

Systemy Sztucznej Inteligencji

dokumentacja projektu Unity Neural Network Car

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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 Neural 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 informacje?"

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 wzorki z randomowych tutoriali do AI (tam mają nawalone tych wzrów wiec coś tam damy.) np. takie coś, to chyba uczenie perceptronu, czyli komórce dawałama sumę 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, następnie funkcje programu wraz ze szczegółowym opisem działania

proszę zwrócić uwagę na wychodzenie poza obszar kartki.

No spoko, ja tu dopilnuje, 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

```
1 public class Neuron
2 {
3     #region -- Properties --
4     public Guid Id { get; set; }
5     public List<Synapse> InputSynapses { get; set; }
6     public List<Synapse> OutputSynapses { get; set; }
7     public double Bias { get; set; }
8     public double BiasDelta { get; set; }
9     public double Gradient { get; set; }
10    public double Value { get; set; }
11    #endregion
12
13    #region -- Constructors --
14    public Neuron()
15    {
16        Id = Guid.NewGuid();
17        InputSynapses = new List<Synapse>();
18        OutputSynapses = new List<Synapse>();
19        Bias = Network.GetRandom();
20    }
21
22    public Neuron(IEnumerable<Neuron> inputNeurons) : this()
23    {
24        foreach (var inputNeuron in inputNeurons)
25        {
26            var synapse = new Synapse(inputNeuron, this);
27            inputNeuron.OutputSynapses.Add(synapse);
28            InputSynapses.Add(synapse);
29        }
30    }
31    #endregion
32
33    #region -- Values & Weights --
34    public virtual double CalculateValue()
35    {
36        return Value = Sigmoid.Output(InputSynapses.Sum(a => a.
            Weight * a.InputNeuron.Value) + Bias);
```

```

37     }
38
39     public double CalculateError(double target)
40     {
41         return target - Value;
42     }
43
44     public double CalculateGradient(double? target = null)
45     {
46         if (target == null)
47             return Gradient = OutputSynapses.Sum(a => a.OutputNeuron.
                Gradient * a.Weight) * Sigmoid.Derivative(Value);
48
49         return Gradient = CalculateError(target.Value) * Sigmoid.
            Derivative(Value);
50     }
51
52     public void UpdateWeights(double learnRate, double momentum)
53     {
54         var prevDelta = BiasDelta;
55         BiasDelta = learnRate * Gradient;
56         Bias += BiasDelta + momentum * prevDelta;
57
58         foreach (var synapse in InputSynapses)
59         {
60             prevDelta = synapse.WeightDelta;
61             synapse.WeightDelta = learnRate * Gradient * synapse.
                InputNeuron.Value;
62             synapse.Weight += synapse.WeightDelta + momentum *
                prevDelta;
63         }
64     }
65     #endregion
66 }

```

Synapse

```

1     public class Synapse
2     {
3         #region -- Properties --
4         public Guid Id { get; set; }
5         public Neuron InputNeuron { get; set; }
6         public Neuron OutputNeuron { get; set; }
7         public double Weight { get; set; }
8         public double WeightDelta { get; set; }
9         #endregion

```

```

10
11     #region -- Constructor --
12     public Synapse() { }
13
14     public Synapse(Neuron inputNeuron, Neuron outputNeuron)
15     {
16         Id = Guid.NewGuid();
17         InputNeuron = inputNeuron;
18         OutputNeuron = outputNeuron;
19         Weight = Network.GetRandom();
20     }
21     #endregion
22 }

```

Network

```

1     public class Network
2     {
3         #region -- Properties --
4         public double LearnRate { get; set; }
5         public double Momentum { get; set; }
6         public List<Neuron> InputLayer { get; set; }
7         public List<List<Neuron>> HiddenLayers { get; set; }
8         public List<Neuron> OutputLayer { get; set; }
9         public bool ShowIterationError { get; set; }
10        #endregion
11
12        #region -- Globals --
13        private static readonly Random Random = new Random();
14        #endregion
15
16        #region -- Constructor --
17        public Network()
18        {
19            LearnRate = 0;
20            Momentum = 0;
21            InputLayer = new List<Neuron>();
22            HiddenLayers = new List<List<Neuron>>();
23            OutputLayer = new List<Neuron>();
24        }
25
26        public Network(int inputSize, int[] hiddenSizes, int
            outputSize, double? learnRate = null, double?
            momentum = null, bool showIterationError = false)
27        {
28            ShowIterationError = showIterationError;

