Systemy Sztucznej Inteligencji

dokumentacja projektu Unity Neural Network Car

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24 maja 2018

Część I

Opis programu

Tutaj, nasz super opis, jaki ten program jest cudowny i superowy. Nikt nie ma tak fajnego autka, które tak fajnie pędzi przez super fajny tor. Panie, inne autka tak nie pojadą jak nasze. Niżej jakiś normalny opis się zacznie;//

Unity Nueral Network Car jest symulacją jazdy samochodu na torze. Samochód jest autonomiczny, co oznacza, że użytkownik nie musi go kontrolować, pojedzie sam. Samochód został nauczony jak jeździć dzięki specjalnie zaprojektowanej sieci neuronowej, dzięki czemu może jeździć po naszym torze nie rozbijając się na każdym zakręcie.

Instrukcja obsługi

Magia dzieje się sama. Nie musisz tego znać.

Dodatkowe informacje

Fajne, co nie? Tylko co mamy na myśli, mówiąc "Dodatkowe informacyje?"

Część II

Opis działania

Tutaj uwzględniamy część matematyczną. - serio? musimy? No dobra, dodam tutaj te fajne wzorki jak np. ten cały sigmoid, jako nasza funkcja aktywacji:

$$S(x) = \frac{1}{1 + e^{-x}} = \frac{e^x}{e^x + 1}$$

Jakieś randomowe wzroki z randomowych tutoriali do AI (tam mają nawalone tych wzrów wiec coś tam damy.) np. takie coś, to chyba uczenie perceptronu, czyli komórce dowalama sume wszystkich wartości pomnożonych przez wagi:

$$\sum_{i=1}^{n} u_i w_i$$

PROPAGACJA WSTECZNA
https://mattmazur.com/2015/03/17/a-step-by-step-backpropagation-example/
xD

Algorytm

mile widziany pseudokod z użyciem biblioteki LaTeX

pseudo kod czego naszego AI tutaj sie da; o ile da rade te wszystkie rzeczy w coś krótkiego zwinąć, bo inaczej jest w tym sens, skoro cały kod będzie niżej?

Jak to nie będzie zbyt ogromne, to mogę zrobić ładny(jak się uda) schemat blokowy.

Bazy danych

Należy pokazać przykładowe dane, które były wykorzystywane podczas uczenia klasyfikatorów.
Czyli te 120 wierszy czy ile tego tam mamy? Czy wystarczy mu pokazać, że mamy dane w takiej formie i wkleić kilka wierszy tego i dać trzy kropki, o takie "...".

Implementacja

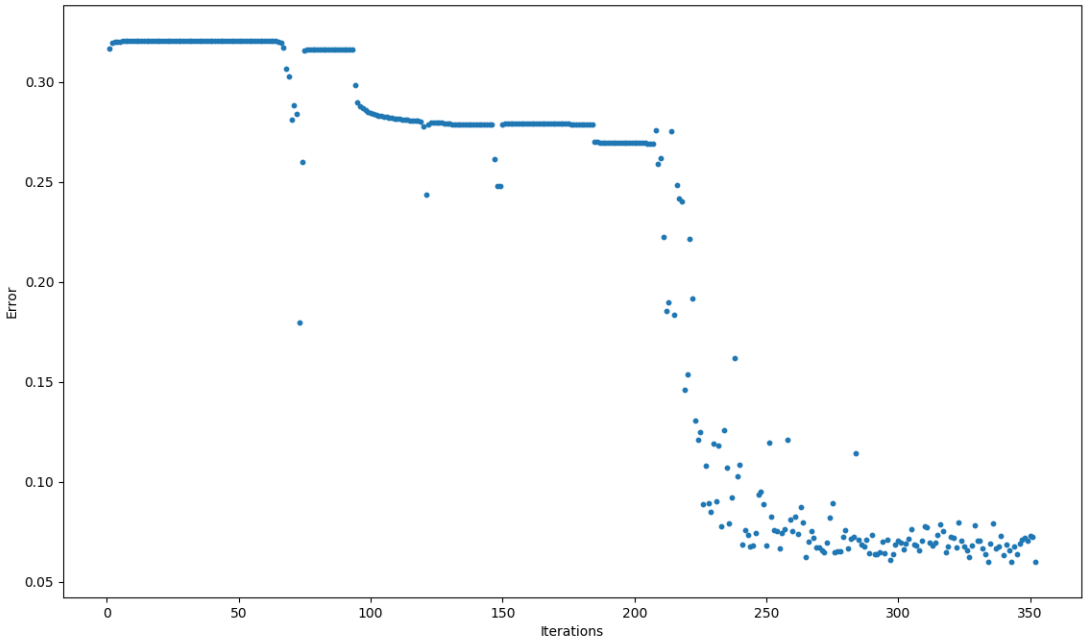
Opis, zasada i działanie programu ze względu na podział na pliki, nastepnie funkcje programu wraz ze szczegółowym opisem działania

