

Homework 11/14 (4-4 Backpropagation)

This is an homework for a neural network course offered by the master's class of the Department of IEM at the NCUT in the first semester of the 2024 academic year (113-1).

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The codes can be viewed on GitHub: [https://github.com/chankai1016/113-1_Neural_Network/tree/main/4-4\(backpropagation\)](https://github.com/chankai1016/113-1_Neural_Network/tree/main/4-4(backpropagation))

Problem

Numerical example of the backpropagation procedure

Write a program to perform the following computational problem of the backpropagation algorithm below:

The initial biases and weights generated by computer for network 2-4-4 (Fig 1) are listed in Tables 1 and 2. When the first pattern, (x_1, t_1) , is presented, where $x_1 = (0.017322, 1.480488)^t$ and $t_1 = (0.494200, 0.495051, 0.494171, 0.501720)^t$.

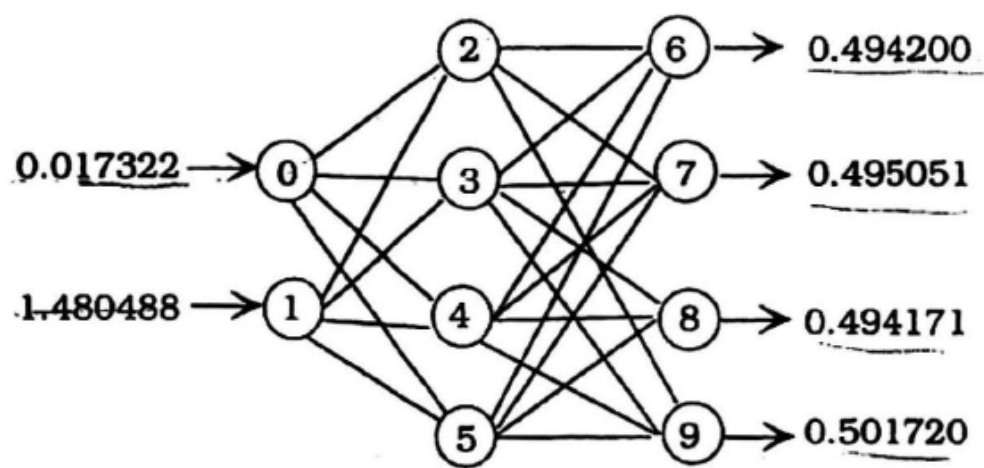


Figure 1 The architecture of network 2-4-4

Table 1 The initial random biases of network 2-4-4

i	b_i	i	b_i
2	-0.444700	6	0.094012
3	0.410733	7	-0.058550
4	0.358089	8	-0.055376
5	-0.005783	9	-0.158925

Table 2 The initial random weights of network 2-4-4

$j-i$	w_{ij}	$j-i$	w_{ij}
0—2	0.121845	2—7	0.326563
1—2	-0.384945	3—7	0.360866
0—3	0.474700	4—7	0.046312
1—3	0.131458	5—7	0.323694
0—4	0.194113	2—8	-0.106006
1—4	0.187948	3—8	0.264275
0—5	-0.318567	4—8	-0.455687
1—5	0.117237	5—8	0.128620
2—6	0.069170	2—9	-0.189261
3—6	-0.088916	3—9	-0.165883
4—6	-0.432951	4—9	-0.068896
5—6	-0.270775	5—9	-0.490692

