In [106]:
```
# Name: Jiajin Liang
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import numpy as np
x = np.load("assignment7_X.npy")
w1 = np.load("assignment7_W1.npy")
w2 = np.load("assignment7_W2.npy")
w1 = w1.astype(float)
w2 = w2.astype(float)
x = x.astype(float)
print(x.shape,w1.shape,w2.shape)

class Node:
    def __init__(self,f,input_list):
        self.value = f(input_list)
        self.df_values = []
        self.edge_dfvalues = []
    def backprop(self,df_list,backp_input_list,prev_dfvalue_list):
        for df in df_list:
            self.df_values.append(df(backp_input_list))
        #print(self.df_values,df_list)
        self.dfvalue = np.array(self.df_values).dot(np.array(prev_dfvalue_list
))
        for i in range(len(self.df_values)):
            self.edge_dfvalues.append(self.df_values[i] * prev_dfvalue_list[i
])
    def tensor_chain_backprop(self,df,bpinput,prevdf):
        self.dfvalue = np.zeros((15,15,15))
        tensor = df(bpinput)
        for i in range(15):
            for j in range(15):
                self.dfvalue[i] += tensor[j]*prevdf[i][j]
    def simple_backprop(self,df,bpinput):
        self.dfvalue = df(bpinput)
    def printnode(self):
        print("forward value: ", self.value, "\ndfvalue (the sum of derivative
s of all outgoing edges/the partial derivative of this node with respect to
 f): ", self.dfvalue)
        for i in range(len(self.edge_dfvalues)):
            print("Derivative of outgoing Edge #", i, " of this node: ", self.
edge_dfvalues[i])
class inputNode(Node):
    def __init__(self,inputv):
        self.value = inputv
        self.df_values = []
        self.edge_dfvalues = []

def fh1(input_list):
    return input_list[1].dot(input_list[0])
def fh2(input_list):
    return input_list[0].dot(input_list[1])
def dh2dh1(bpinput):
    return bpinput
def dh2dw2(bpint):
    toRet = np.zeros((15,15,15))
    for i in range(15):
        toRet[i][i] = bpinput.T
```

```
    return toRet
def dh1dw1(bpinput):
    toRet = np.zeros((15,15,15))
    for i in range(15):
        toRet[i][i] = bpinput.T
    return toRet

nodexi = inputNode(x)
nodexi.value
nodew1 = inputNode(w1)
nodew2 = inputNode(w2)
#nodeb1 =
nodeh1 = Node(fh1,[nodexi.value,nodew1.value])
nodeh2 = Node(fh2,[nodew2.value,nodeh1.value])

#nodeh2.tensor_chain_backprop([dh2dh1,dh2dw2],[nodeh1.value,nodew2.value],[np.
ones((15,15))])
nodeh1.simple_backprop(dh2dh1,nodew2.value)
nodew2.simple_backprop(dh2dw2,nodeh1.value)
nodew1.tensor_chain_backprop(dh1dw1,nodexi.value,nodew2.value)

# compute numerical partial derivative tensor to compare
h = 1e-3
f = w2.dot((w1.dot(x)))
w1_partial_deriv_tensor = np.ones((15,15,15))
for i in range (15):
    for j in range(15):
        w1 = np.load("assignment7_W1.npy")
        w1 = w1.astype(float)
        w1[i][j] += h
        partial_deriv = (w2.dot((w1.dot(x))) - f)/h
        #print(w1)
        for k in range(15):
            w1_partial_deriv_tensor[k][i][j] = partial_deriv[k]
w1 = np.load("assignment7_W1.npy")
h1 = w1.dot(x)
w2_partial_deriv_tensor = np.ones((15,15,15))
for i in range (15):
    for j in range(15):
        w2 = np.load("assignment7_W2.npy")
        w2 = w2.astype(float)
        w2[i][j] += h
        partial_deriv = (w2.dot(h1) - f)/h
        #print(w2)
        for k in range(15):
            w2_partial_deriv_tensor[k][i][j] = partial_deriv[k]
print("dfdw1:")
print(nodew1.dfvalue)
print("numerical dfdw1:")
print(w1_partial_deriv_tensor)
print("dfdw2:")
print(nodew2.dfvalue)
print("numerical dfdw2:")
print(w2_partial_deriv_tensor)
#print("dh2dh1:")
#print(nodeh1.dfvalue)
#print(w2)
```

```
(15,) (15, 15) (15, 15)
dfdw1:
[[[  0.    0.    0.  ...   0.    0.    0. ]
  [  0.5   0.5   0.5 ...   0.5   0.5   0.5]
  [  1.    1.    1.  ...   1.    1.    1. ]
  ...
  [  6.    6.    6.  ...   6.    6.    6. ]
  [  6.5   6.5   6.5 ...   6.5   6.5   6.5]
  [  7.    7.    7.  ...   7.    7.    7. ]]

 [[  7.5   7.5   7.5 ...   7.5   7.5   7.5]
  [  8.    8.    8.  ...   8.    8.    8. ]
  [  8.5   8.5   8.5 ...   8.5   8.5   8.5]
  ...