`proszę zwrócić uwagę na wychodzenie poza obszar kartki.`

`No spoko, ja tu dopiljnuje, żeby wyglądało po ludzku.`

Testy

Tutaj powinna pojawić się analiza uzyskanych wyników oraz wykresy/pomiary.
No lekko, tutaj wleci super wykres nakodzony w pytonie.



Pełen kod aplikacji

tutaj wklejamy pełen kod.
Dalej nie rozumiem sensu tego punktu. ale niech będzie. Pewnie wszystko będzie ważyło trochę zbyt dużo, żeby to wrzucić na platformę xD

Neuron

```
public class Neuron
{
        #region -- Properties --
        public Guid Id { get; set; }
        public List<Synapse> InputSynapses { get; set; }
        public List<Synapse> OutputSynapses { get; set; }
        public double Bias { get; set; }
        public double BiasDelta { get; set; }
        public double Gradient { get; set; }
        public double Value { get; set; }
        #endregion

        #region -- Constructors --
        public Neuron()
        {
                Id = Guid.NewGuid();
                InputSynapses = new List<Synapse>();
                OutputSynapses = new List<Synapse>();
                Bias = Network.GetRandom();
        }

        public Neuron(IEnumerable<Neuron> inputNeurons) : this()
        {
                foreach (var inputNeuron in inputNeurons)
                {
                        var synapse = new Synapse(inputNeuron, this)
                        inputNeuron.OutputSynapses.Add(synapse);
                        InputSynapses.Add(synapse);
                }
        }
        #endregion

        #region -- Values & Weights --
        public virtual double CalculateValue()
        {
                return Value = Sigmoid.Output(InputSynapses.Sum(a =>
        }
```

```
        public double CalculateError(double target)
        {
                return target - Value;
        }

        public double CalculateGradient(double? target = null)
        {
                if (target == null)
                        return Gradient = OutputSynapses.Sum(a => a.

                return Gradient = CalculateError(target.Value) * Sigm
        }

        public void UpdateWeights(double learnRate, double momentum)
        {
                var prevDelta = BiasDelta;
                BiasDelta = learnRate * Gradient;
                Bias += BiasDelta + momentum * prevDelta;

                foreach (var synapse in InputSynapses)
                {
                        prevDelta = synapse.WeightDelta;
                        synapse.WeightDelta = learnRate * Gradient *
                        synapse.Weight += synapse.WeightDelta + mome
                }
        }
        #endregion
}
```

Synapse

```
public class Synapse
{
        #region -- Properties --
        public Guid Id { get; set; }
        public Neuron InputNeuron { get; set; }
        public Neuron OutputNeuron { get; set; }
        public double Weight { get; set; }
        public double WeightDelta { get; set; }
        #endregion

        #region -- Constructor --
        public Synapse() { }

        public Synapse(Neuron inputNeuron, Neuron outputNeuron)
```

```
        {
                Id = Guid.NewGuid();
                InputNeuron = inputNeuron;
                OutputNeuron = outputNeuron;
                Weight = Network.GetRandom();
        }
        #endregion
}
```

