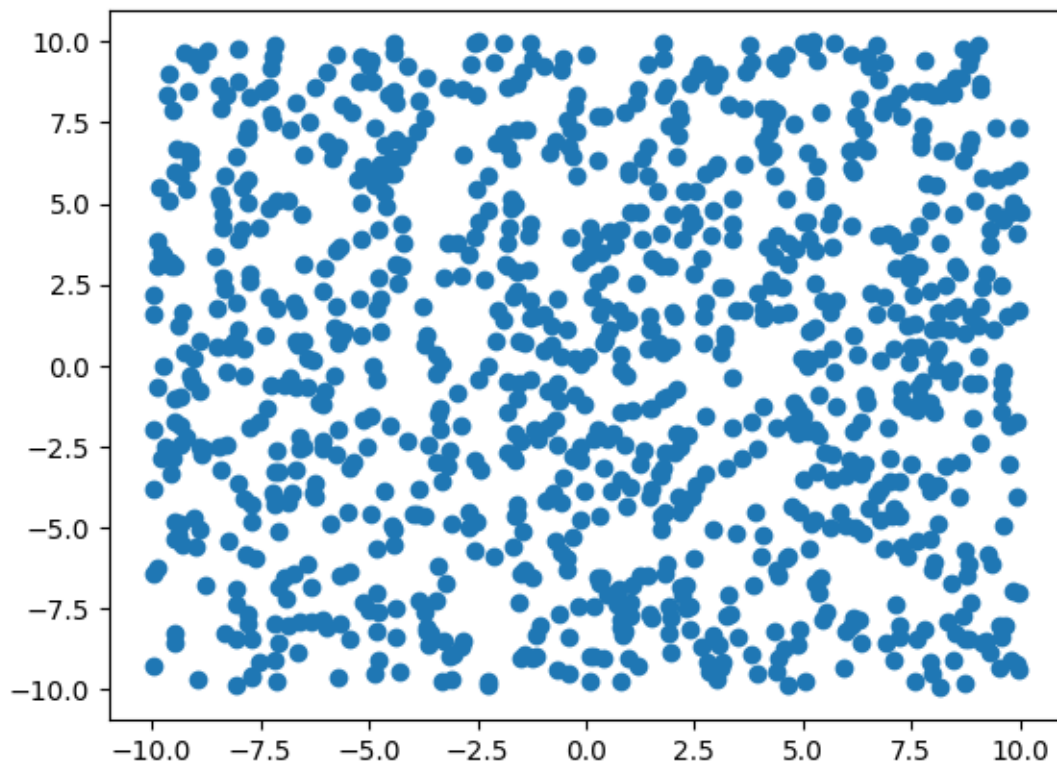# SOC checkpoint 1_updated

June 29, 2024

[14]:
```python
import numpy as np
import matplotlib.pyplot as plt
```

[15]:
```python
#multilayer perceptron

#creating dataset
x=np.random.uniform(-10,10,1000)
y=np.random.uniform(-10,10,1000)
plt.scatter(x,y)
```

