

Einführung in die Neuroinformatik

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1 Backpropagation [Pen and Paper]

1.1



Abbildung 1: Ablauf graphisch dargestellt

1.2

1. Forwärts propagieren:

$$\begin{aligned} u_1^{(1)} &= x_1 \cdot w_{11}^{(1)} + x_2 \cdot w_{21}^{(1)} + b_1^{(1)} \\ y_1^{(1)} &= f_1(u_1^{(1)}) \\ u_1^{(2)} &= y_1^{(1)} \cdot w_{11}^{(2)} + b_1^{(2)} \\ y_1^{(2)} &= f_2(u_1^{(2)}) \end{aligned}$$

2. Fehler in der Ausgabeschicht bestimmen:

$$\delta_1^{(2)} = y_1^{(2)} - T_1$$

3. Backpropagation

$$\delta_1^{(1)} = \delta_1^{(2)} w_{11}^{(2)} f' \left(u_i^{(1)} \right)$$

4. Gewichte adaptieren

$$\tilde{w}_{11}^{(1)} = w_{11}^{(1)} + \eta x_1 \delta_1^{(1)}$$

2 Backpropagation [Matlab]

2.1

```
1 function [weights] = initWeights(inputDimensions, hiddenNeurons,
   outputDimensions)
2 %initWeights initializes the weights of the network
3 % Arguments:
4 %     - inputDimensions: number of input neurons
5 %     - hiddenNeurons: number of hidden neurons
6 %     - outputDimensions: number of output neurons
7 %
8 % Returns:
9 %     - weights: struct with the parameters w1, w2, theta1 and
   theta2
10 %
11 rng(1337, 'combRecursive');
12 weights.w1 = rand(hiddenNeurons, inputDimensions) - 0.5;
13 weights.w2 = rand(outputDimensions, hiddenNeurons) - 0.5;
14 weights.theta1 = rand(hiddenNeurons, 1) - 0.5;
15 weights.theta2 = rand(outputDimensions, 1) - 0.5;
16 end
```

2.2

```
1 function [y2, u2, y1, u1] = forward(inputX, weights, trans)
2 %forward calculates the network output
3 % Arguments:
4 %     - inputX: input data organized as samples x dimensions (
   each row denotes a point)
```

```

5 %      - weights: struct with the parameters w1, w2, theta1 and
      theta2
6 %      - trans: activation function f(x) of the hidden layer
7 %
8      u1 = weights.w1 * inputX + weights.theta1;
9      y1 = trans(u1);
10     u2 = weights.w2 * y1 + weights.theta2;
11     y2 = u2;
12 end

```

2.3

```

1 function [delta1, delta2] = propagateError(T, y2, w2, u1Diff)
2 %propagateError calculates the error of the network (delta1 and
      delta2)
3 % Arguments:
4 %      - T: teacher signal
5 %      - y2: output of the last neuron
6 %      - w2: weights matrix of the second layer
7 %      - u1Diff: f'(u1)
8 %
9      delta2 = T-y2;
10     delta1 = delta2 * (transpose(w2) .* u1Diff);
11 end

```

```

1 function y = transDiff(x)
2     y = ones(size(x))./(cosh(x).^2);
3 end

```

2.4

```

1 function [weights, errors] = train(hiddenNeurons, learnRate,
      inputX, outputT, epochs, trans, transDiff)
2 %train trains the neural network
3 % Arguments:
4 %      - hiddenNeurons: number of hidden neurons
5 %      - learnRate: learning rate \eta
6 %      - inputX: input data organized as samples x dimensions (
      each row denotes a point)
7 %      - outputT: teacher signal as column vector
8 %      - epochs: number of epochs to train the network
9 %      - trans: transfer function to use in the hidden layer (
      activation function)
10 %      - transDiff: derivative of the transfer function