```

```

29     LearnRate = learnRate ?? .4;
30     Momentum = momentum ?? .9;
31     InputLayer = new List<Neuron>();
32     HiddenLayers = new List<List<Neuron>>();
33     OutputLayer = new List<Neuron>();
34
35     for (var i = 0; i < inputSize; i++)
36         InputLayer.Add(new Neuron());
37
38     var firstHiddenLayer = new List<Neuron>();
39     for (var i = 0; i < hiddenSizes[0]; i++)
40         firstHiddenLayer.Add(new Neuron(InputLayer));
41
42     HiddenLayers.Add(firstHiddenLayer);
43
44     for (var i = 1; i < hiddenSizes.Length; i++)
45     {
46         var hiddenLayer = new List<Neuron>();
47         for (var j = 0; j < hiddenSizes[i]; j++)
48             hiddenLayer.Add(new Neuron(HiddenLayers[i - 1]));
49         HiddenLayers.Add(hiddenLayer);
50     }
51
52     for (var i = 0; i < outputSize; i++)
53         OutputLayer.Add(new Neuron(HiddenLayers.Last()));
54 }
55 #endregion
56
57 #region -- Training --
58 public void Train(List<DataSet> dataSets, int numEpochs)
59 {
60     for (var i = 0; i < numEpochs; i++)
61     {
62         foreach (var dataSet in dataSets)
63         {
64             ForwardPropagate(dataSet.Values);
65             BackPropagate(dataSet.Targets);
66         }
67     }
68 }
69
70 public void Train(List<DataSet> dataSets, double
    minimumError)
71 {
72     var error = 1.0;

```



```

73     var numEpochs = 0;
74
75     while (error > minimumError && numEpochs < int.MaxValue)
76     {
77         var errors = new List<double>();
78         foreach (var dataSet in dataSets)
79         {
80             ForwardPropagate(dataSet.Values);
81             BackPropagate(dataSet.Targets);
82             errors.Add(CalculateError(dataSet.Targets));
83         }
84         error = errors.Average();
85         numEpochs++;
86
87         if(ShowIterationError)
88             Console.WriteLine(error);
89     }
90 }
91
92 private void ForwardPropagate(params double[] inputs)
93 {
94     var i = 0;
95     InputLayer.ForEach(a => a.Value = inputs[i++]);
96     HiddenLayers.ForEach(a => a.ForEach(b => b.CalculateValue
97         ()));
98     OutputLayer.ForEach(a => a.CalculateValue());
99 }
100 private void BackPropagate(params double[] targets)
101 {
102     var i = 0;
103     OutputLayer.ForEach(a => a.CalculateGradient(targets[i++])
104         );
105     HiddenLayers.Reverse();
106     HiddenLayers.ForEach(a => a.ForEach(b => b.
107         CalculateGradient()));
108     HiddenLayers.ForEach(a => a.ForEach(b => b.UpdateWeights(
109         LearnRate, Momentum)));
110     HiddenLayers.Reverse();
111     OutputLayer.ForEach(a => a.UpdateWeights(LearnRate,
112         Momentum));
113 }
114
115 public double[] Compute(params double[] inputs)
116 {

```

```

113     ForwardPropagate(inputs);
114     return OutputLayer.Select(a => a.Value).ToArray();
115 }
116
117 private double CalculateError(params double[] targets)
118 {
119     var i = 0;
120     return OutputLayer.Sum(a => Math.Abs(a.CalculateError(
121         targets[i++])))
122 }
123 #endregion
124
125 #region -- Helpers --
126 public static double GetRandom()
127 {
128     return 2 * Random.NextDouble() - 1;
129 }
130 #endregion
131
132 #region -- Enum --
133 public enum TrainingType
134 {
135     Epoch,
136     MinimumError
137 }
138 #endregion