[15]: <matplotlib.collections.PathCollection at 0x1175f4880>

```python
[16]: #random bias
      b=np.random.uniform(-2,2,3)
      #random slopes
      w=np.random.uniform(-3,3,3)
      #creating labels
      labels=[]
      ylabels=[]
      for i in range(len(x)):
          if((w[0]*x[i]+b[0]<=y[i] and w[1]*x[i]+b[1]<=y[i] and w[2]*x[i]+b[2]<=y[i])␣
       ↪or (w[0]*x[i]+b[0]>=y[i] and w[1]*x[i]+b[1]>=y[i] and w[2]*x[i]+b[2]>=y[i])):
              labels.append('blue')
          elif((w[0]*x[i]+b[0]>=y[i] and w[1]*x[i]+b[1]<=y[i] and␣
       ↪w[2]*x[i]+b[2]<=y[i]) or (w[0]*x[i]+b[0]<=y[i] and (w[1]*x[i]+b[1])>=y[i]␣
       ↪and w[2]*x[i]+b[2]>=y[i])):
              labels.append('orange')
          else:
              labels.append('green')
          if(labels[i]=='blue'):
              ylabels.append(0)
          elif(labels[i]=='green'):
              ylabels.append(1)
          else:
              ylabels.append(2)

      labels=np.array(labels)
      color=['blue','orange','green']

      yinlabels=np.array(ylabels)

      plt.scatter(x,y,color=labels)
      plt.plot(x,w[0]*x+b[0],label='line1')
      plt.plot(x,w[1]*x+b[1],label='line2')
      plt.plot(x,w[2]*x+b[2],label='line2')
      plt.ylim(-11,11)
      plt.xlim(-11,11)
```
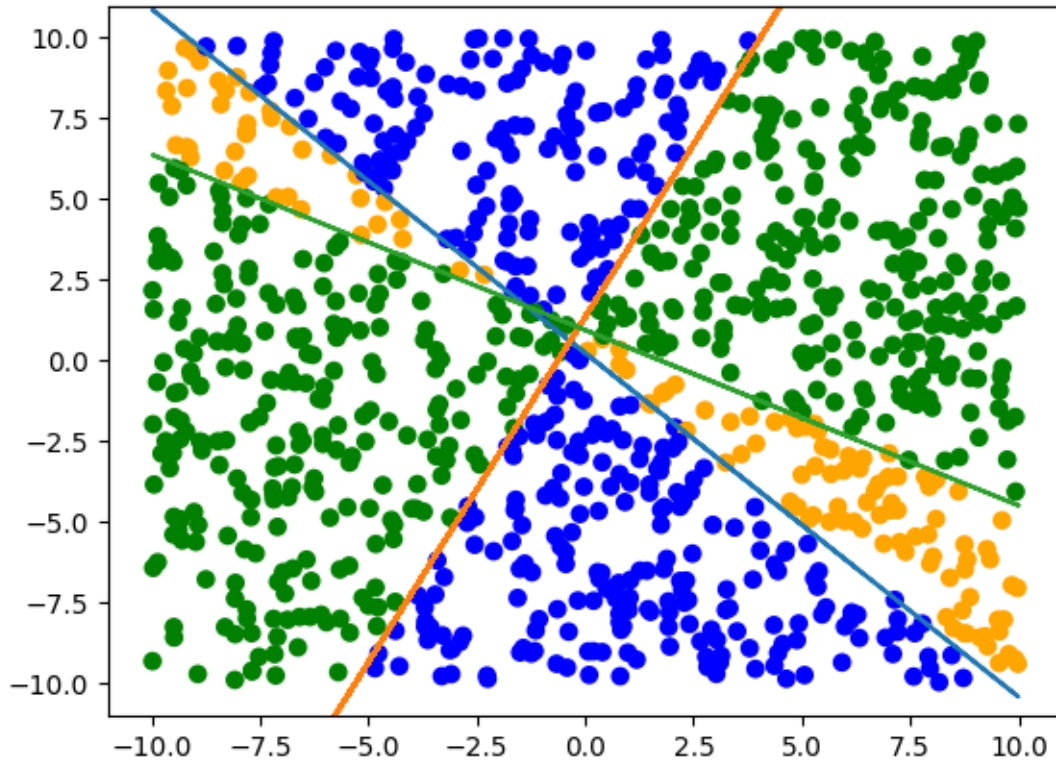
[16]: (-11.0, 11.0)

```
[17]:  #now making a classifier multi class perceptron to
       #estimate those lines just by giving input as scatterpoints and labels
       #2 feature input x,y
       # since there are 3 option we can go with a hidden linear layer with 3 nodes␣
        ↪and activation function as ReLU
       X=x,y # making input as one matrix
       X=np.transpose(X)
       print(yinlabels)
       yinlabels[:,np.newaxis]
       y0=[]
       for i in range(len(yinlabels)):
           if(yinlabels[i]==0):
               y0.append([1,0,0])
           elif(yinlabels[i]==1):
               y0.append([0,1,0])
           else:
               y0.append([0,0,1])
       ylabels=y0
       ylabels=np.array(ylabels)
       print(ylabels)
```

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 1 1 0 1 0 1 1 1 1 2 1 1 1 0 1 0 0 0 2 0 1 2 0 1 0 1 1 0 1 1 1 1 0 2 0 2 1 1
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 1 2 0 0 1 1 1 1 0 2 1 1 1 0 0 1 0 0 0 1 0 0 2 1 1 0 1 0 1 1 1 0 1 1 0 0 0
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 1 1 0 2 0 1 0 0 1 0 1 0 0 0 0 1 2 1 1 0 1 1 0 0 2 1 1 0 0 1 0 1 0 0 2 0 0
 2 2 1 0 0 0 0 2 1 0 0 1 0 0 1 1 1 1 0 0 1 1 0 2 0 0 0 0 0 0 0 0 0 0 0 1 0
 0 0 2 1 2 1 1 0 1 1 2 0 1 1 2 0 1 1 1 1 2 0 0 0 0 1 1 1 1 1 1 0 0 0 1 1 1
 0 2 1 0 2 1 0 1 0 2 1 2 1 1 1 1 0 0 1 2 1 1 2 1 1 1 1 1 0 1 0 0 1 1 0 1 1
 1 1 1 1 1 0 0 0 1 0 1 1 1 1 0 1 1 0 1 1 1 0 0 1 0 1 0 1 0 1 1 1 1 2 0 0 2
 1 1 0 0 0 1 1 2 1 1 1 0 1 0 1 2 2 2 1 1 1 1 0 0 1 1 1 1 1 0 1 1 1 1 1 1 0
 2 1 0 1 1 0 0 1 1 2 1 1 1 2 1 1 1 1 1 1 0 1 1 1 1 0 1 1 0 1 0 2 1 1 1 1 1
 1 1 0 2 1 0 0 1 0 1 0 0 1 0 0 0 2 1 0 1 2 1 2 2 0 1 0 1 0 0 1 1 0 1 2 1 0
 1 1 1 1 1 1 0 1 1 0 1 0 1 2 1 1 1 1 1 1 0 0 1 1 0 0 1 0 2 2 1 0 0 2 0 0 1
 0]
[[1 0 0]
 [1 0 0]
 [1 0 0]
 …
 [1 0 0]
 [0 1 0]
 [1 0 0]]
```

[18]:
```python
class hidden(object):

    def __init__(self,nodes1):
        print('hidden layer constructor called')
        self.hidden1nodes=nodes1
        self.labels=ylabels
    def params_init(self,p1,lr):
        # 6 nodes
        self.b=np.zeros(shape=(1,self.hidden1nodes))
#         self.W=np.random.randn(self.hidden1nodes,2)
        self.W=p1
        self.dW=np.zeros(shape=(self.hidden1nodes,2))
```

