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«Київський політехнічний інститут імені Ігоря Сікорського»
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Лабораторна робота №1

з дисципліни " Програмні засоби проектування та реалізаціїї нейромережевих систем"

Тема: "Парцептрон"

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Зміст:

Мета:

Написати програму, що реалізує нейронну мережу Парцептрон та навчити її виконувати функцію XOR\

Вихідний код

Program:

```
using Lab1;
using SML.Matrices;

namespace Labs;

internal class Program
{
    private static readonly double[,] s_input = new double[,]
    {
        { 0, 0 },
        { 0, 1 },
        { 1, 0 },
        { 1, 1 }
    };

    private static readonly double[,] s_outputs =
    {
        { 0 },
        { 1 },
        { 1 },
        { 0 }
    };

    private static readonly double[,] s_xTest = { { 1, 1 } };
    private static readonly double[,] s_xTest2 = { { 0, 0 } };
    private static readonly double[,] s_xTest3 = { { 0, 1 } };
    private static readonly double[,] s_xTest4 = { { 1, 0 } };

    private static void Main(string[] args)
    {
        Lab1();
    }

    private static void Lab1()
    {
        Perceptron perceptron = new(s_input);
        perceptron.Start();

        Console.WriteLine("Predictions before training:\n");
        RunPredictions(perceptron);

        perceptron.Train(s_input, s_outputs, 10000);

        Console.WriteLine("//////////////////////////////\n");

        Console.WriteLine("Predictions after training:\n");
        RunPredictions(perceptron);
    }

    private static void RunPredictions(Perceptron perceptron)
    {
        Matrix firstPrediction = new(perceptron.Predict(s_xTest));
```

```
        Matrix secondPrediction = new(perceptron.Predict(s_xTest2));

        Matrix thirdPrediction = new(perceptron.Predict(s_xTest3));

        Matrix fourthPrediction = new(perceptron.Predict(s_xTest4));


        Console.WriteLine("Prediction for 1, 1 is:\n");
        Console.WriteLine(firstPrediction.ToString());

        Console.WriteLine("Prediction for 0, 0 is:\n");
        Console.WriteLine(secondPrediction.ToString());

        Console.WriteLine("Prediction for 0, 1 is:\n");
        Console.WriteLine(thirdPrediction.ToString());

        Console.WriteLine("Prediction for 1, 0 is:\n");
        Console.WriteLine(fourthPrediction.ToString());
    }
}
```

Perceptron:

```
using SML.Matrices;

namespace Lab1;

public class Perceptron
{
       #region Fields

       public double[,] Input { get; set; }
       public int RunTimes { get; set; } = 10000;

       private readonly double _bias = 0.03;

       private readonly Random _random = new();

       private double[,] _firstLayerWeights = new double[0, 0];
       private double[,] _secondLayerWeights = new double[0, 0];

       #endregion Fields

       #region Constructors

       public Perceptron(double[,] input)
       {
              Input = input;
       }

    #endregion Constructors

    #region Methods

    public void Start()
    {
        GenerateWeights();
    }

    private void GenerateWeights()
       {
         // During the training phase, the network is trained by adjusting
         // these weights to be able to predict the correct class for the input.

         int firstLayerLength = Input.GetUpperBound(0) + 1;
              int secondLayerLength = Input.GetUpperBound(1) + 1;
```