main.py

```

import numpy as np

def backpropagation(input_v, target, bias, weight):
    print("\n#### 1. Forward Pass")
    print("\n#### A. Hidden Unit")
    print("\n| i | net(i) | a(i) |")
    print("| :--: | ---: | ---: |")
    net = [0] * 10
    a = [0] * 10
    for i in range(len(input_v)):
        a[i] = input_v[i]
    for i in range(2, 5 + 1): # 2, 3, 4, 5 : hidden num
        for j in range(0, 1 + 1): # 0, 1 : input num
            # net_i = a_0*a_0i + a_1*a_1i + b_i
            net[i] += input_v[j] * weight[j][i]
        net[i] += bias[i]
        a[i] = (1 + np.exp(-1 * net[i])) ** -1
        print("| **{}** | {:.6f} | {:.6f} |".format(i, net[i], a[i]))
    print("\n#### B. Output Unit")
    print("\n| i | net(i) | a(i) |")
    print("| :--: | ---: | ---: |")
    for i in range(6, 9 + 1): # 6, 7, 8, 9 : output num
        for j in range(2, 5 + 1): # 2, 3, 4, 5 : hidden num
            # net_i = a_2*a_2i + a_3*a_3i + a_4*a_4i + a_5*a_5i + b_i
            net[i] += a[j] * weight[j][i]
        net[i] += bias[i]
        a[i] = (1 + np.exp(-1 * net[i])) ** -1
        print("| **{}** | {:.6f} | {:.6f} |".format(i, net[i], a[i]))

```

```

print("\n#### 2. Backward Pass")
delta = [0] * 10
print("\n#### A. Output Unit")
print("\n| i |    $\delta(i)$    |")
print("| :--: | ---: |")
for i in range(6, 9 + 1): # 6, 7, 8, 9 : output num
    delta[i] = (target[i - 6] - a[i]) * ( a[i] * (1 - a[i]) ) # 1-6 = 0, 1, 2, 3 :
target num
    print("| **{}** | {:.6f} |".format(i, delta[i]))
print("\n#### B. Hidden Unit")
print("\n| i |    $\delta(i)$    |")
print("| :--: | ---: |")
for i in range(2, 5 + 1): # 2, 3, 4, 5 : hidden num
    for j in range(6, 9 + 1): # 6, 7, 8, 9 : output num
        delta[i] += delta[j] * weight[i][j]
    delta[i] *= a[i] * (1 - a[i])
    print("| **{}** | {:.6f} |".format(i, delta[i]))

print("\n#### 3. Change of Weights and Biases")
print("\n#### A. Weights")
print("\n| i - j |    $\Delta W(i)$    |  $W^{new}(i)$  | i - j |    $\Delta W(i)$    |  $W^{new}(i)$  | i - j |
 $\Delta W(i)$    |  $W^{new}(i)$  | i - j |    $\Delta W(i)$    |  $W^{new}(i)$  |")
print("| :--: | ---: | ---: | :--: | ---: | ---: | :--: | ---: | ---: | :--: | ---: | --
-: |")
d_weight = [[0] * 10] * 6
weight_new = [[0] * 10] * 6
for i in range(0, 1+1): # 0, 1 : input num
    for j in range(2, 5+1): # 2, 3, 4, 5 : hidden num
        d_weight[i][j] = 0.20 * delta[j] * a[i]
        weight_new[i][j] = weight[i][j] + d_weight[i][j]
        print("| **{} - {}** | {:.6f} | {:.6f} ".format(i, j, d_weight[i][j],
weight_new[i][j]), end = "")
    print("|")
for i in range(2, 5+1): # 2, 3, 4, 5 : hidden num
    for j in range(6, 9+1): # 6, 7, 8, 9 : output num
        d_weight[i][j] = 0.20 * delta[j] * a[i]
        weight_new[i][j] = weight[i][j] + d_weight[i][j]
        print("| **{} - {}** | {:.6f} | {:.6f} ".format(i, j, d_weight[i][j],
weight_new[i][j]), end = "")
    print("|")
print("\n#### B. Biases")
print("\n| i |    $\Delta b(i)$    |  $b^{new}(i)$  | i |    $\Delta b(i)$    |  $b^{new}(i)$  |")
print("| :--: | ---: | ---: | :--: | ---: | ---: |")
d_bias = [0] * 10
bias_new = [0] * 10
for i in range(2, 9+1): # 2 , ..., 9 : biases num
    d_bias[i] = 0.20 * delta[i]
    bias_new[i] = bias[i] + d_bias[i]
# for output table
for i in range(2, 5+1):
    print("| **{}** | {:.6f} | {:.6f} | **{}** | {:.6f} | {:.6f} |".format(i, d_bias[i],
bias_new[i], i+4, d_bias[i+4], bias_new[i+4]))
return 0