```

Sigmoid

```

1 public static class Sigmoid
2 {
3     public static double Output(double x)
4     {
5         return x < -45.0 ? 0.0 : x > 45.0 ? 1.0 : 1.0 / (1.0 +
6             Math.Exp(-x));
7     }
8     public static double Derivative(double x)
9     {
10         return x * (1 - x);
11     }
12 }

```

Dataset

```

1  public class DataSet
2  {
3      #region -- Properties --
4      public double[] Values { get; set; }
5      public double[] Targets { get; set; }
6      #endregion
7
8      #region -- Constructor --
9      public DataSet(double[] values, double[] targets)
10     {
11         Values = values;
12         Targets = targets;
13     }
14     #endregion
15 }

```

ExportHelper

```

1  public static class ExportHelper
2  {
3      public static void ExportNetwork(Network network, string
4          filename, ISerializer serializer)
5      {
6          var dn = GetHelperNetwork(network);
7          serializer.Serialize(dn, filename);
8      }
9
10     private static HelperNetwork GetHelperNetwork(Network
11         network)
12     {
13         var hn = new HelperNetwork
14         {
15             LearnRate = network.LearnRate,
16             Momentum = network.Momentum
17         };
18         //Input Layer
19         foreach (var n in network.InputLayer)
20         {
21             var neuron = new HelperNeuron
22             {
23                 Id = n.Id,
24                 Bias = n.Bias,
25                 BiasDelta = n.BiasDelta,
26                 Gradient = n.Gradient,

```

```

27         Value = n.Value
28     };
29
30     hn.InputLayer.Add(neuron);
31
32     foreach (var synapse in n.OutputSynapses)
33     {
34         var syn = new HelperSynapse
35         {
36             Id = synapse.Id,
37             OutputNeuronId = synapse.OutputNeuron.Id,
38             InputNeuronId = synapse.InputNeuron.Id,
39             Weight = synapse.Weight,
40             WeightDelta = synapse.WeightDelta
41         };
42
43         hn.Synapses.Add(syn);
44     }
45 }
46
47 //Hidden Layer
48 foreach (var l in network.HiddenLayers)
49 {
50     var layer = new List<HelperNeuron>();
51
52     foreach (var n in l)
53     {
54         var neuron = new HelperNeuron
55         {
56             Id = n.Id,
57             Bias = n.Bias,
58             BiasDelta = n.BiasDelta,
59             Gradient = n.Gradient,
60             Value = n.Value
61         };
62
63         layer.Add(neuron);
64
65         foreach (var synapse in n.OutputSynapses)
66         {
67             var syn = new HelperSynapse
68             {
69                 Id = synapse.Id,
70                 OutputNeuronId = synapse.OutputNeuron.Id,
71                 InputNeuronId = synapse.InputNeuron.Id,

```

```

72         Weight = synapse.Weight,
73         WeightDelta = synapse.WeightDelta
74     };
75
76     hn.Synapses.Add(syn);
77 }
78 }
79
80     hn.HiddenLayers.Add(layer);
81 }
82
83 //Output Layer
84 foreach (var n in network.OutputLayer)
85 {
86     var neuron = new HelperNeuron
87     {
88         Id = n.Id,
89         Bias = n.Bias,
90         BiasDelta = n.BiasDelta,
91         Gradient = n.Gradient,
92         Value = n.Value
93     };
94
95     hn.OutputLayer.Add(neuron);
96
97     foreach (var synapse in n.OutputSynapses)
98     {
99         var syn = new HelperSynapse
100         {
101             Id = synapse.Id,
102             OutputNeuronId = synapse.OutputNeuron.Id,
103             InputNeuronId = synapse.InputNeuron.Id,
104             Weight = synapse.Weight,
105             WeightDelta = synapse.WeightDelta
106         };
107
108         hn.Synapses.Add(syn);
109     }
110 }
111
112     return hn;
113 }
114 }