```

```

11 %
12 assert(iscolumn(outputT), 'T must be a column vector');
13 assert(size(inputX, 1) == size(outputT, 1), 'Each data point
    must have an associated label');
14 rng(1337, 'combRecursive'); % For reproducibility (does also
    work with parfor: http://de.mathworks.com/help/distcomp/control-random-number-streams.html#btms9o\_)
15 weights = initWeights(size(inputX,2),hiddenNeurons,size(
    outputT,2));
16 errors = zeros(epochs,1);
17
18 for e=1:epochs
19     indexSet = randperm(size(inputX,1));
20     for c=indexSet
21         currentInput = transpose(inputX(c,:));
22         trainerOutput = transpose(outputT(c,:));
23         [mlpOutput,u2,hiddenOutput,u1] = forward(
            currentInput, weights,trans);
24         [delta1,delta2] = propagateError(trainerOutput,
            mlpOutput,weights.w2,transDiff(u1));
25
26         weights.w1 = weights.w1 + learnRate * (delta1 *
            transpose(currentInput));
27         weights.w2 = weights.w2 + learnRate * delta2 *
            transpose(hiddenOutput);
28         weights.theta1 = weights.theta1 + learnRate * delta1
            ;
29         weights.theta2 = weights.theta2 + learnRate * delta2
            ;
30     end;
31
32     [mlpOutput,u2,hiddenOutput,u1] = forward(transpose(
        inputX),weights,trans);
33     diff = norm(mlpOutput-transpose(outputT))^2;
34     errors(c) = diff;
35 end;
36 end

```

2.5

```

1 %% Initialization
2 % Generate data
3 s = 31;
4 [x, y, z] = peaks(s);

```

```

5 data = [x(:) y(:) z(:)];
6 X = data(:, 1:2);
7 T = data(:, 3);
8 eta = 0.01;
9
10 [weights, E] = train(100, eta, X, T, 1000, @tanh, @transDiff);
11
12 figure();
13 subplot(2,2,1);
14 surf(x,y,z);
15 xlabel("x_1");
16 ylabel("x_2");
17 zlabel("peaks(x_1, x_2)");
18 title("Peaks-Funktion");
19
20 subplot(2,2,2);
21 output = forward(transpose(X), weights, @tanh);
22 output = reshape(output, size(z));
23 surf(x,y,output);
24 xlabel("x_1");
25 ylabel("x_2");
26 zlabel("f(x_1, x_2)");
27 title("Netz-Ausgabe");
28
29
30 subplot(2,2,3);
31 surf(x,y,abs(output-z));
32 xlabel("x_1");
33 ylabel("x_2");
34 zlabel("|peaks(x_1, x_2) - f(x_1,x_2)|");
35 title("Differenz der beiden Funktionen");
36
37
38 subplot(2,2,4);
39 plot(E);
40 xlabel("i");
41 ylabel("E(i)");
42 title("Fehlerverlauf");
43
44 print("Plot.eps", "-depsc");

```

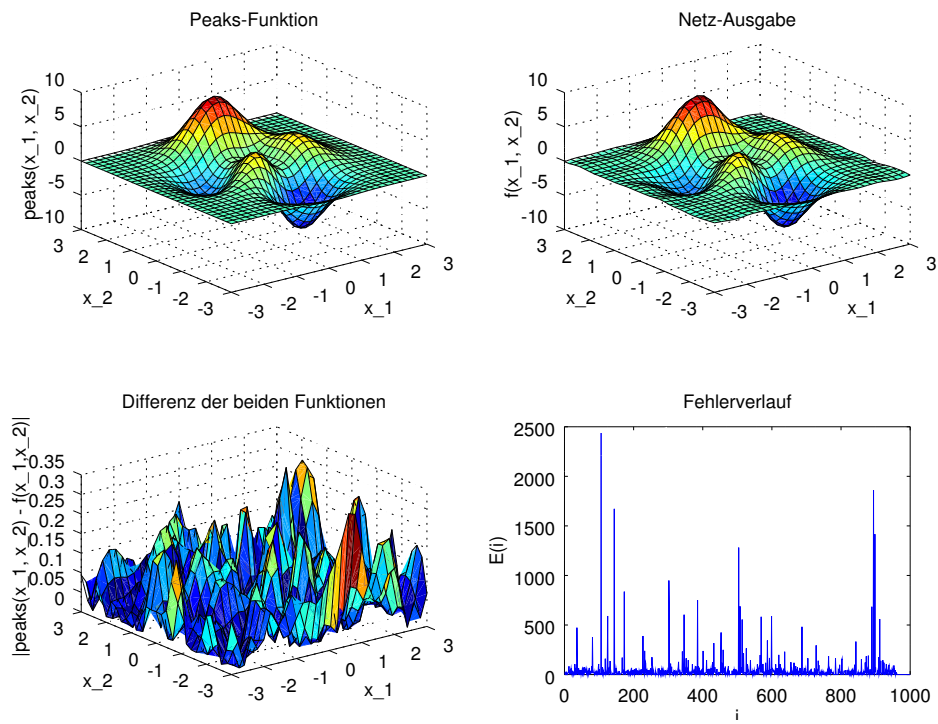


Abbildung 2: Ausgabe des Matlab-Skripts