Network

```
public class Network
{
        #region -- Properties --
        public double LearnRate { get; set; }
        public double Momentum { get; set; }
        public List<Neuron> InputLayer { get; set; }
        public List<List<Neuron>> HiddenLayers { get; set; }
        public List<Neuron> OutputLayer { get; set; }
public bool ShowIterationError { get; set; }
        #endregion

        #region -- Globals --
        private static readonly Random Random = new Random();
        #endregion

        #region -- Constructor --
        public Network()
        {
                LearnRate = 0;
                Momentum = 0;
                InputLayer = new List<Neuron>();
                HiddenLayers = new List<List<Neuron>>();
                OutputLayer = new List<Neuron>();
        }

public Network(int inputSize, int[] hiddenSizes, int outputSize, dou
        {
    ShowIterationError = showIterationError;
                LearnRate = learnRate ?? .4;
                Momentum = momentum ?? .9;
                InputLayer = new List<Neuron>();
                HiddenLayers = new List<List<Neuron>>();
                OutputLayer = new List<Neuron>();

                for (var i = 0; i < inputSize; i++)
```

```
                InputLayer.Add(new Neuron());

        var firstHiddenLayer = new List<Neuron>();
        for (var i = 0; i < hiddenSizes[0]; i++)
                firstHiddenLayer.Add(new Neuron(InputLayer))

        HiddenLayers.Add(firstHiddenLayer);

        for (var i = 1; i < hiddenSizes.Length; i++)
        {
                var hiddenLayer = new List<Neuron>();
                for (var j = 0; j < hiddenSizes[i]; j++)
                        hiddenLayer.Add(new Neuron(HiddenLay
                HiddenLayers.Add(hiddenLayer);
        }

        for (var i = 0; i < outputSize; i++)
                OutputLayer.Add(new Neuron(HiddenLayers.Last
}
#endregion

#region -- Training --
public void Train(List<DataSet> dataSets, int numEpochs)
{
        for (var i = 0; i < numEpochs; i++)
        {
                foreach (var dataSet in dataSets)
                {
                        ForwardPropagate(dataSet.Values);
                        BackPropagate(dataSet.Targets);
                }
        }
}

public void Train(List<DataSet> dataSets, double minimumErro
{
        var error = 1.0;
        var numEpochs = 0;

        while (error > minimumError && numEpochs < int.MaxVa
        {
                var errors = new List<double>();
                foreach (var dataSet in dataSets)
                {
                        ForwardPropagate(dataSet.Values);
```

```
                    BackPropagate(dataSet.Targets);
                    errors.Add(CalculateError(dataSet.Ta
                }
                error = errors.Average();
numEpochs++;

if(ShowIterationError)
    Console.WriteLine(error);
        }
}

private void ForwardPropagate(params double[] inputs)
{
        var i = 0;
        InputLayer.ForEach(a => a.Value = inputs[i++]);
        HiddenLayers.ForEach(a => a.ForEach(b => b.Calculate
        OutputLayer.ForEach(a => a.CalculateValue());
}

private void BackPropagate(params double[] targets)
{
        var i = 0;
        OutputLayer.ForEach(a => a.CalculateGradient(targets
        HiddenLayers.Reverse();
        HiddenLayers.ForEach(a => a.ForEach(b => b.Calculate
        HiddenLayers.ForEach(a => a.ForEach(b => b.UpdateWei
        HiddenLayers.Reverse();
        OutputLayer.ForEach(a => a.UpdateWeights(LearnRate,
}

public double[] Compute(params double[] inputs)
{
        ForwardPropagate(inputs);
        return OutputLayer.Select(a => a.Value).ToArray();
}

private double CalculateError(params double[] targets)
{
        var i = 0;
        return OutputLayer.Sum(a => Math.Abs(a.CalculateErro
}
#endregion

#region -- Helpers --
public static double GetRandom()
```

```
        {
                return 2 * Random.NextDouble() - 1;
        }
        #endregion
}

#region -- Enum --
public enum TrainingType
{
        Epoch,
        MinimumError
}
#endregion
```

Sigmoid

```
public static class Sigmoid
{
        public static double Output(double x)
        {
                return x < -45.0 ? 0.0 : x > 45.0 ? 1.0 : 1.0 / (1.0
        }

        public static double Derivative(double x)
        {
                return x * (1 - x);
        }
}
```

Dataset

```
public class DataSet
{
        #region -- Properties --
        public double[] Values { get; set; }
        public double[] Targets { get; set; }
        #endregion

        #region -- Constructor --
        public DataSet(double[] values, double[] targets)
        {
                Values = values;
                Targets = targets;
        }
        #endregion
}
```