```python
            self.db=np.zeros(shape=(1,self.hidden1nodes))
            self.lr=lr
            print("param_init_called")
            return 1
        def forward(self,X): # X: batch_size,2
            # return (batch_size,6)
            self.X=X
            return np.maximum(np.dot(X,self.W.T)+self.b,0)
        def backward(self,delta): # delta: batch_size,6
            self.dW= np.dot(np.transpose(delta),self.X)
            self.db= np.sum(delta,axis=0)
            return np.dot(delta,self.W)
        def gd_update(self):
            self.W=self.W-np.multiply(self.lr,self.dW)
            self.b=self.b-np.multiply(self.lr,self.db)
```

```python
[19]: class hidden2(object):

          def __init__(self,nodes1):
              print('hidden2 layer constructor called')
              self.hidden1nodes=nodes1
              self.labels=ylabels
          def params_init(self,p2,lr):
              # 3 nodes
              self.b=np.zeros(shape=(1,3))
#               self.W=np.random.randn(3,self.hidden1nodes)
              self.W=p2
              self.dW=np.zeros(shape=(3,self.hidden1nodes))
              self.db=np.zeros(shape=(1,3))
              self.lr=lr
              print("param_init_called")
              return 1
          def forward(self,X): # X: batch_size,6
              # return (batch_size,6)
              self.X=X
#               self.forw=np.maximum(np.dot(X,self.W.T)+self.b,0)
#               print("forw shape",self.forw.shape)
#               a=np.maximum(np.dot(X,self.W.T)+self.b,0)
#               print("np.max of",a.shape)
              return np.maximum(np.dot(X,self.W.T)+self.b,0)
          def backward(self,delta): # delta: batch_size,6
              self.dW= np.dot(np.transpose(delta),self.X)
              self.db= np.sum(delta,axis=0).reshape(1,3)
#               a=np.where(np.maximum(self.forw,0)==0,0,np.dot(delta,self.W))
#               print('a',a.shape)
```

```python
            return np.dot(delta,self.W)
        def gd_update(self):


            self.W=self.W-(self.lr*self.dW)
            self.b=self.b-(self.lr*self.db)
```

```python
[20]: class softmax:
        def __init__(self, ylabels):
            print('Softmax constructor called')
            self.nodes = 3
            self.labels = ylabels
            self.softmax = None

        def forward(self, X):

            max_scores = np.max(X, axis=1,keepdims=True)
    #         max_scores[:,np.newaxis]
    #         print("max score",max_scores.shape)
    #         print("X",X.shape)
            expa=X-max_scores
            exp_scores = np.exp(expa)
    #         print(X.shape)
    #         denom=np.sum(expa, axis=1, keepdims=True)
    #         print(denom)
            self.softmax = exp_scores / np.sum(exp_scores, axis=1, keepdims=True)
    #         print("the fraction",self.softmax)
            return self.softmax

        def backward(self,delta):
            return (self.softmax - self.labels)
```

```python
[21]: class crossentropy:
        def __init__(self):
            print("Cross Entropy constructor called")
            self.y_true = None
            self.y_pred = None

        def forward(self, y_pred, y_true):
            self.y_pred = y_pred
            self.y_true = y_true

            log_y_pred = np.log(y_pred + 1e-10)  # Adding a small value to avoid␣
     ↪log(0)
            return -np.sum(y_true * log_y_pred) / y_pred.shape[0]

        def backward(self):
```

```python
        return -self.y_true / (self.y_pred + 1e-10)  # Adding a small value to
    ↪avoid division by zero
```

```python
[22]: class Linking_Networks:
    def __init__(self,X,ylabels,nodes1,p1,p2,lr):
        print('Training Started')
        self.hidden = hidden(nodes1)
        self.hidden.params_init(p1,lr)
        self.hidden2 = hidden2(nodes1)
        self.hidden2.params_init(p2,lr)
#         self.output = output()
#         self.output.params_init()

        self.X=X
        self.labels=ylabels

        self.softmax=softmax(ylabels)
        self.crossentropy=crossentropy()


    def forward(self):
        hidden_layer_output=self.hidden.forward(self.X)
        hidden_layer_output2=self.hidden2.forward(hidden_layer_output)
#         output1=self.output.forward(hidden_layer_output2)
        softmax_output=self.softmax.forward(hidden_layer_output2)
        output=self.crossentropy.forward(softmax_output,ylabels)
        return output
    def backward(self):
        cross_back=self.crossentropy.backward()
        soft_back=self.softmax.backward(cross_back)
#         out1=self.output.backward(soft_back)
        hidden2_back=self.hidden2.backward(soft_back)
        hidden_back=self.hidden.backward(hidden2_back)
        return hidden_back
    def update(self):
        self.hidden2.gd_update()
        self.hidden.gd_update()
    def forward_test(self):
        hidden_layer_output=self.hidden.forward(self.X)
        hidden_layer_output2=self.hidden2.forward(hidden_layer_output)
#         output1=self.output.forward(hidden_layer_output2)
        softmax_output=self.softmax.forward(hidden_layer_output2)
        return softmax_output
```

1 HyperParameter Tuninng