```

Input

```
input_v = (0.017322, 1.480488)
target = (0.494200, 0.495051, 0.494171, 0.501720)
# b_2 = bias[2] etc...
bias = (0, 0, -0.444700, 0.410733, 0.358089, -0.005783, 0.094012, -0.058550, -0.055376,
-0.158925)
# w_0-2 = weight[0][2] etc...
weight = [
    [0, 0, 0.121845, 0.474700, 0.194113, 0.318567, 0, 0, 0, 0],
    [0, 0, -0.384945, 0.131458, 0.187948, 0.117237, 0, 0, 0, 0],
    [0, 0, 0, 0, 0, 0, 0.069170, 0.326563, -0.106006, -0.189261],
    [0, 0, 0, 0, 0, 0, -0.088916, 0.360866, 0.264275, -0.165883],
    [0, 0, 0, 0, 0, 0, -0.432951, 0.046312, -0.455687, -0.068896],
    [0, 0, 0, 0, 0, 0, -0.270775, 0.323694, 0.128620, -0.490692],
]
backpropagation(input_v, target, bias, weight)
```

Output

以markdown形式輸出

1. Forward Pass

A. Hidden Unit

i	net(i)	a(i)
2	-1.012496	0.266492
3	0.613578	0.648757
4	0.639706	0.654687
5	0.173303	0.543218

B. Output Unit

i	net(i)	a(i)
6	-0.375777	0.407146
7	0.468747	0.615087
8	-0.140639	0.464898
9	-0.628637	0.347820

2. Backward Pass

A. Output Unit

i	δ(i)
6	0.021013
7	-0.028419
8	0.007282

i	$\delta(i)$
9	0.034911

B. Hidden Unit

i	$\delta(i)$
2	-0.002972
3	-0.003644
4	-0.003648
5	-0.007713

3. Change of Weights and Biases

A. Weights

i	$\Delta W(i)$	$W^{new}(i)$	i	$\Delta W(i)$	$W^{new}(i)$	i	$\Delta W(i)$	$W^{new}(i)$	i	$\Delta W(i)$	$W^{new}(i)$
j			j			j			j		
0	-	-	0	-	-	0	-	-	0	-	-
-	-0.000010	0.121835	-	-0.000013	0.474687	-	-0.000013	0.194100	-	-0.000027	0.318540
2			3			4			5		
1	-	-	1	-	-	1	-	-	1	-	-
-	-0.000880	-0.385825	-	-0.001079	0.130379	-	-0.001080	0.186868	-	-0.002284	0.114953
2			3			4			5		
2	-	-	2	-	-	2	-	-	2	-	-
-	0.001120	0.070290	-	-0.001515	0.325048	-	0.000388	-0.105618	-	0.001861	-0.187400
6			7			8			9		
3	-	-	3	-	-	3	-	-	3	-	-
-	0.002726	-0.086190	-	-0.003687	0.357179	-	0.000945	0.265220	-	0.004530	-0.161353
6			7			8			9		
4	-	-	4	-	-	4	-	-	4	-	-
-	0.002751	-0.430200	-	-0.003721	0.042591	-	0.000954	-0.454733	-	0.004571	-0.064325
6			7			8			9		
5	-	-	5	-	-	5	-	-	5	-	-
-	0.002283	-0.268492	-	-0.003088	0.320606	-	0.000791	0.129411	-	0.003793	-0.486899
6			7			8			9		

B. Biases

i	$\Delta b(i)$	$b^{new}(i)$	i	$\Delta b(i)$	$b^{new}(i)$
2	-0.000594	-0.445294	6	0.004203	0.098215
3	-0.000729	0.410004	7	-0.005684	-0.064234
4	-0.000730	0.357359	8	0.001456	-0.053920
5	-0.001543	-0.007326	9	0.006982	-0.151943