ExportHelper

```
public static class ExportHelper
{
public static void ExportNetwork(Network network, string filename, I
{
    var dn = GetHelperNetwork(network);

    serializer.Serialize(dn, filename);
}

        private static HelperNetwork GetHelperNetwork(Network networ
        {
                var hn = new HelperNetwork
                {
                        LearnRate = network.LearnRate,
                        Momentum = network.Momentum
                };

                //Input Layer
                foreach (var n in network.InputLayer)
                {
                        var neuron = new HelperNeuron
                        {
                                Id = n.Id,
                                Bias = n.Bias,
                                BiasDelta = n.BiasDelta,
                                Gradient = n.Gradient,
                                Value = n.Value
                        };

                        hn.InputLayer.Add(neuron);

                        foreach (var synapse in n.OutputSynapses)
                        {
                                var syn = new HelperSynapse
                                {
                                        Id = synapse.Id,
                                        OutputNeuronId = synapse.Out
                                        InputNeuronId = synapse.Inpu
                                        Weight = synapse.Weight,
                                        WeightDelta = synapse.Weight
                                };

                                hn.Synapses.Add(syn);
```

```
        }
    }

    //Hidden Layer
    foreach (var l in network.HiddenLayers)
    {
        var layer = new List<HelperNeuron>();

        foreach (var n in l)
        {
            var neuron = new HelperNeuron
            {
                Id = n.Id,
                Bias = n.Bias,
                BiasDelta = n.BiasDelta,
                Gradient = n.Gradient,
                Value = n.Value
            };

            layer.Add(neuron);

            foreach (var synapse in n.OutputSyna
            {
                var syn = new HelperSynapse
                {
                    Id = synapse.Id,
                    OutputNeuronId = syn
                    InputNeuronId = syna
                    Weight = synapse.Wei
                    WeightDelta = synaps
                };

                hn.Synapses.Add(syn);
            }
        }

        hn.HiddenLayers.Add(layer);
    }

    //Output Layer
    foreach (var n in network.OutputLayer)
    {
        var neuron = new HelperNeuron
        {
            Id = n.Id,
```

```
                                Bias = n.Bias,
                                BiasDelta = n.BiasDelta,
                                Gradient = n.Gradient,
                                Value = n.Value
                            };

                            hn.OutputLayer.Add(neuron);

                            foreach (var synapse in n.OutputSynapses)
                            {
                                var syn = new HelperSynapse
                                {
                                    Id = synapse.Id,
                                    OutputNeuronId = synapse.Out
                                    InputNeuronId = synapse.Inpu
                                    Weight = synapse.Weight,
                                    WeightDelta = synapse.Weight
                                };

                                hn.Synapses.Add(syn);
                            }
                        }

                        return hn;
                    }
                }
```

ImportHelper

```
        public static class ImportHelper
        {
        public static Network ImportNetwork(string filename, ISerializer ser
        {
            var dn = GetHelperNetwork(filename, serializer);
            if (dn == null) return null;

            var network = new Network();
            var allNeurons = new List<Neuron>();

            network.LearnRate = dn.LearnRate;
            network.Momentum = dn.Momentum;

            //Input Layer
            foreach (var n in dn.InputLayer)
            {
                var neuron = new Neuron
```

```
        {
            Id = n.Id,
            Bias = n.Bias,
            BiasDelta = n.BiasDelta,
            Gradient = n.Gradient,
            Value = n.Value
        };

        network.InputLayer.Add(neuron);
        allNeurons.Add(neuron);
    }

    //Hidden Layers
    foreach (var layer in dn.HiddenLayers)
    {
        var neurons = new List<Neuron>();
        foreach (var n in layer)
        {
            var neuron = new Neuron
            {
                Id = n.Id,
                Bias = n.Bias,
                BiasDelta = n.BiasDelta,
                Gradient = n.Gradient,
                Value = n.Value
            };

            neurons.Add(neuron);
            allNeurons.Add(neuron);
        }

        network.HiddenLayers.Add(neurons);
    }

    //Export Layer
    foreach (var n in dn.OutputLayer)
    {
        var neuron = new Neuron
        {
            Id = n.Id,
            Bias = n.Bias,
            BiasDelta = n.BiasDelta,
            Gradient = n.Gradient,
            Value = n.Value
        };
```

```
                network.OutputLayer.Add(neuron);
                allNeurons.Add(neuron);
            }

            //Synapses
            foreach (var syn in dn.Synapses)
            {
                var synapse = new Synapse { Id = syn.Id };
                var inputNeuron = allNeurons.First(x => x.Id == syn.InputNeu
                var outputNeuron = allNeurons.First(x => x.Id == syn.OutputN
                synapse.InputNeuron = inputNeuron;
                synapse.OutputNeuron = outputNeuron;
                synapse.Weight = syn.Weight;
                synapse.WeightDelta = syn.WeightDelta;

                inputNeuron.OutputSynapses.Add(synapse);
                outputNeuron.InputSynapses.Add(synapse);
            }

            return network;
        }

        private static HelperNetwork GetHelperNetwork(string filename, ISeri
        {
            return serializer.Deserialize(filename);
        }

    }
```

