator+(const Matrix& other) const; // add
Matrix operator-(const Matrix& other) const; // subtract
Matrix operator*(const Matrix& other) const; // matrix multiplication

Matrix unitMultiply(const Matrix& other) const;
Matrix transpose();

// stream operator
friend std::ostream& operator<<(std::ostream& out, const Matrix& matrix);

// randomizations
void initNormal();
void init(int m, int n, std::vector<std::vector<double>> &matrix);
// misc operations
double sum();
void normalize();

// accessors
int getRows();
int getCols();
std::vector<std::vector<double>> getVector();

private:
    int m, n;
    std::vector<std::vector<double>> matrix;
};
```

The neuralnet operator contains input layer, hidden layer and output layer.

```
//neuralnet.h
class NeuralNet {
public:
    // constructor
    NeuralNet(int input_size, int output_size, std::vector<int> hidden_sizes, Matrix inputs, Matrix
        outputs);
    NeuralNet(int input_size, int output_size, std::vector<int> hidden_sizes, std::vector<Matrix>
        &weights, std::vector<Matrix> &biases, Matrix inputs);
    // activation functions
    static double sigmoid(double n, bool deriv = false);
    static double relu(double n, bool deriv = false);
    static double htan(double n, bool deriv = false);

    template<typename F> static double activate(F f, double n, bool deriv = false) {
        return f(n, deriv);
    }

    template<typename F> static std::vector<double> activate(F f, std::vector<double> v, bool deriv
        = false) {
        std::vector<double> result = v;
        for (auto &n: result) {
            if (deriv) {
                n = f(n, true);
            }
            else {
                n = f(n, false);
            }
        }

        return result;
    }

    template<typename F> static Matrix activate(F f, Matrix m, bool deriv = false) {
        std::vector<std::vector<double>> vector = m.getVector();
        for (auto &v: vector) {
            if (deriv) {
                v = activate(f, v, true);
            }
            else {
                v = activate(f, v);
            }
        }

        Matrix result {m.getRows(), m.getCols(), vector};

        return result;
    }

    // loss function (average sum of squares)
    double loss();

    // propogation
```

```
Matrix feedForward(Matrix input);
void backProp(int batch_size = 0);
void setInitialWeight(std::vector<Matrix> &weights){
}

// ith weight matrix accessor
Matrix getWeights(int i);

// using the model
void train(int epochs);
Matrix predict(Matrix input);
// stream operator
friend std::ostream &operator<<(std::ostream &out, const NeuralNet &nn);

private:
    const int input_size;
    const int output_size;
    const std::vector<int> hidden_sizes;

    std::vector<Matrix> intermediates;

    Matrix inputs;
    std::vector<Matrix> weights;
    std::vector<Matrix> biases;
    Matrix outputs;
};
```

Initialize the neuralnetwork.

```

\\neuralnet.cc
...
NeuralNet::NeuralNet(int input_size, int output_size, std::vector<int> hidden_sizes,
    std::vector<Matrix> &weights, std::vector<Matrix> &biases, Matrix inputs) :
    input_size{input_size}, output_size{output_size}, hidden_sizes{hidden_sizes}, inputs{inputs}
{
    int totalsize = weights.size();
    int m, n, bm, bn;
    for (unsigned int i = 0; i < totalsize; i++)
    {
        m = weights[i].getRows();
        n = weights[i].getCols();
        bm = biases[i].getRows();
        bn = biases[i].getCols();
        Matrix weight_layer{m, n, weights[i].getVector()}; //initialize the weight matrixes
        Matrix bias{bm, bn, biases[i].getVector()}; //initialize the bias vectors
        this->weights.push_back(weight_layer);
        this->biases.push_back(bias);
        intermediates.push_back(Matrix{0, 0}); //initialize the layers
    }
}

Matrix NeuralNet::feedForward(Matrix input)
{
    Matrix result = input;
    for (unsigned int i = 0; i < weights.size(); ++i)
    {
        result = result * weights[i] + biases[i];
        result = activate(sigmoid, result);
        intermediates[i] = result;
    }

    return result;
}
...
\\main.cc
Matrix input{1, 2, {{1, 2}}};
Matrix WeightIH1{2, 2, {{3, 2}, {1, 4}}};
Matrix WeightIH2{2, 2, {{3, 5}, {2, 1}}};
Matrix bias1{1, 2, {{1, 1}}};
Matrix bias2{1, 2, {{1, 1}}};
Matrix inputs{1, 2, {{1, 2}}};
vector<Matrix> weights{WeightIH1, WeightIH2};
vector<Matrix> biases{bias1, bias2};
vector<int> hidden{2, 2};
NeuralNet nn{2, 2, hidden, weights, biases, inputs};
nn.feedForward(input); \\ The forwardpropagate phase.
cout << nn;

```

The results:

```
0th weight matrix
3 2
1 4
1th weight matrix
3 5
2 1
input:
1 2
0th intermediate layer
0.997527 0.999983
1th intermediate layer
0.997509 0.999078
```

Figure 5: The results