  [ 13.5  13.5  13.5 ...  13.5  13.5  13.5]
  [ 14.   14.   14.  ...  14.   14.   14. ]
  [ 14.5  14.5  14.5 ...  14.5  14.5  14.5]]

 [[ 15.   15.   15.  ...  15.   15.   15. ]
  [ 15.5  15.5  15.5 ...  15.5  15.5  15.5]
  [ 16.   16.   16.  ...  16.   16.   16. ]
  ...
  [ 21.   21.   21.  ...  21.   21.   21. ]
  [ 21.5  21.5  21.5 ...  21.5  21.5  21.5]
  [ 22.   22.   22.  ...  22.   22.   22. ]]

 ...

 [[ 90.   90.   90.  ...  90.   90.   90. ]
  [ 90.5  90.5  90.5 ...  90.5  90.5  90.5]
  [ 91.   91.   91.  ...  91.   91.   91. ]
  ...
  [ 96.   96.   96.  ...  96.   96.   96. ]
  [ 96.5  96.5  96.5 ...  96.5  96.5  96.5]
  [ 97.   97.   97.  ...  97.   97.   97. ]]

 [[ 97.5  97.5  97.5 ...  97.5  97.5  97.5]
  [ 98.   98.   98.  ...  98.   98.   98. ]
  [ 98.5  98.5  98.5 ...  98.5  98.5  98.5]
  ...
  [103.5 103.5 103.5 ... 103.5 103.5 103.5]
  [104.  104.  104.  ... 104.  104.  104. ]
  [104.5 104.5 104.5 ... 104.5 104.5 104.5]]

 [[105.  105.  105.  ... 105.  105.  105. ]
  [105.5 105.5 105.5 ... 105.5 105.5 105.5]
  [106.  106.  106.  ... 106.  106.  106. ]
  ...
  [111.  111.  111.  ... 111.  111.  111. ]
  [111.5 111.5 111.5 ... 111.5 111.5 111.5]
  [112.  112.  112.  ... 112.  112.  112. ]]]
numerical dfdw1:
[[[  0.          0.          0.         ...   0.          0.
     0.        ]
  [  0.49999999   0.49999999   0.49999999 ...   0.49999999   0.49999999
     0.49999999]
  [  1.          1.          1.         ...   1.          1.
```

```
    1.        ]
 ...
 [  5.99999999   5.99999999   5.99999999 ...   5.99999999   5.99999999
    5.99999999]
 [  6.5          6.5          6.5        ...   6.5          6.5
    6.5       ]
 [  7.           7.           7.         ...   7.           7.
    7.        ]]

[[  7.50000001   7.50000001   7.50000001 ...   7.50000001   7.50000001
    7.50000001]
 [  8.00000003   8.00000003   8.00000003 ...   8.00000003   8.00000003
    8.00000003]
 [  8.5          8.5          8.5        ...   8.5          8.5
    8.5       ]
 ...
 [ 13.5         13.5         13.5        ...  13.5         13.5
   13.5       ]
 [ 13.99999997  13.99999997  13.99999997 ...  13.99999997  13.99999997
   13.99999997]
 [ 14.49999999  14.49999999  14.49999999 ...  14.49999999  14.49999999
   14.49999999]]

[[ 15.00000001  15.00000001  15.00000001 ...  15.00000001  15.00000001
   15.00000001]
 [ 15.49999998  15.49999998  15.49999998 ...  15.49999998  15.49999998
   15.49999998]
 [ 16.          16.          16.         ...  16.          16.
   16.        ]
 ...
 [ 21.00000001  21.00000001  21.00000001 ...  21.00000001  21.00000001
   21.00000001]
 [ 21.50000003  21.50000003  21.50000003 ...  21.50000003  21.50000003
   21.50000003]
 [ 22.          22.          22.         ...  22.          22.
   22.        ]]

...

[[ 89.99999985  89.99999985  89.99999985 ...  89.99999985  89.99999985
   89.99999985]
 [ 90.49999993  90.49999993  90.49999993 ...  90.49999993  90.49999993
   90.49999993]
 [ 91.00000001  91.00000001  91.00000001 ...  91.00000001  91.00000001
   91.00000001]
 ...
 [ 95.9999999   95.9999999   95.9999999  ...  95.9999999   95.9999999
   95.9999999 ]
 [ 96.49999999  96.49999999  96.49999999 ...  96.49999999  96.49999999
   96.49999999]
 [ 97.00000007  97.00000007  97.00000007 ...  97.00000007  97.00000007
   97.00000007]]

[[ 97.50000015  97.50000015  97.50000015 ...  97.50000015  97.50000015
   97.50000015]
 [ 98.00000023  98.00000023  98.00000023 ...  98.00000023  98.00000023
   98.00000023]
```

```
 [ 98.49999985  98.49999985  98.49999985 ...  98.49999985  98.49999985
   98.49999985]
 ...