```
[23]: metric=[]
      training=[]

      lr=0.0001
      for j in range(1,101):
          p1=np.random.randn(j,2)
          p2=np.random.randn(3,j)
          Model=Linking_Networks(X,ylabels,j,p1,p2,lr)
          for i in range(1000):
              loss=np.sum(Model.forward())
              if(i==0):
                  print("initial loss:",loss)
      #         print(loss)
      #         print(Model.hidden.W)
              Model.backward()
              Model.update()
          metric.append(loss)
          print('final loss:',loss)
          print(j)


          b=Model.forward_test()
          # print(b.shape)
          a=np.argmax(b,axis=1,keepdims=True)
          b=np.argmax(ylabels,axis=1,keepdims=True)
          error=0
          for i in range(1000):
              if(a[i]!=b[i]):
                  error+=1
          # print(error)
          training_accuracy=1-(error/1000)
          print("training_accuracy",training_accuracy)
          training.append(training_accuracy)
      X1=np.linspace(1,100,100)
      plt.figure(figsize=(10,10))
      plt.subplot(2,1,1)
      plt.plot(X1,metric)
      plt.xlabel("number of nodes")
      plt.ylabel("loss")
      plt.subplot(2,1,2)
      plt.plot(X1,training)
      plt.xlabel("number of nodes")
      plt.ylabel("accuracy")
      plt.show()
```

```
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 2.4075565056535893
final loss: 1.2048386627728864
1
training_accuracy 0.385
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 4.544353707974459
final loss: 1.0456215408709686
2
training_accuracy 0.399
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 4.200000948303598
final loss: 0.683600740099451
3
training_accuracy 0.757
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 2.921834211242267
final loss: 0.7076010255575774
4
training_accuracy 0.7090000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
```

```
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 5.744145450128063
final loss: 0.6644154430164194
5
training_accuracy 0.719
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 5.209986153045837
final loss: 0.6731378699595494
6
training_accuracy 0.738
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 5.144254916723574
final loss: 0.6849504631996091
7
training_accuracy 0.6619999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 9.85109648090168
final loss: 0.5062423641192592
8
training_accuracy 0.8180000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.205792396966528
```

```
final loss: 0.6335315802630259
9
training_accuracy 0.752
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 3.3221953883928106
final loss: 0.761301800928984
10
training_accuracy 0.698
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 8.927507059968285
final loss: 0.502013688334736
11
training_accuracy 0.823
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.174119664426501
final loss: 0.10373930064239013
12
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 4.331651460336012
final loss: 0.8649286532922609
13
training_accuracy 0.8280000000000001
Training Started
```

```
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 4.8178999633665756
final loss: 0.09371314702824081
14
training_accuracy 0.967
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.147839390774153
final loss: 0.09162790472546743
15
training_accuracy 0.96
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 6.365124477224371
final loss: 0.10069657351173078
16
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 3.0918454904305834
final loss: 0.649798861950845
17
training_accuracy 0.7130000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
```

```
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.53091438585446
final loss: 0.37115862350021744
18
training_accuracy 0.867
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 2.958935135459964
final loss: 0.1733104033238152
19
training_accuracy 0.923
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 8.795626288816996
final loss: 0.8350775744024332
20
training_accuracy 0.569
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 9.926420642113735
final loss: 0.11759918685477258
21
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 11.64898222131342
final loss: 0.11719993598825107
```

```
22
training_accuracy 0.959
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.551649637607893
final loss: 0.6424653553087508
23
training_accuracy 0.761
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 1.0463787598462126
final loss: 2.338315405125627
24
training_accuracy 0.558
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 6.537045128453432
final loss: 0.08902872020792729
25
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 8.612271791686501
final loss: 0.09296309890340637
26
training_accuracy 0.96
Training Started
hidden layer constructor called
```

```
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.325035089613117
final loss: 0.16479514541800144
27
training_accuracy 0.935
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.0951993211628865
final loss: 0.09595206258313874
28
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 2.4823532958572594
final loss: 0.1663891544630909
29
training_accuracy 0.946
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 6.52064591774122
final loss: 0.09055773509110289
30
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
```

```
Cross Entropy constructor called
initial loss: 15.576995146171809
final loss: 0.2187282614922226
31
training_accuracy 0.868
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 14.477218978433998
final loss: 0.08488391842593426
32
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.017298390793705
final loss: 0.08820618231972105
33
training_accuracy 0.961
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 10.370363429146428
final loss: 0.08473096034414371
34
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 6.52257796529113
final loss: 0.13928721786750758
35
```

```
training_accuracy 0.964
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 13.43981932500205
final loss: 0.10065262878262468
36
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 6.3556646901944625
final loss: 0.09049821772819068
37
training_accuracy 0.957
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 11.308578607955335
final loss: 0.08375678092556589
38
training_accuracy 0.959
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 10.758367347390323
final loss: 0.08451879591492784
39
training_accuracy 0.961
Training Started
hidden layer constructor called
param_init_called
```

```
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 9.418813363721526
final loss: 0.10878915344910638
40
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 9.59807022913259
final loss: 0.09762663652335979
41
training_accuracy 0.965
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.745025650712865
final loss: 0.09536075899576389
42
training_accuracy 0.956
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.320728369612562
final loss: 0.10691398012206807
43
training_accuracy 0.961
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
```

```
initial loss: 13.117534271632001
final loss: 0.12412629960379896
44
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 9.034256061092158
final loss: 0.08391416066182669
45
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 11.615491581323774
final loss: 0.2229452385714655
46
training_accuracy 0.9
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.932549704810435
final loss: 0.8480419906696238
47
training_accuracy 0.7090000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.60456300578299
final loss: 0.10902720214587913
48
training_accuracy 0.961
```