```

ImportHelper

```

1  public static class ImportHelper
2  {
3      public static Network ImportNetwork(string filename,
4          ISerializer serializer)
5      {
6          var dn = GetHelperNetwork(filename, serializer);
7          if (dn == null) return null;
8
9          var network = new Network();
10         var allNeurons = new List<Neuron>();
11
12         network.LearnRate = dn.LearnRate;
13         network.Momentum = dn.Momentum;
14
15         //Input Layer
16         foreach (var n in dn.InputLayer)
17         {
18             var neuron = new Neuron
19             {
20                 Id = n.Id,
21                 Bias = n.Bias,
22                 BiasDelta = n.BiasDelta,
23                 Gradient = n.Gradient,
24                 Value = n.Value
25             };
26
27             network.InputLayer.Add(neuron);
28             allNeurons.Add(neuron);
29         }
30
31         //Hidden Layers
32         foreach (var layer in dn.HiddenLayers)
33         {
34             var neurons = new List<Neuron>();
35             foreach (var n in layer)
36             {
37                 var neuron = new Neuron
38                 {
39                     Id = n.Id,
40                     Bias = n.Bias,
41                     BiasDelta = n.BiasDelta,
42                     Gradient = n.Gradient,
43                     Value = n.Value
44                 };

```

```

45         neurons.Add(neuron);
46         allNeurons.Add(neuron);
47     }
48
49     network.HiddenLayers.Add(neurons);
50 }
51
52 //Export Layer
53 foreach (var n in dn.OutputLayer)
54 {
55     var neuron = new Neuron
56     {
57         Id = n.Id,
58         Bias = n.Bias,
59         BiasDelta = n.BiasDelta,
60         Gradient = n.Gradient,
61         Value = n.Value
62     };
63
64     network.OutputLayer.Add(neuron);
65     allNeurons.Add(neuron);
66 }
67
68 //Synapses
69 foreach (var syn in dn.Synapses)
70 {
71     var synapse = new Synapse { Id = syn.Id };
72     var inputNeuron = allNeurons.First(x => x.Id ==
73         syn.InputNeuronId);
74     var outputNeuron = allNeurons.First(x => x.Id ==
75         syn.OutputNeuronId);
76     synapse.InputNeuron = inputNeuron;
77     synapse.OutputNeuron = outputNeuron;
78     synapse.Weight = syn.Weight;
79     synapse.WeightDelta = syn.WeightDelta;
80
81     inputNeuron.OutputSynapses.Add(synapse);
82     outputNeuron.InputSynapses.Add(synapse);
83 }
84
85 return network;
86
87 private static HelperNetwork GetHelperNetwork(string
88     filename, ISerializer serializer)

```

```

87         {
88             return serializer.Deserialize(filename);
89         }
90
91     }

```

Helpers

```

1  public class HelperNetwork
2  {
3      public double LearnRate { get; set; }
4      public double Momentum { get; set; }
5      public List<HelperNeuron> InputLayer { get; set; }
6      public List<List<HelperNeuron>> HiddenLayers { get; set; }
7      public List<HelperNeuron> OutputLayer { get; set; }
8      public List<HelperSynapse> Synapses { get; set; }
9
10     public HelperNetwork()
11     {
12         InputLayer = new List<HelperNeuron>();
13         HiddenLayers = new List<List<HelperNeuron>>();
14         OutputLayer = new List<HelperNeuron>();
15         Synapses = new List<HelperSynapse>();
16     }
17 }
18
19 public class HelperNeuron
20 {
21     public Guid Id { get; set; }
22     public double Bias { get; set; }
23     public double BiasDelta { get; set; }
24     public double Gradient { get; set; }
25     public double Value { get; set; }
26 }
27
28 public class HelperSynapse
29 {
30     public Guid Id { get; set; }
31     public Guid OutputNeuronId { get; set; }
32     public Guid InputNeuronId { get; set; }
33     public double Weight { get; set; }
34     public double WeightDelta { get; set; }
35 }

```

Serializer


```

1  public interface ISerializer
2  {
3      void Serialize(HelperNetwork network, string filename);
4      HelperNetwork Deserialize(string filename);
5  }
6
7  public class XmlSerializer : ISerializer
8  {
9      public HelperNetwork Deserialize(string filename)
10     {
11         using (var reader = new StreamReader(filename))
12         {
13             var serializer = new System.Xml.Serialization.
14                 XmlSerializer(typeof(HelperNetwork));
15             return serializer.Deserialize(reader) as
16                 HelperNetwork;
17         }
18     }
19
20     public void Serialize(HelperNetwork network, string filename
21         )
22     {
23         using (var writer = new StreamWriter(filename))
24         {
25             var serializer = new System.Xml.Serialization.
26                 XmlSerializer(network.GetType());
27             serializer.Serialize(writer, network);
28         }
29     }
30 }