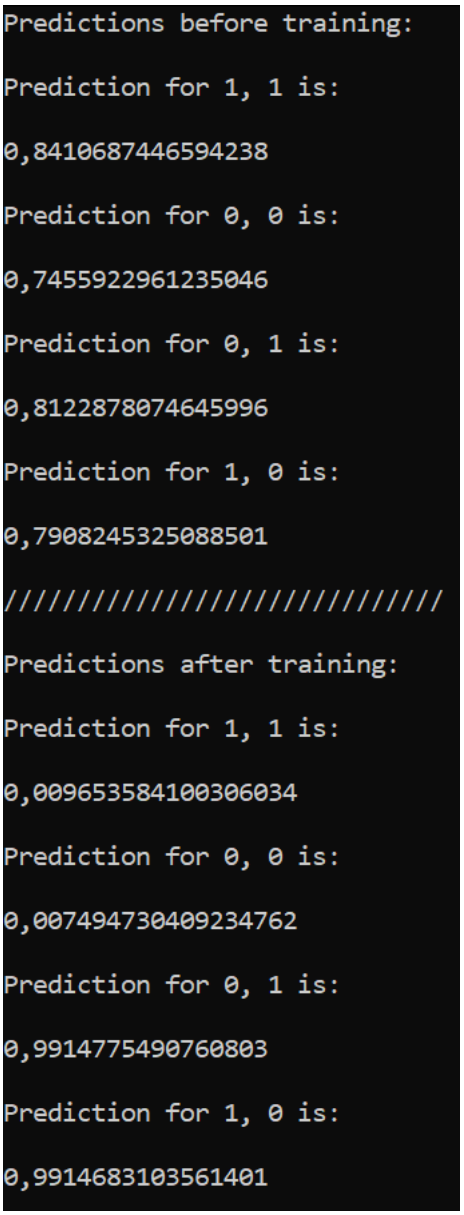
```
            _firstLayerWeights = new double[secondLayerLength, firstLayerLength];

            for (int i = 0; i < secondLayerLength; i++)
            {
                  for (int j = 0; j < firstLayerLength; j++)
                  {
                        _firstLayerWeights[i, j] = _random.NextDouble();
                  }
            }

            _secondLayerWeights = new double[firstLayerLength, 1];

            for (int i = 0; i < firstLayerLength; i++)
            {
                  for (int j = 0; j < 1; j++)
                  {
                        _secondLayerWeights[i, j] = _random.NextDouble();
                  }
            }
      }

      private static double Sigmoid(double x)
            {
                  return 1 / (1 + (float)Math.Exp(-x));
            }

      private static double SigmoidDerivative(double x)
            {
                  return Sigmoid(x) * (1 - Sigmoid(x));
            }

      public double[,] Predict(double[,] xTest)
      {
            Matrix xTestMatrix = new(xTest);

            Matrix firstLayerWeightsMatrix = new(_firstLayerWeights);

            Matrix xTestDotfirstLayerWeights =
xTestMatrix.Multiply(firstLayerWeightsMatrix);

            double[,] firstLayer = xTestDotfirstLayerWeights.Array;

            for (int i = 0; i < xTestDotfirstLayerWeights.Rows; i++)
            {
                  for (int j = 0; j < xTestDotfirstLayerWeights.Columns; j++)
                  {
                        firstLayer[i, j] = Sigmoid(firstLayer[i, j]);
                  }
            }

            Matrix firstLayerMatrix = new(firstLayer);

            Matrix secondLayerWeightsMatrix = new(_secondLayerWeights);

            Matrix firstLayerDotsecondLayerWeights = firstLayerMatrix
           .Multiply(secondLayerWeightsMatrix);

            double[,] secondLayer = firstLayerDotsecondLayerWeights.Array;

            for (int i = 0; i < firstLayerDotsecondLayerWeights.Rows; i++)
            {
                  for (int j = 0; j < firstLayerDotsecondLayerWeights.Columns; j++)
                  {
                        secondLayer[i, j] = Sigmoid(secondLayer[i, j]);
                  }
            }
```

```
            return secondLayer;
      }

      public void Train(double[,] xTrain, double[,] yTrain, int iterations)
      {
            for (var k = 0; k < iterations; k++)
            {
                  Matrix xTrainMatrix = new(xTrain);

                  Matrix firstLayerWeightsMatrix = new(_firstLayerWeights);

                  Matrix dotXTrainAndFirstLayerWeigth =
xTrainMatrix.Multiply(firstLayerWeightsMatrix);

                  double[,] firstLayer = dotXTrainAndFirstLayerWeigth.Array;

            // Adjusting with bias and activating training

                  for (int i = 0; i < dotXTrainAndFirstLayerWeigth.Rows; i++)
                  {
                        for (int j = 0; j < dotXTrainAndFirstLayerWeigth.Columns;
j++)
                        {
                              firstLayer[i, j] += _bias;
                              firstLayer[i, j] = Sigmoid(firstLayer[i, j]);
               }
                  }

                  Matrix firstLayerMatrix = new(firstLayer);

                  Matrix secondLayerWeightsMatrix = new(_secondLayerWeights);

                  Matrix dotFirstLayerAndSecondLayerWeights =
               firstLayerMatrix.Multiply(secondLayerWeightsMatrix);

                  double[,] secondLayer = dotFirstLayerAndSecondLayerWeights.Array;

                  for (int i = 0; i < dotFirstLayerAndSecondLayerWeights.Rows; i++)
                  {
                        for (int j = 0; j <