```
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 6.501027467108843
final loss: 0.08740055943074228
49
training_accuracy 0.96
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 10.587852323639718
final loss: 0.1381773592911407
50
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 14.181407688411015
final loss: 0.08215255823166019
51
training_accuracy 0.966
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 10.544526882612686
final loss: 0.09590381520036613
52
training_accuracy 0.955
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
```

```
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 9.989278430977825
final loss: 0.10338384824581297
53
training_accuracy 0.957
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 11.922084187762561
final loss: 0.08341900969119889
54
training_accuracy 0.959
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 6.480809033121577
final loss: 1.2606744437135493
55
training_accuracy 0.851
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.296639589498975
final loss: 0.16390800768032177
56
training_accuracy 0.95
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.865543411845614
```

```
final loss: 0.0925917366600258
57
training_accuracy 0.956
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 17.23233182342602
final loss: 0.09374293434769786
58
training_accuracy 0.956
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.542545763664837
final loss: 0.08068300646769067
59
training_accuracy 0.961
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 5.61600739848659
final loss: 1.5185514226978942
60
training_accuracy 0.6679999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 14.12433392773926
final loss: 0.10352285769529854
61
training_accuracy 0.961
Training Started
```

```
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 9.54807512059217
final loss: 0.10486107548480861
62
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.882698148994224
final loss: 0.11235476762447559
63
training_accuracy 0.964
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.2169174458600684
final loss: 0.2278019933610589
64
training_accuracy 0.94
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.340588592250949
final loss: 0.14119696951419633
65
training_accuracy 0.955
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
```

```
Softmax constructor called
Cross Entropy constructor called
initial loss: 11.97625468932192
final loss: 0.16744451051835535
66
training_accuracy 0.958
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.3129480131740525
final loss: 0.10582180703734
67
training_accuracy 0.957
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 10.810185854971952
final loss: 0.10922564321809487
68
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 11.017219333655472
final loss: 0.14655080706711518
69
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 16.810860497138023
final loss: 0.11076501859612037
```

```
70
training_accuracy 0.957
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.061743279583125
final loss: 0.28550198629917406
71
training_accuracy 0.924
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 13.282102714827868
final loss: 0.0953686874588536
72
training_accuracy 0.959
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 8.698979346867482
final loss: 0.27685004949278996
73
training_accuracy 0.942
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 8.563286681078807
final loss: 2.2080205427130517
74
training_accuracy 0.85
Training Started
hidden layer constructor called
```

```
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 11.8758101657243
final loss: 0.12242706664428249
75
training_accuracy 0.96
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 5.548025302243675
final loss: 0.2791608505921745
76
training_accuracy 0.943
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 6.976289651771396
final loss: 0.16286299355627074
77
training_accuracy 0.959
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.947187149629576
final loss: 0.08838923134927054
78
training_accuracy 0.961
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
```
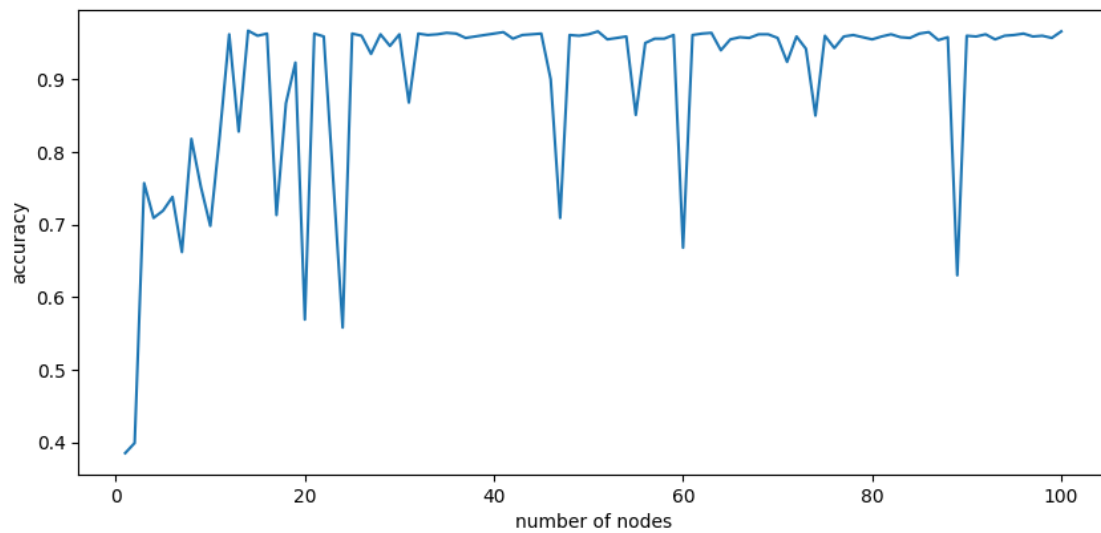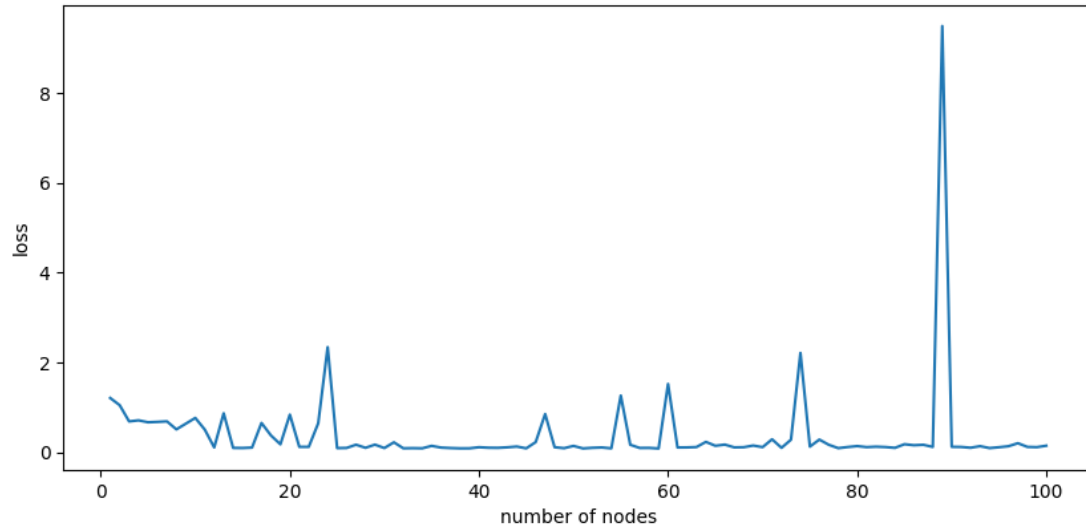
```
Cross Entropy constructor called
initial loss: 15.731448547958578
final loss: 0.11332100752850033
79
training_accuracy 0.958
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 7.67364856499589
final loss: 0.13426613078649222
80
training_accuracy 0.955
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 13.51339413247228
final loss: 0.11124597285292492
81
training_accuracy 0.959
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.699696450071206
final loss: 0.12114636942387752
82
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 13.505675408966399
final loss: 0.11265829209024537
83
```