```

CarController

```

1  public abstract class CarController : MonoBehaviour
2  {
3      [Header("Steering")]
4      public int MovementSpeed;
5      public int RotationSpeed;
6
7      [Header("Sensors")]
8      public float SensorLength;
9      public float SensorAngle;
10
11     public float DistanceToLeftWall { get; private set; }
12     public float DistanceToRightWall { get; private set; }
13 }

```

```

14
15 // Update is called once per frame
16 protected virtual void Update () {
17     getDistanceToWalls();
18 }
19
20 public void MoveForward()
21 {
22     transform.position += transform.forward * MovementSpeed
23         * Time.deltaTime;
24 }
25 public void TurnLeft()
26 {
27     transform.Rotate(Vector3.down * Time.deltaTime *
28         RotationSpeed);
29 }
30 public void TurnRight()
31 {
32     transform.Rotate(Vector3.up * Time.deltaTime *
33         RotationSpeed);
34 }
35 private void getDistanceToWalls()
36 {
37     RaycastHit leftHit;
38     RaycastHit rightHit;
39     Vector3 leftSensorStartPosition = transform.position;
40     Vector3 rightSensorStartPosition = transform.position;
41
42     if (Physics.Raycast(leftSensorStartPosition, Quaternion.
43         AngleAxis(-SensorAngle, transform.up) * transform.
44         forward, out leftHit, SensorLength))
45     {
46         DistanceToLeftWall = Vector3.Distance(
47             leftSensorStartPosition, leftHit.point);
48         Debug.DrawLine(leftSensorStartPosition, leftHit.
49             point);
50     }
51
52     if (Physics.Raycast(rightSensorStartPosition, Quaternion
53         .AngleAxis(SensorAngle, transform.up) * transform.
54         forward, out rightHit, SensorLength))
55     {

```

```

50         DistanceToRightWall = Vector3.Distance(
51             rightSensorStartPosition, rightHit.point);
52         Debug.DrawLine(rightSensorStartPosition, rightHit.
53             point);
54     }
55 void OnTriggerEnter(Collider other)
56 {
57     SceneManager.LoadScene(SceneManager.GetActiveScene().
58         name);
59 }

```

AutonomicCarController

```

1 public class AutonomicCarController : CarController
2 {
3     [Header("Neural network holder")]
4     // Odwołanie do obiektu z siecia neuronowa
5     public BrainController Brain;
6
7     private const double turnRightCondition = 2f / 3f;
8     private const double turnLeftCondition = 1f / 3f;
9
10    // Update is called once per frame
11    protected override void Update ()
12    {
13        base.Update();
14        MoveForward();
15        steer();
16    }
17
18    private void steer()
19    {
20        neuralNetworkSteer();
21    }
22
23    private void simpleSteer()
24    {
25        var difference = DistanceToRightWall -
26            DistanceToLeftWall;
27        makeDecision(difference, 1, -1);
28    }
29    private void neuralNetworkSteer()

```

```

30     {
31         var networkOutput = Brain.Compute(DistanceToLeftWall,
32             DistanceToRightWall);
33         makeDecision(networkOutput, turnRightCondition,
34             turnLeftCondition);
35     }
36     private void makeDecision(double value, double
37         turnRightCondition, double turnLeftCondition)
38     {
39         if (value > turnRightCondition)
40             TurnRight();
41         else if (value < turnLeftCondition)
42             TurnLeft();
43     }
44 }

```

ManualCarController

```

1 public class ManualCarController : CarController
2 {
3     [Header("Steering")]
4     public KeyCode UpKey = KeyCode.W;
5     public KeyCode RightKey = KeyCode.D;
6     public KeyCode LeftKey = KeyCode.A;
7
8     [Header("Learning Data")]
9     public bool CollectLearningData;
10    public double CollectiongDataInterval;
11    public string LearnignDataFileName;
12
13    private double elapsedTimeSinceLastCollection = 0;
14    private const char learningFileDelimiter = ',';
15
16
17    // Update is called once per frame
18    protected override void Update ()
19    {
20        base.Update();
21
22        move();
23
24        if (CollectLearningData)
25        {
26            elapsedTimeSinceLastCollection += Time.deltaTime;
27