dotFirstLayerAndSecondLayerWeights.Columns; j++)
                        {
                              secondLayer[i, j] = Sigmoid(secondLayer[i, j]);
                        }
                  }

            // Calculate the prediction error

            double[,] secondLayerError = dotFirstLayerAndSecondLayerWeights.Array;

                  for (int i = 0; i < dotFirstLayerAndSecondLayerWeights.Rows; i++)
                  {
                        for (int j = 0; j <
dotFirstLayerAndSecondLayerWeights.Columns; j++)
                        {
                              secondLayerError[i, j] = yTrain[i, j] - secondLayer[i,
j];
                        }
                  }

                  Matrix secondLayerErrorMatrix = new(secondLayerError);

                  for (int i = 0; i < secondLayer.GetUpperBound(0)+1; i++)
                  {
                        for (int j = 0; j < secondLayer.GetUpperBound(1)+1; j++)
                        {
                              secondLayer[i, j] = SigmoidDerivative(secondLayer[i,
j]);
```

```
                        }
                    }

                    Matrix secondLayerMatrix = new(secondLayer);

                    Matrix secondLayerDeltaMatrix = secondLayerMatrix.
                        Hadamard(secondLayerErrorMatrix);

                    Matrix secondLayerWeightsMatrixTransposed =
                        secondLayerWeightsMatrix.Transpose();

                    Matrix firstLayerErrorMatrix = secondLayerDeltaMatrix.
                        Multiply(secondLayerWeightsMatrixTransposed);

                    double[,] firstLayerDerivative = firstLayer;

                    for (int i = 0; i < firstLayerDerivative.GetUpperBound(0) + 1; i++)
                    {
                        for (int j = 0; j < firstLayerDerivative.GetUpperBound(1) +
1; j++)
                        {
                            firstLayerDerivative[i, j] =
SigmoidDerivative(firstLayer[i, j]);
                        }
                    }

                    Matrix firstLayerDerivativeMatrix = new(firstLayerDerivative);

                    Matrix firstLayerDeltaMatrix = firstLayerDerivativeMatrix.
                        Hadamard(firstLayerErrorMatrix);

                    // Adjusting the weights
            // Second Weights

                    Matrix dotFirstLayerAndSecondLayerDelta =
firstLayerMatrix.Transpose()
                .Multiply(secondLayerDeltaMatrix);

                    for (int i = 0; i < _secondLayerWeights.GetUpperBound(0) + 1; i++)
                    {
                        for (int j = 0; j < _secondLayerWeights.GetUpperBound(1) + 1;
j++)
                        {
                            _secondLayerWeights[i, j] +=
dotFirstLayerAndSecondLayerDelta[i, j];
                        }
                    }

            // First Weights

            Matrix xTrainTransposedMatrix = xTrainMatrix.Transpose();

                    Matrix dotXTrainTransposedAndFirstLayerDeltaMatrix =
                xTrainTransposedMatrix.Multiply(firstLayerDeltaMatrix);

                    for (int i = 0; i < _firstLayerWeights.GetUpperBound(0) + 1; i++)
                    {
                        for (int j = 0; j < _firstLayerWeights.GetUpperBound(1) + 1;
j++)
                        {
                            _firstLayerWeights[i, j] +=
dotXTrainTransposedAndFirstLayerDeltaMatrix[i, j];
                        }
                    }
             }
        }

        #endregion Methods
```

```
}
```

Результат роботи:



Висновки:

Я дізнався більше інформації про нейронні мережі, як вони навчаються. Створив власний перцептрон та навчив його розв’язувати проблему XOR