```
training_accuracy 0.958
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 11.23405570701972
final loss: 0.09519553064549777
84
training_accuracy 0.957
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 4.488607659143648
final loss: 0.17565778039974556
85
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.573348122361303
final loss: 0.15321883950336157
86
training_accuracy 0.965
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 13.087810268742768
final loss: 0.16323152186968404
87
training_accuracy 0.954
Training Started
hidden layer constructor called
param_init_called
```

```
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 19.443012755033433
final loss: 0.11507476805804998
88
training_accuracy 0.958
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 6.962804336759349
final loss: 9.490264471415056
89
training_accuracy 0.63
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 5.713441761755695
final loss: 0.11811283655552451
90
training_accuracy 0.96
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 13.609360184431196
final loss: 0.11479779197893901
91
training_accuracy 0.959
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
```

```
initial loss: 13.287869176123008
final loss: 0.09740001842231794
92
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 14.19822825865985
final loss: 0.1328654156568297
93
training_accuracy 0.955
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 9.238459479752997
final loss: 0.08981464334395739
94
training_accuracy 0.96
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 9.8184078357833
final loss: 0.10860851745173318
95
training_accuracy 0.961
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 3.9552321129192713
final loss: 0.13124504332813555
96
training_accuracy 0.963
```

```
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 4.566169324804229
final loss: 0.19811128126817193
97
training_accuracy 0.959
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 9.373302449044154
final loss: 0.11627419492804758
98
training_accuracy 0.96
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.408546191881388
final loss: 0.11043592155035116
99
training_accuracy 0.957
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 10.523042645429403
final loss: 0.14260816534548632
100
training_accuracy 0.966
```

2 45 nodes in one layer performs best

```
[24]: metric=[]
      training=[]
      p1=np.random.randn(45,2)
      p2=np.random.randn(3,45)
      lr=0.00001
      for j in range(1,101):

          Model=Linking_Networks(X,ylabels,45,p1,p2,lr*j)
          for i in range(1000):
              loss=np.sum(Model.forward())
```

```python
        if(i==0):
            print("initial loss:",loss)
    #      print(loss)
    #      print(Model.hidden.W)
        Model.backward()
        Model.update()
    metric.append(loss)
    print('final loss:',loss)
    print(j)


    b=Model.forward_test()
    # print(b.shape)
    a=np.argmax(b,axis=1,keepdims=True)
    b=np.argmax(ylabels,axis=1,keepdims=True)
    error=0
    for i in range(1000):
        if(a[i]!=b[i]):
            error+=1
    # print(error)
    training_accuracy=1-(error/1000)
    print("training_accuracy",training_accuracy)
    training.append(training_accuracy)
X1=np.linspace(1,100,100)
plt.figure(figsize=(10,10))
plt.subplot(2,1,1)
plt.plot(X1,metric)
plt.xlabel("learning rate(1e-5)")
plt.ylabel("loss")
plt.subplot(2,1,2)
plt.plot(X1,training)
plt.xlabel("learning rate(1e-5)")
plt.ylabel("accuracy")
plt.show()
```

```
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.18593409782592227
1
training_accuracy 0.906
Training Started
hidden layer constructor called
```

```
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.1404143211230286
2
training_accuracy 0.942
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.11856104758524526
3
training_accuracy 0.954
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.10835172058350383
4
training_accuracy 0.961
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.10327529112493745
5
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
```

```
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.10055423573272289
6
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.09977191315822088
7
training_accuracy 0.964
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.09833690591031581
8
training_accuracy 0.963
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.09661214637468808
9
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.09286446214780765
10
```