```

```

28         if (elapsedTimeSinceLastCollection >=
                CollectiongDataInterval)
29         {
30             collectLearningdata();
31             elapsedTimeSinceLastCollection = 0;
32         }
33     }
34 }
35
36 private void move()
37 {
38     if (Input.GetKey(UpKey))
39     {
40         MoveForward();
41     }
42
43     if (Input.GetKey(RightKey))
44     {
45         TurnRight();
46     }
47     if (Input.GetKey(LeftKey))
48     {
49         TurnLeft();
50     }
51 }
52
53 private void collectLearningdata()
54 {
55     using (var writer = File.AppendText(LearnignDataFileName
        ))
56     {
57         var expectedOutput = Sigmoid.Output(
            DistanceToRightWall - DistanceToLeftWall);
58         Debug.Log(expectedOutput);
59         writer.WriteLine(string.Format("{0}{3}{1}{3}{2}",
            DistanceToLeftWall, DistanceToRightWall,
            expectedOutput, learningFileDelimiter));
60         Debug.Log(DistanceToLeftWall + " " +
            DistanceToRightWall + " " + expectedOutput);
61     }
62 }
63 }

```

BrainController

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1 public class BrainController : MonoBehaviour

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```

2  {
3      [Header("Learned")]
4      public string LearnedNetworkFileName;
5
6      [Header("Learning")]
7      public bool TrainOnInit;
8      public string LearningFileName;
9      public double MaxError;
10
11     private const char _learningFileDelimiter = ',';
12
13     public NeuralNetwork.NetworkModels.Network NeuralNetwork {
14         get; private set; }
15
16     // Use this for initialization
17     void Start ()
18     {
19         if (TrainOnInit)
20             Train();
21         else
22             Load();
23     }
24
25     /// <summary>
26     /// Wyciaga z sieci wynik na podstawie odleglosci od scian
27     /// </summary>
28     /// <param name="distanceToLeftWall"></param>
29     /// <param name="distanceToRightWall"></param>
30     /// <returns></returns>
31     public double Compute(double distanceToLeftWall, double
32         distanceToRightWall)
33     {
34         return NeuralNetwork.Compute(new double[] {
35             distanceToLeftWall, distanceToRightWall })[0];
36     }
37
38     public void Train()
39     {
40         NeuralNetwork.Train(getDatasets(), MaxError);
41     }
42
43     public void Save()
44     {
45         ExportHelper.ExportNetwork(NeuralNetwork,
46             LearnedNetworkFileName, new XmlSerializer());
47     }
48 }

```

```

43     }
44
45     public void Load()
46     {
47         NeuralNetwork = ImportHelper.ImportNetwork(
48             LearnedNetworkFileName, new XmlSerializer());
49
50     public void TestNetwork()
51     {
52         double l = 14;
53         double r = 14;
54         Debug.Log (NeuralNetwork.Compute(new double[] { l, r })
55             [0] );
56
57         l = 20;
58         r = 10;
59         Debug.Log(NeuralNetwork.Compute(new double[] { l, r })
60             [0]);
61
62         l = 10.72468;
63         r = 42.37657;
64         Debug.Log(NeuralNetwork.Compute(new double[] { l, r })
65             [0]);
66     }
67
68     private List<DataSet> getDatasets()
69     {
70         var result = new List<DataSet>();
71
72         using (var reader = new StreamReader(LearningFileName))
73         {
74             while(!reader.EndOfStream)
75             {
76                 var elements = reader.ReadLine().Split(
77                     _learningFileDelimiter);
78                 var dataset = new DataSet(new double[] { double.
79                     Parse(elements[0]), double.Parse(elements[1])
80                     }, new double[] { double.Parse(elements[2])
81                     });
82                 result.Add(dataset);
83             }
84         }
85
86         return result;
87     }

```

80 }
81 }