 [103.5000002  103.5000002  103.5000002  ... 103.5000002  103.5000002
  103.5000002 ]
 [104.00000028 104.00000028 104.00000028 ... 104.00000028 104.00000028
  104.00000028]
 [104.4999999  104.4999999  104.4999999  ... 104.4999999  104.4999999
  104.4999999 ]]

[[104.99999998 104.99999998 104.99999998 ... 104.99999998 104.99999998
  104.99999998]
 [105.50000006 105.50000006 105.50000006 ... 105.50000006 105.50000006
  105.50000006]
 [106.00000015 106.00000015 106.00000015 ... 106.00000015 106.00000015
  106.00000015]
 ...
 [111.00000003 111.00000003 111.00000003 ... 111.00000003 111.00000003
  111.00000003]
 [111.50000012 111.50000012 111.50000012 ... 111.50000012 111.50000012
  111.50000012]
 [111.99999973 111.99999973 111.99999973 ... 111.99999973 111.99999973
  111.99999973]]]
dfdw2:
[[[ 105.  330.  555. ... 2805. 3030. 3255.]
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  ...
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]]

 [[   0.    0.    0. ...    0.    0.    0.]
  [ 105.  330.  555. ... 2805. 3030. 3255.]
  [   0.    0.    0. ...    0.    0.    0.]
  ...
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]]

 [[   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  [ 105.  330.  555. ... 2805. 3030. 3255.]
  ...
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]]

 ...

 [[   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  ...
  [ 105.  330.  555. ... 2805. 3030. 3255.]
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]]
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 [[   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  ...
  [   0.    0.    0. ...    0.    0.    0.]
  [ 105.  330.  555. ... 2805. 3030. 3255.]
  [   0.    0.    0. ...    0.    0.    0.]]

 [[   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  ...
  [   0.    0.    0. ...    0.    0.    0.]
  [   0.    0.    0. ...    0.    0.    0.]
  [ 105.  330.  555. ... 2805. 3030. 3255.]]]
numerical dfdw2:
[[[ 105.          330.          554.99999999 ... 2804.99999999
   3030.         3255.        ]
  [   0.            0.            0.         ...    0.
      0.            0.        ]
  [   0.            0.            0.         ...    0.
      0.            0.        ]
  ...
  [   0.            0.            0.         ...    0.
      0.            0.        ]
  [   0.            0.            0.         ...    0.
      0.            0.        ]
  [   0.            0.            0.         ...    0.
      0.            0.        ]]

 [[   0.            0.            0.         ...    0.
      0.            0.        ]
  [ 104.99999998  330.00000002  554.99999999 ... 2804.99999999
   3030.00000003 3255.        ]
  [   0.            0.            0.         ...    0.
      0.            0.        ]
  ...
  [   0.            0.            0.         ...    0.
      0.            0.        ]
  [   0.            0.            0.         ...    0.
      0.            0.        ]
  [   0.            0.            0.         ...    0.
      0.            0.        ]]

 [[   0.            0.            0.         ...    0.
      0.            0.        ]
  [   0.            0.            0.         ...    0.
      0.            0.        ]
  [ 104.99999998  330.00000002  554.99999999 ... 2804.99999999
   3030.00000003 3255.        ]
  ...
  [   0.            0.            0.         ...    0.
      0.            0.        ]
  [   0.            0.            0.         ...    0.
      0.            0.        ]
  [   0.            0.            0.         ...    0.
```

```
        0.            0.        ]]

...

[[   0.            0.            0.         ...    0.
     0.            0.        ]
 [   0.            0.            0.         ...    0.
     0.            0.        ]
 [   0.            0.            0.         ...    0.
     0.            0.        ]
 ...
 [ 104.99999998  330.00000007  554.9999997  ... 2805.00000017
  3030.00000026 3254.99999989]
 [   0.            0.            0.         ...    0.
     0.            0.        ]
 [   0.            0.            0.         ...    0.
     0.            0.        ]]

[[   0.            0.            0.         ...    0.
     0.            0.        ]
 [   0.            0.            0.         ...    0.
     0.            0.        ]
 [   0.            0.            0.         ...    0.
     0.            0.        ]
 ...
 [   0.            0.            0.         ...    0.
     0.            0.        ]
 [ 104.99999998  330.00000007  554.9999997  ... 2805.00000017
  3030.00000026 3254.99999989]
 [   0.            0.            0.         ...    0.
     0.            0.        ]]

[[   0.            0.            0.         ...    0.
     0.            0.        ]
 [   0.            0.            0.         ...    0.
     0.            0.        ]
 [   0.            0.            0.         ...    0.
     0.            0.        ]
 ...
 [   0.            0.            0.         ...    0.
     0.            0.        ]
 [   0.            0.            0.         ...    0.
     0.            0.        ]
 [ 104.99999998  330.00000007  554.9999997  ... 2805.00000017
  3030.00000026 3254.99999989]]]
```