Helpers

```
        public class HelperNetwork
        {
                public double LearnRate { get; set; }
                public double Momentum { get; set; }
                public List<HelperNeuron> InputLayer { get; set; }
                public List<List<HelperNeuron>> HiddenLayers { get; set; }
                public List<HelperNeuron> OutputLayer { get; set; }
                public List<HelperSynapse> Synapses { get; set; }

                public HelperNetwork()
                {
                        InputLayer = new List<HelperNeuron>();
                        HiddenLayers = new List<List<HelperNeuron>>();
                        OutputLayer = new List<HelperNeuron>();
```

```
                Synapses = new List<HelperSynapse>();
            }
        }

        public class HelperNeuron
        {
            public Guid Id { get; set; }
            public double Bias { get; set; }
            public double BiasDelta { get; set; }
            public double Gradient { get; set; }
            public double Value { get; set; }
        }

        public class HelperSynapse
        {
            public Guid Id { get; set; }
            public Guid OutputNeuronId { get; set; }
            public Guid InputNeuronId { get; set; }
            public double Weight { get; set; }
            public double WeightDelta { get; set; }
        }
```

Serializer

```
        public interface ISerializer
{
    void Serialize(HelperNetwork network, string filename);
    HelperNetwork Deserialize(string filename);
}

public class XmlSerializer : ISerializer
{
    public HelperNetwork Deserialize(string filename)
    {
        using (var reader = new StreamReader(filename))
        {
            var serializer = new System.Xml.Serialization.XmlSerializer(type
            return serializer.Deserialize(reader) as HelperNetwork;
        }
    }

    public void Serialize(HelperNetwork network, string filename)
    {
        using (var writer = new StreamWriter(filename))
        {
            var serializer = new System.Xml.Serialization.XmlSerializer(netw
```

```
            serializer.Serialize(writer, network);
        }
    }
}
```

CarController

```
        public abstract class CarController : MonoBehaviour
{
    [Header("Steering")]
    public int MovementSpeed;
    public int RotationSpeed;

    [Header("Sensors")]
    public float SensorLength;
    public float SensorAngle;

    public float DistanceToLeftWall { get; private set; }
    public float DistanceToRightWall { get; private set; }


        // Update is called once per frame
        protected virtual void Update () {
        getDistanceToWalls();
    }

    public void MoveForward()
    {
        transform.position += transform.forward * MovementSpeed * Time.deltaT
    }

    public void TurnLeft()
    {
        transform.Rotate(Vector3.down * Time.deltaTime * RotationSpeed);
    }

    public void TurnRight()
    {
        transform.Rotate(Vector3.up * Time.deltaTime * RotationSpeed);
    }

    private void getDistanceToWalls()
    {
        RaycastHit leftHit;
        RaycastHit rightHit;
        Vector3 leftSensorStartPosition = transform.position;
```

```
        Vector3 rightSensorStartPosition = transform.position;

        if (Physics.Raycast(leftSensorStartPosition, Quaternion.AngleAxis(-S
        {
            DistanceToLeftWall = Vector3.Distance(leftSensorStartPosition, l
            Debug.DrawLine(leftSensorStartPosition, leftHit.point);
        }

        if (Physics.Raycast(rightSensorStartPosition, Quaternion.AngleAxis(S
        {
            DistanceToRightWall = Vector3.Distance(rightSensorStartPosition,
            Debug.DrawLine(rightSensorStartPosition, rightHit.point);
        }
    }

    void OnTriggerEnter(Collider other)
    {
        SceneManager.LoadScene(SceneManager.GetActiveScene().name);
    }
}
```