```
training_accuracy 0.962
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.08954829026735356
11
training_accuracy 0.961
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.6561005648715932
12
training_accuracy 0.718
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8735266900149828
13
training_accuracy 0.7070000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.6604987573388862
14
training_accuracy 0.764
Training Started
hidden layer constructor called
param_init_called
```

```
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.7415715744725292
15
training_accuracy 0.783
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.6777853051674858
16
training_accuracy 0.765
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.584547603488961
17
training_accuracy 0.6910000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.7077567715880442
18
training_accuracy 0.778
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
```

```
initial loss: 12.738013219887351
final loss: 0.9836249954804223
19
training_accuracy 0.602
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8686607355843156
20
training_accuracy 0.5529999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8616287134931249
21
training_accuracy 0.506
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8646547196342126
22
training_accuracy 0.628
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8373100688967139
23
training_accuracy 0.634
```

```
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9346902516274914
24
training_accuracy 0.604
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8446875545553044
25
training_accuracy 0.473
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.911908985772546
26
training_accuracy 0.663
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8169861885128006
27
training_accuracy 0.552
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
```

```
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8709338444162472
28
training_accuracy 0.679
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9383262167825042
29
training_accuracy 0.532
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9330719152874298
30
training_accuracy 0.521
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8420898963805441
31
training_accuracy 0.5589999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
```

```
final loss: 0.8929505771241246
32
training_accuracy 0.5900000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8225925240263812
33
training_accuracy 0.613
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.0165805258186835
34
training_accuracy 0.528
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.0079528835048432
35
training_accuracy 0.5409999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.925940402527714
36
training_accuracy 0.487
Training Started
```

```
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8154216842935652
37
training_accuracy 0.524
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8822147564007436
38
training_accuracy 0.5489999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.7314635847163429
39
training_accuracy 0.606
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9650652951399207
40
training_accuracy 0.593
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
```

```
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9106003627848671
41
training_accuracy 0.646
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.1738546838174893
42
training_accuracy 0.593
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8811707073732545
43
training_accuracy 0.5449999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.730192748228751
44
training_accuracy 0.732
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.0480447447799046
```

```
45
training_accuracy 0.687
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9307372456736217
46
training_accuracy 0.55
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8614219915287425
47
training_accuracy 0.6679999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.7265048814009621
48
training_accuracy 0.632
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.7905774906126806
49
training_accuracy 0.637
Training Started
hidden layer constructor called
```

```
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8960463930063076
50
training_accuracy 0.42500000000000004
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8762419060530134
51
training_accuracy 0.532
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8702536786696154
52
training_accuracy 0.5820000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.1266429590388567
53
training_accuracy 0.5740000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
```

```
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8869586593032863
54
training_accuracy 0.546
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8038399341475421
55
training_accuracy 0.5529999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9211147301701704
56
training_accuracy 0.54
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.6655753605117272
57
training_accuracy 0.7150000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8365212389457035
58
```

```
training_accuracy 0.653
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9165775939496893
59
training_accuracy 0.485
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9033110615895412
60
training_accuracy 0.5529999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8398501029234646
61
training_accuracy 0.581
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9890919232938093
62
training_accuracy 0.5880000000000001
Training Started
hidden layer constructor called
param_init_called
```

```
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8082025271012987
63
training_accuracy 0.593
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.7077660416860091
64
training_accuracy 0.692
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8366624564226295
65
training_accuracy 0.5920000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.6444307974607874
66
training_accuracy 0.725
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
```

```
initial loss: 12.738013219887351
final loss: 0.7940448198484868
67
training_accuracy 0.677
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.7820766413394376
68
training_accuracy 0.5449999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.6727583777600546
69
training_accuracy 0.722
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.7706520322201386
70
training_accuracy 0.618
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.9390070398488907
71
training_accuracy 0.744
```

```
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.8413647594257618
72
training_accuracy 0.708
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 0.7278105245993891
73
training_accuracy 0.634
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 2.0278768324157763
74
training_accuracy 0.733
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.4785950529606064
75
training_accuracy 0.5640000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
```