AutonomicCarController

```
public class AutonomicCarController : CarController
{
    [Header("Neural network holder")]
    // Odwolanie do obiektu z siecia neuronowa
    public BrainController Brain;

    private const double turnRightCondition = 2f / 3f;
    private const double turnLeftCondition = 1f / 3f;

    // Update is called once per frame
    protected override void Update ()
    {
        base.Update();
        MoveForward();
        steer();
        }

    private void steer()
    {
        neuralNetworkSteer();
    }

    private void simpleSteer()
```

```
    {
        var difference = DistanceToRightWall - DistanceToLeftWall;
        makeDecision(difference, 1, -1);
    }

    private void neuralNetworkSteer()
    {
        var networkOutput = Brain.Compute(DistanceToLeftWall, DistanceToRigh
        makeDecision(networkOutput, turnRightCondition, turnLeftCondition);
    }

    private void makeDecision(double value, double turnRightCondition, doubl
    {
        if (value > turnRightCondition)
            TurnRight();
        else if (value < turnLeftCondition)
            TurnLeft();
    }
}
```

ManualCarController

```
public class ManualCarController : CarController
{
    [Header("Steering")]
    public KeyCode UpKey = KeyCode.W;
    public KeyCode RightKey = KeyCode.D;
    public KeyCode LeftKey = KeyCode.A;

    [Header("Learning Data")]
    public bool CollectLearningData;
    public double CollectiongDataInterval;
    public string LearnignDataFileName;

    private double elapsedTimeSinceLastCollection = 0;
    private const char learningFileDelimiter = ';';


    // Update is called once per frame
    protected override void Update ()
    {
        base.Update();

        move();

        if (CollectLearningData)
```

```
        {
            elapsedTimeSinceLastCollection += Time.deltaTime;

            if (elapsedTimeSinceLastCollection >= CollectiongDataInterval)
            {
                collectLearningdata();
                elapsedTimeSinceLastCollection = 0;
            }
        }
    }

    private void move()
    {
        if (Input.GetKey(UpKey))
        {
            MoveForward();
        }

        if (Input.GetKey(RightKey))
        {
            TurnRight();
        }
        if (Input.GetKey(LeftKey))
        {
            TurnLeft();
        }
    }

    private void collectLearningdata()
    {
        using (var writer = File.AppendText(LearnignDataFileName))
        {
            var expectedOutput = Sigmoid.Output(DistanceToRightWall - Distan
            Debug.Log(expectedOutput);
            writer.WriteLine(string.Format("{0}{3}{1}{3}{2}", DistanceToLeftW
            Debug.Log(DistanceToLeftWall + " " + DistanceToRightWall + " " +
        }
    }
}
```

BrainController

```
public class BrainController : MonoBehaviour
{
    [Header("Learned")]
    public string LearnedNetworkFileName;
```

```
[Header("Learning")]
public bool TrainOnInit;
public string LearningFileName;
public double MaxError;

private const char _learningFileDelimiter = ';';

public NeuralNetwork.NetworkModels.Network NeuralNetwork { get; private

    // Use this for initialization
    void Start ()
{
    if (TrainOnInit)
        Train();
    else
        Load();
}

/// <summary>
/// Wyciaga z sieci wynik na podstawie odleglosci od scian
/// </summary>
/// <param name="distanceToLeftWall"></param>
/// <param name="distanceToRightWall"></param>
/// <returns></returns>
public double Compute(double distanceToLeftWall, double distanceToRightW
{
    return NeuralNetwork.Compute(new double[] { distanceToLeftWall, dista
}

public void Train()
{
    NeuralNetwork.Train(getDatasets(), MaxError);
}

public void Save()
{
    ExportHelper.ExportNetwork(NeuralNetwork, LearnedNetworkFileName, nev
}

public void Load()
{
    NeuralNetwork = ImportHelper.ImportNetwork(LearnedNetworkFileName, ne
}
```

```
    public void TestNetwork()
    {
        double l = 14;
        double r = 14;
        Debug.Log (NeuralNetwork.Compute(new double[] { l, r })[0] );

        l = 20;
        r = 10;
        Debug.Log(NeuralNetwork.Compute(new double[] { l, r })[0]);

        l = 10.72468;
        r = 42.37657;
        Debug.Log(NeuralNetwork.Compute(new double[] { l, r })[0]);
    }

    private List<DataSet> getDatasets()
    {
        var result = new List<DataSet>();

        using (var reader = new StreamReader(LearningFileName))
        {
            while(!reader.EndOfStream)
            {
                var elements = reader.ReadLine().Split(_learningFileDelimite
                var dataset = new DataSet(new double[] { double.Parse(elemen
                result.Add(dataset);
            }
        }

        return result;
    }
}
```