```
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.3415055380375485
76
training_accuracy 0.5820000000000001
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.2074814782951198
77
training_accuracy 0.645
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.2170821766199968
78
training_accuracy 0.628
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.2256742272758516
79
training_accuracy 0.605
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
```
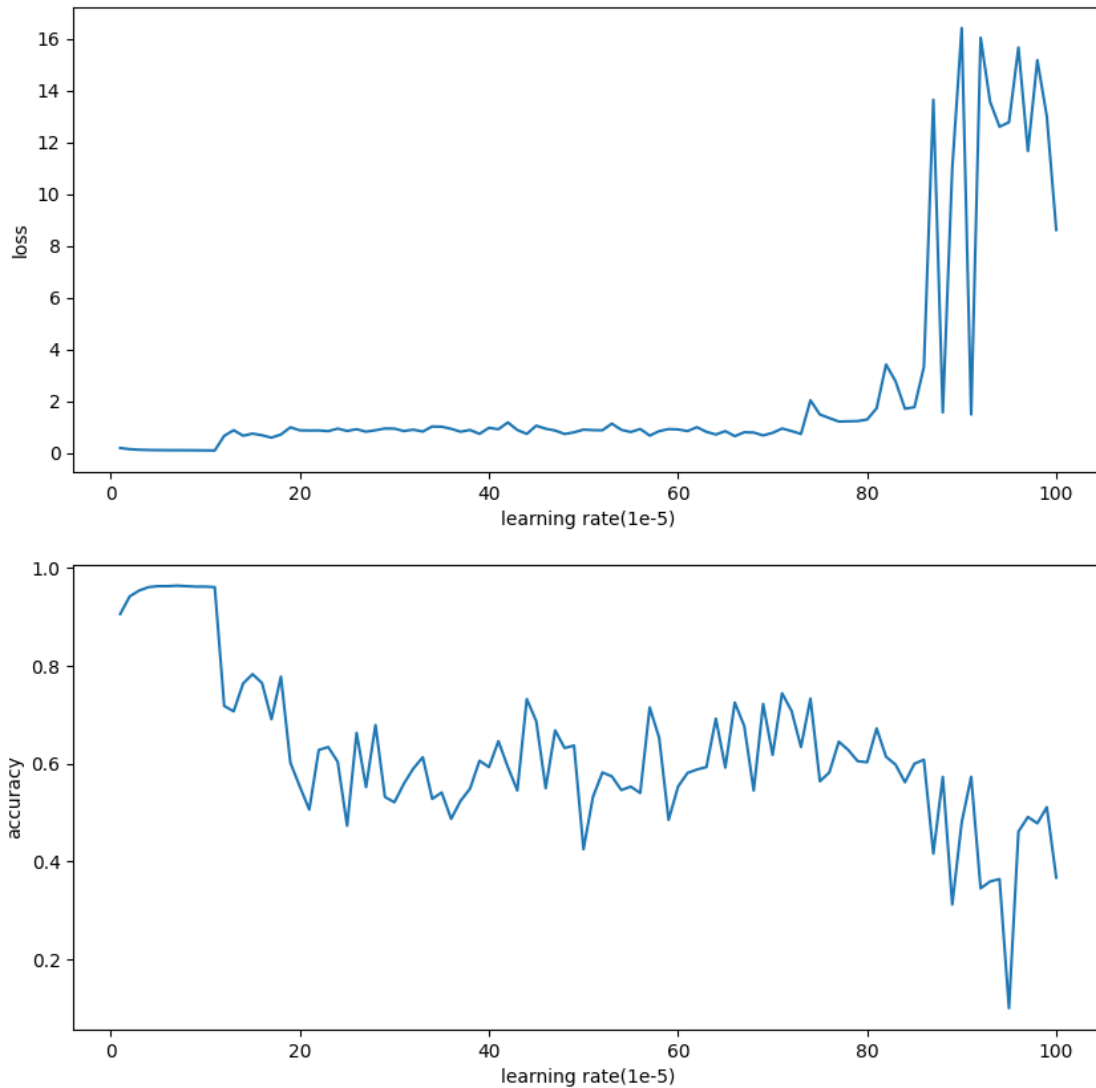
```
final loss: 1.2861150180301633
80
training_accuracy 0.603
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.7207885905578422
81
training_accuracy 0.6719999999999999
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 3.41060499455846
82
training_accuracy 0.614
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 2.76491889479025
83
training_accuracy 0.598
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.703038691945823
84
training_accuracy 0.562
Training Started
```

```
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.7623845262002538
85
training_accuracy 0.6
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 3.316269698367543
86
training_accuracy 0.608
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 13.638581551519822
87
training_accuracy 0.41600000000000004
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.5623342488817156
88
training_accuracy 0.573
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
```

```
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 10.992985523324146
89
training_accuracy 0.31200000000000006
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 16.409930352684874
90
training_accuracy 0.48
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 1.4803673024997752
91
training_accuracy 0.573
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 16.03625646650423
92
training_accuracy 0.345
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 13.56222619769383
```

93
training_accuracy 0.359
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 12.59654850495298
94
training_accuracy 0.364
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 12.77077196302402
95
training_accuracy 0.09999999999999998
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 15.657578632327512
96
training_accuracy 0.46099999999999997
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 11.65780694901801
97
training_accuracy 0.491
Training Started
hidden layer constructor called

```
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 15.167673712625106
98
training_accuracy 0.478
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 12.999917911410705
99
training_accuracy 0.511
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
initial loss: 12.738013219887351
final loss: 8.611668247735132
100
training_accuracy 0.367
```

3 (7 to 8)* 1e-5 is performing best as learning rate

```
[26]: p1=np.random.randn(45,2)
      p2=np.random.randn(3,45)
      Tuned_model=Linking_Networks(X,ylabels,45,p1,p2,7e-5)

      # print(b.shape)
      for i in range(1000):
          Tuned_model.forward()
          loss=np.sum(Tuned_model.forward())
          Tuned_model.backward()
          Tuned_model.update()
```

```
#      print("loss",loss)
    a=Tuned_model.forward_test()
    a=np.argmax(a,axis=1,keepdims=True)
    b=np.argmax(ylabels,axis=1,keepdims=True)
    error=0
for i in range(1000):
    if(a[i]!=b[i]):

        error+=1
#      print(error)
training_accuracy=1-(error/1000)
print("training_accuracy",training_accuracy)
```

```
Training Started
hidden layer constructor called
param_init_called
hidden2 layer constructor called
param_init_called
Softmax constructor called
Cross Entropy constructor called
training_accuracy 0.96
```

4 Since the data are linearly separable. Any random testing data will also perform the same way as the training did.

[ ]: